LEED certification using BIM framework in Qatar

Introduction

The global drive towards building with low environmental impact has led to the need to consider developments in terms of their sustainability and life-cycle implications. Recently, for example, environmental awareness has prompted designers to combine technical advances in materials and energy systems with traditional and vernacular designs (Jefferson, 2006: 572). Examples in the Gulf Region include the 'Masdar' project (http://masdarcity.ae/en/) the world's first zero waste and zero energy project, which relies upon relies on narrow streets, architectural overhangs and wind-catchers to cool the air (see for example, Reiche, 2010).

In order to satisfy these aspirations to design, build and occupy buildings sustainably, there has arisen the need for classification systems that allow actual performance to be measured against targets (Greenwood *et al.* 2010). As a result, over the last two decades, there have appeared several rating tools that aim to measure a building's environmental performance (Ding, 2008). The earliest and most familiar examples are BREEAM and LEED®.

The Building Research Establishment Environmental Assessment Method (BREEAM) was developed in 1990 to provide 'comprehensive and widely recognised measures of a building's environmental performance' (BREEAM, 2013). The rating of a particular building design is based upon a report by an accredited external assessor, and the weighted scoring system involves the award of performance credits under the areas of Management, Health and Wellbeing, Energy, Transport, Water, Material and Waste, Land-use & Ecology, and Pollution which combine into a single score which represents a *Pass, Good, Very good, Excellent,* or *Outstanding* result.

LEED® (Leadership in Energy and Environmental Design) was developed about 10 years after BREEAM by the United States Green Building Council (see, US Green Building Council, 2009). There is an online rating system which produces scores on *choice of site, water efficiency, energy & atmosphere, materials & resources, indoor environmental quality, locations & linkages, awareness & education, innovation in design,* and *regional priority*. The results combine and successful projects are rated as *Certified, Silver, Gold* or *Platinum*.

There are now many other such schemes that have been adapted to local conditions and purposes (Reed *et al*., 2009) and a number of authors have compared their various approaches (see, for example, Lee and Burnett, 2008; Fowler and Rauch, 2006).

The Gulf Region has been particularly ready to adopt such tools and embrace practices that reduce environmental and ecological impacts, especially in respect of water scarcity in the Region, and the typically high *per capita* energy consumption that is characteristic of the desire to maintain indoor comfort in hot, dry climatic conditions. These needs are, of course, set against the particularly high volume of construction in the Region over the last decades, which, even in global recession, shows continuing growth; an example being the economic growth of 4.9% for 2013 predicted for Qatar by the International Monetary Fund (I.M.F., 2012). The ability to address environmental issues at an early stage of design is therefore crucial. Although, examples of locally-developed and locally-orientated systems (for example, QSAS (www.qsas.org/) in Qatar, and Estidama (www.estidama.org) in Abu Dhabi) according Reed *et al.* (2009) BREEAM and LEED® remain the most widely-used in the Middle East.

Aims, objectives and background

The aim of the study reported in this paper was to build upon work by Azhar *et al.* (2011), who carried out exploratory research to validate a conceptual framework designed to carry out a LEED®-based environmental assessment in a Building Information Modelling (BIM) environment, and using 'BIM-based sustainability analyses software' (Azhar *et al.* 2011:217). Their 'two-step methodology' involved developing, through literature review and interview, a conceptual framework that related BIM and the LEED® rating processes, and then to test it on a live case.

In line with this earlier work, though in a quite different contexts (e.g. in terms of project location; Qatar, rather than the USA), the study reported in this paper describes an attempt to streamline an environmental assessment process by exploring effective methods of exploiting the existence of the required data within a BIM model. A number of environmental assessment systems were considered as candidates for this exercise, but because of its ubiquity, the team's relative familiarity with its workings, and the fact that it potentially permitted comparisons with the work of Azhar and his colleagues, the chosen environmental assessment method was the LEED® system (in this instance LEED® 2009). However, before describing the method and outcomes of the exercise, there follows a brief résumé of its main elements, namely BIM; the potential for the use of BIM in environmental assessment; and a summary of the functionality of LEED®.

