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IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

BIM Enabled Sustainable Facility Management

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DOI: https://doi.org/10.30880/ijie.2021.13.07.013
Received 21 October 2020; Accepted 23 March 2021; Available online 30 September 2021

Abstract: The scope of facility management spans from traditional activities like repair & maintenance, health & safety, through to real estate management, financial management, change management, and even contract management, tender and procurement, construction, and demolition and disposal of the constructed facility. It therefore requires considering sustainability aspects of construction, which are better addressed through sustainable design strategies. A consolidated but holistic framework has been conceptualized to ensure sustainability in facility management, especially to practice in building and AEC (architecture, engineering and construction) sectors. Although testing and validation is needed, the conceptualized framework is expected to achieve sustainability in the relevant sectors.

Keywords: Building information modelling, Conceptual framework, Facility Management, Integration, Sustainability, Sustainable design.

1. Introduction

Facility Management (FM) evolved over the past 150 years or so. *Since* late 1950s, facility management became associated with the effective and efficient coordination of services applied holistically to enhance the performance of organizations. Today, FM is a service sector in its own right and an established new professional discipline with its own principles, processes, standards, codes and technical vocabulary [1]. However, FM is new to the buildings and AEC (architecture, engineering and construction) sectors. This is because it has been seen in the traditional sense of cleaning, janitorial services, repairs and maintenance.

Goals of FM in the organization are to support people in their work and in other activities, enhance individual well-being, enable the organization to deliver effective and responsive services, make the physical assets highly cost-effective, allow for future change in the provision and use of space to provide competitive advantage to the core business, and enhance the organization's culture and image [2].

Now-a-days, FM covers real estate management, financial management, human resources management, health, safety, security and environment (HSSE), change management, and contract management, in addition to minor building works, building maintenance and operations, building services engineering maintenance, tendering and procurement, domestic services (such as cleaning and catering) and utility supplies [3]. All these need to be holistically considered from the planning of a facility / building, through to the design, construction, and to the eventual demolition or re-use of the building [4]. The scope of FM is now therefore encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology. This essentially implies to craft sustainable design aspects [5] in the facility / design from planning to the end of its life cycle, where building information modelling (BIM) can play a significant role, especially to provide a holistic solution, including the cost of ownership, life cycle costs, integration of services, design optimization and other various sustainability aspects [6, 7]. This will also help to adopt

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Industry 4.0 in Building and AEC sectors [8], since BIM is considered a key process to accomplish such adoption, which is being considered elsewhere and in a separate paper.

Drawing on the above, this paper briefly introduces BIM, discusses various sustainable design aspects, and then presents a conceptualized framework on how BIM can help achieve a sustainable and integrated facility management.

2. Building Information Modelling (BIM)

Building information modelling (BIM) is an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure [9]. It allows the opportunity of analyzing and comparing between all possible alternatives, to eventually deciding on the desired design, construction and operation of a facility or building [7]. BIM uses a computer model database of building design information that contains information about the building's construction, operations, maintenance and management [10, 11]. The concept evolved with the introduction of 'object' (such as walls, roofs, doors and windows) oriented CAD (computer aided design), which contains both graphical (i.e. drawings) and non-graphical (e.g. schedule and specifications) data of the building in a logical structure, forming a highly coordinated repository. Changes in each item are made at only one place, and all project participants see the same information. This allows increased communication, considerably reduces time and cost, and avoids many potential disputes [7].

BIM allows time sequencing of usual 3D geometric model in visual environments, which is commonly referred to as 4D modelling [12]. 4D modelling allows demonstration of the building construction process before any real construction activity takes place, helps to identify any possible mistakes and conflicts at early project stages, and enables prediction of construction methods and schedule [13]. nD modelling extends the concept of 4D modelling, and further integrates 'n' number of design dimensions, in a holistic model to portray and visually project the building design over whole project lifecycle [10].

