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Intergrating Building Information Modelling (BIM) and Tools with Green Building Certification System in Designing and Evaluating Water Efficiency of Green Building for Sustainable Buildings

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Abstract. Designing green buildings has become a common trend in many developed countries as a way to promote energy savings and environmental protection. In Viet Nam, the number of certified green buildings remains few, mainly applied LOTUS – the green building rating system introduced by the Vietnam Green Building Council in 2009. It is mainly due to the length of time it takes to design and evaluate green buildings. Applying the Building Information Modeling (BIM) in the design and evaluation of green buildings will address this shortcoming. The integrated BIM-Green Buildings solution kit efficiently provides the architects and engineers with a tool to make preliminary estimation of the green building scoring in term of water efficiency in their design phase; thus they can actively evaluate their performance against key green building criteria and accordingly adjust their designs to meet the criteria at the desired level. This software therefore saves designing time and facilitates the selection of suitable designs.

1. Introduction

The construction industry and building sector are creating many adverse impacts. Building construction is estimated to contribute approximately 26% of the global waste and considered as one of the main sectors that notably emits anthropogenic greenhouse gases (Illankoon et al, 2017). Therefore, it is essential to develop building sector in a more sustainable manner, and designing green building has become a flagship of sustainable development in many countries in recent decades (Ali & Nsairat, 2009). Generally, green buildings refer to the facilities that are designed, built and operated in a way to reduce their impacts on human health and natural environment. Green buildings are designed to efficiently use energy, water, and other natural resources, protect occupant health, improve productivity, and reduce pollution (USGBC, 2011). Once completed, green buildings must meet the requirements of sustainable buidling, efficient use of water, energy efficiency, materials and resources, and good indoor environment quality according to definition of USGBC.

Numerous assessment tools have been developed to assist the green building development. The world's first Environmental Assessment Method for green building designs (BREEAM) was launched in 1990 in United Kingdom. The most popular green building rating system in the world - Leadership in Energy and Environmental Design (LEED) was introduced in United States in 1995. Other leading assessment tools are also made available, including Green Building Council of Australia Green Star (GBCA, Australia), Green Mark Scheme (Singapore), etc... All these green building assessment tools were developed by the green building councils in each country/region and are not legally binding. The assessments are undertaken by accredited professionals that are commissioned by the green building councils. In Vietnam, LOTUS assessment system was introduced in 2009 by Vietnam Green Building Council. LOTUS certification for green buildings is divided into four levels, namely Certification, Silver, Gold, and Platinum, based on the total points the building achieves in the assessment. The number of certified green buildings in Vietnam is few. According to Vietnam Green Building Council, there were 25 certified green buildings in 2010 - 2019 period and 39 buildings are in the pipeline.

Building information modeling (BIM) - one of the most promising recent developments in architecture, engineering, and construction industry (AEC), is an innovative method for designing and managing construction projects. BIM simulates the building in a virtual environment to illustrate three-dimisional (3D) space of a building by computer tools. It can be used to represent the entire life cycle of the construction from the design, construction to operation stage. A completed building information model contains precise shape and relevant data of all items needed to support the design, procurement, fabrication, as well as construction activities (Azhar, 2011). BIM has been used extensively around the world thanks to the improved awareness of the governments on its critical role in construction management.

Various studies and applications have been conducted to intergrate BIM and green building rating tools so as to evaluate water efficiency of buildings in the world. In Vietnam, BIM has also been widely applied in construction project management (Solla et al, 2016). Many buildings have been assessed and certified as green facilities. However, no research or project applying both BIM and LOTUS tools has been implemented to evaluate water efficiency of buildings in the context of Viet Nam. This research aims to investigate the efficiency and applicability of intergrating BIM, LOTUS and green building certification system in the design and evaluation of green building's water efficiency for sustainable facilities.

Table 1. LOTUS NR Weighting.

Categories	Max Points	Weight (%)
Energy	31	28
Water	13	12
Materials	9	8
Ecology	9	8
Waste & Pollution	8	7
Health & Comfort	14	13
Adaptation & Mitigation	10	9
Community	6	6
Management	10	9
Total	110	100

Source: (VGBC, 2015).

