The Contribution Of Reformulating Environmental Architecture Redevelopment In Reducing The Negative Environmental Impacts Of Railway Stations

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Abstract: The United Nations Panel on Climate Change's multiple environmental assessments emphasized the importance of addressing effective circumstances for reducing the impact of worldwide warming and carbon emissions and adapting to climate change. This requires the solidarity of existing railway stations' architectural and urban development to reimage the sense of place, respect climate response, and reduce the negative environmental impact. Case study: Beni Suef railway station, where the methodology is based on the development of the present station in terms of the architectural concept, environmental impact, and energy conservation as the biophilic perspective to improve customer satisfaction and station performance.

Keywords: Environmental Impact, Architecture Redevelopment, HumanitariaArchitecture, Senses of Place, Beni Suef railway station.

1- Introduction

The national climate change approach reflected the strategy of dealing with the negative effects of worldwide warming to enhance client fulfillment, accomplish environmentally friendly progress, improve revenue, protect resources, and promote ecosystems. This necessitates encouraging participation from all sectors of society, including non-profit, social, and volunteer entities. Because transportation and energy are the two largest contributors to greenhouse gas emissions, alternative energy sources are emphasized [1]. Egypt's Ministry of Electricity and Renewable Resources adopted multiple actions to increase the investment in renewable energy to 42% of total electricity generation by 2035 [2]. The Egyptian government is working to improve rail station efficiency, expand public transit systems, including trains, activate carbon capture techniques, develop the goods train network, make optimal use of available clean energy resources, and encourage the switch to a green economy as well. New and existing buildings and communities must adhere to strict sustainability standards to reduce local electricity use while maintaining environmentally friendly conditions. Furthermore, global energy licenses must be activated at the architectural and urban scales [3]. Enforce national and international green coding and promote regional manufacturing of energy-efficient devices, mostly solar thermal energy conversion systems, piezoelectric floors, and photovoltaics. Building civil society agencies to measure carbon emissions from different entities and provide appropriate support to institutions that reduce carbon emissions Establishing automated systems, particularly in railway stations, and employing the most advanced and effective environmental methods to rationalize electricity use, increase efficiency, and increase productivity [4]. Figure 1 depicts the interconnections between the 2030 targets for sustainable development over climate action and the National Society's Climate Change Methodology, representing the standards required to reduce harmful environmental impacts and emissions in the railway station sector.

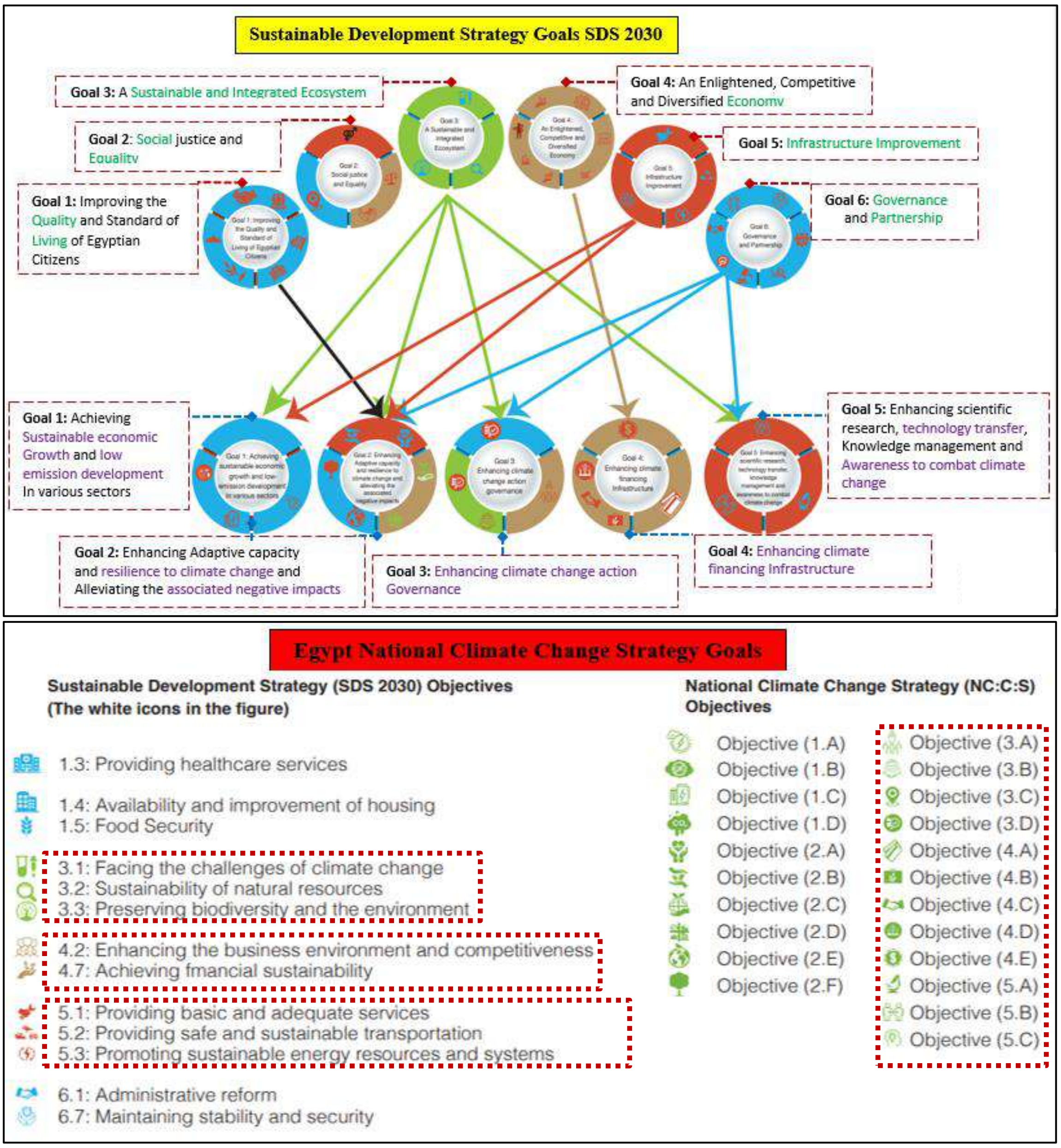


Fig.1: The Interconnections between Sustainable Development and the Climate Change Methodology [2]

2- Green Railway Stations

The world's consideration is focused on enhancing the efficiency of railway stations and mitigating their environmental impacts, as well as implementing green solutions to increase cost efficiency and improve passenger safety and well-being. Increasing investment and improving railway performance. One of the era’s challenges is the increasing emissions of CO2 and energy consumption, particularly by the railway sector, which requires solutions to boost energy efficiency and productivity and reduce the carbon footprint. One-fourth of CO2 emissions in the transport sector and 7% of total emissions are driven by urban transport. As the 27th session of the United Nations Conference on Climate Change reported, Egypt believes in enhancing reliance on green means of transportation. Because of this, environmentally friendly, integrated architectural solutions to eliminate the production of carbon and improve the standard of living in urban areas are crucial. The sustainability rating system is the most widely used for reviewing transportation systems, particularly railway stations, which include passenger terminals, warehouses, service buildings, and facilities. The assessment includes all energy, water, and waste use rates, all of which affect users’ lives and the environment, to find green solutions to reduce the environmental footprint. It is recommended that efficiency in railway stations involve the following: lighting Control (10–30%), exchange of wasteful lighting (10–40%), HVAC control through temperature control devices (10–20%), envelope insulation (10–30%), environmental techniques (20%), plus energy-efficient heat pumps (A+) up to 30% The appliance has an energy efficiency rating of A+ and a control range of 10–40%. In addition, activate investment and privileges for shops and kiosks to achieve 20% reductions in energy consumption [5]. Recently, the global architectural trend has shifted towards reducing negative environmental impacts, especially in railway stations, by adhering to the basic concepts of environmentally friendly building design, reducing energy use and carbon emissions, and implementing productive architectural approaches towards promoting a green economy and sustainability. The United Nations Programme's international climate change reports point to mitigating the consequences of warming climates in the short to medium term (until 2030) and indicate that the buildings and transport sectors contribute the most to the increase in global greenhouse gas emissions over the coming decades, which requires reducing them to about half of the current levels [6]. While reducing pollution, noise, and vibration levels at railway stations by greening the surrounding area, particularly those parallel to the railways. Use sound-absorbing materials, devices for train movement, and glass curtains [7]. Our country occupies the 27th place in the world ranking regarding energy pollutants responsible for global warming and generating carbon dioxide, accounting for 0.75% of the world's pollutants and nearly two tonnes of greenhouse gases per person. Figure 2 shows Egypt's greenhouse gas pollutants and the expected production from the electrical power industry. Where electricity accounts for approximately forty percent of total greenhouse gas emissions, followed by twenty percent for transport, fifteen percent for manufacturing facilities, five percent for building processes, and twenty percent for other categories [8].