Building Information Modelling (BIM)

BIM is 'a process involving the structured creation, sharing, use and re-use of digital information about a building or built asset throughout its entire lifecycle, from design through procurement and construction and beyond, into its operation and management. This involves the use of coordinated 3D design models enriched with data which are created and managed using a range of interoperable technologies' (BIM Academy, 2013). BIM has been mandated by the UK Government for public-sector construction projects from 2016 and its adoption is advocated by regulatory and governmental bodies in China, Singapore, South Korea, Australasia, the Nordic Countries, some Gulf States and the USA. An important aspect of BIM is that it allows the centralised storage of project-related information in a form accessible to different stakeholders for different uses, which in the context of the current study, includes environmental assessment.

The use of BIM can bring significant technological advantages compared with conventional methods of producing and handling project information. For example, Kriegel and Nies (2008) have indicated that BIM can aid in areas of building design such as

- Building Massing
- Daylight analysis
- Energy Modelling
- Sustainability

and Succar (2009) has usefully defined and delineated the 'expanding boundaries' of BIM, and presents a BIM Framework that identifies and rationalises its conceptual elements.

It is a commonly-made observation that BIM is not merely about software: it entails a process and requires significant changes in the workflow and management of project delivery (see, e.g. Hardin, 2009) as well as the adjustment of participants' approaches to a project (Sebastian, 2011). Recently the concept of Integrated Project Delivery (IPD) has emerged as the natural 'companion' to BIM and has become a preferred project delivery system for all major projects involving BIM in the United States (see, for example, Eastman, *et al.* 2008).

Potential for the use of BIM in environmental assessment

Environmental assessment methods have been at the heart of identifying the sustainability of a building since the establishment of a clear link between sustainable development and environmental impact of buildings, and as environmental issues come increasingly to the fore of regulatory policy the assessment of buildings has become both more urgent and more comprehensive, against a backdrop of increasingly demanding building standards. Systems of environmental assessment have a two-fold role, broadly identified by Ding (2008) as firstly, enhancing awareness and directing the attention of practitioners and those who influence building developments; and secondly providing 'a way of structuring environmental information, an objective assessment of building performance, and a measure of progress towards sustainability' (Ding, 2008:452).

A feature that is common to all environmental assessment systems is their demand for large amounts of design and construction data in different formats. This situation is not enhanced where there is a lack of integration, communication or technological collaboration amongst the project team.

While such assessment methods continue to evolve, they have not, as yet, been integrated into the effective communication, data storage, scheduling and reporting that is now fundamental to the majority of larger, more complex projects being constructed in the developed world, and is at the heart of BIM adoption. Despite their increased importance, and the recognition that 'the early design and preconstruction phases of a building are the most critical times to make decisions on its sustainability features' (Azhar *et al.*, 2010), such analysis is still 'typically performed after the architectural design and construction documents have been produced' (Azhar *et al.*, 2009). This lack of integration of environmental assessment into the design process leads to significant inefficiencies characterised by 'extensive modifications afterwards to meet performance criteria' (Schlueter and Thessling,2008:153).

The existence of such sequential systems can result in:

- Lack of specification and data supplied which in turn can result in delays in carrying out the assessments
- Sustainability documentation being divorced from project documentation, and data is unusable within a 3D BIM environment
- Considerable variation in terms of implementation of sustainability options between design stage and construction stage
- Breakdown in communication due to design teams' lack of understanding of specific steps needed to achieve a rating.