LOTUS is a green building rating tool developed by the Viet Nam Green Building Council specifically for Viet Nam's construction environment. In general, LOTUS rating tools share the same targets with the existing international green building rating systems (LEED, Green Star, BREEAM, GBI, Green Mark, Greenship, etc.) and aim to set criteria and benchmarks to guide local construction industries towards further efficient usage of natural resources and application of environment-friendly practices. LOTUS is developed after a long-term research and consists of six rating tools: Non-Residental (NR), Residental, Building in Operation, Single Family Homes, Comercial Interior, and Neibourhoods (VGBC, 2015).

For LOTUS-NR tool, the weighting method is based on nine categories including energy, water, materials, ecology, waste and pollution, health and comfort, adamtation and mitigation, mommunity and management. The corresponding assessment points are presented in Table 1.

The maximum score of water efficiency components is 13 points, accounting for 12% of the LOTUS assessment result. LOTUS concentrates on minimizing the use of freshwater and puts it as a reprequisite condition with the awareness that water efficient building is prominent trend of the future. LOTUS assessment system operates on the following four key criteria: (1) Water Efficient Fixtures; (2) Water Efficient Landscaping; (3) Sustainable Water Solutions; and (4) Water Monitoring.

1.1. Water efficient fixtures

This criteria aims to reduce the water amount that the building spends by applying water efficient equipments and facilities. Related indicators are presented in Table 2.

Table 2. Water Efficient Fixtures.

Indicator	Points
Reduce building domestic water consumption through fixtures by 10% in comparison to baseline figure	Water Prerequisite 1
Reduce building domestic water consumption through fixtures by 20% in comparison to baseline figure	1
1 point for every additional 5% reduction of the building domestic water consumption through fixtures (Up to 40%)	5

Calculation of annual water consumption through fixtures

Annual Water Consumption Through Fixtures (L $year^{-1}$)

$$= [\sum(F.Q_{flush}.n.P) + \sum(F.Q_{flow}.t_{flow}.n.P)] \times O \quad (1)$$

Where

F = Proportion of fixtures

$$F = \frac{\text{Number of Fixtures with a Specific Flush}}{\text{Flowrate.Total Number of Fixture of This Type}} \quad (2)$$

n = Number of daily uses per person per fixture type

P = Number of building occupants

Q_{flush} = Water used per flush for each type of flush fixture [L]

Q_{flow} = Flow rate per type of flow fixture [L s^{-1}]

t_{flow} = Duration of use per type of flow fixture [s]

O = Number of operation days per year

Water Consumption Through Fixtures Reduction (%)

$$= 1 - \frac{\text{Annual Water Consumption Through Fixtures (Design Case)}}{\text{Annual Water Consumption Through Fixtures (Baseline Case)}} \quad (3)$$

1.2. Water efficient landscaping

This criteria encourages the use of indigenous plants and reduction of domestic water for watering in landcaping designs. Its requirements are presented in Table 3.

Table 3. Water Efficient Landscaping.

Indicator	Points
Reduce the amount of domestic water used for landscaping by 50% compared to benchmark figure	1
Reduce the amount of domestic water used for landscaping by 80% compared to benchmark figure	2

$$\text{Total Irrigation Demand} \quad (\mathrm{m}^3\ \mathrm{year}^{-1}) = \sum_{n=1}^{n} \text{Irrigation Demand}_i \tag{4}$$

$$\text{Irrigation Demand}_i\ (\mathrm{m}^3\ \mathrm{year}^{-1}) = \text{Area}_i \,.\sum_{m=1}^{12} \left(\frac{\mathrm{ET}_{0m}\,.\mathrm{Ks}_i\,.\mathrm{Kd}_i\,.\mathrm{Km}_i}{1000.\mathrm{IE}_i} - \frac{\mathrm{E}_{\mathrm{rain\ m}}}{1000}\right) \tag{5}$$

Where:

Total landscaped area is split into n different sub-areas each with different landscape characteristics.