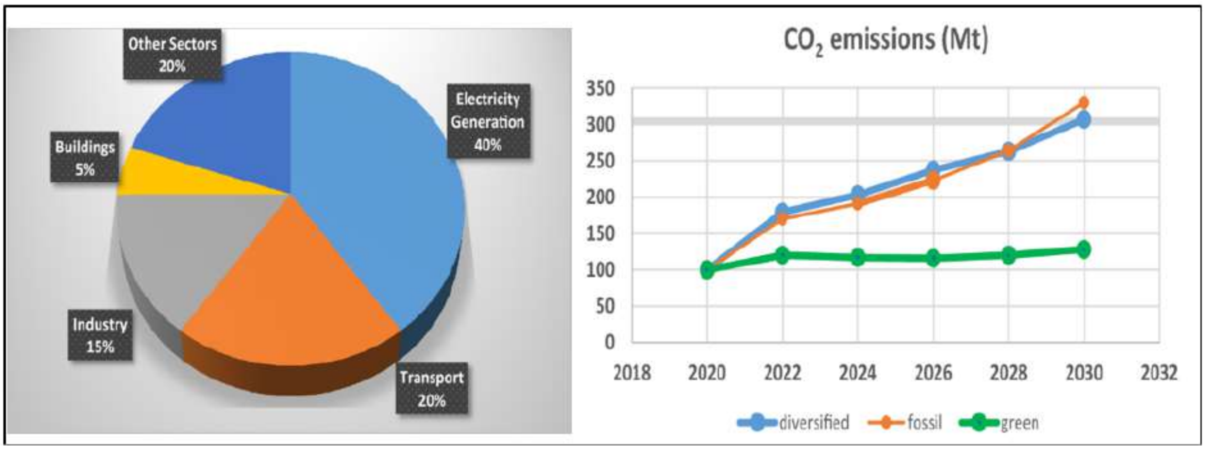


Fig.2: Emission rates of different sectors in Egypt of greenhouse gases [8]

Accordingly, the world's attention is directed toward alternative architectural environmental solutions to mitigate negative environmental impacts environmental issues must be considered when planning, designing, implementing, and operating economic growth and expansion projects. The architectural concepts currently required contribute to reforming railways and public buildings by enhancing the use of sunlight and fresh air, applying electric floors, green walls and roofs, recycling water and materials, green spaces, and photovoltaic panels.

3-Station comfort for users

Railway station design factors include spaces designed to accommodate the maximum capacity; separation of arrivals and departures; setting up information centers; reducing overlapping flows of passenger circulations; removing obstacles from passengers' paths; separating services for employees and passengers; and using electronic tickets. The Ideal design of the passenger sidewalk cross-section (pavement edge - walkway - waiting area). Conversely, the average for every person inside the station is 1.5 m2 throughout peak hours. Table 1 shows the average per person in railway station spaces [9].

Table 1: The Average Per Person in Railway Station Spaces.

Space	Main Halls	Shops	Ticket	Pavement	Administration
Per Person	**1.90**	**2.25**	**1.5**	**1.44**	**2.25**
Customers Satisfaction Factore in Railway Stations					
					

The architectural challenge experienced to create passenger, visitor, and employee comfort, as well as a sense of public and functional spaces, including the station building and services, reflected an entire sensory journey [10]. The customers' architectural satisfaction factors in railway stations include reliability, comfort (environmental and psychological), and experience.

4-Sustainable technical solutions

Architecture concepts have recently evolved to become more than just buildings, intending to achieve integrated construction of environmental systems. Two concepts represent architectural solutions: the first is improving the use of energy and achieving interior green quality. This concept is distinguished by a high degree of immediate closure. The other concept is passive environmental technique maximization, which enhances station performance and lowers energy consumption. In our current time, the combination of the two concepts is the best for climate response between the internal and external environments for a sustainable environmental re-imagining of train stations. On the other hand, green architectural solutions include an integrated design that capitalizes on and isolates external climatic effects, representing the successful exchange between the station's outer envelope and the internal station system. Figure (3) depicts the interactions across the various levels of environmental architectural solutions. The pyramid's base represents the broader level, which includes orientation, design concept, design standards, zoning, and circulations throughout indoor and outdoor environments. The next level includes passive environmental techniques and energy-saving methodologies that use climatic data to promote environmental effectiveness, visitor comfort, and energy investments. The higher level is energy-saving technologies like natural daylight and natural ventilation, including piezoelectric floors, green walls, and ceilings; recycling of water and materials; green spaces; and photovoltaic panels. While overall performance. And finally green power. [11]

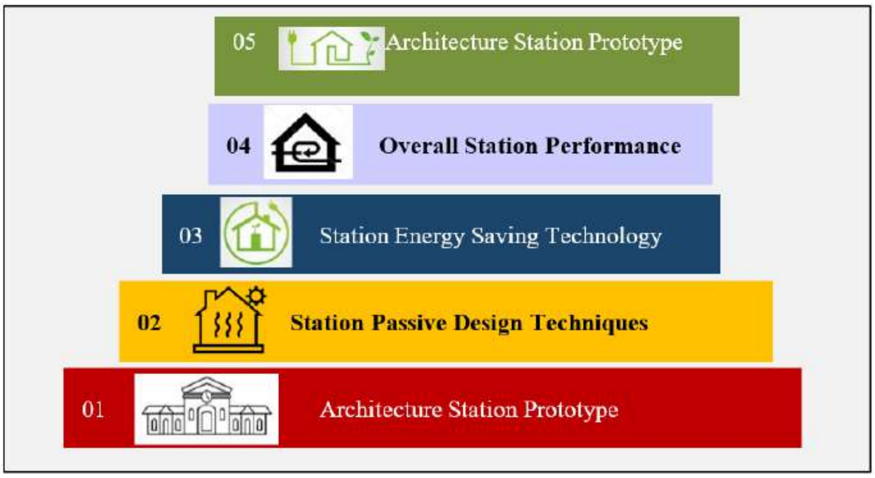


Fig.3. levels of Environmental and Architectural Solution Interactions

Design strategies in a dry, hot climate depend on each of the following: preventing the heat of solar radiation through isolation of the building envelope, openings, shading, and walls of thermal mass; ventilation and natural lighting by studying openings, courtyards, air ducts, and solar chimneys; and complementary equipment to treat heat and humidity problems, including fans, air conditioning, and heating [11]. Energy generators, including photovoltaic, thermal collectors, and piezoelectric tiles as shown in Table 2.