The 'demand for sustainability' is cited by leading BIM software provided Autodesk (2008:3) as a potential driver for BIM adoption as 'sustainable building design hinges on … analysis, prediction and optimization of the design to reduce environmental impact through reduced energy consumption, carbon footprint and use of fresh water' (Autodesk, 2008:3). And as BIM allows for information from a variety of sources to be used and re-used for a variety of purposes, an opportunity exists for 'sustainability measures to be incorporated throughout the design process' (Azhar *et al.*, 2011:217).

Summary of the functionality of LEED®

The *Prerequisites and Credits* content of the LEED® 2009 system (for New Construction and Major Renovations) includes seven *Topics* that represent categories of major concern for sustainable development. These are: *Sustainable Sites; Water Efficiency; Energy and Atmosphere; Materials and Resources; Indoor Environmental Quality; Innovation in Design;* and *Regional Priority*.

Within these topics, and contributing to the overall performance rating of the project under consideration, are two types of criteria, designated as *Required* (i.e. essential conditions for any award and therefore carrying no points) or *Credit Items*, which carry specified points and contribute incrementally to the credit score of the topic they represent. The description of each item (required or credit-bearing) contains its *Intent* (a brief description of the aim of the credit item); *Requirements*, where objectives that would lead to the accomplishment of the aim are specified (these come, in most cases, with *Options*) and *Potential technologies & Strategies* whereby the objectives could be met. Only the achievement of *Required* items is mandatory; the decision as to which *Credit Items* are attempted may be made on a project-by-project basis.

Based on the accumulation of points, an award can be made under one of the following rating levels

- Certified 40–49 points
- Silver 50–59 points
- Gold 60–79 points
- Platinum 80 points and above

Schemes are evaluated by a LEED-accredited assessor to produce one of the above ratings.

Table 1 shows how Topics in the system are aggregated from individual items (both prerequisite and credit-bearing). In examining this table, it becomes clear that not all items are equally susceptible to analytical methods. This has been identified by Humbert, *et al. (*2007:49) who state that, in some cases (they specifically identify *Indoor Environmental Quality and Innovation in the Design Process*) the constituents of LEED topics ''vary on a case-by-case basis and thus cannot be modeled on a standard basis' and that '*direct and tangible benefits … cannot be quantified based on currently practiced LCA'* [Life Cycle Assessment]. The same, clearly, is true of *Regional Priority* credits, which, as well as not being quantifiable in the same way as, say heat-loss calculations, are in essence a specific device relating to the siting of developments in different parts of the United States, and are, therefore, not directly translatable to uses of the system elsewhere. Finally, some of the credit-bearing items are not applicable to all projects (particularly in the case of some within the Materials & Resources topic, which apply only when there is demolition, and thus the potential for re-cycling).

The conceptual framework constructed by Azhar *et al.* (2011) identified relationship between various individual elements contributing to LEED® credits and 'associated BIM-based sustainability analyses' (i.e. Energy, Daylighting/solar and Acoustic analyses; Material documentation; Value/cost analysis, Site analysis and Water use) and is illustrated in Table 2 of their paper (2011: 218-219) but circumstances restricted their validation to credits in *Energy and Atmosphere*, *Water Efficiency*, and *Indoor Environmental Quality*.

For these reasons, many of the items in Table 1 were not investigated in the study by Azhar and his colleagues; the items that they did consider are double-underlined (thus) in the table.

Table 1. Table of LEED ® prerequisites (R) and items attracting credit points (indicating items considered by Azhar *et al.,* 2011)