Thus, BIM can play a significant role in delivering construction projects and improving the efficiency and effectiveness of the integrated design and construction process. The BIM process can conduct a series of 'what-if' analyses to simulate and compare the impacts of different variables through the whole life cycle of the buildings / projects for a range of trade-offs, such as: predict & plan the construction process, determine cost options, maximize sustainability, investigate energy requirements, examine accessibility, determine maintenance needs, incorporate crime deterrent features, examine the building's acoustics, and suggest an optimized solution between a wide range of FM elated attributes. The eventual outcome of BIM process is to develop project specific multi-dimensional and fully functional (building information) model, which can be used during the construction of the project, through to operation phase, e.g. in repair and maintenance, and finally to the demolition of the structure [14].

A wide range of BIM tools and software are currently available in market, including: Revit, Navisworks, Luban, AECOsim Building Designer & ProjectWise, Archicad, Vectorworks, and SketchUp & Tekla [15, 16]. These BIM tools / software are used to plan, design, model checking, quantity take-off, construction management, prefabrication, operation and maintenance, preservation, and visualization; although their most common focus areas are design, energy conservation and estimating [16, 17]. The use of such software is increasing very fast, and in many different aspects of a facility, e.g. sustainability aspect is not only seen to be practiced in different project phases for new construction, but also in refurbishment and demolition [18]. The use also includes green building assessment [19], fire rescue [20], and even a collaborative platform for teamwork [21]. On the other hand, in addition to availability and applicability in international markets, adaptation and development of local version of many software is also seen popular, e.g. in China [16]. It is therefore imperative that many of the available software can be used as it is, some may need to be tailored, while some others need to be developed to suit the facility or project.

3. Sustainable Design

Sustainable design helps to achieve two main aspects of sustainability: (i) increase the efficiency of using energy, materials and water in buildings / facility, and (ii) reduce the impact of building/facility on environment and human health [7]. It is argued that sustainability aspects are more effectively achieved if they are considered in the design. As such, design must consider sustainable construction principles crafted in design strategies by all concerned professionals, i.e. green or sustainable design, that deals with various energy conservation features, use of renewable energy, water conservation features, use of recycled and low greenhouse gas (GHG) emitting materials, reduced construction waste, and less environmentally destructive site development. Sustainable design also ensures optimized life cycle costing of the facilities, in terms of construction, operation, maintenance, renovation and ultimate demolition. In addition to these, wide varieties of requirements and scope of FM as it is being practiced are better to be managed by an intelligent system like BIM, for a balanced environmental and business related achievement [3, 5, 14].

3.1 Sustainable Architectural Design

As proposed by the University of Michigan, sustainable design in architecture works with three principles: economy of resources, life cycle design, and humane design [22]. As summarized in Figure 1 below, each of these three principles has three specific strategies. For example, the first principle ‘economy of resources’ is approached through three strategies of energy conservation, water conservation, and material conservation. This principle is also termed as the principle of conservation, since it deals with conservation of different natural resources. Such conservation is concerned with reduction, reuse, and recycling of the natural resources that are used in buildings, which are again planned to be achieved through a number of alternative methods. Similarly, the other two principles have their specific sets of strategies, which are planned to be achieved through certain other alternative methods. Certainly, extensive analysis with very high number of iterations is necessary to obtain the optimum result, and/or the best possible and responsive solution, where BIM can be useful [7, 14].

