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Assessing Sustainability Indicators of a Commercial Building: A LEED Approach

Mohamed Abdelmawjoud Abdelgaffar
College of Architecture & Planning,
University of Dammam, Saudi Arabia

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Abstract. Construction industry has been proven to cause environmental problems ranging from excessive consumption of natural resources in construction, to the pollution of the environment. Studies on green building to minimize environmental impact are already underway. Tools of assessment of environmental performance of buildings are plenty. However, Middle East countries together with Gulf region are still away from practicing the concept of mitigating the impacts of buildings on the environment. Reasons could be relying on the insufficient awareness of building stakeholders, or the privilege of much fortune. The main objectives of this paper are to arouse the people's attention to the importance of assessment of environmental performance of buildings in KSA, and to introduce a sustainability model for project appraisal based on a multi-dimensional approach, that will be used for the assessment of a case study in KSA. The approach is using the LEED (Leadership in Energy and Environmental Design) rating system as a guide for the assessment. The plan of work includes reviewing the literature on the assessment of sustainability performance of buildings, displaying the LEED system, and assessment of a commercial building in Dammam. The paper uses the descriptive approach to study the problem and collect the data, and the comparative approach to compare the obtained data with the required standards of LEED. The case study, which is a commercial complex in Dammam, is one of these types of buildings widely spread in the development schemes of current real estate investment in KSA. While the building achieved some credits and prerequisites of LEED system, the building lacks many other points. The overall credits achieved are 22%, and the overall prerequisites achieved are 43%. The main problem of the building is related to energy and atmosphere aspects. The maximum performance efficiency

of the building is recorded in water use, which is relatively accepted. As a result, the building is poor in its environmental performance. The building needs much more thorough studies and environmental management policies to enhance its sustainability criteria for better microclimate, health, and productivity for the occupants and users, and for a better environmental quality for the site location and surrounding context.

Keywords: Building performance; Environmental assessment; Sustainable construction; Sustainable development, LEED.

1. Introduction

There are concerns about how to improve construction practices to minimize their effects on the natural environment. The environmental impact of construction, green buildings, designing for recycling and eco-labeling of building materials, have captured the attention of building professionals across the world. Building performance is a major concern in the building industry and environmental building performance assessment has emerged as one of the major issues in sustainable construction [1]. The built environment has a profound impact on our natural environment, economy, health, and productivity. Buildings affect people's lives and the health of the planet and transform land that provides valuable ecological resources (Fig. 1). In the United States alone, buildings account for: 72% of electricity consumption, 39% of energy use, 38% of all carbon dioxide emissions, 40% of raw materials use, 30% of waste output, and 14% of potable water consumption [2].

The research importance is reflected in promoting the green concept in building industry in order to gain the potential vital advantages of the green building and to eliminate the serious problems of traditional building techniques. This helps create a more sustainable community for current and future generations.

The way of life in the Gulf countries is very far from sustainable criteria and performance. High consumption rates, resource exhaustion, dispersed communities, gated development accompanied with low densities and very luxurious schemes, very excessive car use, huge energy consumption of air-conditioning and transportation, excessive water usage, waste and pollution, *etc*. all constitute crucial problems that threaten the future of life in and out of the gulf countries. Unsustainable construction industry forms serious problems with the excessive

expansion and the huge increase in construction industry and real estate development. Researcher should emphasize on decreasing the environmental problems related to construction industry, a small effort enhancing the performance of construction, will have great revenues with the huge capital investment in real estate industry in the Gulf countries.

The aims of work are: 1) to protect the environment and natural resources, 2) to identify the principles of sustainable construction, 3) and to assess the performance of a commercial building based on the LEED system.

The plan of work includes reviewing the literature on the assessment of sustainability performance of buildings, displaying the LEED system, assessment of a commercial building in Dammam, KSA. The data presented here are collected based on observation of the current situation and performance of the building, together with interviews with the design office working and interacting with the building.

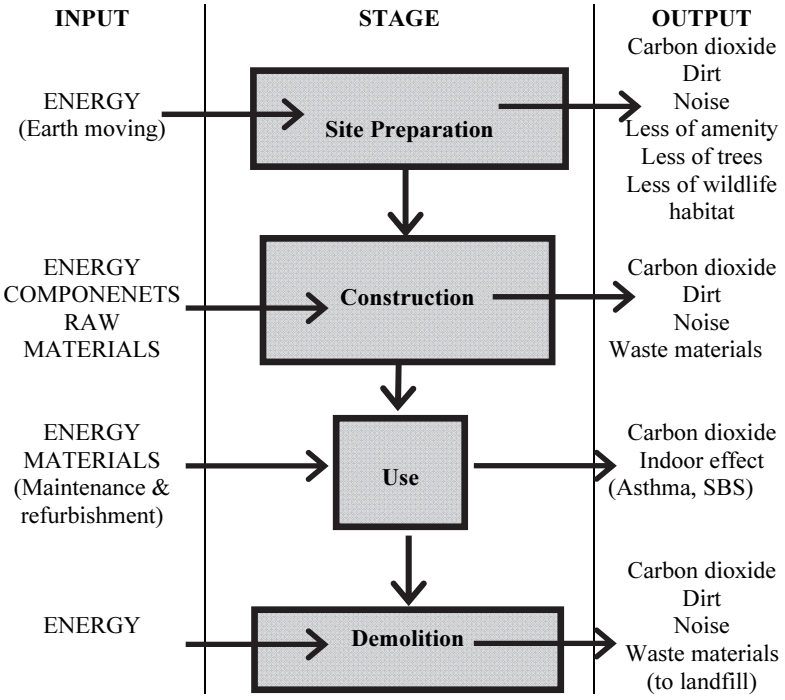


Fig. 1. Environmental impact of buildings through its life-cycle [3].