Irrigation demand $_i$ = Irrigation demand for the soft landscape i

Area i = Area of the soft landscape i (m2),

$ET_{0\,m}$ = Average monthly reference evapotranspiration value (mm/month) of the month m

Ks_i = Species factor specific for sub-area i (for the purposes of this calculation Ks for all native species can be considered as "low"

Kd_i = Density factor specific for sub-area i

Km_i = Microclimate factor specific for sub-area i (e.g. well shaded and sheltered area Km - "low", area next to pavement or on roof - "high")

IE_i = Irrigation efficiency factor specific for sub-area i (e.g. drip irrigation IE = 0.9, sprinkler IE = 0.625, xeriscape garden with no irrigation IE = 1)

$E_{rain\ m}$ = Monthly effective rainfall of the month m (mm). The effective rainfall refers to the percentage of rainfall which becomes available to plants and can be calculated with the following formula:

$$\text{Monthly effective rainfall of the month m (mm)} = \sum_d (Daily\ rainfall_d - 5) \times 0.75 \tag{6}$$

Daily rainfalld is the rainfall of the day d.

The irrigation demand should then be converted to a demand per square metre of landscaped area using the following equation:

$$\text{Irrigation Demand}_i\ (\mathrm{m}^3\ \mathrm{m}^{-2}\ \mathrm{year}^{-1}) = \frac{\text{Irrigation Demand } (\mathrm{m}^3\ \mathrm{year}^{-1})}{\text{Soft Lanscape Area } (\mathrm{m}^2)} \tag{7}$$

The soft landscape (excluding hard areas) water demand benchmark for Vietnam is = 1.1 m^3 m^{-2} $year^{-1}$

Calculate irrigation demand savings using the following equation:

Irrigation Demand Reduction [%]

$$\text{Irrigation Demand Reduction} \quad (\%) = \left(1 - \frac{\text{Annual Irrigation Demand m}^{-2}}{1.1\ \mathrm{m}^3\ \mathrm{m}^{-2}\ \mathrm{year}^{-1}}\right) 100 \tag{8}$$

1.3. Sustainable water solutions

This criteria encourages water recycling and reuse as well as rainwater collection to reduce the amount of domestic water consumption. Its indicators are shown in Table 4.

Table 4. Sustainable Water Solutions.

Criteria	Points
Recycled water, reused water or harvested rainwater contribute to 10% of the building's total water consumption	1
1 point for every additional 10% contribution of recycled water, reused water or harvested rainwater to the building's total water consumption (Up to 40%)	4

1.4. Water monitoring

This criteria aims to monitor and manage water sources so as to adjust the water consumption level and identify water leaks/ water loss. Its indicators are presented in Table 5.

The water monitoring system includes water meters of all building's major water uses, i.e main water supplies for each floor or for the swimming pool, watering facilities, etc. The central water monitoring system facilitates the efficient monitor of the project's water consumption (by connecting all water meters to the the automatic central monitoring system).

Table 5. Water Monitoring.

Indicator	Points
Install water meters for all major water uses	1
Set up central water monitoring system	2

2. Scope and methodology

Special functions for designing and assessing green buildings are not available in most of the current architectural and engineering design softwares in general and BIM software in particular. Extended functions (referred to as plugins or add-ins) must be designed for BIM softwares to realize this task. The modified software is called the integrated BIM- Green buildings.

This integrated software reduces the communications between the designer and the green building consultants, facilitates the evaluation and adjustment of the green building designs to ensure green building criteria in sofware designing phase. It also improves the awareness and knowledge of the designers, facilitates their works and promotes the green building orientation in concept phase.

The below chart reflects the comparision between traditional and integrated BIM-based evaluations of green building designs.