LEED Topic	LEED Prerequisites (R) and Credit Items
Sustainable Sites	- Construction activity Pollution Prevention (R)
	- Site selection
	- Development Density & Community Connectivity
	- Brownfield redevelopment
	- Public transportation access
	- Bicycle storage & Changing rooms
	- Low-Emitting/fuel-Efficient vehicles
	- Alternative Parking Capacity
	- Protect or restore Habitat
	- Maximize open space
	- Stormwater (Quantity Control)
	- Stormwater (Quality Control)
	- Heat island Effect (Non-roof; Roof)
	- Light Pollution reduction
Water Efficiency	- Water use reduction (R)
	- Water Efficient Landscaping
	- Innovative wastewater technologies
	- Water use reduction
Energy and Atmosphere	- Fundamental Commissioning of Building Energy systems (R)
	- Minimum Energy Performance (R)
	- Fundamental Refrigerant Management (R)
	- Optimize Energy Performance
	- On-site Renewable Energy
	- Enhanced Commissioning
	- Enhanced Refrigerant Management
	- Measurement and verification
	- Green Power
Materials & Resources	- Storage & Collection of recyclables (R)
	- Maintain Existing walls, floors & roof
	- Maintain Existing Interior Non-structural
	- Construction waste Management
	- Materials reuse
	- Recycled Content
Indoor Environmental Quality	- Min^{m} indoor air Quality Performance (R)
	- Env. Tobacco Smoke Control (R)
	- Increased ventilation
	- Outdoor Air Delivery Monitoring
	- Construction indoor air Quality Management Plan (During Construction, Before occupancy)
	- Low-Emitting Materials (Adhesives & sealants, Paints & Coatings, Flooring systems, Composite wood and Agrifiber
	- Indoor Chemical and Pollutant Source Control
	- Controllability of systems (Lighting, Thermal Comfort)
	- Thermal Comfort (Design, Verification)
	- Daylight and Views
Innovation in Design	- Innovation in Design
	- LEED accredited Professional
Reg. Priority	- Regional Priority

Method: the 'Build Qatar Live' case study project

The case examined in the present paper has two distinctive characteristics. First, the geographical locus of the work was Qatar. The project was the 'Build Qatar Live 2012' competition, which took place between November 27th and 29th, 2012.

The competition was a 48 hour virtual collaborative design competition requiring competing international teams to develop an outline proposal and make presentations to the press and a judging panel. The basic information was published in interoperable formats and competing teams were thus free to exploit any technology they chose.

Thus, the second distinctive characteristic, and where the study differs from previous studies (including that of Azhar *et al.*, 2011) was that the building in question was a hypothetical, rather than a real one. Nevertheless, the environment in which the Build Qatar Live (BQL) project took place was realistic, albeit accelerated, and as such offered a unique opportunity to experiment in the context of multi-disciplinary teams, and in particular, to test whether an environmental assessment of the developed building could be quickly and automatically produced to a recognised standard from data accrued in the BIM model.

The competition winners (and the project upon which this paper is based) were a team led by BIM Academy, an industry-academia joint venture based at Northumbria University, formed in 2011 to support the adoption of BIM through research, consultancy and education (www.bimacademy.ac.uk).

In order to produce a design that was as environmentally sustainable as possible, the team took into account, alongside the stated desire for a landmark building, environmental considerations appropriate to its location.

One of the challenges undertaken by the team was to carry out an environmental assessment of the design as it developed. As already noted, a number of environmental assessment systems were considered, including the Qatari Sustainability Assessment System (QSAS), but for reasons noted earlier the LEED® system was adopted for the exercise.

As with the earlier study, not all items were investigated. In Table 2., the items considered in the current (Build Qatar Live) study are identified in bold-face (**thus**). For purposes of comparison, the indication of items considered by Azhar *et al.,* has been retained (double-underlined; thus), and those Items in the Table 1 that were common to both studies are represented in double-underlined bold-face type (**thus**) (see Table 2, below).

