Feasibility Assessment of Renovating Schools in Arid Regions

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Abstract. Nowadays, renovation of buildings including schools is a common practice to enhance their indoor environmental conditions and resource efficiency, and to reduce their operation cost. Construction industry always has its reservation regarding the perceived excessive renovation costs when greening a building. Such perception has been discouraged by property owners from greening and certifying their existing buildings according to USGBC’s Leadership in Energy and Environmental Design (LEED) rating systems. This research established an optimization model with ability of distinguishing and sorting LEED feasible credits according to their costs to achieve cost-effective LEED certifications. Nine random existing schools in Dubai were assessed to form a case study. The assessments’ results proved that less than 1% and 5% of total construction cost should be devoted to modify buildings as per LEED guideline and certify them up to Gold certificate or Platinum certificate, respectively. Attaining platinum certificate resulted in 27% and 30% water and energy consumption reductions, respectively. The estimations revealed that the projected capital spending in energy and water conservation might be returned in a maximum period of seven years with lower utility bills.

1 Introduction

Sustainable (or green) construction can be perceived as construction of resource-efficient structures, though substantially costly buildings to construct. Investors may not consider proposals that need slightly more capital investment despite of the financial saving for building users. Beyond direct cost saving, those investing in kindergarten to high schools should also consider long-term benefits of sustainable buildings due to enhancements in the students’ learning ability. Moreover, frequent studies revealed green schools’ positive impacts on students’ social, physical, and mental well-being (Anne & Janet, 2008).

Regardless of improvements of the learning environment, clients and construction professionals may still attempt to reduce the overall cost of "greening" buildings. The decision-maker intend to understand how local regulations and different rating systems achieve sustainability goals and what would be the associated renovation costs. Attention must also be devoted to the local environmental condition and how such conditions may affect the project pursuing sustainability. Such informative records assist professionals to determine a balance between their budget and sustainability goals aimed for each tier of certification. This research will specifically concentrate on the United Arab Emirates, located in arid climate with its already implemented green building regulations; nevertheless, the proposed and developed methodology in this paper might be applicable to other countries especially with similar environmental conditions.
2 Literature Review

UAE vision 2021 emphasizes on delivering a superb system of education and establishing a resource-efficient learning environment and facilities including schools. Hence, there is a vast potential for retrofitting schools to be converted into sustainable learning facility (Khan & John, 2017). It worth mentioning that about 80% of all electricity consumption in the UAE occurs in buildings (Alkhateeb, Abu Hijleh, Rengasamy, & Muhammed, 2016). Education sector is known responsible for 4% to 13% buildings’ energy demand in different countries, which is mainly used to attain desirable thermal comfort. This shows the importance of energy saving plans especially for cooling and heating systems at schools (Hikmat & Rifqa, 2019). Additional studies reported that certified green schools, including LEED certified schools, required an average additional capital investment of 2% more than the average required investment for ordinary schools (Kate, 2003). However, an assessed savings of 32% and 33% are attained annually due to water conservation and energy savings techniques employed in sustainable buildings (Khan & John, 2017). Although UAE has enforced green building regulations on new designs and construction projects, the renovation of existing buildings, including schools, are not required by the regulations.

Retrofitting of existing buildings and schools reduce energy consumption and greenhouse gas emissions associated with building operation. Energy retrofitting schools help operators to maintain classrooms comfortable even on hot summer days (Johann, 2014). Alkhateeb et al. (2016) reported that a substantial retrofitting project might be able to attain up to 50% savings in energy demand and the emission of CO₂. As stated by Dubai Chamber of Commerce (2015) the financial feasibility of green schools has been still ambiguous for the investors and construction professionals.

Children spend almost 12% of their time in classrooms and the number of occupants per unit of area is four times of that in office buildings (Santamouris, et al., 2008). In many schools, the extent of ventilation and CO₂ concentration are both reported outside the ASHRAE standards (Santamouris, et al., 2008; Simoni, et al., 2010; W.J., et al., 2018). This supports the necessity of resource-efficient retrofitting techniques to improve the schools for public health. Studies in Europe revealed that nasal patency and respiratory diseases were prevalent in children due to insufficient ventilation in classrooms. A greater exposure to rhinitis and dry cough was observed among Children inhaling air with concentration of CO₂ beyond 1,000 ppm (Simoni, et al., 2010). As reported by an official in Dubai, poor indoor air quality lowers students’ wellbeing and ability to focus and learn. Indoor Air Quality for Schools Case Studies (2018) provided details regarding considerable presence of indoor respiratory irritants in schools and identified them as the reason for health degrading symptoms including headaches, and in asthma. In addition, high classrooms’ temperature was identified as the cause for the observed frequent absenteeism, low productivity, headaches, and rapid transmission of diseases.