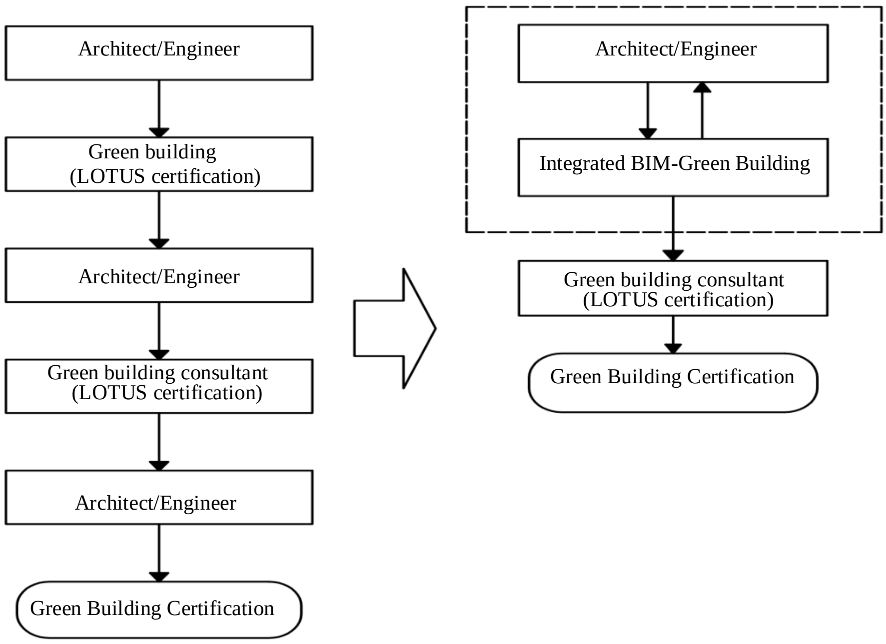

Figure 1. Comparision of the traditional and integrated BIM-based evaluations of the green building designs.

The integrated software ensures that the designers can actively evaluate and adjust the designs to meet criteria of green buildings instead of getting the green building consultants involved since early designing stage or having various rounds of discussion with them. It is efficient not only in terms of time saving but also the consultant's awareness on green buildings.

Application Program Interface (API) is the key to develop BIM's plug-in functions related to green buildings. API is a set of guidance, instructions and tools for the sofware development. It is the intermediate tool connecting different application programs for their interactions and data sharings. It provides the programmers with access to sofware and development of additional functions for the original software based on accepted command codes.

Our study shows that it is convenient to use Autodesk Revit API as an software development tool. Autodesk Revit API is selected since it is the most popular BIM software in Viet Nam, accounting for 56% of the softwares applied in designing architectual facilities, electricity or water system, structure calculation, etc. This is the standard and popupar BIM software globally which is regularly updated by Autodesk. Its community is huge. Therefore, it is efficient to select Autodesk Revit API for future software application.

Revit API provides the software developers with the following main functions: creating plug-ins to make Revit's functions automatically process, extracting BIM information and automatically creating related tables and reports, data input and creating new parameters for BIM model, integrating functions with other analyzing softwares (such as energy, lighting, ventilation analyzing softwares, etc.)

It is concluded that using supporting functions of Revit API facilitates the development of additional tools thanks to the creation of plug-ins on this platform. The supporting tools receives the required data input which found the basis for future developments. These data and Revit's data are the sources for automatic analysis and evaluation of the integrated software.

The project's scope is confined to civil engineering facilities such as housing, office, etc. Which are listed in the current evaluation criteria of LOTUS.

The software development follows the three steps which are described below.

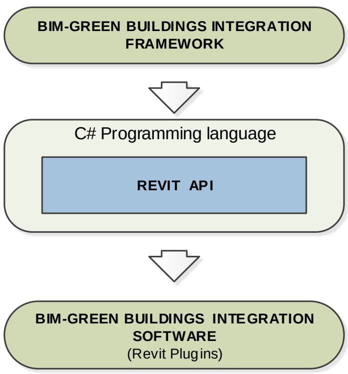

Figure 2. The Project's steps of software development.

- Step 1: Develop the BIM-Green buildings integration framework
- Step 2: Develop the integrated software based on *Autodesk Revit API* in the integrated framework
- Step 3: Apply the developed integrated BIM-Green buildings software into related facilities of the green buildings.

First of all, the project should propose the BIM-Green buildings application framework which presents the overall methods for applying BIM software in green building design according to LOTUS standards.