Table 2. Table of LEED prerequisites (R) and items attracting credit points (incorporating the indication of items considered in the Build Qatar Live' study)

LEED Topic	LEED Prerequisites (R) and Credit Items
Sustainable Sites	- Construction activity Pollution Prevention (R) - **Site selection** - Development Density & Community Connectivity - Brownfield redevelopment - Public transportation access - Bicycle storage & Changing rooms - Low-Emitting/fuel-Efficient vehicles - Alternative Parking Capacity - Protect or restore Habitat - Maximize open space - Stormwater (Quantity Control) - Stormwater (Quality Control) - Heat island Effect (Non-roof; Roof) - **Light Pollution reduction**
Water Efficiency	- Water use reduction (R) - Water Efficient Landscaping - Innovative wastewater technologies - Water use reduction
Energy and Atmosphere	- Fundamental Commissioning of Building Energy systems (R) - **Minimum Energy Performance (R)** - Fundamental Refrigerant Management (R) - **Optimize Energy Performance** - **On-site Renewable Energy** - Enhanced Commissioning - Enhanced Refrigerant Management - Measurement and verification - Green Power
Materials & Resources	- **Storage & Collection of recyclables (R)** - Maintain Existing walls, floors & roof - Maintain Existing Interior Non-structural - Construction waste Management - Materials reuse - Recycled Content
Indoor Environmental Quality	- Min^{m} indoor air Quality Performance (R) - Env. Tobacco Smoke Control (R) - Increased ventilation - Outdoor Air Delivery Monitoring - Construction indoor air Quality Management Plan (During Construction, Before occupancy) - Low-Emitting Materials (Adhesives & sealants, Paints & Coatings, Flooring systems, Composite wood and Agrifiber - Indoor Chemical and Pollutant Source Control - Controllability of systems (Lighting, Thermal Comfort) - **Thermal Comfort (Design,** Verification) - **Daylight and Views**
Innovation in Design	- Innovation in Design - LEED accredited Professional
Reg. Priority	- Regional Priority

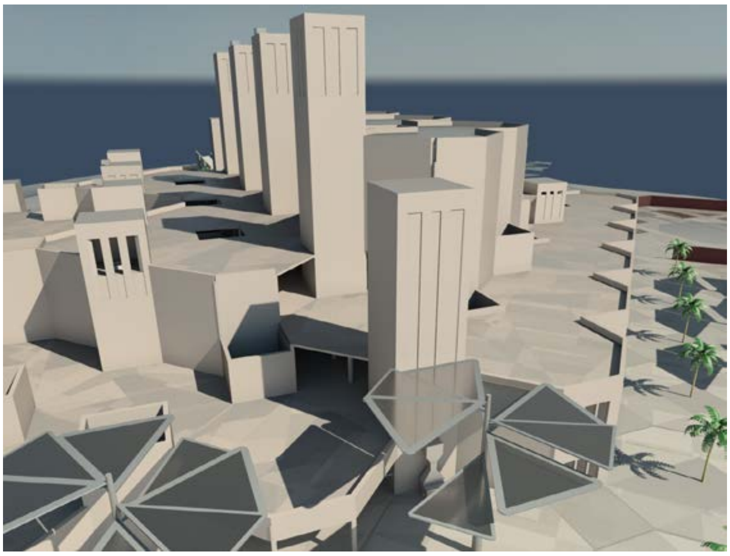
The project; Build Qatar Live, Museum of Architecture

The project upon which the Build Qatar Live Competition was based, was a proposed Museum of Architecture, Doha. The museum was to be designed to hold both a cultural and a social record of design within the Built Environment. The facility was to be located on a new man-made island, and transform this into a landmark destination encompassing the new build museum complete with sustainable infrastructure, green space and renewable energy sources. The basic intent has been for compliance with all local environmental laws and regulations, and the aim was to achieve the equivalent of a LEED 'Gold' rating.

To achieve this, the concept design for the proposed Architecture Museum involved a deep plan building to maximise thermal mass and solar shading. It was also envisaged that stack ventilation towers, located on regular grids, would reduce cooling requirements. In addition a series of break out and courtyards gardens were conceived so as to provide good natural daylight use with solar shading to cut out solar gains.

Figure 1. shows the final design rendered images of BIM Academy's competition entry, detailing its architectural features.