2. Indicators and Instruments

Building sector started to realize the impact of their activities on the environment in the 1990s. Environmental indicators were developed for the needs of interest groups. The first attempt to establish means of assessing environmental impacts in buildings was the Building Research Establishment Environmental Assessment Method (BREEAM). It was in 1990 in the UK [4]. Since then, many tools have been launched around the world such as LEED, BEES, Green Building Tool, and HK-BEAM. Based on the previous studies, the indicators for measuring a construction's environmental performance include general environmental impact, utilization of environmental resources, contribution to sustainability, public impact, and care for labor [5]. Table 1 indicates the factors affecting the environmental impacts of buildings. There are many tools to environmentally improve buildings. Some of these approaches have mandatory requirements. Others are of a guidance type to show potential for improvement.

Table 1. Factors influencing environmental impact associated with buildings.

Factor	*Effect on indoor environment*	*For instance by*	*Effect on Environment*	*For instance by*
Design	Yes	Ventilation	Yes	Influencing energy use
Sitting/orientation	Yes	Radon exhalation soil and influence on energy use and Indoor temperature	Yes	Effect on landscape
Location and infrastructure	Yes	Determining quality incoming Air	Yes	Influencing transport from and to building
Building materials construction/maintenance/ refurbishment	Yes	Exhalation of volatiles	Yes	Life cycle impacts with various effects
User behavior	Yes	Smoking	Yes	Influencing water and energy use
Energy input during use	Yes	Combustion products	Yes	Life cycle impacts of energy supply
Water input during use	No		Yes	Life cycle impacts of water supply
Demolition	No		Yes	Solid wastes

Source: Reijnders, L., and Roekel, A. van, Comprehensiveness and adequacy of tools for the environmental improvement of buildings, *Journal of Cleaner Production*, 7, 221–225, (1999).

2.1 Requirement Type Instruments

An environmentally mandatory requirements in Europe is summarized in Table 2. At the building level, requirements relate to energy and water consumption efficiency, and to demolition and the wastes generated. There are very limited mandatory requirements related to building components and materials used in buildings. The mandatory requirements have limited interactions between buildings and the environment. It seems that mandatory requirements are not a source for comprehensive improvements [5].

Table 2. Mandatory requirements in European countries.

Requirement pertinent to	*Belgium*	*Denmark*	*Finland*	*France*	*Germany*	*Netherlands*	*Norway*	*Sweden*	*UK*
Buildings									
Energy efficiency	+	+	+	+	+	+	+	+	
Water efficiency	+	+							
Selective demolition		+	+				+	+	+
Reuse building wastes	+	+	+			+	+		
Components									
Water boiler/space heating							+		
Insulation			+				+		
Water saving fittings		+					+		
Wash down toilets		+					+		
Materials									
Raw materials/additives		+							
Mineral wool		+							
Substances									
Arsenic components	+	+	+	+	+	+	+	+	+

Source: Reijnders, L., and Roekel, A. van, Comprehensiveness and adequacy of tools for the environmental improvement of buildings, *Journal of Cleaner Production*, 7, 221–225, (1999).

2.2 Guidance Type Instruments

In European and North American countries, there are many of relatively comprehensive instruments that include [5]:

- Environmental preference lists for building materials and components;
- Manuals for sustainable building;

- Eco-labeling schemes for building products;
- Life cycle analysis for the environmental improvement of building;
- Scoring systems, suggesting environmental improvements;
- Blueprints to set the standard for an environmentally improved building;
- Computer-based guidance for the improvements of complete buildings.

The approaches including products comparisons and information sources are BEES 4 (Building for Economic and Environmental Sustainability), and TEAM [4]. BEES implements a rational systematic technique for selecting environmentally preferred, cost –effective building products. It is a Window based software includes actual economic and environmental performance data for over 230 building products [6]. The approaches including full LCA of buildings are ECOPT-ECOPRO-ECOREAL, ECO-QUANTUM, and ATHENA. These instruments allow for quantitative environmental assessment of differences in building design, component and materials choice. Table 3 shows some of these methods and their coverage of the indoor environment and environmental impacts in general. While Table 4 displays the list of building assessment tools, origin, and characteristics.

The scoring methods include:

- LEED (Leadership in Energy and Environmental Design), USA
- BEPAC (Building Environmental Performance Assessment Criteria), Canada
- Eco-Profile for buildings, Norway
- BREEAM, the United Kingdom

All instruments consist of lists of suggestions for the improvement of buildings linked with a score. Therefore the paper emphasizes on one of the tools that have recently been developed and widely spread in assessment of building performance, LEED, which covers almost all the factors influencing environmental impacts associated with buildings except user behavior (Fig. 2).

Table 3. Coverage of factors influencing environmental impacts associated with buildings.

Method	*Indoor environment*	*Design*	*Sittings*	*Orientation*	*Building materials*	*User behavior*	*Energy input*	*Water input*	*Demolition*
ATHENA	0	+++	0	0	+++	0	0	0	+
BREEAM	+	++	+	+	+	+	++	+	0
EcoProfile	++	++	+	+	+	+	++	+	+
ECOPT-ECOPRO/ECOREAL	0	+++	0	+	+++	0	++	0	++
ECO-QUANTUM	0	+++	0	+	+++	0	++	+	++

0: No (direct coverage); +: Limited (direct) coverage; ++: Substantial coverage; +++: Extensive coverage.

Source: Reijnders, L., and Roekel, A. van, Comprehensiveness and adequacy of tools for the environmental improvement of buildings, *Journal of Cleaner Production*, 7, 221–225, (1999).