Inputs for green building assessment will be taken from areas with complete survey data in Viet Nam. These data should have been digitalized to .TMY and .TRY (which are readable in most of professional mapping softwares in Viet Nam).

The integrated BIM-Green buildings software is a plugin software running on Autodesk Revit platform. It includes two main modules: BIM information module and Green buildings standard module.

BIM information module: It realizes two main functions of data collection for green building analysis and direct connection with Revit model (BIM model) of the project. This module allows the users to update feature data of special areas into each component and integrate them with Revit data or results of other softwares for professional calculations and analysis.

Green buildings standard module: This module contains standards, formulas and calculation requirements of Viet Nam's LOTUS. The building's information collected by BIM module will be processed in this module and compared with the standards mentioned above. Based on the results of this module, the architects or designers can calculate the scores of each components according to green buildings's indicators. Therefore they can adjust the designs accordingly.

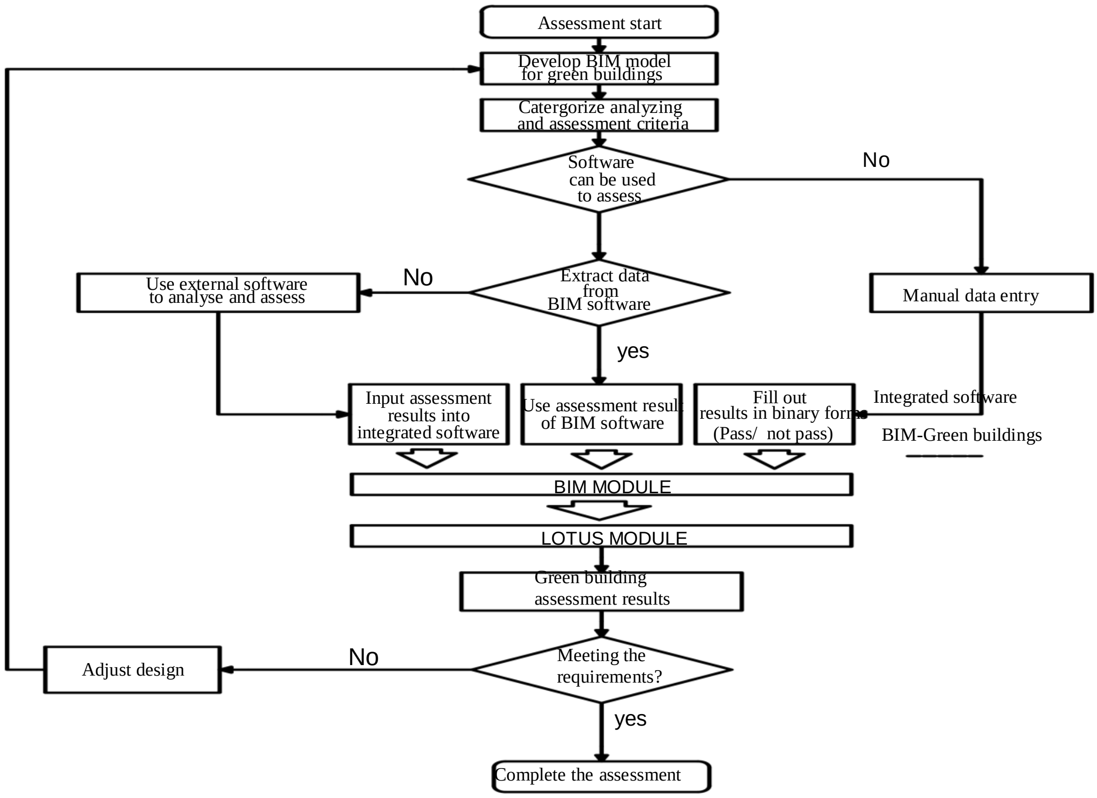

Figure 3. BIM application framework in assessing green building designs according to green building standards.

In addition to calculating the scores of the building's components, this module facilitates the result extraction into suitable forms for application of green buidling certification, such as into Excel files, regional maps or calculation results.