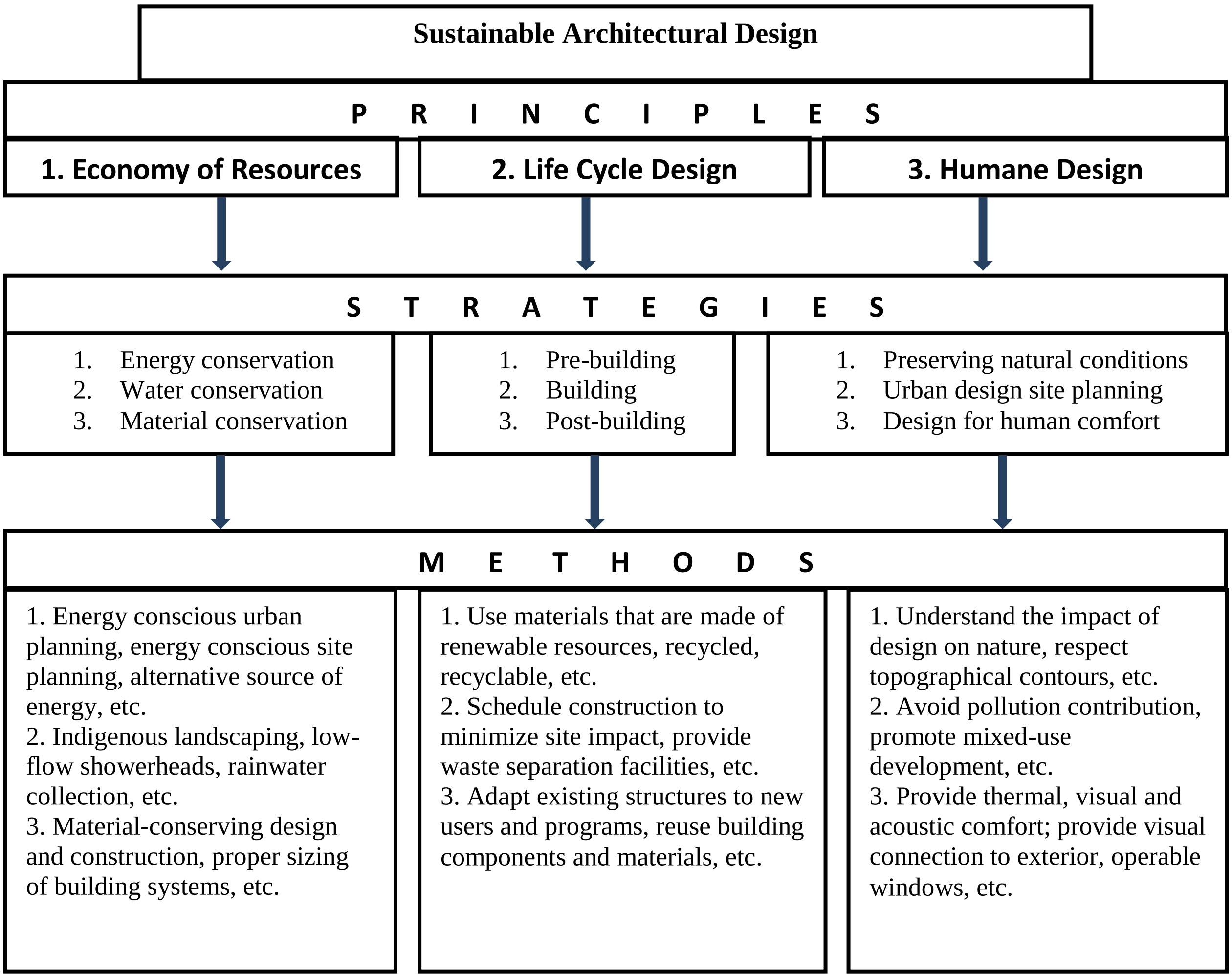

Fig. 1 - Sustainable Architectural Design: principles, strategies and methods

3.2 Sustainable Structural Design

One of the objectives of sustainable structural design is to minimize the impact of the building or facility on the environment and natural resources. In this regard, Danatzko and Sezen [23] compiled five methods, and Shams and Rahman [14] summarized their key principles:

- minimizing materials use, by combinations of various material types to form more efficient structural members and systems, or optimization of a structural model employing a single material type.
- minimizing material production energy, i.e. reducing the amount of energy and natural resources required for the production of construction materials, and thereby reducing production energy cost.
- minimizing embodied energy, by assessing the energy cost of construction versus the operational energy expenditure. The most important factor in reducing the impact of embodied energy is to design long life, durable and adaptable buildings.
- conducting life cycle analysis, e.g. the tools that are often employed to justify or qualify the net cost-to-benefit ratio or economic impact of a design decision.
- maximizing structural system reuse, i.e. generating layouts & designs that produce least amount of solid waste at end-of-life, or allow for the greatest amount of whole/ partial system and/or structural component reuse.