Table 2: The Hot and Dry Climate Environmental Techniques.

Dry, Hot Climate Strategies	Passive Technique	Envelope		Types of Equipment
		Opaque	Transparent	
Block Radiant Gain	Shading Devices	Thermal Mass- Sunshade Screen - High Reflectivity Finishing	Screen Panels	
Natural Lighting	Skylights		Light Shelf– Light Pipes- Reflectors	
Natural Ventilation	Wind Catchers- Solar Chimney			
Complementary Equipment				Fans- Air-conditioning -sensing control systems
Energy Generators				Photovoltaic - Solar Collectors- Piezoelectric Tiles

The integrated design of railway stations fulfills the contemporary functional and environmental requirements, including block design, facade formation, passive technologies, energy production, and environmental impact assessment. Architectural environmental solutionsinclude activating natural light and fresh air, electric piezo floors, green walls, and roofs, water and material recycling, green areas, and solar energy systems.

5. Research Methodology

Egypt is moving towards improving the performance of the railway sector, which requires architectural solutions to become more sustainable, energy-producing, and with less emissions.

Where Upper Egypt's passenger transport relies heavily on the railway sector. The Beni Suef train station is the main entrance to Upper Egypt anda future link between Upper Egypt and the new capital. The evaluation of transportation projects, particularly railway stations, is based on the efficiency of social impacts, which are intended to enhance user comfort, the satisfaction of surrounding communities using station lands and site selection, and increase user and employee satisfaction rates. While the financial performance of the project, such as feasibility, life cycle cost, and return on investment. Furthermore, the long-term environmental impacts of ventilation quality and emission reductions, dust, waste, exhaust, carbon footprint, and noise effects necessitate the installation of sound barriers at the station [12]. The analysis of the following figure (4) of the environment surrounding the Beni Suef railway station, where the presence of the Egypt Youth Fair, public commercial areas, and an empty electric kiosk next to the railway station represents a bad environmental, social, and economic impact. Environmental, economic, and social degradation is a major threat due to extremely negative effects with serious long-term consequences. This necessarily requires the investigation of comprehensive management strategies to find environmental solutions with economic returns. Towards a framework for sustainable railway stations, which requires long-term investments to meet recent climate challenges through socio-economic development, environmentally friendly response, and development cooperation.

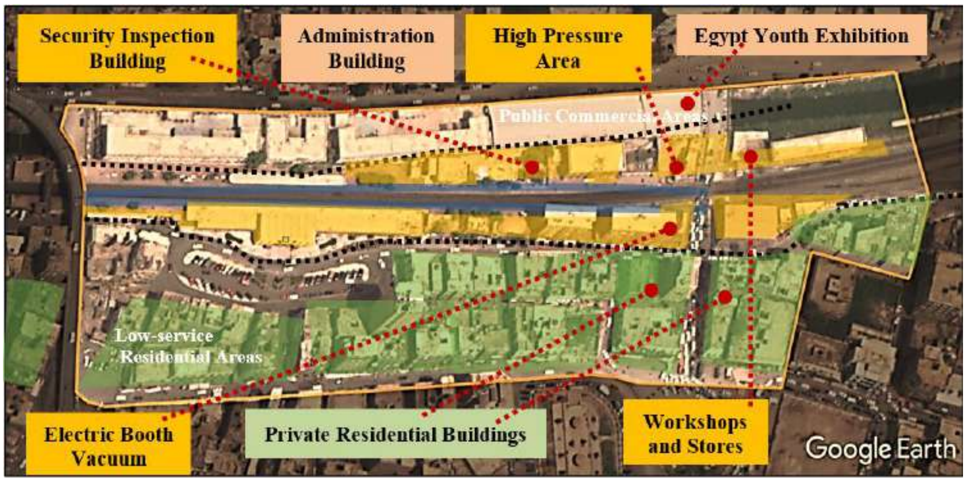


Fig.4. Beni Suef Rail Station Surrounding Context

Sustainable railways face numerous challenges, including low-carbon and sustainable fuels, climate-conscious transportation networks, net-zero transportation paths, sustainable infrastructure materials, urban mobility and goods movement, positive impacts on the surrounding community, life-cycle assessment and costs, and efficiency analysis. Material flow and natural resource use, waste recycling, and pollutant reduction are a range of environmental issues. The environmental condition change per capita, poor air quality, nuisance noise, land usage, and resource use efficiency must all be considered [13]. The analytical research is addressed in three stages, as shown in the following Fig. 5.

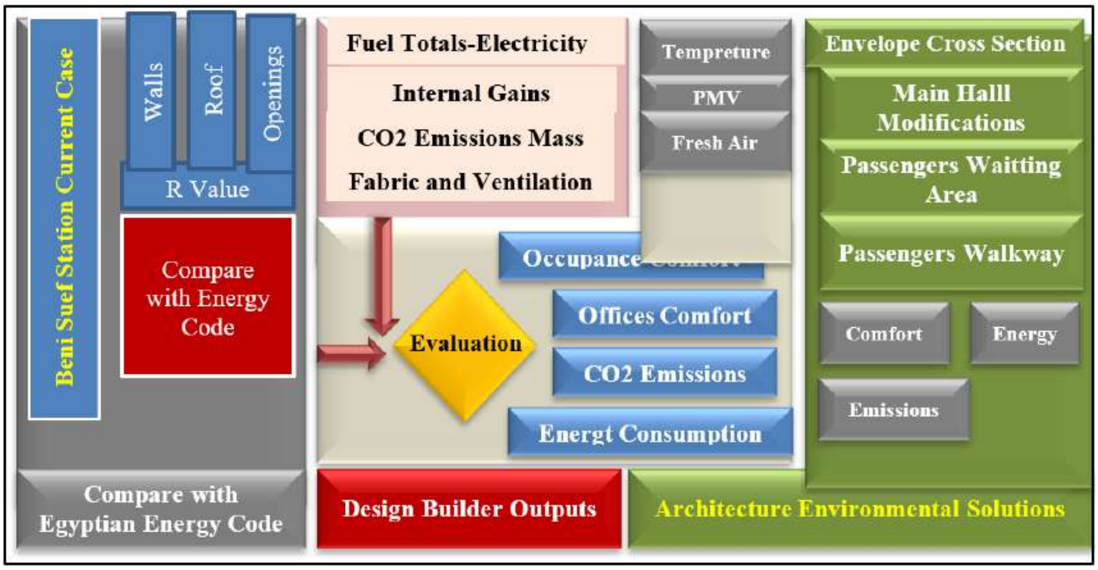
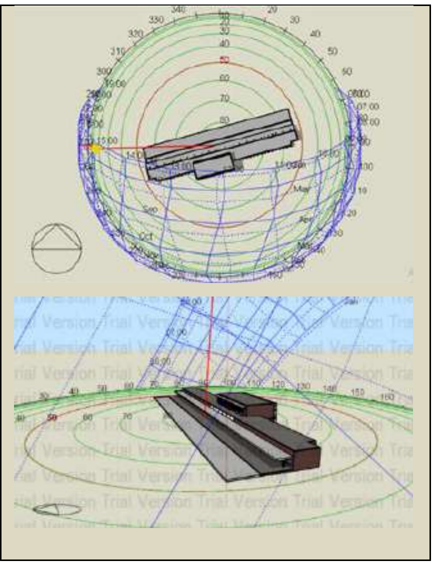


Fig.5. Research Methodology Stages

6. Discussion and Results

Beni Suef station was chosen in the applied study due to the use of the researchers since 2009 when traveling by train to the present time. As a result, the need for environmental architectural solutions became the requirement that travelers demanded. Table (3) represent Beni Suef Station parameters.