This project apply Revit sofware for designing work. Revit software allows the use of available API to intervene and create supporting applications for the design work. VB.NET programming language is also receiving supports from Revit API. Within this project's scope, the programming team used Visual Basic .NET of framework 4.0 for the interface. VB.NET facilitates the development of suitable interface and interventions into Revit software to address the issues of concern. The software is developed to assess civil works of LOTUS-Non Residential according to LOTUS's criteria, V2.0 launched in 2015.

The development of designing model for water efficient system includes three steps, namely development of input database system, programming calculation modules and extraction of the scorings of the water efficient system design.

Step 1 on input database system development involves the establishment of calculation formulas, scoring system and API for water component according to LOTUS's criteria.

The analysis of water treatment system's operations inclues statistic work, calculations and comparision. Calculation formulas depend on the two principle elements: selected green building standard (LOTUS, etc.) and input data system of the design work. The project team has consolidated all required calculation formulas for the assessment of management modules. In addition, any change in the designing system will be considered modified inputs and consequently change the system's scorings. These changes will be recorded and provided to the designers for their comparision and selection of the suitable designing and management system.

Step 2 refers to the programming of the framework for entering inputs and calculating the scores of the efficient water system. In addition to basic indicators, we include calculation formulas and collaborate with Revit data and datasheets to get the scorings of the other complicated modules. In parallel, the project team also develops the input framework for designing work. Based on the existing input system, the system will conduct calculations using excel functions or HTML5 functions of Revit API. Calculation results vary with different criteria systems.

Step 3 is the extraction of the scorings made by water system design. Based on the existing input system, the system will conduct calculations using excel functions or HTML5 functions of Revit API. Scoring result of each indicator varies depending on the indicator system.

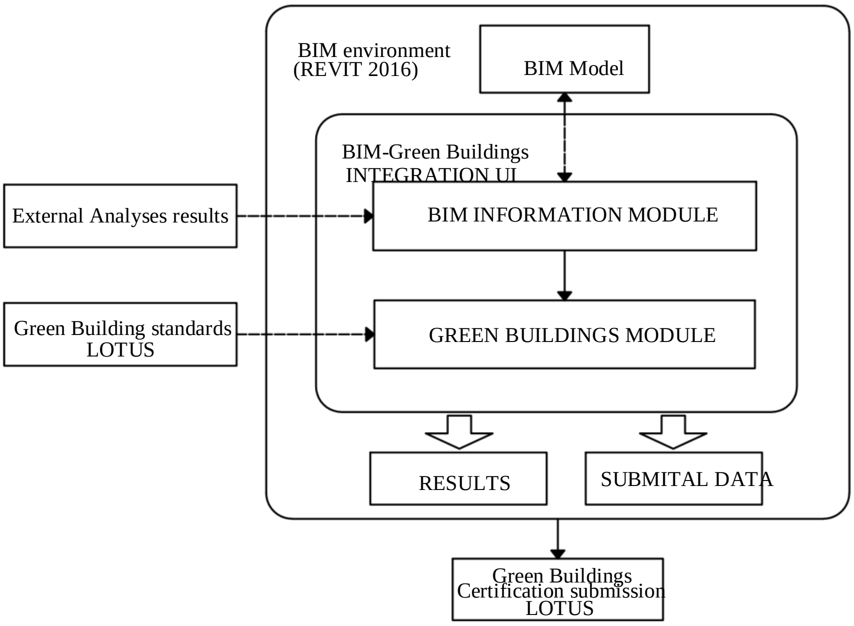

Figure 4. Information exchange between modules of the integrated BIM-Green building software.

This project assesses the water efficiency of the system design produced by integrated BIM-Green buildings software and compares the scorings with the certified building of the Viet Nam Green Building Council. The target is an office tower in Hanoi on an area of 1,288m2 with three basements, 18 floors (one female and one male latrine are located on each floor) which serves approximately 600 people.