Figure 1: Final design rendered images of BIM Academy's 'Build Qatar Live' competition entry



The BIM Academy-led team for the project included a range of design and construction professionals, senior academics and technologists experienced in the practical application of BIM. The team comprised BIM Academy (BIM Execution Planning and management, 4D and 5D generation and visualisation), Ryder Architecture (Architectural Design), Cundall (Services and Structural Engineering), Mott Macdonald (Pedestrian Analysis), National Building Specification (Specification / Data migration), Colour UDL (Landscape Design) and Turner and Townsend (Cost Management). The team were co-located in the 'BIM Hub' at Northumbria University for the 48-hour duration of the competition.

In terms of environmental assessment, the competition provided a unique opportunity by allowing the project team to share the model and updated it regularly through the design stage. Several BIM-related software products were employed, but the most important for the purposes of environmental assessment were: Revit Architecture and Revit MEP, IES software (by Integrated Environmental Solutions), and Project Vasari, a beta-version product from Autodesk, with integrated energy modelling and analysis features.

A framework, as shown in Table 3., was drawn up to map the relationship between BIM-based sustainability analysis methods and the elements of the LEED certification process. This formed the basis for the concurrent environmental assessment procedure.

Table 3: BIM software tools and their relationship with the selection of LEED credits considered in this study

BIM software tool	Revit Architecture	Revit MEP	IES	Project Vasari
LEED® credits				
Site selection	x			x
Renewable energy		x	x	x
Enhanced energy performance		x	x	
Minimum energy performance		x	x	
Light pollution reduction			x	
Thermal comfort	x		x	
Daylight and views			x	
Material and resources	x			

The relationships within the framework were then examined throughout the 48-hour design process in order to test whether the software packages could generate data to inform the LEED certification process and thus offer the prospect of a transition to an intelligent BIM-enabled process for a standard system of environmental assessment concurrent with the building design process.

Methodology for data exchange Results of using BIM software for partial environmental assessment

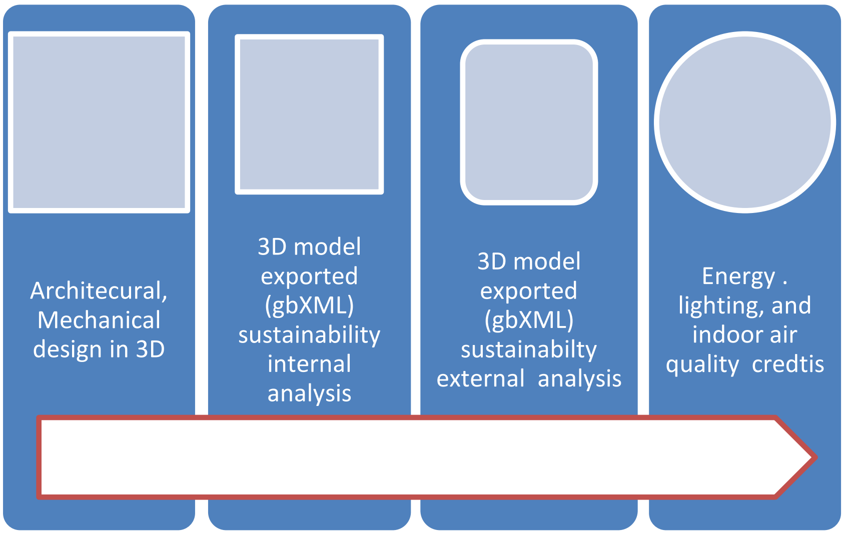
The ability to exchange data within a BIM enabled project was vital to make sure parallel processes within the design are carried out and deadlines are met. The ability for the 3D model to be used and interpreted between different software application is also very important .Data exchanges between two applications are typically carried out in one of the four formats according to Eastman *et al* (2008, p.86) these include:

1- Direct links between specific BIM tools
2- Proprietary file exchange dealing with geometry
3- Public product data model exchange format
4- XML- based exchange formats

XML option was chosen in this case, while this systems has the inability to transfer large volumes of data, in the case of this competition this method provided the best option. Mainly due to reduction in information error associated with file transfer and provided huge time, and software upgrade savings associated of re-entering the information within parallel software. A specific XML schema, gbXML (Green building XML) was applied in the case for optimum file transfer , this version was developed to transfer information needed for preliminary energy analysis of building envelopes , zones and mechanical simulations.