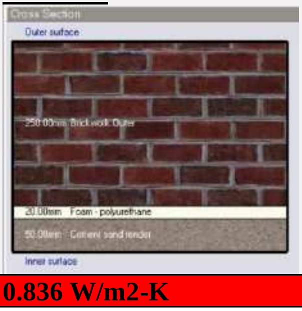
Table 3: Beni Suef Station Simulation parameters.

Designation	**Features**	
Building type	Railway Station Offices	
Location	Beni Suef	
Number of Stores	2-1	
Floor height	4.0 M	
Occupation (persons/m2)	7 (ASHRAE STANDARD)	
Office hours	8:00 A.M.–4:00 P.M.	
Orientation	The North-East	
Metabolic Rates	0.75	
Clothing **HVAC template**	0.3 CLO No Active Cooling Systems	
Glazing	Clear Glazing, SHGC: 0.76, U Value: 5.84	
Natural ventilation	Natural Ventilation Across Windows	
Lighting	Lamps With a Standard Intensity of 350 Lux	
Shading	N0-Shading Devices	

The analytical research methodology is addressed in three stages: First compare the station's current situation with Egyptian Energy Code, including building walls, roofs, and openings. Second, Design Builder Outputs evaluation stage leads to architecture environmental solutions. The third stage is enhancing modification, which includes the station envelope, main hall, waiting areas, and walkways.

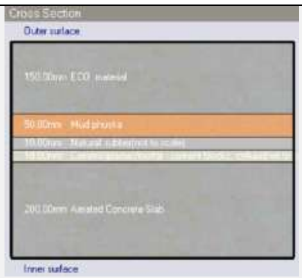
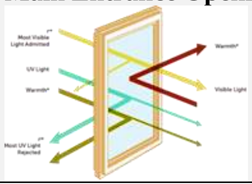
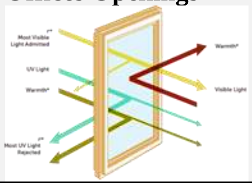
<u>6-1 Station Building Compare with Egyptian Energy Code (R-U Values):</u> The comparison of the station's current status variables with the Egyptian Energy Code as follows Table 4:

Table 4: Evaluation of Beni Suef Station’Currentnt Status according to the Egyptian Energy Code

<table>
<tr><th>Comparison</th><th colspan="3">Evaluation of Beni Suef Station’Currentnt Status according to Egyptian Energy Code</th></tr>
<tr><td>Beni Suef Station Envelope Layers Cross–Section (Current Case)</td>
<td><u>External Wall Main Entrance</u>

 </td>
<td><u>External Wall Offices</u>

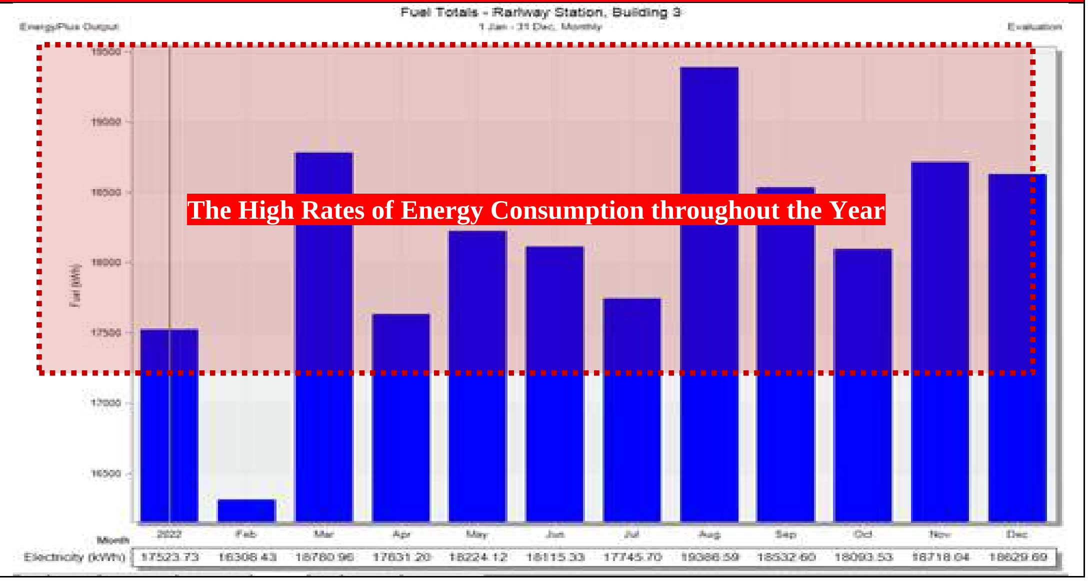
 </td>
<td><u>Main Hall Roof Cross-Sec.</u>

 </td></tr>
<tr><td>U-value</td><td>0.836 W/m2-K</td><td>1.765 W/m2-K</td><td>0.853 W/m2-K</td></tr>
<tr><td>Egyptian Code</td><td>1.6 m^{2} °C/W</td><td>1.5 m 2 °C/W</td><td>3.4 m^{2} °C/W</td></tr>
<tr><td>Analysis</td><td colspan="3">The Egyptian Energy Code's thermal resistance requirements for non-residential buildings with no air conditioning located in the North Upper Egypt region are related to 3.4 m2 °C/W (roof), 1.5 m2 °C/W (north facade), and 1.6 m2 °C/W (south facade). Where Heat Transfer Coefficient Converter = W/m2-K = m 2 °C/W [17]. The main entrance façade and roof are out of code (red highlighted).</td></tr>
<tr><td>Beni Suef Station Cross–Section (Current Case)</td><td colspan="2"><u>Walkways Roof Cross-Sec.</u></td><td><u>Offices Roof Cross-Section</u></td></tr>
</table>

		
U-value	**0.423 W/m^2-K**	**0.853 W/m2-K**
Egyptian Code	**3.4 m 2 °C/W**	**3.4 m 2 °C/W**
Analysis	By comparing the layers of thewalkway and office roofs (**red highlighted**), it was found that they were out of the Egyptian Energy Code's thermal resistance requirements for non-residential buildings with no air conditioning located in the North Upper Egypt region.	
	Main Entrance Openings 	**Offices Openings** 
U-value	Single Clear Glazing – Poorly Fitted **5.894 W/m2-K**	Single Clear Glazing – Poorly Fitted **5.894 W/m^2-K**
SHGC	**50%S**	**60% N**
Analysis	The Energy Code for Buildings recommends that the percentage of openings in facades be no more than 50% in the north and no more than 30% in the south. The maximum solar heat gain coefficient SHCG is not allowed, while the percentage of solar glass SGR must not be less than 90%, as the percentage of openings in the northern and southern facades exceeds 30%. Since the slots are countersunk Which reduces solar gain as well as the difficulty of adjusting the types of treated glass for cost. But it is necessary to activate the control of opening and closing due to visitors' complaints about the low ventilation rates when **closing windows all the time**.	