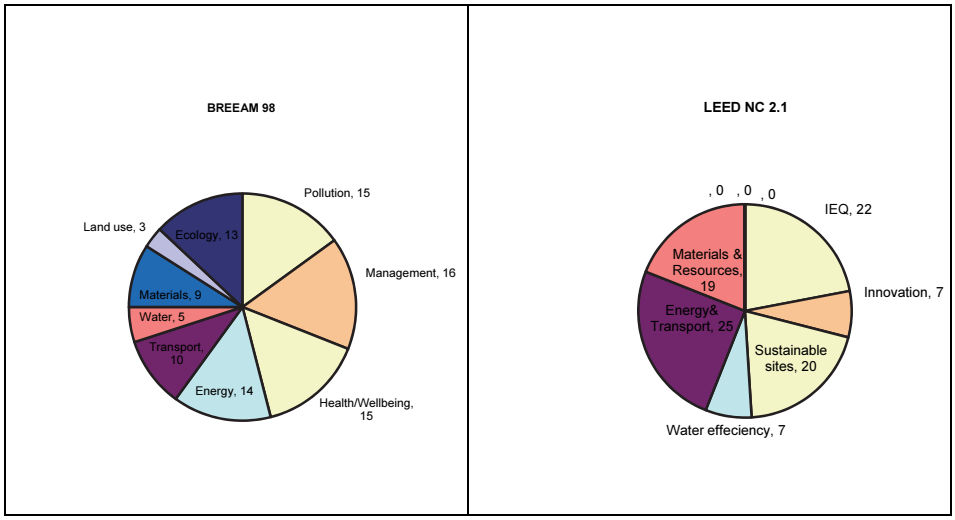


Fig. 2. BREEAM and LEED components [7].

3. Benefits of Green Building

A clear definition for a green building is provided by ASTM (2001) "a building that provides the specified building performance requirements while minimizing disturbance to and improving the functioning of local, regional, and global ecosystems both during and after its construction and specified service life, a green building

optimizes efficiencies in resource management and operational performance; and minimizes risks to human health and the environment"[8]. The notion includes improved eco-efficiency, economic and social dimensions of sustainable development [7].

Green buildings have many advantages over the traditional ones [2]:

o *Environmental benefits:* Enhance and protect ecosystems and biodiversity, improve air and water quality, reduce solid waste, conserve natural resources;

o *Economic benefits:*Reduce operating costs, enhance asset value and profits, improve employee productivity and satisfaction, optimize life-cycle economic performance;

o *Health and community benefits:* Improve air, thermal and acoustic environments, enhance occupant comfort and health, minimize strain on local infrastructure, and contribute to overall quality of life.

Table 4. Summary of environmental building performance assessment methods.

Assessment methods		Origin	Characteristics
ABGR	Australian Building Greenhouse Rating	Department of Commence, NSW, 2005	A performance-based accredited assessment tool Using star rating on a scale of one to five star Provide a national approach to benchmarking greenhouse performance of buildings and tenancies Based on 12 months of energy consumption
AccuRate		CSIRO, 2006	The new version of NatHERs Addresses problems associated with rating homes in tropical and sub-tropical environment through the inclusion of a ventilation model It includes an extensive database of materials Allows users to modify construction elements
BASIX	Building sustainability Index	Department of Infrastructure, Planning and Natural Resources, 2004	Web-based planning tool for residential development To assess the water and energy efficiency of new residential developments NatHERS and AccuRate are simulation packages used to assess energy performance It is mandatory for all new residential development and a BASIX certificate is required for development approval
BEPAC	Building environmental performance assessment criteria	Canada, 1993	Developed by the University of British Columbia Similar to BREEAM but a more detailed and comprehensive assessment method Limited to new and existing office Uses a point system for rating, A voluntary tool

CASBEE	Comprehensive assessment system for building environmental efficiency	Japan, 2004	A co-operative project between industry and government Applicable in accordance with the stages of a development in pre-design, new construction, existing building and renovation It is based on the concept of closed ecosystems to determine the environmental capacities Consideration for regional character
CEPAS	Comprehensive environmental performance assessment scheme	HK, 2001	Developed by the Building Department For all types of existing and new buildings To serve as a unified yardstick for a common, comprehensive assessment scheme for buildings Eight performance categories Employing an additive/weighting approach
CPA	Comprehensive project Evaluation	UK, 2001	Developed by the Royal Institution of Chartered Surveyors and the Environment Agency Different from a building performance method as it is used to assess projects during the development process using a combination of financial & economic approach A multi-criteria analysis approach to assess environmental and social impacts of a project A checklist-type evaluation framework that requires an independent assessor to undertake the assessment A voluntary tool
SPeAR	Sustainable project appraisal routine		A project assessment methodology within Over Arup's consulting projects To enable a rapid review of project sustainability Use a graphical format to present sustainable design To identify opportunities to optimize performance Rated on a scale of +3 to -3 In 4 main elements: environment, social, economic and natural resources
Eco-Quantum		Netherlands	The only method that is explicitly and comprehensively based on life-cycle assessment Assess the environmental burden of a complete building on the basis of LCA Easy to use and has extensive database of the most commonly used materials and products Not a comprehensive assessment method Only applicable to single residential buildings
EMGB	Evaluation manual for green buildings	Taiwan, 1998	Operated by the Ministry of Interior Consists of 9 environmental criteria A single tool for all types of buildings Not able to reflect regional differences Only assess the quantifiable criteria and non quantifiable issues are omitted Assess the least number of performance criteria

EPGB	Environmental performance guide for building	Department of Public Works and Services, NSW	Assess buildings using a framework of environmental performance into 5 categories Useful to consider resource consumption & loadings Buildings are rated and a single indicator for the total performance
DQI	Design quality indicator	UK	Supported by the UK Construction Industry Council A toolkit used throughout the development process Aims at improving the design of buildings by providing feedback and capturing perceptions of design quality embodied in buildings Assess buildings in three main categories: functionality, build quality and impact Aim at assisting clients in defining their aspirations to which project's success will be measured against
GBTool	Green building challenge	International 1995	The most comprehensive framework International collaboration of over 20 countries Absolute performance indicators to complement the relative scores More than 90 individual performance assessment Four levels of weighting
GHEM	Green home evaluation Manual	China, 2001	Introduced by the Science and Technology Development Promoting Centre and Ministry of Construction The first environmental standards and design guidelines related to performance standards Only relates to residential projects Simple rating that without explicit weighting system to address resources allocation and indoor environmental quality No clear definition for the degree of severity for unsatisfied pre-requisite requirements
Green Star		Green Building Council	Australia's first comprehensive method for evaluating environmental building performance For commercial buildings only Rating system on a scale from 0 to 6 stars
HKBEAM	Hong Kong building environmental assessment method	Hong Kong, 1996	Has separate assessment methods for new and existing office buildings It has been criticized as assessing the quantifiable criteria but the non-quantifiable social and environmental issues have been deliberately ignored Assessing new building 'as built' rather than 'as designed' Assessment process not transparent Assessment categorized under the global, local & indoor scales Emphasis on life-cycle impacts Assessing building performance in grades ranging from fair to excellent