Clearly, a balance must be reached, not only within each of the above key principles, but also among all the five key principles. The required extensive analysis will not be easy for any, e.g. to match and compare between efficient use of resources, life cycle cost and embodied energy / emissions, and eventually to decide on a certain arrangement. As shown in Figure 2, BIM can effectively analyze and compare such different alternatives with a range of client options and/or user preferences, e.g. in terms of suitability, affordability, accessibility and many others, to decide on a suitable sustainable solution for the facility. The eventual solution may not be the best in any single key principles, but will be a balanced option. Most importantly, such analysis will allow a well informed decision making to clients, while also ensuring minimization of burden on the natural resources and other environmental consequences.

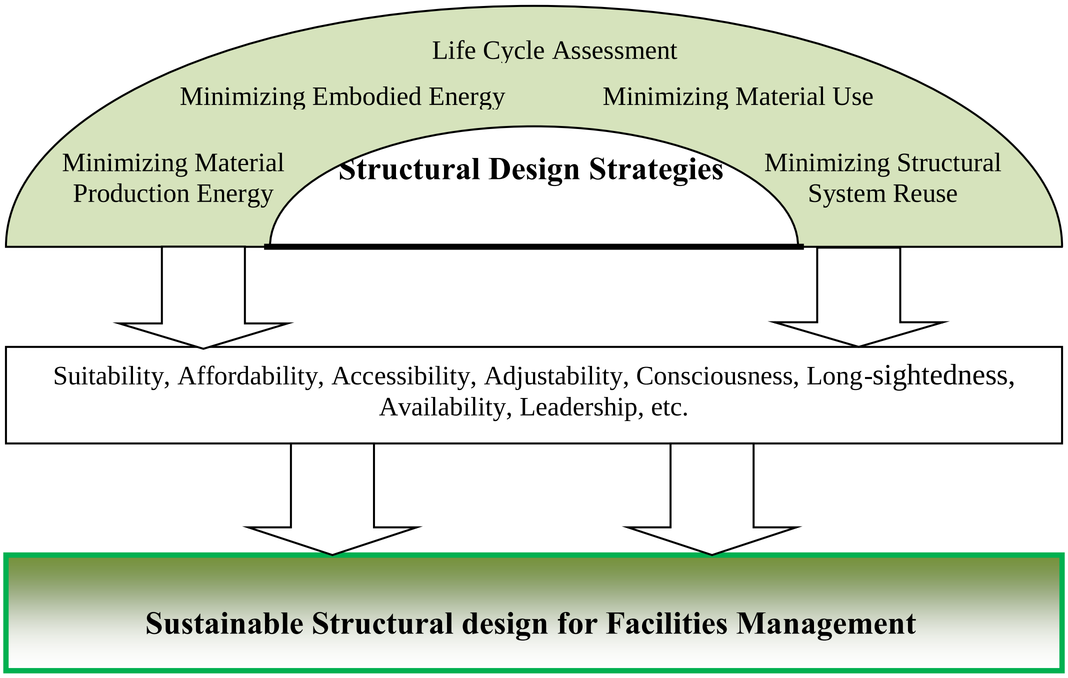

Fig. 2 - Sustainable Structural Design

3.3 Passive Design Strategies

'Passive design' strategies consider two major aspects: (i) the use of the facility/ building's location and site to reduce its energy profile, and (ii) the design of the facility/building itself. No direct resources are used, but two natural phenomena are considered in the background to decide on the design: the sun for heat and light, and wind for ventilation [7, 14]. It is based on the concept and/or strategies like: aspect ratio, i.e. the ratio of length to width of the building and the use of smaller or larger window/door size considering the facing of the sun, orientation, ventilation paths, massing, fenestration, and other measures [24]. The target is to optimize the design to remarkably reduce the energy costs of heating, cooling, ventilation, and lighting. Its success is highly dependent on factors such as local climate, site conditions, building aspect ratio, and building orientation [14]. Various techniques and/or tactics include: different types of roofing systems [25], external painting and coloring [26], passive cooling and flooring [27], and daylighting for selecting different types of overhangs, shades or blinds [28]. Azizi et al. [29] found that people staying in such 'green' or sustainable buildings make personal and psychological adjustment to use less energy, compared to people living in conventional buildings.

Clearly, conducting the appropriate level of analyses, and combining those to come up with a suitable solution with reasonable accuracy is very difficult, if done manually or using the traditional methods. BIM can help in doing all the analyses and help to decide on the appropriate measures with higher degree of accuracy.

4. The Conceptualization

The proposed framework shown in Figure 3 has been conceptualized to provide sustainable solution for facility management. It assumes four different groups of sub-frameoworks. The 'facility management dimensions' is the overacrching sub-framework, whose criteria will eventually lead to take the final decision. The other three sub-frameworks are: sustainability related design dimensions, project and client related design dimensions, and sustainable design strategies.

The 'sustainable design strategies' sub-framework is composed of a number of other small frameworks, as shown in Figures 1 and 2. There will be a number of small frameworks, for architectural design, structural design, and passive design strategies, including those relating to geography, climate, place, surrounding systems and resources. These will again interact with modern technologies like Internet of thing, and Industrial Revolution 4.0 (IR 4.0). As BIM allows, each of these small frameworks will be self-contained, as well as relational to the other small frameworks. For example, architectural design may suggest a certain material to be used, but structural design may consider another material with low embodied energy. This will then be interatcted with natural ventilation, temperature and comfort level of occupants under passive design strategies. Internet of Thing may allow a cloud based system from where all relevant information may be called for, and IR 4.0 may trigger collaboration among all small frameworks. All these may jointly suggest a specific direction or alignment of the building/facility.

