Intelligent Sustainable Government Buildings in the UAE

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Abstract
Due to the rapid development in technology, intelligent buildings like other fields are rapidly developing. Evaluating a building intelligence will help in configuring the status of the building to show the functionality level of the intelligent components installed as well as the integration level between the different systems in that same environment where the higher integration between the systems indicates the higher level of intelligence and functionality. This research is investigating the intelligence level of a selected sustainable case study building. The similarities and differences between intelligent and sustainable buildings are compared through a case study, and recommendations are made for enhancing the intelligence level of the same building based on the criteria developed by other researchers in 2007. In the study, a 3-storey office building of Dubai Electricity and Water Authority was chosen and evaluated, which is located in Al Quoz industrial area of Dubai. Creating a working environment for 1000 employees, the most important feature of the building is its sustainability aspect. The case study is a USGBC LEED Platinum certified building with 98 points out of 110 rating from the criteria set for this green building standard. The building is considered to be the largest and first governmental green building achieving this rating in the world. The aim of this study is to provide an exemplar-building model in the UAE and the wider region setting a new standard in terms of ‘sustainable intelligent buildings’ for researchers, designers, and investors to look at and get inspired from for developing smart future building projects.

Keywords - intelligent building; building automation, building intelligence, integration, sustainable design

1. Introduction

Intelligent buildings are often defined differently by different organizations. This variation in definition can indicate the importance and the multidisciplinary areas covered in such buildings. All the vast definitions fall under different categories of system, service, and performance oriented categories [1].

Due to the rapid development in technology, intelligent buildings like other fields are developing constantly. By looking at the intelligent building pyramid specification, the criteria set for considering intelligent buildings in different times are changing [2]. Accordingly, a building that was considered intelligent in the past may not be considered the same over time.
Evaluating a building intelligence will help in configuring the status of the building. In fact, the evaluation is carried out to show the functionality level of the intelligent components installed inside the building. In addition, the integration level between the different systems in that same environment is considered [1]. The higher integration between the systems indicates higher level of intelligence and functionality.

The aim of this study is to investigate the intelligence level of a chosen building, in this case, a sustainable building, to find out the weaknesses and strengths of the intelligent components inside. Based on the evaluation made, the potential areas for improvements in the building are pointed out and recommendations are made for further enhancements in terms of the intelligence level.

Moreover, the chosen case study building is a United States Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) certified building, and therefore the study included a further focus towards making a comparison between sustainable and intelligent buildings. This comparison clarified the main differences and similarities between the two types and the main features in terms of classifying a building ‘sustainable’ or ‘intelligent’. Choosing a successful sustainable case study building can clearly shows whether sustainable buildings can be considered as intelligent buildings.

As the chosen building is a well-known, top-rated sustainable building, giving a strong first impression of the intelligent systems to the visitors will make greater appreciation, respect and motivation for such projects. In addition, a governmental building can be used for educational purposes. The study is aimed to provide another level of intelligence within the governmental building environments that can be accessed by visitors and beneficial for its occupants with high levels of intelligence in the same environment, which can be sensed from early time of stepping inside the building. The environment itself will help the visitors resolve their visiting requirements in a highly entreating method.

Methodology

The main method used in this study is extracted from a research paper by Wong, Li and Lai (2008) for assessing the intelligence level of a building. A case study building was chosen in order to evaluate the intelligence levels, investigating the key indicators from the proposed framework by the same research in 2008 [1].

Initial evaluation towards the indoor environment of the chosen building was completed through a site visit. Based on the building specification as well as the sustainability aspect, a literature review focusing on the differences between sustainable buildings and intelligent buildings are considered.

A list of questions about different indicators of intelligent buildings was prepared using Wong, Li and Lai article [1], and sent to the building management department of the chosen case study building. Following on, a comparison between the adapted technologies in each category of the building and the latest available technology are
made, as well as potential areas for improvements are investigated to enhance the current conditions of the building.