LEED	Leadership in energy and environmental design	USA, 2000	Developed by the US Green Building Council A certification process developed to create an industrial standard Self-assessing system awards rating of certified, silver, gold and platinum Use simple checklist format to rate building performance For new and existing commercial, institutional, high-rise residential & major renovation Comprises 5 areas of sustainability A voluntary tool
NABERS	National Australian building environmental rating system	Department of Environment and Heritage,	A performance-based rating system that measures an existing building's overall environmental performance during operation For existing commercial buildings and houses Self-assessment accredited ratings score out of 10
NatHERS		CSIRO	Computer-based house energy rating system To give houses an energy efficiency rating from 0 to 5 stars 0 star being inefficient whilst 5 star indicates high level of energy efficiency

Source: Ding, G.K.C., Sustainable construction—The role of environmental assessment tools, *Journal of Environmental Management*, 86, 451–464, (2008).

4. LEED Rating Systems

LEED System was first published in 1999, it has been helping to improve the quality of buildings and their impact on the environment. LEED is a certification program that gives the tools to have a measurable impact on buildings' performance. LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality [9]. LEED rating system includes the following scoring modules[2]:

- ***New Construction***

LEED for New Construction and Major Renovations is designed to guide and distinguish high-performance commercial and institutional projects.

- ***Existing Buildings*****:** Operations & Maintenance

LEED for Existing Buildings: Operations & Maintenance provides a benchmark for building owners and operators to measure operations, improvements and maintenance.

- ***Commercial Interiors***

LEED for Commercial Interiors is a benchmark for the tenant improvement market that gives the power to make sustainable choices to tenants and designers.

- ***Core & Shell***

LEED for Core & Shell aids designers, builders, developers and new building owners in implementing sustainable design for new core and shell construction.

- ***Schools***

LEED for Schools recognizes the unique nature of the design and construction of K-12 schools and addresses the specific needs of school spaces.

- ***Retail***

LEED for Retail recognizes the unique nature of retail design and construction projects and addresses the specific needs of retail spaces.

- ***Healthcare***

LEED for Healthcare promotes sustainable planning, design and construction for high-performance healthcare facilities.

- ***Homes***

LEED for Homes promotes the construction of high-performance green homes.

- ***Neighborhood Development***

LEED for Neighborhood Development integrates the principles of smart growth, urbanism and green building into the national program for neighborhood design.

5. Assessment Process

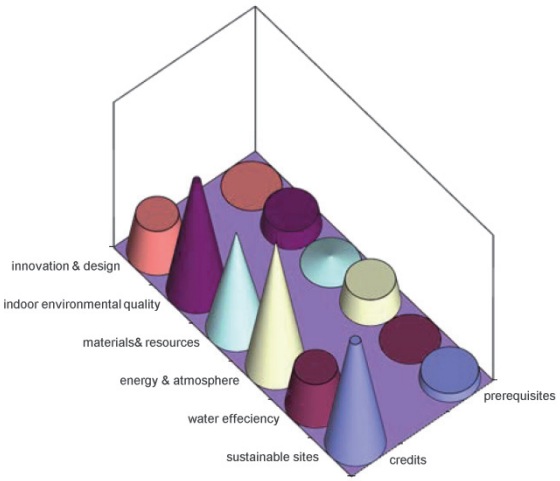
LEED checklist has six categories: 1) site selection, 2) water efficiency, 3) energy and atmosphere, 4) indoor environment, 5) materials used, and 6) innovation and design process. The categories have some prerequisites must be achieved, and some credits. Based on the number of recorded points, the project can be rated to get the platinum, golden, silver, or certified rates. But as for the evaluation here, and because it is not a matter of ranking, the paper only benchmarks the

points achieved as percentage of each categories as a guide for the overall performance of the building (Fig. 3) [9].

Project Totals are 69 Possible Points. For LEED NC., V2.2, Certified 26–32 points Silver 33–38 points Gold 39–51 points Platinum 52–69 points [9], while for LEED NC. 2009, there are some more points for can be awarded for (Regional Priority), up to 4 credits are identified as Regional Priority credits. Projects outside of the U.S. are not eligible for Regional Priority credits [10].

6. The Case Study

The case study presented and evaluated is a commercial building, located in Dammam city, Eastern Province, KSA. The lot area is 59,113.13 m^2, and the building area is 50,589.54 m^2. The building consists of ground floor used as covered parking, entrances and few anchor stores and shops, the first floor is mainly for shopping and food courts, while the mezzanine is for administrative offices and services. The building accommodates 180 shops, restaurants, play area, services, and 1,395 covered and on streetcar parking (Fig. 4- 6).



	credits		prerequisites
sustainable sites	14		1
water effeciency	5		0
energy & atmosphere	17		3
materials& resources	13		1
indoor environmental quality	15		2
innovation & design	5		0

Fig. 3. LEED's Categories and their credits and prerequisites [9].