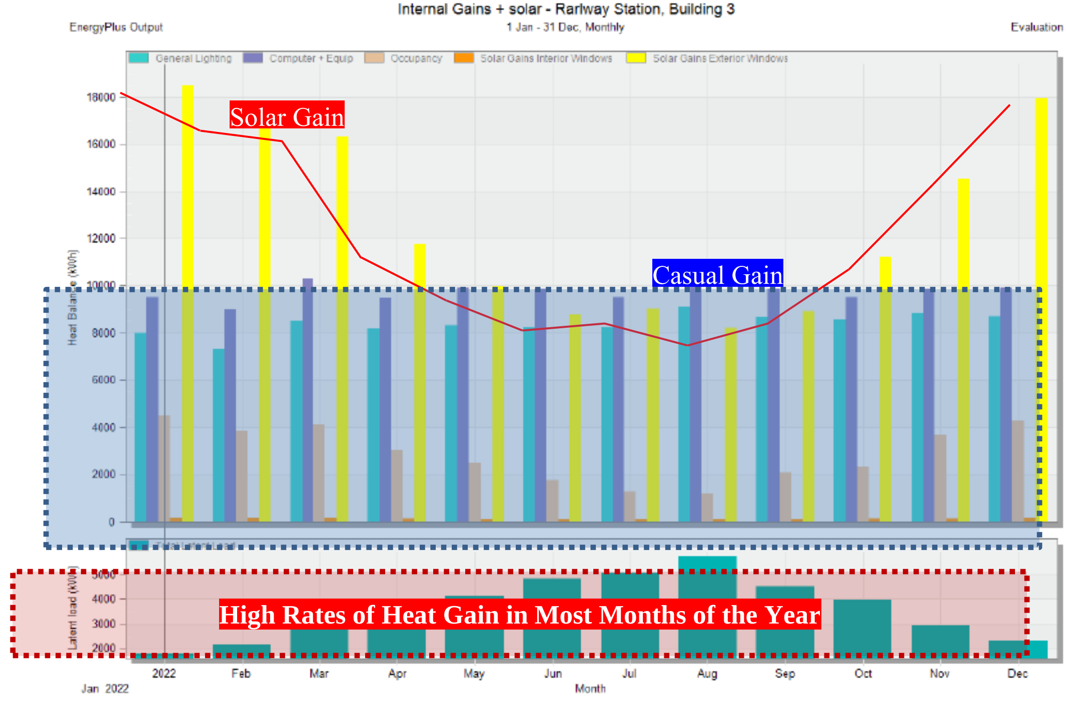
<u>6-2 Design Builder Outputs:</u> The software simulation tool Design Builder (DB), type 7.2, with an interface to the simulation program Energy Plus (E+), type 8.2.0.024, was chosen. The simulation tool E+ was preferred because it is widely used within the scientific community for thermal and energy performance calculations. It is also thought to be more user-friendly and better suited for creating reasonable simulation models with remarkably accurate architecture models. Calculate the total fuel amounts (electricity, internal gains, CO2 emissions mass, fabric, and ventilation) as shown in Table 5.

Table 5: Amounts of Fuel (Electricity, Internal Gains, CO2 Emissions Mass, Fabric, and Ventilation

Total Building Energy Consumption kWh	

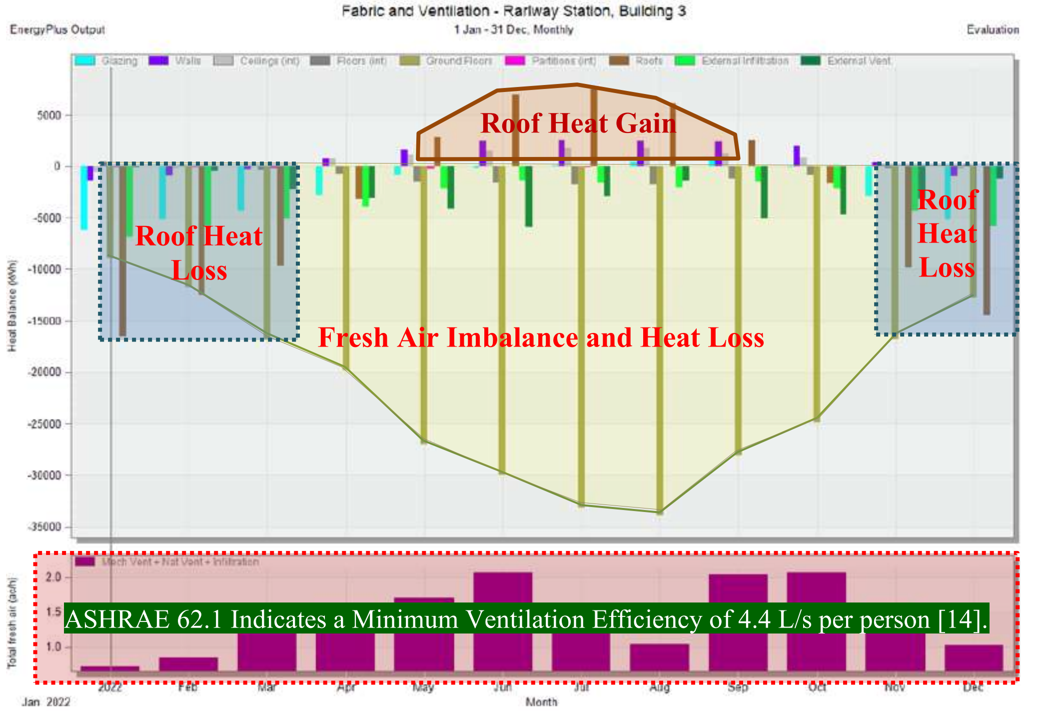
Analysis: Average Value = 18140.8 kWh = Fuel Totals-Electricity kWh. The high rates of energy consumption (yellow highlighted) are caused throughout the year by heat gain in the reception hall, ticket windows, and office rooms. Despite the size of the southern wall cross-section, the constant shuttering of the windows caused thermal discomfort due to a lack of natural ventilation and fresh air flow. In terms of office rooms, the window area does not correspond to the office room area. The station's roof layers are incompatible with the code requirements, resulting in increased heat gain and a sense of thermal discomfort. As well as increasing consumption rates for the use of inefficient artificial lighting.

Internal Gains



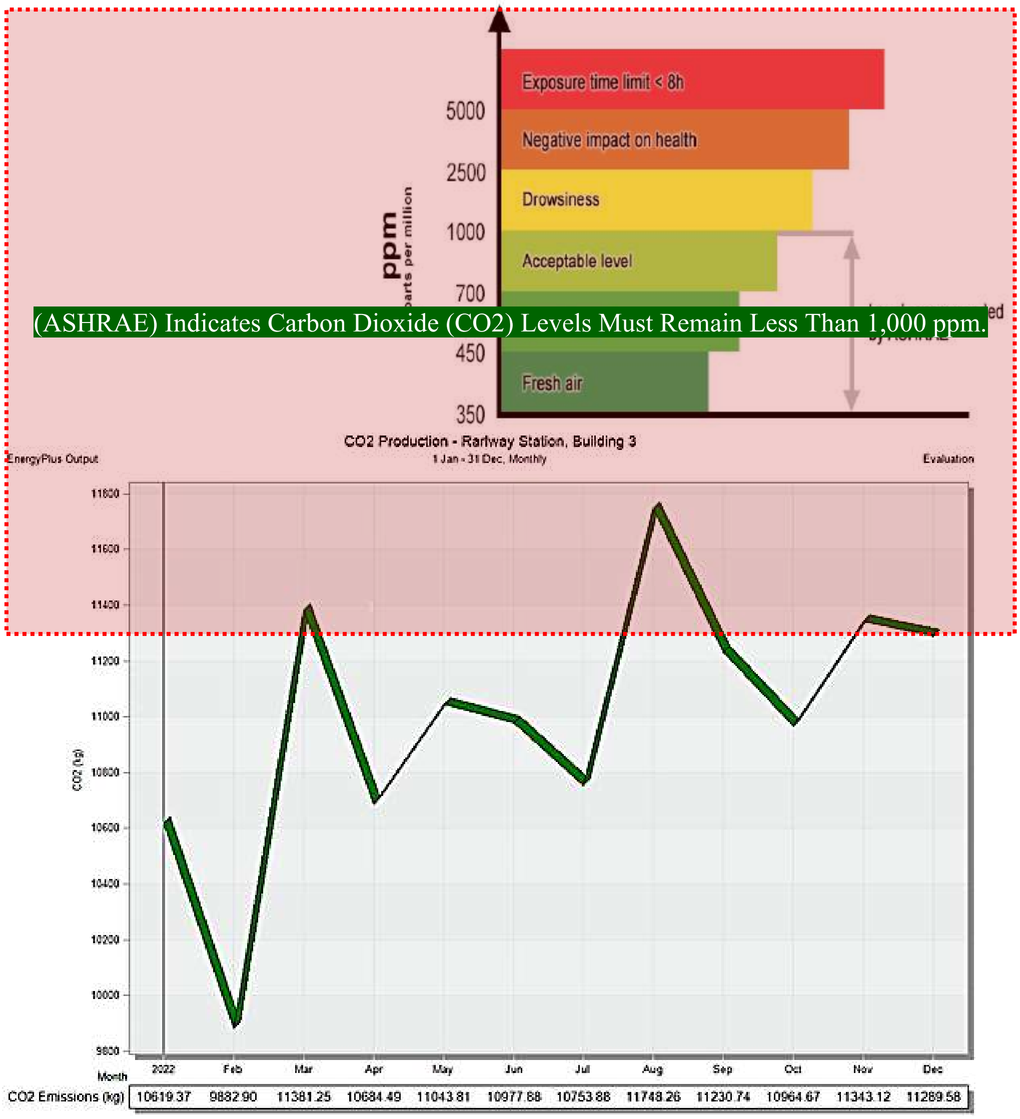
Analysis: The high rates of heat gain (red highlighted) in most of the year are due to the non-use of windows as a source of lighting and natural ventilation and the disproportionate space of the openings for the different spaces, especially the office. As well as the lack of treatment of the roof and the full use of non-energy-saving artificial lighting (blue highlighted).