In order to rank the intelligence level of the building, the results obtained from a questionnaire-based survey were converted into a score-based system. Meeting each point from the extracted questionnaire checklist led to obtaining ‘1’ point. Therefore, the absence resulted in ‘0’ point. This type of classification is pioneer in this field that is contributing in making clear ranking of the intelligence level for evaluating different buildings. The extracted questionnaire checklist included four sections with eight categories including total of 76 points, and the different scores specified for each key intelligent indicator are shown in Table 2.

Case Study Building

Dubai Electricity and Water Authority (DEWA) sustainable building was chosen for this study. DEWA building was opened in 2013 functioning as the 14th customer service building for the Emirate of Dubai. This 3-storey office building is located in Al Quoz industrial area of Dubai next to Nour Islamic Bank metro station with total gross floor area of 337,764 square feet, creating a working environment for 1000 employees.

The most important feature of the building is its sustainability aspect and having had a LEED Platinum certification by USGBC, after obtaining 98 points out of 110, from the criteria set for green buildings. The building is considered to be the largest and the first governmental green building achieving this rating in the world. This building is also following the green building regulations set by Dubai Municipality.
The basement of the building is utilized for parking spaces as well as storage areas for the files. Ground floor is dedicated for customer service, gymnasium, prayer room, nursery and canteen. First floor is mainly for offices while the rooftop is having vegetation areas as well as the solar panels for generating the needed power for the building. It is designed in a way to utilize solar panels above the vegetation area in order to provide shading and to prevent direct solar radiation to the plants while investing in electricity power generation and solar water heating. The case study building is also featuring for recycling all its wasted water on-site and mainly for the irrigation of the plants.

**Literature Review**

An ‘intelligent building’ is one that provides a productive and cost-effective environment through optimisation of its basic elements such as structure, system, services and managements, and the interrelationship between them as described by Wong, Li and Lai (2008) [1]. Since there are a large numbers of articles discussing the intelligent buildings from different viewpoints and accordingly coming up with definitions providing different concentrations [2, 7 and 8]. Some believe this variation is due to the geographic differences. [3] Others related this to the developments happened in different periods worldwide, resulting in advancing the definitions by time. The ‘intelligent building’ title was used in early 1980s in the United States addressing buildings advanced in information technology, which was developed by time [2].

Moreover, recent studies have related the difference of definitions to the different orientations of the organizations and their business objectives in providing the definitions. Wang categorised them into system, service, and performance oriented definitions [2]. Yang and Peng (2007) stated an important aspect about the reason of having limited number of intelligent buildings. They believe that academics are more acknowledged of different aspects of intelligent buildings while building professionals, owners and project developers are less aware of all the positive aspects of them. Thus, leading to less intelligent building initiatives in general [3]. Alwaer and Clements (2010) identified some methods in order to increase intelligent building projects and they related them to regulations set by governments and rules. It is noteworthy that this method has increased the number of such projects. Intelligent and sustainable buildings require higher budget in terms of initial coast, but the life cycle and the running cost are much reduced in such buildings [4]. Since building professionals usually prefer lower initial cost projects, regulations and rules will enforce them towards coping with them.

Accordingly with Wong, Li and Lai (2008) study, the intelligence level in the building are categorised to the following eight key indicators: (1) Integrated Building Management System (IBMS); (2) HVAC and ventilation control systems; (3) Telecom and data system (ITS); (4) Addressable Fire detection and Alarm (AFA) systems; (4) Smart/ Energy efficient Lift System (LS); (5) Security monitoring and access (SEC);
(6) Digital Addressable Lighting Control (DALI); (7) Computerized Maintenance Management System (CMMS).

These indicators should be evaluated based on four different categories from the system adopted in the buildings: (1) Autonomy; (2) Controllability for complicated dynamics; (3) Bio-inspired behaviour; (4) Man-machine interaction [1]. Since the case study building is a platinum LEED certified building, it is highly likely that it would meet the key intelligent indicators. Thus, the study will be expanding the available indicators in order to push this field into a more intelligent environment by suggesting enhancements and ideas to be applicable in the chosen case study building, which is sustainable as designed and in-use.