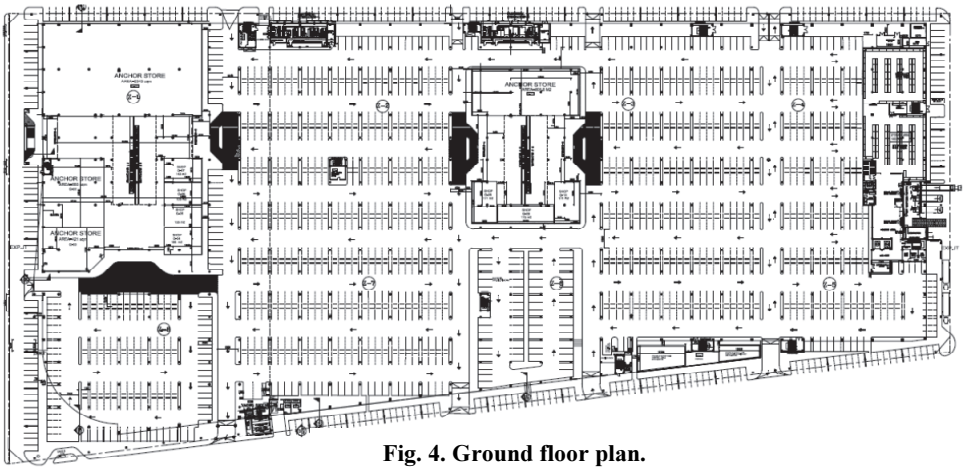


Fig. 4. Ground floor plan.

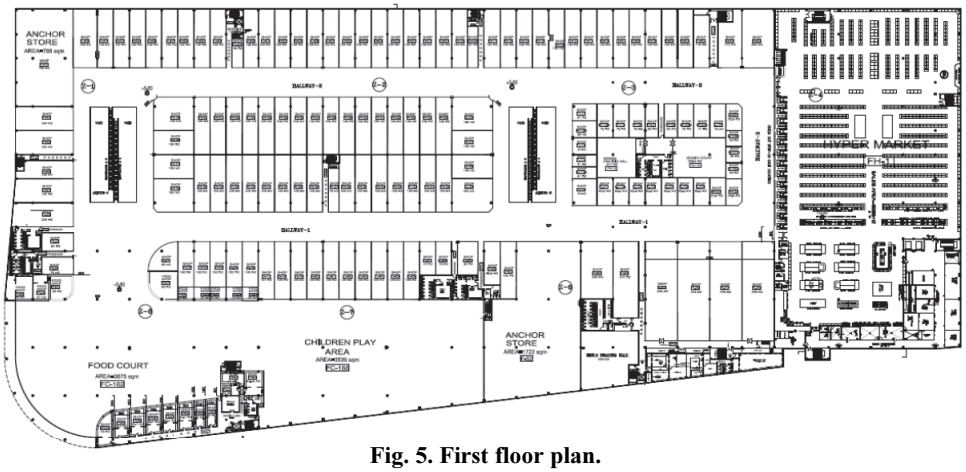


Fig. 5. First floor plan.

Fig. 6. The case study.

7. Analysis and Findings

Table 5 summarizes the findings, technical changes suggested, and expected outcomes of changes. Applying the evaluation and scoring system of LEED, the following results are recorded:

7.1 Sustainable Sites

The building scores only few points for:

o Site selection: the building is not built on a farmland, or on land specified for threatened habitat lists, location is not within 50 feet of water bodies, and its land is not a parkland site.

o Development density and community connectivity: the building is constructed within 1/2 mile of a residential zone and within 1/2 mile of basic services with pedestrian access between the building and the services. The location is along a high street connecting different districts of the city of Dammam. Basic services available there are: public park, mosques, grocery shops, bookshop, bakery, barbershop, laundry, meat shop, fresh vegetables and fruits shop, and schools.

o Alternative transportation, parking capacity: the parking capacity is designed to meet local zoning requirements, and there are parking areas can be used for carpools or vanpools with drop off and pick up areas.

o Heat island effect non-roof: as the project places more than 50% of parking spaces under the building. The ground floor is all designated for parking, with minimum area for the entrances of the mall.

o Heat island effect roof: as the finishing materials of the roof are of high-reflectance materials that reflect much of the sunlight. Materials used are very light color coating plaster applied on the plain concrete on the slabs. In addition, for the skylight, the corrugated sheets used have high reflectance value that does not affect the microclimate of the building.

o Light pollution reduction: most of the building facades are opaque, without windows. Minimum external curtain walls are used for the entrances only. As a result most of the internal lighting fixtures don not leak light to outside of the building.

7.2 Water Efficiency

The building scores only few points for:

o Water efficient landscape, reduce by 50%: as there is no landscape around the building and as a result there is no use of potable water.

o Water efficient landscape, no potable use or no irrigation: As there is, no permanent irrigation required for the site.

o Water use reduction by 20%: the lavatory faucets are of the photocell type, that open and close automatically by sensors of users. This helps reduce the burden on the municipal water supply and waste water systems.

7.3 Energy & Atmosphere

The building scores only one point for:

o Fundamental commissioning of the building energy system: As the project, owner has designated an individual as the Commissioning Authority to lead, review and oversee the completion of the commissioning process activities.

7.4 Materials & Resources

The building scores only few points for:

o Storage & Collection of recyclables: there is an area that serves the entire building and is dedicated to the collection and storage of non-hazardous materials for recycling, including paper, corrugated cardboard, glass, plastics and metals.

o Regional materials, 10& 20% extracted, processed& manufactured: as there are many building materials, which are regionally produced in KSA and Emirates or less than 500 miles, based on the cost. The materials include bricks, cement, reinforcement, ceramic tiles and others.

7.5 Indoor Environmental Quality

The building scores only few points for:

o Environmental Tobacco Smoke: smoking is prohibited in the building.

o Low emitting materials, composite wood & agrifiber products: as the particleboard, medium density fiberboard (MDF), plywood composite wood products used on the interior of the building contain no added urea-formaldehyde resins. Laminating adhesives used to fabricate on-site and shop-applied composite wood and agrifiber assemblies contain no added urea-formaldehyde resins.

o Indoor chemical & pollutant source control: there are permanent entryway systems in the primary direction of travel to capture dirt and particulates from entering the building. The system includes grilles and slotted systems that allow for cleaning underneath. In addition, parking lot occupies the ground floor in the open space so that it helps take cars exhaust out of building and allow fresh and clean air to replace it.

o Controllability of systems, lighting: there are individual lighting controls for the shops and spaces in the building to enable adjustments to suit individual task needs and preferences.

o Controllability of systems, thermal comfort: there are individual thermal comfort control system for the shops, which have their own AC units separate from the AC system used for the corridors and food court areas. This enables adjustments to suit individual task needs.

