

# Performance Assessment for Existing Jordanian Governmental School Buildings and Exploring the Impact of Sustainable Strategies

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**Abstract—** The building project can be considered sustainable only when dealing with all dimensions of sustainability (environmental, economic, social and cultural). Reducing of the environmental impact, promoting human health, and increasing environmental awareness among sustainable users and schools is the most appropriate strategy for renewing and achieving quality education. The purpose of this study is to measure problems related to comfort (thermal, visual and acoustic) and satisfaction of school users (students, teachers, and other staff) and improve the performance of the building by assessing the impact of proposed strategies for sustainability in performance building. This research paper was based on the selection of a sample of governmental schools in Jordan and the study of energy and water consumption for this sample to reach a series of results. The research includes two main axes, the first axis focuses on measuring the problems related to the comfort of school users (students, teachers, and other staff) through the research questionnaire, and the second axis is how to improve the performance of the building by assessing the impact of proposed strategies on building performance through a Simulation Program (Design Builder Program). The need for such research in Jordan is increasing, especially in the public sector (government schools) where there are no indicators to measure sustainable buildings specifically in governmental schools.

**Keywords—** Educational Environment; Sustainability; Day lighting; Indoor Air Quality; Thermal Comfort; Visual Comfort; Sound Comfort; Energy Consumption; Water Consumption

## I. INTRODUCTION

The goal of sustainable architecture is to build an environment and a well-designed and healthy site for users, with minimal impact on the environment, efficient in the use of natural resources and economically efficient. Although visible impacts are visible only after the start of construction and the tangible effects are actually within the building strategies and objectives, the decisions taken on the

drawing board have long-term environmental consequences for the building as well as the surrounding environment. Based on the above, sustainable school is a building which can Reduce the environmental impact, promote human health, and increase environmental awareness among users. Therefore, it is a strategy for renewing education and enhance it quality. [1].

The school environment plays a major role in increasing or decreasing learning capacity. They spend about five to seven hours a day at school for about twelve years. In all these hours and days, the school uses energy and electricity to provide good conditions for students to achieve the goal of the study. this research will reduce energy consumption by reducing the use of electricity and water in the school building through the proposed sustainable strategies while ensuring a comfortable environment for users, whether students or workers.

### A. Issue

The main issues in this research are that there is no indicator of the application of sustainable technology in governmental school buildings in Jordan, lack of plans to increase levels of the sustainable school environment, and the growing demand for energy and water in a country poor in the fields of water and energy, such as Jordan.

### B. Background context of research

This study focuses on Jordanian government schools, as it constitutes the largest sector that serves the educational process in Jordan, The taken case study is the Ateka Primary school for girls in Wadi Musa at Petra Region Authority, The school is located in a medium-density residential area that has a close community, and grades are from the First to the Seventh grade.

### C. Methodology

This research will use an exploratory study by extracting general framework guidelines from previous theories and studies, in addition to a descriptive and analytical study through the case study that has been chosen to be analyzed, a simple 3-page questionnaire was conducted on the satisfaction of students in the classroom with regard to comfort issues (thermal,

visual and sound) School for information related to energy and water in school and other information as well as interviews with stakeholders, staff, and teachers at school as well as observations by researchers from the school, the results from the questionnaires, interviews, and observation will be compared to the data which will be extracted from the simulation program - Design-builder - which is a performance evaluation tool that was selected for evaluation because of its popularity and widespread use, which is a state-of-the-art software tool for checking building environmental performance including energy, carbon, lighting, comfort and cost performance.

The occupants of the school are the (students, teachers, and staff who work there), the number of students in the school is 140 students and the number of teachers and staff 20. the principle of the school was selected as targeted sampling in order to fill the interview and the questionnaire of energy and water, 20 students were selected as a random sampling for the questionnaire.

## II. LETTRATURE REVIEW

Sustainable building is a fully built, fully integrated design, construction, and operation process. Sustainable buildings, known as green buildings or high-performance buildings, are designed to achieve optimal environmental and economic performance; to increase the efficiency of energy, water, and other resources; Renewable energy and renewable energy; renewable productivity; and education of building occupants on conservation and efficiency, also referred to as the high-performance building; energy saving, high efficiency, optimum productive, environmental and economic performance; Use of renewable; and educating occupants about efficiency and conservation.[1]. Sustainable schools create an environment where teachers and faculty can cultivate a positive and progressive school culture.[2] [3].

There are many sustainability strategies that the building must go along with, and based on previous studies, sustainability strategies in relation to the field of school buildings are as follows.