As compared to standard building, greater thermal loads in schools are expected which requires a well-developed plan with special attention to indoor thermal loading to lower overall building energy demand (Giuliano, et al., 2013). Proper daylighting coupled with the implementation of passive cooling measures might save up to 70 percent of electricity consumption and expenses for lighting and cooling (Stephen & Shana, 2003). Priscilla & William (2010) reported that students in classrooms with proper daylighting revealed 26% higher ability in problem-solving in comparison with those exposed to insufficient daylighting. Daylighting adjustments are considered fundamental aspect of schools’ sustainable renovation. Although numerous technologies are easily available to retrofit existing schools; however, there is still a need to develop strategies to employ the most economical retrofit techniques for each individual project. The projects characteristics such as building specifications, architectural aspects, services change, human performance differences and official policies might directly affect the arrangements to attain most cost-effective design and construction (Zhenjun, Paul, Daniel, & Laia, 2012).

Feasible retrofitting plans typically do not necessitate any major structural reconstructions and mostly focus on enhancing established Indoor Environmental Quality (IEQ) with efficient time and resource usage. Three key qualities that noticeably affect the IEQ of school buildings are Energy efficiency, IAQ, and thermal comfort (Hikmat & Rifqa, 2019). LEED code addresses such qualities in about 50% of total LEED credits, mainly addressed in two Energy and Atmosphere (EA) and IEQ
categories. Hikmat & Rifqa (2019) reported that retrofitting building envelope in hot and arid climate of Jourdan could enhance buildings’ energy savings up to 54% in a financially attractive payback period of 5.5 years.

Among numerous case studies associated with retrofitting existing school and analysis of the corresponding benefits, a building energy assessment implemented at Melbourne University’s campus indicates that about 30% of energy consumption cost is relevant to the campus’s electrical lighting fixtures (Ben, 2018). Retrofitting project conducted at Cairo University also resulted in considerable energy savings and CO₂ emission reduction. The retrofitting schemes applied were including thermal insulation of external walls, enhancement of daylighting, development of green roof, and using glazed window glasses. Hence, energy consumption reduction was estimated to be about 15% (Mohsen & Mohamed, 2016). Majority of building energy demand is to run HVAC and lighting systems; Consequently, the façade and architectural components of the buildings’ external envelope have substantial role in energy demand of buildings. The assessment conducted in Al Ain International School in UAE revealed that instalment of Living (or green) wall systems on the facades of building in such arid regions could successfully reduce 18% of the building’s annual cooling load. It should be highlighted that the reviewed retrofitting aspects have been discretely implemented for different buildings in different climates. However, for each individual building a comprehensive assessment should be conducted based on existing schools specifications, location and surrounding weather conditions to appropriately identify and implement a cost effective and resource efficient retrofitting schemes.

The age of schools buildings is an essential characteristic of the school in Dubai as the Municipality enforced its Green Building Regulation and Specification (DGBRS) for new public or governmental buildings in 2010 (Green Building Certification, 2016). Private sectors’ construction projects such as private schools were only required to follow DGBRS from 2014. The sum of schools constructed according to DGBRS is unknown and there have not been any research assessing what LEED credits, prerequisites and certificate these new buildings may attain. Categorizing buildings built “before 2014” and “after 2014”, also called “Old” and “New” buildings, will be advantageous to recognize the influence of applying local green building regulation. Evident enhancement in the performance and resource-efficiency of new buildings, might indicate and justify the effectiveness of implementing partial green building regulations.

About 15 credits out of 110 total available credits the LEED v4 are established to particularly acknowledge the value of building access to useful amenities. The location of a school may qualify it to achieve some of 15 points without any extra investment and modification. The density of schools’ location is one of parameters that might affect retrofitting expenses and should be considered in assessments.

3 Methodology
To attain comprehensive school retrofitting assessment, a wide range of schools should be assessed; However, it is unrealistic to study all schools. The existing operational conditions of 9 selected schools were evaluated and the results were employed to identify essential green retrofitting techniques. To include school in different conditions, minimum two schools from the identified important parameters (called school category) were selected randomly. Figure 1 shows considered categories of studied school in this assessment. High-density areas and low-density areas are the way buildings are categorized based on their locations. This project classification was based on the population of surrounding area and is described qualitatively in density form. The areas populated with above 3000 people per kilometer square are considered high-density areas, and the areas with population below 3000 people per kilometer square are considered low-density areas. The Dubai Statistics Center reports called Dubai Population Bulletin of Emirate of Dubai (2018) was used to identify population or location densities and to classify schools.