While the building achieved some credits and prerequisites of LEED system, (displayed in Fig. 7, 8), the building lacks many other points. The overall credits achieved are 15 credits (22%) out of 69 possible ones. In addition, the overall prerequisites achieved are 3 (43%) out of required 7 prerequisites. The main problem of the building is related to the energy and atmosphere aspects. The building gains zero credit out or the 17 credits related to the energy and atmosphere. The maximum performance efficiency of the building is recorded in water use, which is relatively accepted as the building gains 3 credits (60%) out of 5 available credits.

The building performance records 43% in sustainable sites selection aspects, 27% in indoor environmental quality aspects, and 15% in materials and resources aspects. As a result, the building is poor in its environmental performance related to sustainability issues established by LEED rating system. The building needs much more thorough studies and environmental management policies to enhance its sustainability criteria for better microclimate, health, and productivity for the occupants and users, and for a better environmental quality for the site location and surrounding context.

Table 5. Summery Sheet of the Assessment of the Building and Technical Changes Suggested and Their Expected Impacts.

Assessment criteria (USGBC 2009)	achieved	Not achieved	Suggested technical changes	Impacts of changes
Sustainable Sites				
Prereq 1 Construction Activity Pollution Prevention		×	NA	
Credit 1 Site Selection	✓			
Credit 2 Development Density & Community Connectivity	✓			
Credit 3 Brownfield Redevelopment		×	NA	
Credit 4.1 Alternative Transportation, Public Transportation Access		×	Arrange with the municipality to provide a bus line and station	reduce dependency on private cars and fuel consumption
Credit 4.2 Alternative Transportation, Bicycle Storage		×	Provide cycle racks, storage and shower rooms near to the building entrance	reduce dependency on private cars and fuel consumption
Credit 4.3 Alternative Transportation Fuel Efficient Vehicles		×	Support the use of fuel-efficient vehicles by providing parking areas assigned for this type of vehicle in very suitable locations. Install alternative fuel fueling stations.	reduce fuel consumption by transportation
Credit 4.4 Alternative Transportation, Parking Capacity	✓			
Credit 5.1 Site Development, Protect or Restore Habitat		×	Provide plantation areas around the site and indoor plants as well	promote biodiversity
Credit 5.2 Site Development, Maximize Open Space		×	Provide open spaces in the lot next to the site, and study the possibility of providing a partially covered roof garden in the building	promote biodiversity
Credit 6.1 Storm water Design, Quantity Control		×	Collect storm water and reuse for landscape irrigation and toilet flushing. use vegetated roofs, and pervious paving materials	save storm water flows and promote infiltration
Credit 6.2 Storm water Design, Quality Control		×	Use vegetated filters and open channels to treat storm water runoff.	reduce pollution of runoff water
Credit 7.1 Heat Island Effect, Non-Roof	✓			
Credit 7.2 Heat Island Effect, Roof	✓			
Credit 8 Light Pollution Reduction	✓			
Water Efficiency				
Credit 1.1 Water Efficient Landscaping, Reduce by 50%	✓			
Credit 1.2 Water Efficient Landscaping, No Potable, No Irrigation	✓			

Table 5. Ccontd.

Assessment criteria	achieved	Not achieved	Suggested technical changes	Impacts of changes
Credit 2 Innovative Wastewater Technologies		×	Use onsite wastewater treatment such as biological nutrient removal systems, and high efficiency filtration systems	reduce wastewater volume
Credit 3.1 Water Use Reduction, 20% Reduction	✓			
Credit 3.2 Water Use Reduction, 30% Reduction		×	Increase the use of water saving fixtures and fittings such as water closets and kitchen sinks.	reduce the burden on the municipal water and waste
Energy & Atmosphere				
Prereq 1 Fundamental Commissioning of the Energy Systems	✓			
Prereq 2 Minimum Energy Performance		×	Use a computer simulation model to assess the energy performance and the most cost-effective measures. Comply with ASHREA Energy Design Guide of Retail Buildings 2006	reduce environmental and economic impacts resulting from use of excessive energy
Prereq 3 Fundamental Refrigerant Management		×	Identify HVAC equipments that use CFC refrigerants and prepare replacement schedule for them, then specify new equipment that use no CFC –based refrigerants	reduce ozone depletion
Credit 1 Optimize Energy Performance		×	NA	
Credit 2 On-Site Renewable Energy		×	Use any of photovoltaic cells, wind power, biogas, or geothermal power systems to provide part of the required building energy	reduce use of fossil fuels and its related environmental problems
Credit 3 Enhanced Commissioning		×	NA	
Credit 4 Enhanced Refrigerant Management		×	NA	
Credit 5 Measurement & Verification		×	Create a baseline performance of a similar energy efficient building by computer simulation. Install metering equipments to measure energy use, and evaluate the energy system performance of the building, compare the actual consumption with the baseline performance	provide continuing liability of energy consumption of the building
Credit 6 Green Power		×	Connect the building to a grid source of renewable energy with adjacent buildings	reduce pollution related to energy to zero

Table 5. Contd.