Using a selection of software platforms (including those highlighted above) the team, within the time constraints of the competition, devised a strategy for sharing the BIM model, including the identification of interoperability of different sustainability tools to gain an overall environmental assessment, as well as which element of LEED® can be gained under different software platforms (see Figure 2).

Figure 2: Export of files between software tools using the gbXML format

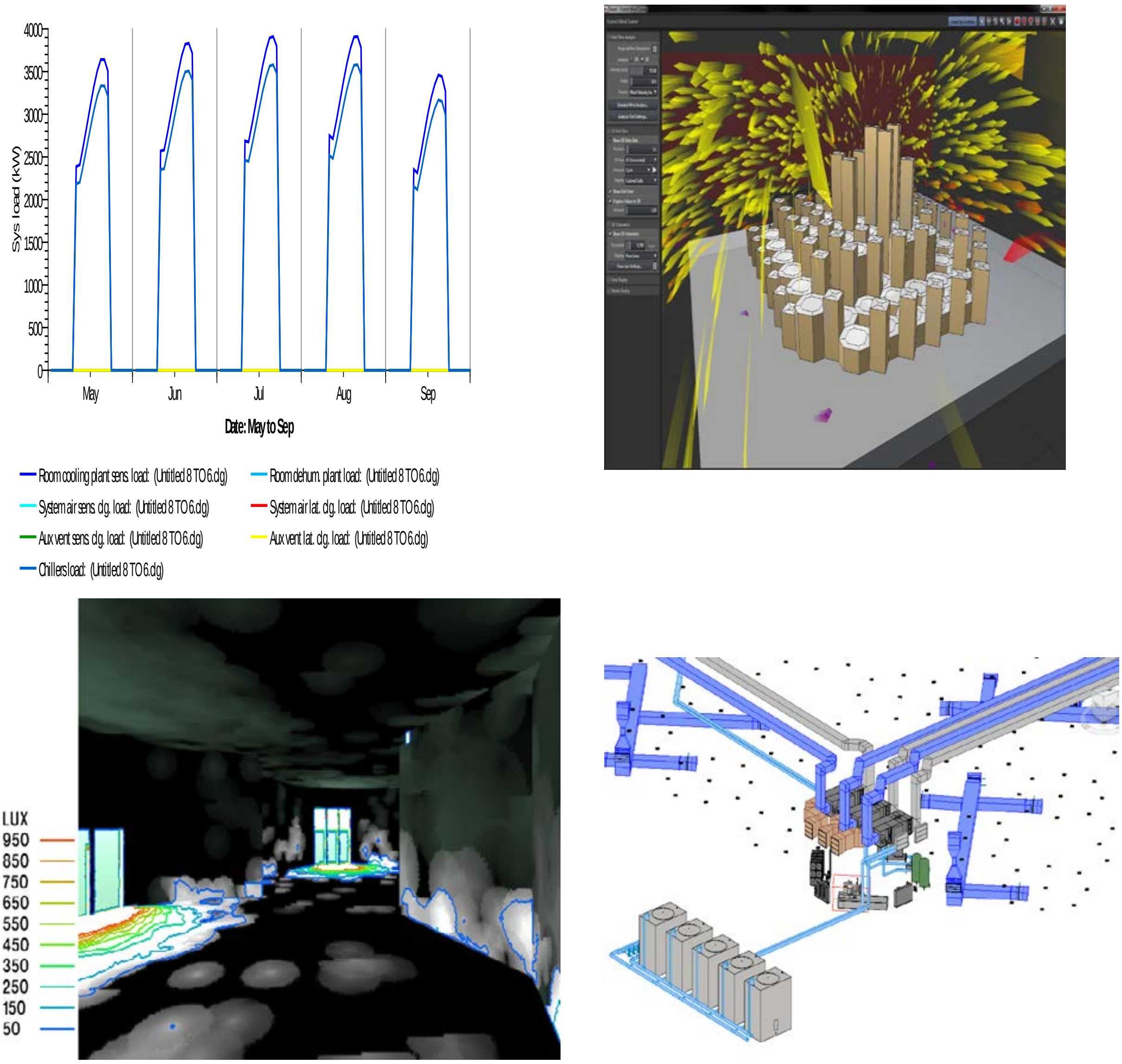

Architecural, Mechanical design in 3D
3D model exported (gbXML) sustainability internal analysis
3D model exported (gbXML) sustainabilty external analysis
Energy . lighting, and indoor air quality credtis

Results of the BIM-enabled concurrent sustainability analysis

The environmental assessment of the project was by no means perfectly detailed and many assumptions were made, due, not least, to the fact that not all LEED credit items were being tackled using the BIM design process . Taking these into account, however, the LEED assessment indicated a credit score of 66 points, which is within the targeted LEED Gold rating range of 60-79 points.

Figure 3 indicates the energy analysis profile of the whole building derived (summer load of 4000kW and at this stage of early stage. While the energy results are not fully accurate at this stage, they are within an acceptable benchmark the Built Qatar live design team is able to appreciate and visualize the energy demand at a parallel stage to building design. These advanced and streamlined systems applying BIM principles allowed the design team to skip the conventional system of completing the building design drawings and then waiting for MEP teams to carry out separate energy simulations, and associated calculations needed for the LEED® energy credits.

Figure 3: Visuals of data generated from BIM sustainability tools for the project (Showing, clockwise from top left: (i) total energy load for building; (ii) lighting levels for interior space; (iii) mechanical plant layout; and (iv) external wind flow analysis.



Lighting design is particularly important in a museum environment. The results of lighting scheme were produced using IES and this allowed the design team to make simultaneous changes to window sizing and elimination of excessive sunlight to reduce the daylight factor , and avoid excessive heating. There was a limit to the elements that can be modelled by BIM, variation existed when the BIM model needed to be updated on a regular internal and that would have some bearing on the different elements of the LEED® overall outcome.