There are vast definitions for both sustainable and intelligent buildings. Sustainable buildings can almost be considered as intelligent buildings. They are designed to enhance the building performance in terms of systems and services they have, in order to meet the user needs and to have better functionality in comparison with the ordinary buildings. Similarly, depending on their sustainability level, they are more integrated with the outer environment. However, there are some evidence that sustainable buildings cover wider scope of economical, environmental and social aspects of the building and its environment while intelligent buildings are limited to smaller scope and related to the advancement of technology in terms of their components [4].

The following Table 1 is showing comparisons between sustainable and intelligent buildings.

<table>
<thead>
<tr>
<th>Sustainable Buildings</th>
<th>Concerned Areas</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location and Transportation</td>
<td>Efficiently using energy, water, land, and materials</td>
</tr>
<tr>
<td></td>
<td>Sustainable Sites</td>
<td>Protecting occupant health and improving employee productivity</td>
</tr>
<tr>
<td></td>
<td>Water Efficiency</td>
<td>Reducing waste and pollution from each green building</td>
</tr>
<tr>
<td></td>
<td>Energy and Atmosphere</td>
<td>Continuously looking for ways to improve performance</td>
</tr>
<tr>
<td></td>
<td>Indoor Environmental Quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regional Priority</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Sustainable building vs. Intelligent building [5]
Intelligent Buildings Concerned Areas

- Integrated building management system (IBMS)
- HVAC and ventilation control systems
- Telecom and data system (ITS)
- Addressable fire detection and alarm (AFA) systems
- Smart/ Energy efficient lift system (LS)
- Security monitoring and access (SEC)
- Digital addressable lighting control (DALI)
- Computerized maintenance management system (CMMS)

Results

- Productive environment
- Cost-effective environment
- Optimising and interrelating basic elements of building: Structure, system, services and managements

Based on the information provided in above table; sustainable buildings are covering wider aspects of the building and its environment in general. Sustainability in buildings can be achieved through different various activities while intelligent buildings are focused on specific narrow areas inside the building and its components. In order to achieve a sustainable intelligent building, it is important to include all the areas of concern advancing the building’s intelligence as well as sustainability for its environment in general.

Analysis and Results

Having a unique governmental platinum LEED certified building in a region that is ranking as one of the highest in carbon footprint reflects the attention and high level of awareness of the government towards the global challenges and their willingness to improve and enhance for further future developments. DEWA sustainable building is the first governmental building in the world to achieve such a green standard, and therefore it is a successful case to be considered as an example to be a role model for both national and international projects to look at and get inspired from. Choosing a successful sustainable case study building can clearly show whether sustainable buildings can be considered as intelligent buildings. Based on the site visit conducted, a simple checklist was prepared to evaluate the existing building. The following is the feedback related to each key intelligent indicator:

1. **Integrated Building Management System (IBMS)**
   
   This key intelligent indicator is gathering and relating all the other indicators in one part. In order to understand and evaluate the IBMS, it is important to check the other indicators in detail and then, based on the results, to provide a conclusion in this matter. All in all, the checklist contained total of 76 points for all the different intelligent indicators expressed in further details below.

2. **Telecom and Data System (ITS)**
   
   The key indicator is specifically designed for DEWA by SYSTIMAX and CISCO. The main feature of this network is the universal BACnet technology [6]. BACnet is a
protocol developed by AHSRAE for data communication in building automation and control networks. It is a known standard by ANSI and ISO [7]. The good points of this system are its adaptability to change and create future updates. Integrating different service providers together as well as having transmission analysis.

According to the control engineer responsible, the system meets all the categories of ITS indicators except in diagnosing the timeworn parts of the system as well as the lack of interactive voice options [6]. From this aspect, 5 different points were assigned for the ITS, 3 out of all the advancement and intelligence of the ITS is adopted in the building.