### A. Sustainability of the Site

Site planning is critical in any architectural drawing; you must pay close attention to it and important details should not be neglected or ignored in order to make them sustainable. It's important to show the location limits, improves the overall quality of the building design as well as helps restore and maintain the natural features of the site. [4].

- Enhance the current environment

A typical Architectural site plan must include some basic items such as the accessibility, circulation, and driveway to the site, surrounding streets, green areas, parking, land drainage, privacy, security, shelter, property lines, and all boundaries, the existing and proposed conditions of the site with well-detailed

dimensions. [5]. To achieve a sustainable site plan, the site should have the least environmental impact, serve a minimum cost, fits within the typical project parameters as well as meets the client's and users' project goals. A sustainable site plan meets the needs of the local community by support activities life of the community, encourage to healthy lifestyles create ecosystem services and sense of place. [6].

- Land use and ecology of the building site

Sustainable sites promote responsible, innovative and practical principles of site maintenance, using plant, wildlife, and water and air quality strategies. These principles also reduce some of the negative impacts of its buildings on the local and regional environment. Environmentally sensitive site maintenance practices reduce site operations and maintenance costs through creating outdoor space that is attractive and healthy for both buildings, built environment and local flora and fauna. [7].

### B. Transportation and connection to the boarder urban

Pedestrian walkways and school routes should be improved to provide more security and comfort and to encourage parents about the safety of walking and transfer to school.[8]. this should be improved in the development of policies and programs which related to safe routes to school safer, this effort implied by road safety education for both children and drivers, traffic flow enforcement around the school and by environmental engineering along the road to school to control traffic flow, pedestrian and cycling facilities. [9].

### C. Community of the School

- Use of functions

The distribution of vacancies in schools is closely related to cost. Students, teachers, and staff are affected by the distribution and quality of these spaces, and there are many alternatives that aim to reduce material costs while achieving the objectives of comfort and satisfaction of users and have little impact on the environment. [10].

- Integrating with surroundings and local community

When families, community groups, businesses, and schools come together to support learning, young people get more at school, stay in school longer, and enjoy the experience more. [11].

### D. Educational Environment

The design of sustainable school buildings is of great importance to sustainability education, which is reflected in the Convention on the Rights of the Child. Some of these standards are appropriate lighting to ensure the comfort of places of education, the use of daylight as much as possible, the comfort of sound in places, Natural ventilation, air conditioning, energy efficiency, and green spaces. [2].

- Daylighting and Student Performance

Daylighting refers to the natural sunlight to illuminate the tasks normally provided by artificial lighting fixtures, also, Daylight is an effective way to provide better learning and health conditions in schools. Poor Daylight causes discomfort, which reduces learning and is harmful to the physical and mental health of the students. Synthetic lighting causes stress, fatigue, and dysfunction among students. [12]. Sustainable schools with natural light sources reported significant increases in test scores, advances in reading and mathematics. [3].

- Indoor Air Quality

Air quality is concerned with chemical and biological that can have a negative impact on the health of students, faculty and staff. [13]. Indoor air quality (IAQ) is an important issue that has both short term and long-term impacts on the health of users. [14], educational places are those that contain educational activities such as reading and writing. In order to make these activities possible, the indoor air environment must meet the requirements of comfort and identify the parameters of the indoor air quality. [15].

The quality of the internal environment is a significant internal experience of the internal environment of buildings includes aspects of design, analysis, and operation of energy-efficient, healthy, and comfortable buildings and fields include architecture, HVAC design, thermal comfort, indoor air quality, lighting, acoustics, and control systems. [16].

*E. Physical Comfort levels*

- Thermal Comfort

Thermal comfort has been defined as that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation. The thermal comfort of occupants in a given environment depends on different psychological, physiological and behavioral factors. The thermal comfort varies in different thermal environments from person to person. [16], Schools offer the same thermal environment to students coming from different socio-economic backgrounds. In ventilated classrooms, students adapt to the environment through exposure for a longer period of time or by controlling fan use, window openings, clothing, etc. According to the Humphreys study, in the event of a change to cause discomfort, people interact in ways that tend to restore their comfort. [17].

- Visual Comfort

Visual comfort in the classroom is a crucial factor in learning and is recognized as an enhanced learning process. Lighting levels define the quality of visual sense. Visual comfort is defined in the European Standard is a subjective condition of visual well-being induced by the visual

environment. Visual comfort depends on (i) the physiology of the human eye, (ii) the physical quantities describing the amount of light and its distribution in space, and (iii) the spectral emission of the light source. It has been commonly studied through the assessment of a series of factors regulating the relationship between the human needs and the light environment, such as (i) the amount of light, (ii) the uniformity of light, (iii) the quality of light in rendering colors, and (iv) the prediction of the risk of glare for occupants. [18].