Fabric and ventilation

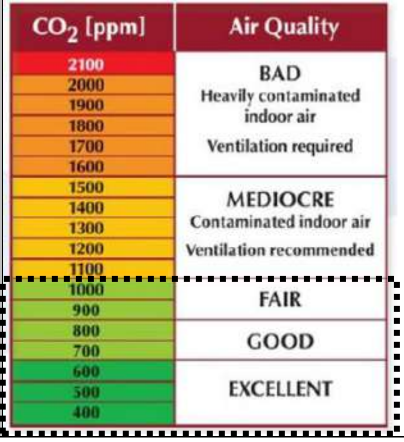


Analysis: Increasing the loss and gain of heat values, consequently consuming more energy and dropping customer and employee satisfaction due to the absence of thermal comfort. The aforementioned is due to a lack of natural ventilation sources that enable the movement of fresh and renewable inner air around standard levels. Even though

<table>
<tr><td colspan="2">there are many openings, almost all of them constantly stay closed, causing discomfort inside the reception hall, ticket offices, and administrative offices.</td></tr>
<tr><td>Total CO2 emissions mass</td><td>



(ASHRAE) Indicates Carbon Dioxide (CO2) Levels Must Remain Less Than 1,000 ppm.



CO_2 [ppm]	Air Quality
2100	BAD Heavily contaminated indoor air Ventilation required
2000	
1900	
1800	
1700	
1600	
1500	MEDIOCRE Contaminated indoor air Ventilation recommended
1400	
1300	
1200	
1100	
1000	FAIR
900	
800	GOOD
700	
600	EXCELLENT
500	
400	

Level Recommended by ASHRAE 1000 ppm [15-16]

</td></tr>
<tr><td colspan="2">Analysis: ASHRAE indicates that carbon dioxide (CO2) levels must remain under 1,000 ppm(Parts Per Million). Where 1 kg/m3 = 1000 ppm. As a result, the train station must implement green environmental architectural changes to increase ventilation rates, achieve thermal comfort, and reduce emissions.</td></tr>
</table>

6-3 Architecture Environmental Solutions: Towards integrated architectural and environmental solutions for the station building and its services to reduce the harmful effects on neighboring areas and the entire station, the contributions of the Egyptian sectors to the production of carbon emissions showed that the energy and transportation sectors are the most contributing, accounting for about 62% of the total emissions [18]. Whereas it is globally proposed to shift architectural orientation towards biophilic principles to achieve each of the following goals: customer and employee comfort, a sense of station place, reducing greenhouse gas emission levels, and engaging energy efficiency for a station with energy-producing human resources. Figure 6 represents the proposed architectural solutions to experiment with their efficiency, representing environmentally friendly technologies towards enhancing the environmental and architectural efficiency and sustainability of the Beni Suef train station.

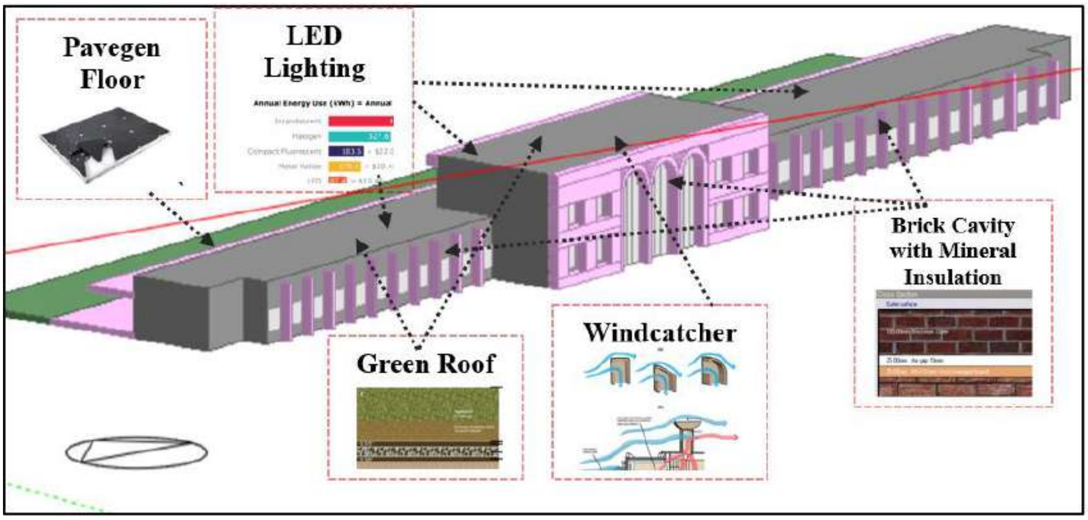


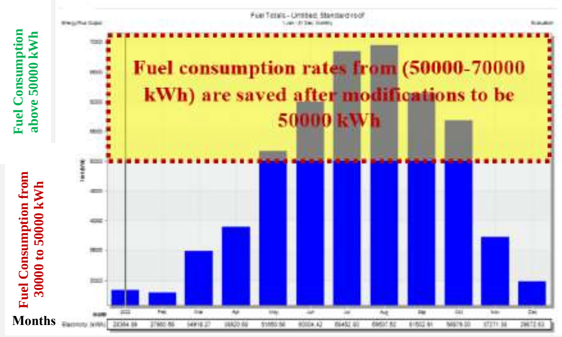
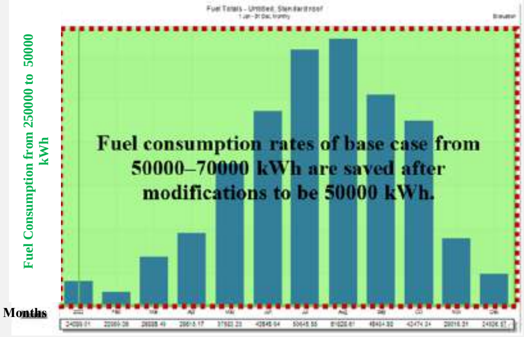
Fig.6. The Proposed Environmental