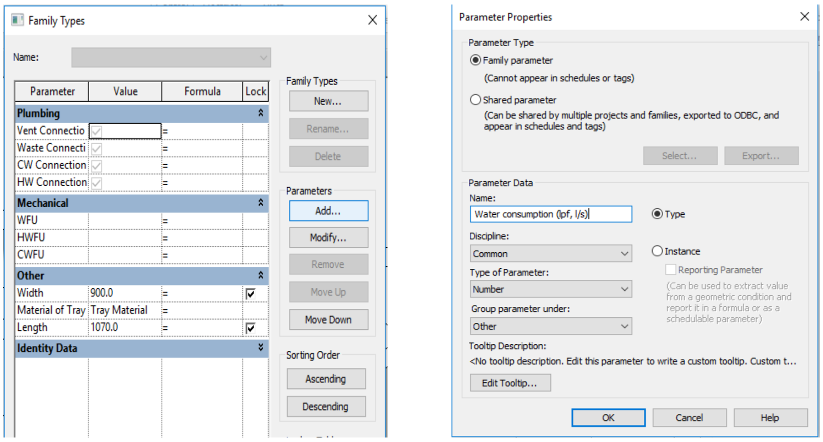

Figure 5. Input framework for calculations.

The activities include a 3D design and establishment of parameters for water supply and drainage system of the building. We apply BIM (Autodesk Revip MEP) for the basic design of the water supply and drainage system, and illustrate the system with Revit 2016 tools. Input data of the latrine facilities must be entered, including water capacity, water consumption duration, discharging flow of the water efficient facilities and normal facilities in order to get the scorings against LOTUS water indicators. Latrine facilities are listed in Revit software. By using the developed plug-in that is loaded in the BIM tools, we can calculate the scorings of the latrine facilities's water efficiency against LOTUS water indicators.

3. Results and discusions

The results shows the designing interface of the building's water supply and drainage facilities and the scorings of each criteria.

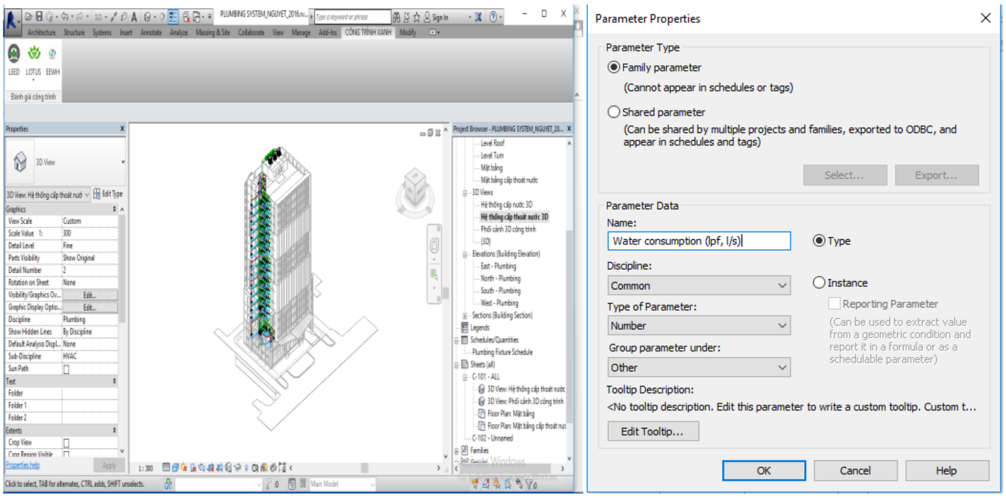

Figure 6. 3D model of the water supply and drainage of the building.

Figure 6 shows the designing interface of the building's water supply and drainage facilities with their parameters and input data. Once the data has been entered, the software will automatically calculate the scorings of the facilities against indicators of the Water Efficient component. The software interface related to Water Efficient includes the following contents: Water efficient fixtures, water/ rainwater recycling equipments, water efficient landcaping facilities and water monitoring equipments.

Figure 7 shows the scorings with regards to indicator on reduced domestic water consumption: 5 points. Figure 8 shows that the building gets 1 points for indicator on water efficient landscaping. Table 7 indicates that the total scorings of the building's water component is 6 points. Viet Nam Green Building Council gave this buiding 7 points on related assessment. Therefore our calculations produce similar results as the assessment of the Viet Nam Green Building Council. The difference between Table 6’s figure and the assessment of the Viet Nam Green Building Council is due to the round-up. In conclusion, the integrated BIM-Green buildings tool kit is reliable and can be used for the designing and evaluation of green buildings. It can be scaled up to assess non-residential buildings.