- Sound Comfort

Sound comfort in Classroom is an important, often neglected aspect of learning environment. More than 60% of classroom activities involve speech between teachers and students or between students indicating the importance of environment that support clear communication. The Sound comfort parameters in classrooms have been focused on many issues related to sound comfort as surrounding noise levels, reverberation time, sound insulation, speech clarity, and acoustical materials. [19].

*F. Energy Consumptions in schools*

Energy is provided through the study of the integrated design of the building and construction by improving the external cover of the building through the use of special materials to prevent water leakage, moisture and heat insulation to prevent the transmission or infiltration of heat from inside to outside is the same through various thermal transfer (such as conduction, The use of high-efficiency heaters, lighting, and energy-saving through the direction of the building, as well as the use of variable speed ventilation systems that mean "renew, change, pass, replace" air in the vacuum by fresh air by creating airflow and air transfer in architectural spaces in this Natural entry and exit of the air, naturally entering the air and mechanically exiting, mechanically entering and exiting the air naturally and mechanically in and out of the air. The most efficient energy consumed in lighting is obtained by maximizing the use of daylight and the use of reflective shelves, in addition to the use of solar tubes. [20] [21].

*G. Water Consumptions in schools*

Schools need water for heating and cooling systems, restrooms, drinking water taps, tank rooms, cafeterias, laboratories, outdoor playgrounds, and lawns. To reduce water use in school, consider replacing old appliances such as dishwashers with energy-saving devices. Repair leaks and leaking toilets. Install water ventilators and automatic closures on taps. Use low-flow showerheads and temporary closures to minimize water use during showering. Install toilet dams on old models. Install flush toilets that separate water needs. [1].

The literature review leads us to say is that the conclusion is about the Jordanian government should begin to take action in designing and building the green school by referring to the general guideline, also to think uniquely for the Jordanian climate and culture.

### III. RESULTS AND DESSCUSSION

The results of this project were divided into three sections:

- Results and discussion of the questionnaire

Through our questionnaire in the classroom environment to measure the interior comfort in the classroom (thermal, visual and acoustic comfort), the selected classrooms where the Northern and Southern Classrooms. Accordingly, the results and discussion were shown as follows:

Firstly, The Southern Classrooms - Sixth Grade – first floor as the figure (1) below.

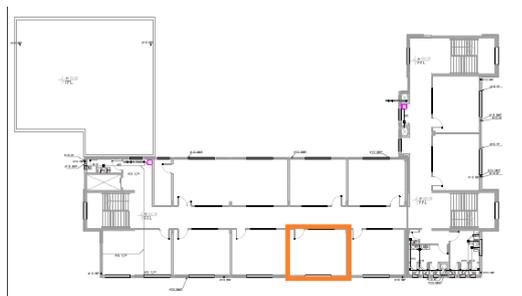


Figure (1): Sixth grade class

For the Thermal Comfort, 100% of students feel that the temperature is moderate in their class, 28% of students feel that the temperature is comfortable, 42% feel fairly comfortable, 28% do not know if the temperature is comfortable or not. 28% of the students feel that the temperature changes a lot during the day and 57% feel that the temperature changes slightly during the day, and 14% feel that the temperature never changes during the day, 14% of the students prefer to increase the temperature in the class, 28% prefer that the temperature drop in the class and 57% prefer to keep the temperature as it is in the classroom, 100% of students believe that the temperature is acceptable in class. 28% of the students feel that the air in class is very static, and 14% of the students feel that the air inside the classroom is static, 14% of the students feel that the air movement within the classroom is moderate, and 42% of students in the classroom feel that the air is moving slightly inside the classroom, 28% of the students prefer to increase the speed of air inside the classroom, 57% of the students prefer to lower the airspeed inside the classroom, and 14% of the students prefer to keep the airspeed as it is in the classroom, 100% of students feel that the airspeed is acceptable within the classroom, 14% of students feel

that the grade is wet, 28% of students feel that the grade is slightly damp, 57% of students feel that the humidity in the grade is moderate, 28% of students prefer to have less moisture in the classroom, and 71% of students prefer to keep the humidity as it is in the classroom, 28% of the students feel that the humidity in the class is unacceptable, while 71% of the students see that the humidity in the class is acceptable.