3. **HVAC and Ventilation Control Systems**

Water-cooled chillers are used for the HVAC system in the building resulting in very low power consumption. This is a known available technology in the region and adopted in different buildings mainly for saving power and reducing electricity bills. Water-cooled chillers are basically cooling the condenser of the HVAC with chilled water instead of other fluids [8].

From the study by Wong, Li and Lai (2008), eight different aspects were assigned for the HVAC. This system obtained 6 out of 8 points, i.e. included six out of eight different categories. The two shortcomings were as follows; (1) not interacting with the sunblind’s system and (2) not utilizing natural ventilation inside the building.

4. **Addressable Fire Detection and Alarm (AFA) Systems**

According to DEWA, the AFA system is featured to be user friendly, centralised and addressable. It does not allow access for customers, and has no self-diagnosis functionality to detect old parts. However, out of the 13 points, i.e. the different categories mentioned in [1], it achieved 10 points where the building specialists did not answer one question. Not allowing customers to access the system was initially configured as the building is a public building and should limit the accessibility for the important systems for security reasons.

5. **Security Monitoring and Access (SEC)**

The important aspect of the building is its adaptability for future updates. According to DEWA, the building is not yet monitored, however, the plan is to upgrade it next year with allowing security monitoring and access inside the building. After adopting SEC to the building, the system will obtain the 12 points assigned for security monitoring and access.

6. **Smart / Energy Efficient Lift System (LS)**

The building is using KONE elevator systems. Their products are well known for their energy efficiency solutions, rating A-class energy standards and specifications (e.g. 28% less from ordinary elevators) [14]. While evaluating the building, it is also important to keep the function of the building in mind. Although according to [1], the components of intelligent system should be adaptive to different functions of the building for its life span, some level of intelligence would not be as effective due to the building specification and function. A good example is the smart lift systems that allow access to certain floors based on the user id or fingerprint. In this public
customer service building of three floors, this system is not as beneficial as installing it would be in a high-rise tower. Since management offices are located in the middle floor, customers might need to meet them occasionally depending on their needs. Thus, this floor should be accessible as well and because the building is a LEED certified and based on the requirement, they should provide educational tours to public beside their original purpose.

Accordingly, with the feedback gathered from the professionals working in the building, only 7 points were obtained out of the total of 14 points, considering different criteria set in the checklist terms of LS. This might be due to the limited number of the floors as well as the strategy considered in increasing physical activity of the building occupants at the same time.

7.  **Digital Addressable Lighting Control (DALI)**
About DALI, the building is benefiting from Honeywell control system [6]. Another well-known manufacturer for its various power saving products. The following shortcomings, i.e. losing 5 points, in the system installed in DEWA building:
- The lighting system does not provide monitoring capabilities that lamp performance and hours run can be logged;
- Not having self-diagnoses for time worn parts;
- The system does not provide access for customers and occupants concurrent information of the services provision;
- The system does not provide user interface via internet/intranet or remote control;
- The system is not linked to shading controls.

As mentioned previously, customer access to the systems is not recommended because of the type of public buildings. Moreover, not being linked with shading controls might be due to the utilisation of photovoltaic panels installed on the building rooftop. By this, the obtained score for DALI were 10 out of 15 points.

8. **Computerized Maintenance Management System (CMMS)**
According to DEWA facility management team, the building management system does not have CMMS, resulting in losing 9 points for it. This is a very important point to be considered for the building in the future when upgrading process takes place.