LEED v4 O+M rating system was utilized in this research to rate and assess the design of a school then prescribe its required modifications. Any costs associated with required tasks and implementations for achieving credit or satisfying a prerequisite must be estimated. A clear and thorough procedure is created to estimate required cost of any modifications. A model consisting a
questionnaire with 55 inquiries is established to first identify buildings properties, check what credits are achievable, and estimate the quantity and cost of attaining LEED credit or satisfying a prerequisite. The developed model questionnaire and sample questions are presented in the thesis report (Elkhapery & Kianmehr, 2019).

In all projects, there will be some credits initially achievable without requiring investment or modifications. These credits will be titled as total LEED credits initially earned by the project. The cost of other achievable prerequisites and credits by retrofitting will be estimated based on available price quotations and expert consultation, or occasionally by referring to published articles.

Figure 1. Sample Organization

Microsoft Excel’s “Solver” menu was used to sort most applicable cost-effective credits and select enough number of the credits to achieve a certain tier of certification at minimum applicable cost. The minimum required number of LEED credits for Platinum, Gold, Silver, and certified tiers are 80, 60, 50, and 40 credits, respectively.

4 Results and Discussion

The average percentage costs of retrofitting school projects to attain different LEED tiers is estimated based on the original building costs and reported in Figure 2. The average estimated percentage investment required to retrofit school building projects for all LEED tiers from Platinum to Certified are 4.98%, 1.43%, 0.46%, and 0.15%, respectively. As expected, higher tiers require more credits and modifications to be qualified. The results reveal that the higher the attempted LEED tier, the steeper rise in retrofitting costs observed. This is expected as attaining remaining less financially attractive credits is more costly than those readily available or inexpensive credits that have been already attained in lower tiers.

Figure 2. Average Retrofitting Cost % vs. LEED Certification Tiers
A 95% confidence intervals one-way Analysis of Variance confirmed significant disparity among the cost associated with achieving each tier of certification. The cost of achieving certificates up to Gold certification imposes below 2% additional percentage cost, which deems reasonable in the market. Additional percentage cost of 5% to attain platinum certificate may not necessarily deem reasonable for investors and they may find Gold certificate satisfactory enough.

Dubai Municipality’s Green Building Regulation and Specifications (DMGBRS) has been implemented since 2014. The studied samples are categorized as schools built between 2000 and 2014 and those built after 2014 to determine the effects of DMGBRS on the required investment for upgrading the schools. The results revealed that DMGBRS does have no significant effect on the upgrading cost of attaining tiers of LEED.

The population densities of the assessed school projects are estimated according to Population Bulletin of the Emirate of Dubai (2018) and direct area measurement using google earth, and the results are reported in Table 1.

| S# | Density (people/km²) | Classification |
|----|----------------------|----------------|
| 1  | 7,262                | High-density   |
| 2  | 8,222                | High-density   |
| 3  | 598                  | Low-density    |
| 4  | 164                  | Low-density    |
| 5  | 6,179                | High-density   |
| 6  | 3,323                | High-density   |
| 7  | 739                  | Low-density    |
| 8  | 2,500                | Low-density    |
| 9  | 2,308                | Low-density    |

Figure 3 shows total LEED certification costs for the low-density and high-density schools when different tiers of certification is aimed. As exhibited in Figure 3, a greater average percentage costs are imposed on schools in low-density areas. It is partly due to absence of extensive public transportation systems in areas with low population density where students are enrolled for school shuttle or bus. The less certification costs for the schools in high population density areas are anticipated since some readily available Location and Transportation credits including “Alternative Transportation Credit” are achieved without any investment and modification. Published results by Dabash et al. (2019) regarding building location impact on the cost of LEED certification revealed that extra investment is needed to certify projects far from the stations of popular public transportation systems.
Figure 3. Percentage cost of certifications in high and low location densities

About one third of LEED points are devoted to the conservation of energy. Figure 4 shows estimated average saved energy for all studied schools as different tiers of LEED are aimed. The figure reveals 2.9%, 6.9%, 12.6%, and 30% estimated electricity savings for upgraded buildings from Certified to Platinum, respectively.