Assessment criteria	achieved	Not achieved	Suggested technical changes	Impacts of changes
Materials & Resources				
Prereq 1 Storage & Collection of Recyclables	✓			
Credit 1.1 Building Reuse, Maintain 75% of Existing elements		×	NA	
Credit 1.2 Building Reuse, Maintain 95% of Existing elements		×	NA	
Credit 1.3 Building Reuse, Maintain 50% of Non-Structural Elements		×	NA	
Credit 2.1 Construction Waste Management, Divert 50% from Disposal		×	NA	
Credit 2.2 Construction Waste Management, Divert 75% from Disposal		×	NA	
Credit 3.1 Materials Reuse, 5%		×	NA	
Credit 3.2 Materials Reuse, 10%		×	NA	
Credit 4.1 Recycled Content, 10% (post-consumer + 1/2 pre-consumer)		×	NA	
Credit 4.2 Recycled Content, 20% (post-consumer + 1/2 pre-consumer)		×	NA	
Credit 5.1 Regional Materials, 10% Extracted & Manufactured regionally	✓			
Credit 5.2 Regional Materials, 20% Extracted & Manufactured regionally		×	NA	
Credit 6 Rapidly Renewable Materials		×	NA	
Credit 7 Certified Wood		×	NA	
Indoor Environmental Quality				
Prereq 1 Minimum IAQ Performance		×	Change the ventilation system to meet ASHREA standards	ensure comfort and wellness of the users
Prereq 2 Environmental Tobacco Smoke (ETS) Control	✓			

Table 5. Contd.

Assessment criteria	achieved	Not achieved	Suggested technical changes	Impacts of changes
Credit 1 Outdoor Air Delivery Monitoring		×	Install airflow and Co^{2} measuring tools, and use alarm systems for possible deficiency in outdoor air delivery	promote occupants comfort and wellness
Credit 2 Increased Ventilation		×	Use heat recovery systems to minimize the additional energy consumption associated by higher rates of ventilation	promote users health and productivity
Credit 3.1 Construction IAQ Management Plan, During Construction		×	NA	
Credit 3.2 Construction IAQ Management Plan, Before Occupancy		×	NA	
Credit 4.1 Low-Emitting Materials, Adhesives & Sealants		×	When refurbishing the buildings, use materials that comply with the Air Quality Management, or the Green Seal Standard, whichever is appropriate	reduce indoor contamination
Credit 4.2 Low-Emitting Materials, Paints & Coatings		×	When refurbishing the buildings, use materials that comply with the Air Quality Management, or the Green Seal Standard, whichever is appropriate	reduce indoor contamination
Credit 4.3 Low-Emitting Materials, Carpet Systems		×	When refurbishing the buildings, use materials that comply with the Air Quality Management, or the Green Seal Standard, whichever is appropriate	reduce indoor contamination
Credit 4.4 Low-Emitting Materials, Composite Wood Products	✓			
Credit 5 Indoor Chemical & Pollutant Source Control	✓			
Credit 6.1 Controllability of Systems, Lighting	✓			
Credit 6.2 Controllability of Systems, Thermal Comfort	✓			
Credit 7.1 Thermal Comfort, Design		×	Introduce passive heating and cooling systems within the buildings such as: Trombe wall, sun space, thermal chimney …	reduce AC heating and cooling loads
Credit 7.2 Thermal Comfort, Verification		×	Provide monitoring systems for the thermal environment and prepare corrective measures.	assess the thermal comfort of occupants
Credit 8.1 Daylight & Views, Daylight 75% of Spaces		×	NA	
Credit 8.2 Daylight & Views, Views for 90% of Spaces		×	NA	

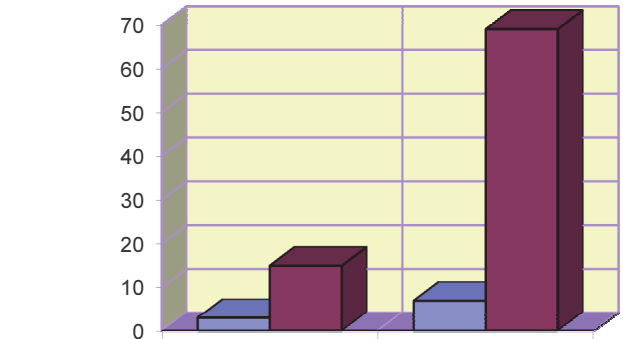
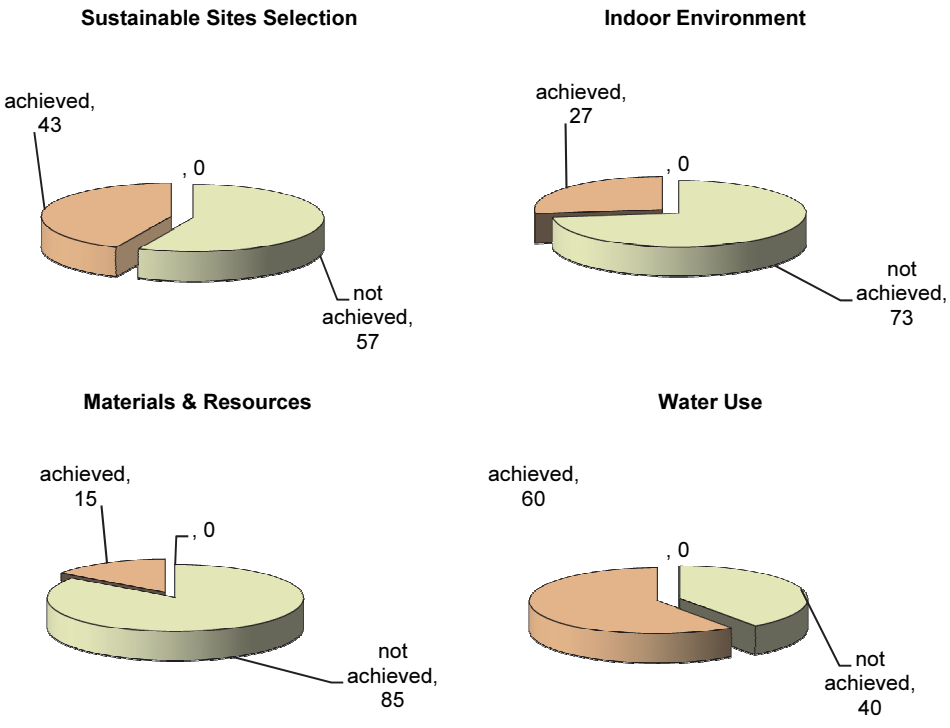


Fig. 7. The case study environmental performance based on LEED rating system.