<table>
<thead>
<tr>
<th>Intelligent Indicator</th>
<th>Total Scores</th>
<th>Obtained Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITS</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>HVAC</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>AFA</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>SEC</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>LS</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>DALI</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>CMMS</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>IBMS</td>
<td>76</td>
<td>36</td>
</tr>
</tbody>
</table>
Overall, as shown for each key intelligent indicator above, and from the feedback received, the evaluation indicated that the integrated building management system in the building obtained 36 points out of the total of 76 points, which is a lower score than that was expected before conducting the study. However, the planned future upgrades in the building system can also result in obtaining extra 12 points in addition to what is achieved currently, which would lead to higher levels on intelligence. The results reflected that the high-ranking of sustainable buildings does not necessarily integrate different parts of the building components together. The positive points are all referring to the functions that are directly linked to power savings and the sustainable aspects of the project. Moreover, from this evaluation, the significant influence of sustainable aspects of the building toward driving it to be also intelligent building can be easily understood. However, it might be also considered that this rating of intelligence level in this building is highest among other governmental buildings in the region. Accordingly, with the gathered feedback about this case study building, improvements/upgrades can be easily completed when compared with other buildings.

Discussion

In order to improve the current intelligence level of the chosen case study building, i.e. the assigned key indicators, it is essential to identify the lacking areas and missing parts. Since the building is adaptive to any future changes, implementing several recommendations via updates and upgrades to some of the components of available systems can easily address the mentioned aspects, which can enhance the intelligence level of the building. However, all the main aspects mentioned by [1] are based on advancements in 2008 and therefore, in today’s fast developing technologies, and considering that the building is sustainable, featuring key indicators, which are mandatory for receiving a top-rated sustainable building beside demonstrating the intelligence level respectively.

Dubai government has already moved into an e-government status and transformation into smart government is happening currently. This aspect is advancing this region and both the services and systems involving public services. In this aspect, the following are some of the recommendations in terms of advancing the current human-machine interaction in the intelligent building:

- Integrating and linking different governmental parties within the same environment without creating crowd or clash in provided service.
- Transforming the ordinary customer services in governmental buildings into interactive, intelligent and entertaining services, reflected in their building environments.
- Allowing more educational tours and activities to learn from the sustainable aspects adopted for the space.
- Usage of augmented reality and interactive surfaces within the environment.
Intelligent and user-friendly self-service systems for each customer to reduce the waiting time.
Allowing different functions and usage in the same space and involving occupants and visitors in different activities.
Directing the visitors to different sections in order to fulfil their needs through creative signage systems (i.e. directions).
Providing smart intelligent walls entertaining the kids and visitors while waiting.

Conclusions

Overall, the study evaluated the intelligence level of the selected DEWA sustainable building based on the key indicators set by [1] with some comparisons between sustainable buildings and intelligent buildings. The building obtained 36 points out of 76, which is the total of the different aspects assigned for the eight key intelligent indicators mentioned in this study. The missing points or in other words the unclaimed points were mainly due to not having two of the key intelligent indicators, which are, in this case, the CMMS (9 points) and the SEC (12 points) in the chosen case study building.

The results can conclude that the high-ranking of sustainable buildings does not necessarily integrate different parts of the building systems/components together. Thus, may not include all the eight key indicators required for intelligent buildings’ status. However, on the basis that contribution in saving energy and the environment, almost all points from the questionnaire can achieve high levels. Moreover, some points are related to the building function and not obtaining them is needed for having smooth building function, and therefore may differ from one function to another.

In this part of the study, feedback were obtained from DEWA professionals, facility management team, and the study will continue in the next part to also include feedback from both building occupants and visitors, which is another important aspect when evaluating intelligent buildings in order to evaluate the understandings of the building users as well. However, to enhance and complete this study, it is crucial to include another case study building that is not sustainable and to make a comparison between the two buildings based on the same checklist. This will help showing the impact of sustainable buildings in obtaining different levels of intelligence integrated in the buildings.

The recommendations made was to transform the building from being ordinary customer service governmental building into an educational entertaining and multipurpose space that people can visit, interact, and learn from besides fulfilling the customer needs in highly entertaining/inspiring environment. Furthermore, the study is an attempt to provide some necessary guidelines for researchers and building professionals in transforming sustainable buildings into sustainable intelligent buildings. Moreover, making buildings function as primary educational sources beside their main purpose, e.g. customer services as in the selected case study, will allow more awareness and influence to younger generations.
Acknowledgment

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References