Utilising other benefits of the Autodesk Revit environment, it was possible to Quantify materials and thereby reducing waste generated later during the construction process.

Conclusions and suggestions for further research

Technological advances in the 3D modelling specifically in BIM, can enable the generation of data very quickly and rapidly at the design stage, facilitating, amongst other things, the environmental assessment of a project. In this reported case a LEED process was carried out concurrently with the design of a building using the same model data which were automatically transferred between applications.

The study aimed to introduce smart processes in terms of streamlining environmental assessment within a BIM environment in the Gulf region.

Previous similar experiments involving the populating of LEED analyses from BIM-generated data, have shown that such software can be used to inform a number, though not all, of the credit items involved in LEED assessment. These findings were confirmed by the current study, in which 14 LEED credits were covered.

There are major advantages in producing an environmental assessment concurrently with the design process, and could be achieved early on in a design process and maintained throughout the construction stage. This allows decisions to be changed and ‘optioneering’ to take place; for example, adopting a material with improved environmental credentials or changing the design details which can be flagged within the BIM model for gaining an improved rating. There is, however, currently a limit to the information generated by the BIM models which can be used for sustainability analysis. Such automated, streamlined systems cannot yet, therefore, replace manual environmental assessment methods, but could certainly compliment them, subject to manual checking.

BIM-related software is constantly evolving. Further work is recommended to continue such investigations and extending the facility of data exchange between BIM software packages and environmental assessment systems, such as LEED. Similar experiment with other assessment systems would also prove useful.

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