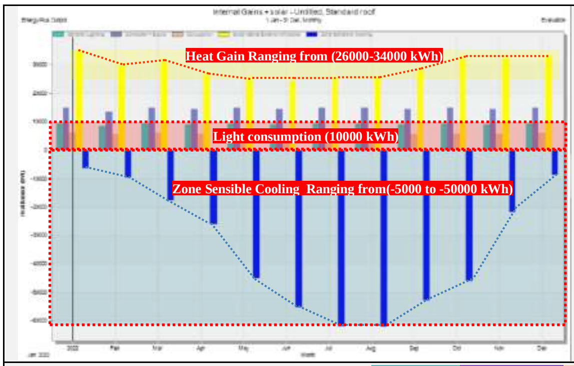
Architectural Solutions

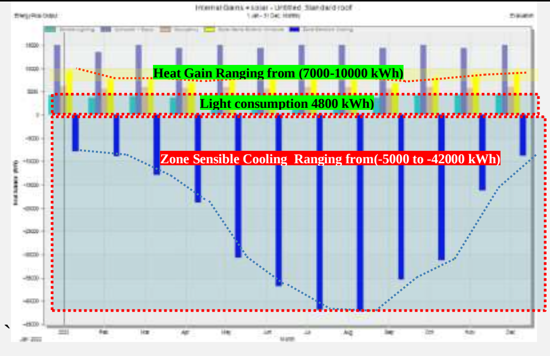
The approach to improving the station's performance includes adopting environmentally friendly architectural approaches in three phases: first, improving the current circumstances through the addition of an envelope and artificial lighting systems to achieve user convenience and reduce energy consumption rates. second, generation of electricity by applying piezoelectric floor tiles in walkways to capture passengers' power and following circulation pathways within the station to produce electricity. Third, applying passive ventilation techniques to improve the internal environment of the ticket and reception hall due to passenger complaints about low ventilation rates and high temperatures.

Stage 1: Enhancing the current condition by improving envelope performance by using a green roof (U-Value=0.375 W/m2-K), an internal brick cavity (U-Value=0.739 W/m2-K), and LED lighting to increase user convenience and reduce energy consumption rates. Table 6 shows the results of integrating modifications of a green roof, internal brick cavity, and LED lighting.

Table 6: The simulation study of Modifications (green roof, internal brick cavity, and LED lighting).

Total fuel Consumption of the Station- Fuel Totals-Electricity kWh	
Current Case	**Retrofitted Case**
	
Internal gains: Internal gains include equipment, lighting, occupancy, solar, and HVAC heating/cooling.	
Total Fuel Consumption - kWh: - Electricity: 47107 kWh	**Total Fuel Consumption - kWh:** - Electricity: 21887 kWh
Analysis: The combination of a green roof (U-Value=0.375 W/m2-K), an interior brick cavity (U-Value=0.739 W/m2-K), and LED lighting reduced fuel consumption by 25,220 kWh. (saving approximately 54 % of electricity per kWh)	
Internal Gains	



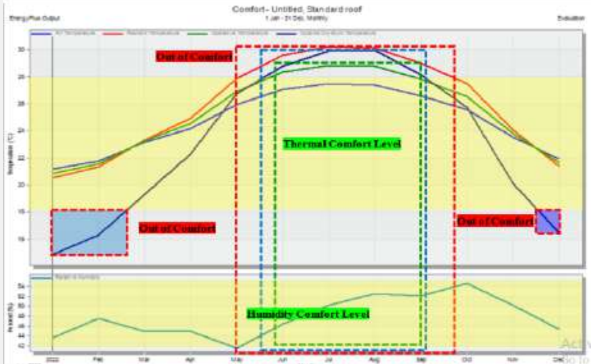


Lighting | Equipment | Occupancy | Solar Gain | Sensible cooling

- General Lighting: 9147 kWh - Solar Gains Exterior Windows: 29031 kWh - Zone Sensible Cooling: 33790 kWh	- General Lighting: 3874 kWh - Solar Heat Gains from Exterior Windows: 7949 kWh - Zone Sensible Cooling: 24282 kWh

Analysis: Solar gain decreased ranging from (26000-34000 kWh) in the current case to (9000 kWh) after modification. Light consumption decreased from 10000 kWh to 4800 kWh. The zone sensible cooling (the overall sensible cooling effect on the zone) of the base case and retrofitted achieve 33790 and 24282 respectively.

Thermal Comfort Range - (Monthly results of Building Thermal Comfort range)



Air Temperature | Radiant Temperature | Operative Temperature | Outside Dry Bulb Temperature

Highest values achieved. - Operative Temperature: 30.2 °C - Fanger PMV: +4.6 - Relative Humidity: 52.5 %	Highest values achieved. - Operative Temperature: 26.7 °C - Fanger PMV: +1.6 - Relative Humidity: 54.9 %

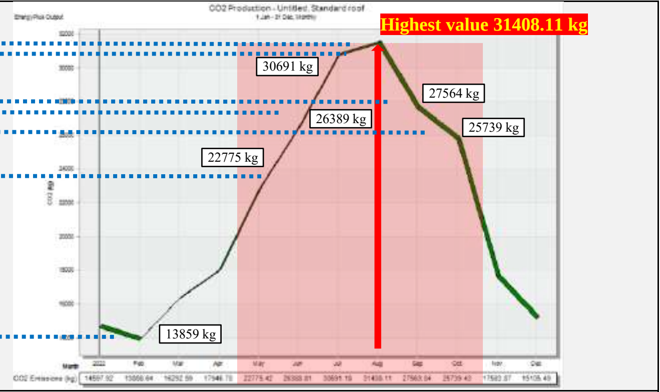
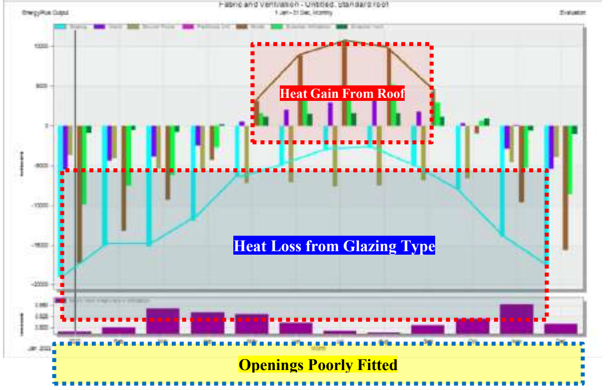
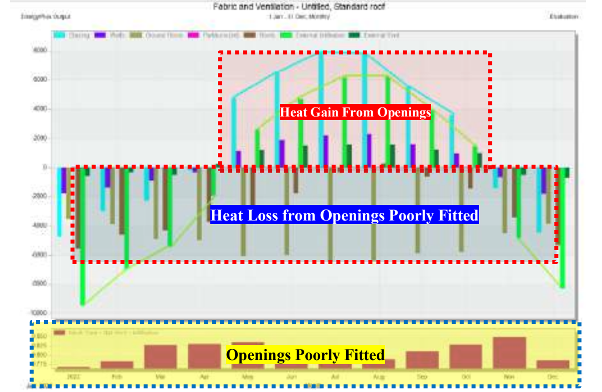
Analysis: The first improvement phase succeeded, and it includes the outer cover, green roof, and artificial lighting systems to achieve user comfort and reduce energy consumption rates. All months are within the thermal comfort range (green highlighted); however, the Fanger PMV is +1.6 (improved, yellow highlighted), which requires raising air renewal rates and controlling window opening and closing times.