For the Visual Comfort, 28% of students feel that the intensity of lighting in the classroom is very comfortable, and 28% of the students feel that the intensity of the lighting in the classroom is somewhat comfortable, 28% of the students feel that the intensity of the lighting in the row a little annoying, And 14% of students feel that the intensity of lighting in the classroom is uncomfortable, 57% of the students feel that the intensity of lighting in the classroom should increase, 14% of the students feel that the intensity of the lighting should be lower, and 28% of the students feel that the intensity of the lighting should remain the same, 57% of the students feel that the light intensity in the classroom is acceptable, while 43% of the students feel that the lighting intensity in the class is unacceptable.

For the Acoustic Comfort, In the noise issue, sources of noise were divided into sources from inside the school and sources from outside the school. 34% of the students feel that the sounds coming from outside the school are not annoying, 14% of the students feel that the sounds coming from outside the school are a bit annoying, 28% of the students feel that the outside sounds are annoying, and 14% feel that The sounds coming from outside the school are very annoying, 28% of the students feel that the sounds coming from the schoolyard or adjacent classrooms are a bit annoying, and 28% of the students feel that the sounds coming from the schoolyard or adjacent classrooms are annoying, and 43% of the students feel that the sounds coming from the schoolyard or adjacent classrooms are very annoying.

Secondly, The Northern Classrooms - Seventh Grade – first floor as the figure (2) below.

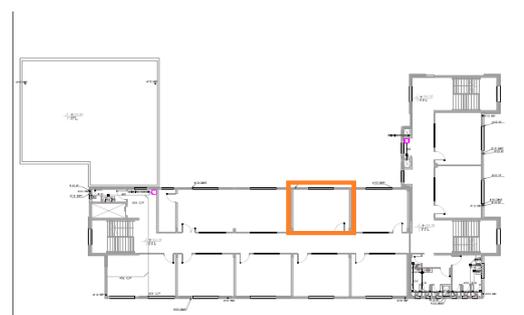


Figure (1): Sixth grade class

For the thermal Comfort, 83% of students feel that the temperature is moderate in their class, 8% of students feel that the temperature is a little cold, and 8% of students feel that the temperature is a little hot, 50% of students feel that the temperature is comfortable, 41% feel fairly comfortable, 8% do not know if the temperature is comfortable or not, and 8% of the students feel that the temperature is very comfortable, 8% of the students feel that the temperature changes a lot during the day and 60% feel that the temperature changes slightly during the day, and 8% feel that the temperature never changes during the day, and 16% of the students feel that the temperature changes during the day, 25% of the students prefer to increase the temperature in the class, and 75% prefer to keep the temperature as it is in the classroom, 91% of students believe that the temperature is acceptable in class, while 9% of the students believe that the temperature is unacceptable in the class.

The results showed that the northern seasons were slightly better in terms of thermal comfort, air movement, and moderate solar input. This variation was a result of the southern orientation of the southern classrooms, where the sun entering the southern classrooms and their long stay in these rooms increased heat and pressure.

For the Visual Comfort, 58% of students feel that the intensity of lighting in the classroom is comfortable, and 25% of the students feel that the intensity of the lighting in the classroom is somewhat comfortable, 8% of the students feel that the intensity of the lighting is annoying, And 8% of students feel that the intensity of lighting in the classroom is uncomfortable, 44% of the students feel that the intensity of lighting in the classroom should increase, 16% of the students feel that the intensity of the lighting should be lower, and 50% of the students feel that the intensity of the lighting should remain the same, 83% of the students feel that the light intensity in the classroom is acceptable, while 17% of the students feel that the lighting intensity in the class is unacceptable.

The results showed that the northern seasons were slightly better in terms of thermal comfort, air movement, and moderate solar input. This variation was a result of the southern orientation of the southern classrooms, where the sun entering the southern classrooms and their long stay in these rooms increased glow.

For the Acoustic Comfort, 41% of the students feel that the sounds coming from outside the school are not annoying, 33% of the students feel that the sounds coming from outside the school are a bit annoying, 25% of the students feel that the outside sounds are annoying, 8% of the students feel that the sounds coming from the schoolyard or adjacent classrooms are not annoying, 25% of the students feel

that the sounds coming from the schoolyard or adjacent classrooms are a little bit annoying, 58% of the students feel that the sounds coming from the schoolyard or adjacent classrooms are annoying, and 16% of the students feel that the sounds coming from the schoolyard or adjacent classrooms are very annoying.