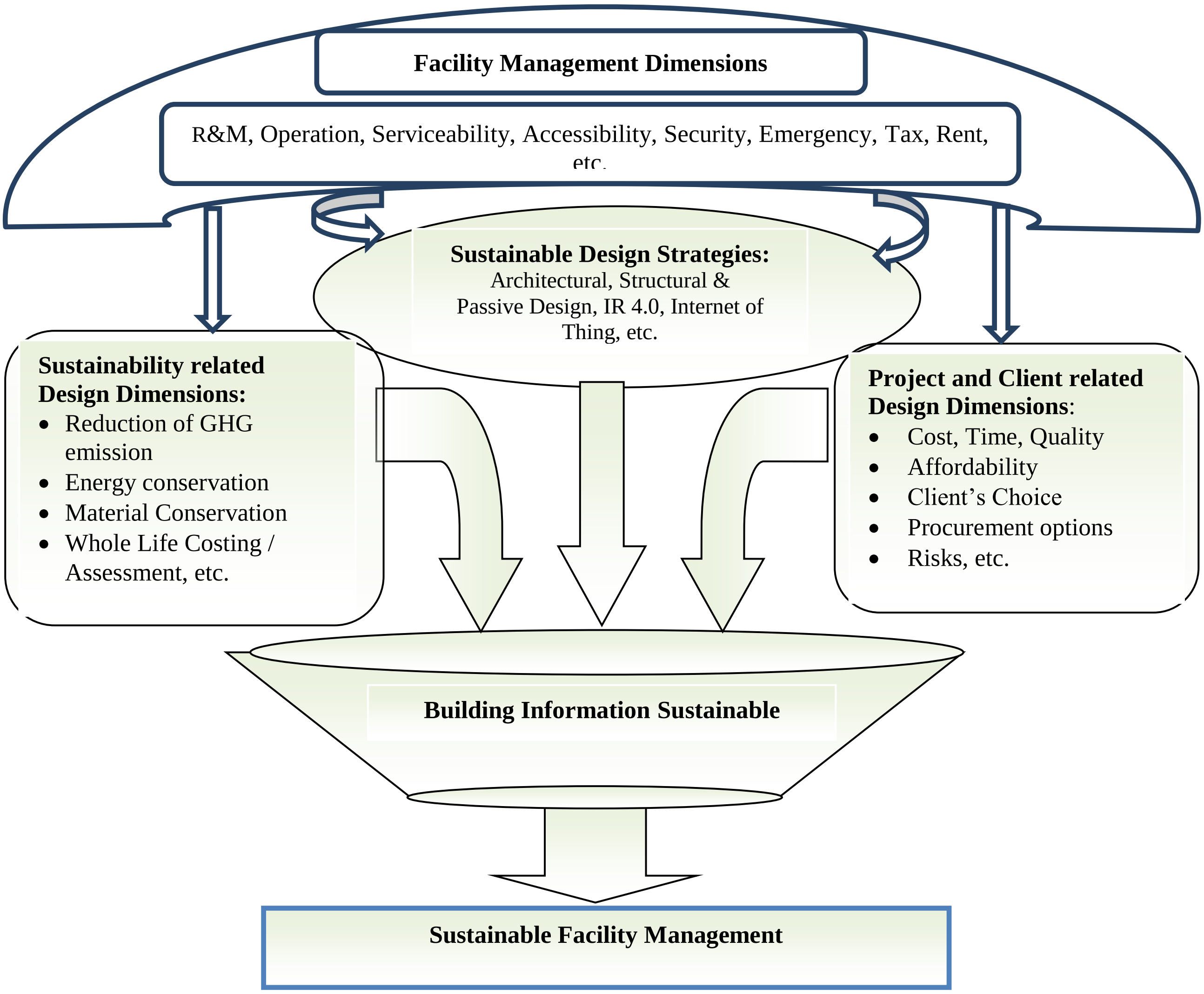

Fig. 3 - Sustainable facility management

The 'sustainability related design dimensions' sub-framework will contain small frameworks like reduction of GHG emission, energy conservation, material conservation, whole life costing, waste generation, life cycle cost and other similar variables or options, and thereby improve sustainability rating. The 'project and client related design dimensions' sub-framework will target a balance between small framework like cost, quality, schedule, affordability, risks, procurement options, and other relevant options. All these will then be analyzed and collated with the small frameworks under the overarching sub-framework of 'facility management dimensions' to decide and develop a building or facility-specific building information model. This model will be used for construction, operation, repair & maintenance, and eventual demolition and disposal of wastes. The framework is expected to offer a best possible solution in terms of various aspects of sustainability, including economy of resources, life-cycle consideration, cohabition with the nature, just a few to mention. With the help of BIM, as it enables, the holistic conceptual framework thus presented will provide sustainable FM to building and AEC industry.

5. Concluding Observations

Facility Management, as practiced today, covers a wide range of disciplines, including real estate management, financial management, human resources management, health, safety, security and environment (HSSE), change management, and contract management. It also includes building maintenance and operations, building services engineering maintenance, tendering and procurement, domestic services and many others. On the other hand, sustainability in FM requires the principles of sustainable construction to be included in FM practices. Clearly, traditionally oriented individual and sporadic consideration to different approaches is unable to harvest the potential benefits of consolidation. Therefore, a conceptual framework was developed using BIM to consolidate all relevant aspects, and to provide an integrated sustainable solution. The key element of the framework is its overarching sub-framework of 'facility management dimensions'. This sub-framework govern the decision making by collating and consolidating other three sub-frameworks of sustainable design strategies, sustainability related design dimensions, and project & client related design dimensions. The eventual outcome will be a building/facility-specific model, which will allow plan, design, construction, repair & maintenance, operation, demolition and disposal of the waste from the building/facility. Such theatrical conceptualization requires further expansion and testing/validation in real rife environment.

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