Figure 4. The Average Electricity Savings versus LEED Certification

Two-tail T-tests with 95% confidence interval established that all comparison groups (except LEED Certified vs. LEED Silver) had significant cost differences. Such disparity is expected as building upgrades to higher tiers requires enhancing energy efficiency of buildings, which are considerably expensive. Such energy saving credits in Gold and Platinum tiers are typically financially infeasible.

A statistical analysis was conducted to study likely energy consumption disparity between schools constructed before and after the implementation of DMGBRS. Even though a trend was observed visually, two-tail T-tests with 95% confidence interval revealed no significant disparities in energy consumption of both age groups are identified.

The water percentage saving is estimated only for indoor water demands at each LEAD tier. Figure 5 exhibits the results of water savings for upgrades to each LEED tier. As shown in Figure 5, all schools aiming Silver and higher tiers of LEED could attain highest water saving. This saving was achieved mainly by installment of water fixtures such as efficient faucets, toilet flushes and shower heads. The presented trend by the figure determines that most water savings techniques are attempted at initial LEED Certified tier as the modifications are relatively inexpensive and no feasible water
saving techniques remained to be implemented beyond LEED Silver certificate. According to Figure 5, the cap of indoor water conservation is 27%.

![Water Savings of All LEED Tiers](image1)

**Figure 5. Water Savings of All LEED Tiers**

Water conservation credits are mostly achieved in first two tiers of LEED as the techniques and fixtures are identified to be exceptionally low-cost modifications in all schools. A Two-tail 95% confidence interval T-tests was conducted, and the results revealed that no significant differences are observed in water conservation of old and new schools when any Tier of the LEED is aimed.

The net profit return of investment in water and energy, and implementation of photovoltaic is expected to be satisfied in 5 to 10 years. In this study, the financial viability of greening schools is assessed by estimation of the payback period of modifications using the Net Present Value (NPV) for applicable cashflow periods. The period of payback is described by the time required to recover the capital investment. As per local data, the interest rate of 2.25% was considered to calculate the payback period. Figure 6 shows estimated payback periods for investment on indoor water saving, electricity consumption reduction and installation of photovoltaic system. The results indicate that the payback period associated with water and electricity savings are shorter than 6 months and 2 years, respectively. With payback period of 7 years, the investment on photovoltaic systems might be still regarded a reasonable investment for some clients.

![Payback Period of Investments on Upgrades](image2)

**Figure 6. Payback Period of Investments on Upgrades**

According to the discussed results, the applicability of the generated questionnaire and model to estimate costs and identify resource savings is evident. The model could successfully estimate the
costs associated with retrofitting schools, determine the extent of water and electricity savings, and provide fundamental information to calculate payback period of electricity and water saving measures. The developed information might be valuable for professionals planning to initiate similar retrofitting projects. The model initiates further discussions regarding the potential and validity of such decision analysis tools that can better function by utilizing neural networks and artificial intelligence. This utilization might facilitate the consideration of additional factors such as local energy and labor costs, climate characteristics, and regional material accessibility. Yet, there is plenty of potentials for expanding the intelligent aptitude of such model in the future. This research studied the significance of the local population density and access to public transportation on the percentage cost of retrofitting and certifying schools. Such results are informative for project owners to cautiously select their projects’ land.

5 Conclusion
The research focused on school buildings in the metropolitan of Dubai with a compulsory primary green building regulation. It was primarily focused on economic advantages of retrofitting, and greening schools including water and electricity savings. Nine schools in Dubai were randomly selected and categorized as buildings in either low population density or high population density areas. The schools were also categorized as old or new schools, built either before 2014 or after 2014 according to enforced green building regulation. The selection of qualitative information and quantitative records collected from the studied schools are introduced to the developed model to sort cost-effective modifications and credits; Then, the model estimated the minimum investment required to implement the upgrades. The required capital investment was presented as a percentage of additional cost with respect to the initial building cost.

The results revealed that there were no significant disparities among percentage cost of attained Gold Silver and Certified tiers. However, retrofitting schools to attain Platinum tier was frequently found economically unfeasible. The school area population density was identified to be a effective characteristics on certification percentage cost. The results indicate that lower investment is required in high population density locations. The Statistical comparison of old and new buildings revealed that there were no significant differences in cost, energy, or water consumption of the two age groups. The average water and electricity savings at the Platinum tier are estimated to be 27% and 30%, respectively. Gradual energy saving was observed when suggested modifications required to upgrade from Certified tier to Silver tier are implemented. Lastly, the cost estimation of upgrading schools established that water saving, electricity consumption reduction, and installation of photovoltaic systems can be retrieved in up to seven years. Considering the estimated return period, investments in greening schools might be justifiable for various investors.

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