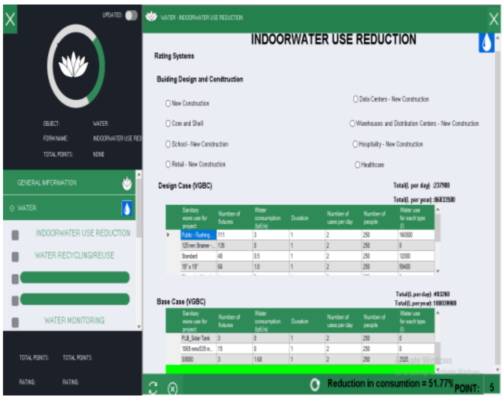

Figure 7. Water efficient fixtures indicator scoring.

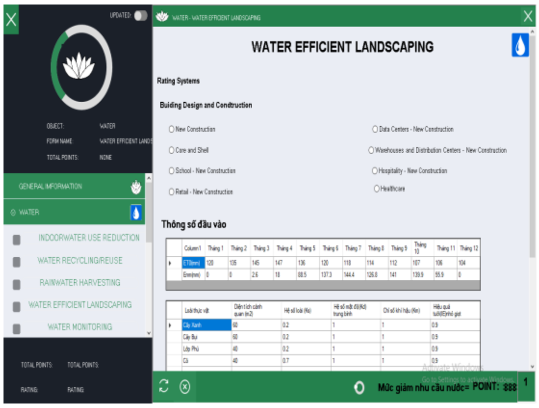

Figure 8. Water efficient landscaping indicator scoring.

Table 6. Comparision of the LOTUS’s Water Efficient component.

Indicator	Maximum scoring	Score by VGBC	Score by the integrated software	Comment
Water efficient fixtures	5	5	5	Similar result.
Water efficient landscaping	2	2	1	VGBC gives 2 points if the facilities reduce more than 50% of the water consumption; however the integrated software gives the same points only if the water consumption amount is reduced by 80% or more. It is therefore the different figures in assessing this indicator.
Water monitoring	-	-	-	N/A
Sustainable water solutions	-	-	-	N/A
Total	13	7	6	

The development of a software that integrates REVIT and LOTUS for the design of water efficient system according to LOTUS’s criteria is a novel and efficient tool which has high commercial potential. The BIM-Green buildings approach and software have been developed based on actual demand of designing consultation practice in Viet Nam. The software is user-friendly and facilitates rapid and early assessment in the basic and engineering designing phases. This software is suitable to the current infrastructure conditions in Viet Nam for BIM application and complies with the prevailing legal regulations on designing and construction works. These are favourable conditions for the application of the software and approach. The demonstrated assessment on specific building in Viet Nam proves the feasibilty and efficiency of the software in green building designing and assessment.

4. Conclusion

The project has successfully integrated LOTUS requirements into REVIT software for green building designing and evaluation. The pilot assessment proves that API add-ins perform well and produce reliable results. The integration of LOTUS requirements into REVIT software improves the feasibility and efficiency of REVIT software in particular and BIM software in general, facilitates the design adjustments in early state to meet the green building requirements, saves costs (in terms of labor, time, etc.) and optimizes the work arrangements, etc.

The software helps the architects and designers to adjust their designs and estimate the scorings of the buildings before submitting their dossiers to the Viet Nam Green Building Council for consideration and certification, reduces the designing time and processing time for green building certification in Viet Nam. Therefore it promotes the development of green buildings in Viet Nam. In addition, this tool kit is very useful for the operation and replacement of the equipment in the future.

This approach can be replicated in other fields of expertise, such as integrating the relevant tools to select environment-friendly materials, calculate product life-cylce and realize circular economy, optimize construction procedure, audit and apply efficient energy for the building, etc.

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