- Results and discussion of the Simulation program

In the simulation program, the results were found in the period of whole school year from September to June. During the full school year, the dry bulb temperature ranges from 4 - 37 ° C, culminating in January and the lowest in January. At full school year, Air temperature is 24 ° C, which agrees with student's answers in temperature comfort, in the section of questionnaire results, the Total design capacity is 131.90 K.W, the Total flow rate is 7.78 m<sup>3</sup>/s, the Total Cooling load is 114.69 K.W, the sensible energy is 97.79 K.W, and the Latent energy is 16.90 K.W. At full school year, Air comfort temperature is 20.75° C, which agrees with student's answers in temperature comfort in the section of questionnaire results, the Total design capacity is 45.710 K.W.

- Results and discussion of the Observation

Through the researcher's visit to the school, the researcher's observations have a big role in the results and discussion section in this research, where they were linked to the results of the questionnaire and the results of the simulation program and appeared as follows.

In northern classrooms, the sun enters during the day because there are no sun protection shadings, so the temperature changes in the class during the day and this is agreed with the results of the questionnaire taken in this class, and the solution for this case is to put effective shading elements on the windows of the classes. Entering sunlight through the windows increases the intensity of the light on the school board which effects on the students' vision and achievement, and this is agreed with the results of the questionnaire taken in this class, and the solution for this case is to put effective shading elements on the windows of the classes.

The researcher noticed that there is a single glazed window as the figure above in each class in the school, which makes a noise distribution between the classes, and that agrees with the questionnaire results where the student's answers that they are feels a high level of noise coming from other classes, the solution would be making these windows double or triple glazed to navigate less noise.

The researcher noticed that windows of classes where double glazed which they are close to the schoolyard and the area near to school, which makes a noise for the students, and this agrees with the results of a questionnaire which shows that the students feel annoying because of the noise coming

from the schoolyard and near the area from the school, the solution would be making the windows triple glazed.

The researcher noticed that the lighting in the classroom, clearly showing a good and fair distribution of lighting for the users, but it would have been better if the lamps were energy-saving to reduce energy consumption in the school.

The researcher noticed that the Ceiling and wall material and temperature have a significant effect on the cooling load, and they look like the most optimized materials for ceiling and wall identified among several options, due to their colors, smoothness and design, the energy-saving of building elements such as walls, floors, windows, and ceilings was examined through the simulation program of the existing school building, how can the integration of these improved elements with the efficient air quality factor contribute to the achievement of the final energy-saving design, the results of the simulations show that the temperature in the cooling mode was 24 ° C and it's an appropriate temperature degree which agrees with the results of the questionnaire collected from the students, But these results can also be improved by the adoption of triple glazing for windows.

#### IV CONCLUSION

The primary goal of sustainability in schools is to promote learning and learning environments through healthy and vibrant internal environments, including excellent levels of natural light, ventilation, and high-quality outdoor environments that facilitate outdoor activities and does not cause unnecessary waste of energy, water or materials due to short life, poor design, inefficiency or poor construction and manufacturing procedures. So, the Good Sustainable school design is about providing schools and spaces suitable for purpose and designed to last, but also heightens the morale of all who use them, and design schools can enhance the performance of students and a more innovative approach to teaching and learning.

The design process in architecture depends on manipulating a large number of variables. The objective of the analysis of the results in this study was to identify these variables and to provide a method of optimal assistance in the physical configurations of the school that affect the standards of environmental comfort, this assistance is aimed at providing alternatives to improve minimizing energy consumption.

To promote sustainable design in schools, we recommend that sustainable school designs should give preference to materials that reduce environmental impact on their circuit. School management should have expertise in material performance assessment, and advice on the best solutions for thermal efficiency and users' comfort. Through the results obtained through the data collected from the questionnaires, interviews, researchers' notes and simulation programs, which show many important aspects of

sustainability that have not been used although they can be provided, which results from a clear saving in energy consumption.

Through this study, three main axes were found to demonstrate the need for sustainable school buildings where many studies have shown that student satisfaction and performance have a strong relation to the school environment by measuring the level of visual, auditory and thermal comfort and this was confirmed by the questionnaires that were carried out and the results analyzed, The second is the simulation program that was applied in the case study in this research which assesses the performance of the existing school building and develops alternatives that seek to reach a more sustainable school building, The third is the researcher's observations to assess the performance of the building and its surrounding environment in design and construction and its agreement with the results of the questionnaire the simulation program. The building, in this case, was evaluated by the simulation program and we found that the building in the southern classrooms needs increased cooling and protection from the sun and that the northern and southern classes need to increase their isolation because of the lack of acoustic comfort between them. This is done by using double or triple glazing in the interior windows of the building.

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