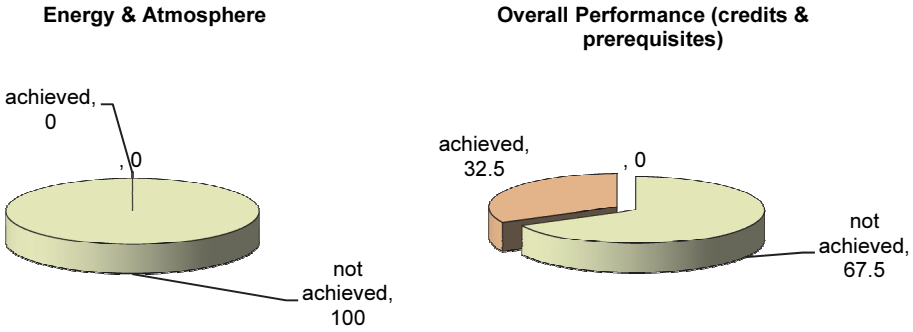


Fig. 8. The performance of the case study.

8. Recommendations

Based on the outcomes of this paper, two levels of recommendation are suggested;

o Case study related recommendations: More attention should be directed to the building performance especially in the aspects of: providing parking spaces and changing rooms for cyclists, light pollution reduction through the building envelop, waste water treatment technology, water use reduction, minimum energy performance, on-site renewable energy production and green power, minimum IAQ performance, outdoor air delivery monitoring, increased ventilation, control and verification of thermal comfort, and day lighting wherever appropriate.

o General aspects recommendations: Sustainability issues should be a benchmark in all real estate development in KSA and the governmental should have a very strong role to ensure the achievement of such issues. Workshops, training courses, symposiums should be planned for building professionals in both private and public sectors to emphasize the importance and strategies of achieving sustainable built environment. Schools, architectural groups, engineers syndicate, should have leading efforts in increasing the public awareness of sustainable environmental development for the public.

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استخدام نموذج LEED للتقييم البيئي لمعايير الاستدامة: دراسة حالة بمركز تجاري

محمد عبد الموجود عبد الغفار

كلية العمارة والتخطيط، جامعة الدمام، المملكة العربية السعودية

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المستخلص: ثبت عمليا التأثير البيئي الضار لصناعة البناء، الذي تمثل في مشاكل منها الاستهلاك الزائد للموارد الطبيعية، والتلوث. لذا تهتم العديد من الدراسات بالتصميم البيئي واستخدام مواد البناء بطرق تقلل التأثيرات الضارة كما تطورت نظم التقييم البيئي لأداء المباني. بالرغم من ذلك، فما زالت العديد من دول الشرق الأوسط بما فيها دول الخليج، لا تولي الاهتمام اللازم للمشاكل البيئية المرتبطة بصناعة البناء. قد يكون ذلك لنقص الوعي البيئي لدي المجتمع وعند صناع التشييد في دول الشرق الأوسط عامة، أو للاعتماد علي الثروات التي أتاحت الاستخدام الجائر لمصادر الطاقة والموارد الطبيعية بدون اعتبارات لاحتياجات الغد.

تتمثل أهداف البحث في جذب انتباه المستخدمين إلي أهمية التقييم البيئي للمباني بالمملكة العربية السعودية، وعرض لوسائل التقييم البيئي لتحقيق مبادئ الاستدامة، وتقديم نموذج تقييم الأداء البيئي للمباني LEED ، ثم استخدامه كوسيلة في تقييم أحد المجمعات التجارية بالدمام. وتم التقييم علي أساس المواصفات البيئية الخاصة بالموقع والمبنى وطريقة البناء والتشغيل وكفاءة استخدام الطاقة واستهلاك المياه ونوعية البيئة الداخلية التي يوفرها ونوعية مواد البناء المستخدمة.

يقدم البحث شرحا مبسطا لنموذج التقييم أولاً، ثم يعرض حالة تطبيقية لتقييم مركز تجاري بالدمام، وقد تم اختيار النشاط التجاري لأنه السمة الغالبة والاتجاه الملحوظ في معظم مشروعات التنمية والتطوير العقاري بدول الخليج عامة وهو من أهم عناصر الاستثمار العقاري السائد في مخططات التنمية العمرانية الحالية بكامل أنحاء المملكة. وقد استخدم المنهج الوصفي لوصف الظاهرة المدروسة وتصويرها كميا، والمنهج المقارن لإجراء مقارنة بين الظاهرة المدروسة وما يماثلها من متطلبات نموذج LEED . وأظهرت نتائج البحث أن المبنى حقق بعض النقاط المطلوبة في تقييم LEED وغابت عنه كثير من النقاط الأخرى. وما حققه المبنى يمثل ٢٢٪ (١٥ نقطة من إجمالي ٦٩ نقطة متاحة)، أما المتطلبات الأساسية في التقييم فقد حقق المبني منها ٤٣٪ (٣ نقاط من بين ٧ مطلوبة).

ترتبط المعضلات الأساسية بالمبنى بالطاقة و المناخ، فلم يحقق المبنى أيا من النقاط من بين ١٧ نقطة متاحة. أما أعلى كفاءة حققها المبنى فكانت في استخدام المياه (٣ نقاط من بين ٥ نقاط). وبالنسبة لخصائص الموقع وارتباطه بالاستدامة، فقد حقق المبنى ٤٣٪ منها، وحقق المبنى ٢٧٪ في عناصر البيئة الداخلية وجودة الهواء بالمبنى، وحقق ١٥٪ في عناصر مواد البناء والموارد الطبيعية. لذلك يعتبر المبني فقيرا في أدائه البيئي.

أوضحت التوصيات أن المبني يحتاج إلى العديد من الدراسات والإدارة البيئية الدقيقة المهتمة بالتفاصيل لتطوير أدائه وتحقيق مناخ داخلي أفضل لزيادة صحة وإنتاجية المستخدمين وتحقيق جودة بيئية أفضل للموقع وما يحيطه.

الكلمات المفتاحية: أداء المباني، التقييم البيئي، الإنشاء المستدام، التنمية المستدامة، نظام ليد.