The Comparison of Solar Gains, Zone Sensible Cooling, and Thermal Comfort

Date /Time	Solar Gains Exterior Windows kWh	Zone Sensible Cooling kWh	Relative Humidity %	Operative Temperature °C		Solar Gains Exterior Windows kWh	Zone Sensible Cooling kWh	Relative Humidity %	Operative Temperature °C
Jan	34831.07	6436.9	43.6	20.53	Integrating Modifications	9467.88	7755.68	40.9	21.5
Nov	32138.22	21733.1	50.1	24.05		8519.85	16097.7	50.1	23.8
Dec	33126.02	8762.98	45.2	21.41		9234.90	8785.74	43.6	22.2
June	24656.72	55240.8	46.3	29.61		7759.85	36817.5	50.7	26.1
July	25109.06	61958.4	50.1	30.24		7827.21	41830.3	54.9	26.6
August	25573.64	62088.9	52.5	30.14		7446.71	42231.5	57.1	26.7

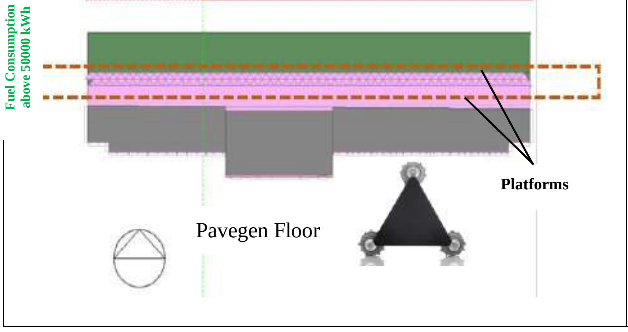
Analysis: By comparing the results of the external windows, solar gains, zone-sensitive cooling, and thermal comfort for the base case and modified case in the hottest and coldest months of the year, it was found that there was a significant improvement in all rates and their entry into the comfort zone. However, it is necessary to raise the rates of comfort in the reception hall and tickets due to the complaints of travelers about the lack of flow and renewal of air, which is a result of the southern orientation and crowding

CO2 Emissions Electricity kWh

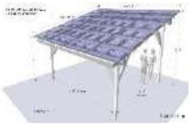
<table>
<tr><td> </td><td> </td></tr>
<tr><td><u>Analysis for CO₂ Emissions:</u>
- Highest value achieved: 42121.52 kg
- Average Annual achieved: 28547.5 kg</td><td><u>Analysis for CO2 Emissions:</u>
- Highest value achieved: 31408.11 kg
- Average Annual achieved: 21662.6 kg</td></tr>
<tr><td colspan="2"><u>Analysis:</u> The modifications significantly reduced the maximum value of carbon dioxide emissions by 10714 kg, which is an improvement of approximately 25%, while the annual average is 24%.Because of the emissions from trains and the separation of the reception hall and tickets from the train platforms, it is necessary to continue improving the renovation and ventilation of the reception hall and tickets, which are the subject of complaints from travelers.</td></tr>
<tr><td colspan="2">Fabric and ventilation kWh</td></tr>
<tr><td> </td><td> </td></tr>
<tr><td colspan="2">Glazing Walls Ground Floor Partitions Roof Infiltration External Vent Net Vent</td></tr>
<tr><td colspan="2"><u>Analysis:</u> Material and airflow surfaces such as walls, floors, ceilings, and ventilation provide heat gains to the space. Heat loss from the space is indicated by negative values. After merging the treatments, it became clear that the problem of the envelope and roof layers had been solved, but the problem of controlling ventilation from the openings and related issues of poor fitting and infiltration remained.</td></tr>
<tr><td>- Glazing: 10282.1 (kWh)
- Walls: 2959.88 (kWh)
- Ground Floors: 5886.76 (kWh)
- Partitions (int): 13.25 (kWh)
- Roof: 8925 (kWh)</td><td>- Glazing: 4367.44 (kWh)
- Walls: 1408.89 (kWh)
- Ground Floors: 5197.9 (kWh)
- Partitions (int): 10.99 (kWh)
- Roof: 2918 (kWh)</td></tr>
</table>

Stage 2: Apply piezoelectric floor tiles in walkways to capture passenger power and follow circulation pathways within the station to generate electricity, as shown in Table 7.

Table 7: The simulation study of Integrate Piezo Flooring Tiles & Photovoltaic Cells

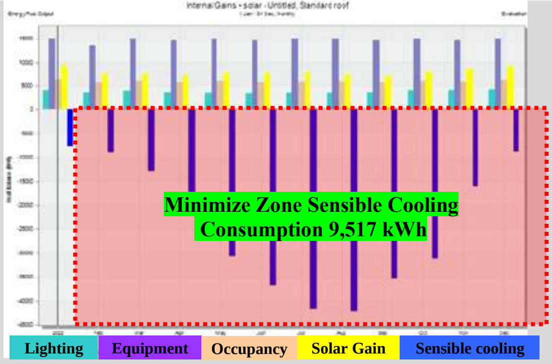
<table>
<tr><td colspan="2">Total fuel Consumption of the Station- Fuel Totals-Electricity kWh</td></tr>
<tr><td>Current Case</td><td>Retrofitted Case</td></tr>
<tr><td colspan="2">tegrate Piezo Flooring Tiles & Photovoltaic Cells</td></tr>
<tr><td> </td><td><u>Pavegen flooring tiles produce around:[19]</u>
- every footstep, three joules of power are expended
- as well as a maximum electrical output of five watts
whereas walking is needed to power services such as sensors, LEDs, screen frameworks, and power source recharging.<u>Photovoltaic cells: [20]</u>
</td></tr>
</table>

- Above the waiting area shading with an area where the unit produces between 1 kW and 4 kW.
- Average daily sunlight hrs.(8hrs) * PV capacity (400watts) * 0.75(constant)
= 2100 watt-hours / day * Pv no. (1121+2432)
= 2100*3553= 7,461,300 watt-hours / day
= **7,461.3 KW. hrs/day**



Analysis: Site and Source Energy - The total amount of site and source energy consumed. The net electricity from the utility is used to calculate the electric contribution. The conversion factors used by the site are those entered by the user. These are recorded in the data for Environmental Impact Factors and Fuel Factors.

Saving Electricity & Minimizing Zone Sensible Cooling kWh- After Applying Piezo Tiles(only)



Before: Zone Sensible Cooling: 33790 kWh
After: Zone Sensible Cooling: 24273 kWh

Before: Electricity: 47107 kWh
After: Electricity:35745 kWh

The results showed that the rates of energy consumption decreased by minimizing zone sensible cooling consumption by 9,517 kWh, which led to the saving of 11,362 kWh of electricity.

The Site and Source of Power- The Base Case - Asphalt PiezoTiles

The site and Source of Power	Total Power [kWh]	Power per Total Building Area [kWh/m^2]	Power per Conditioned Building Area [kWh/m^2]
Total Site Power	788911.99	311.66	311.66
Net Site Power	788911.99	234.70	311.66
Total Source Power	1436194.72	433.35	567.36

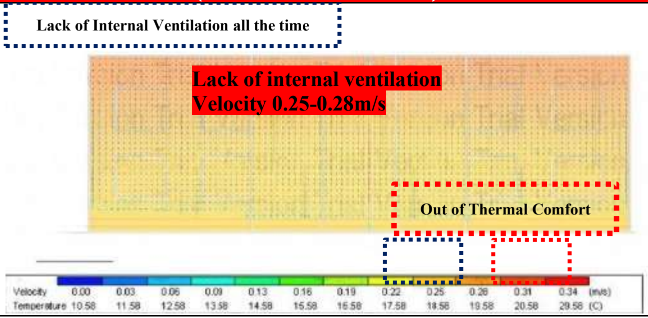
The Site and Source of Power - The Base Case -Piezo Tiles

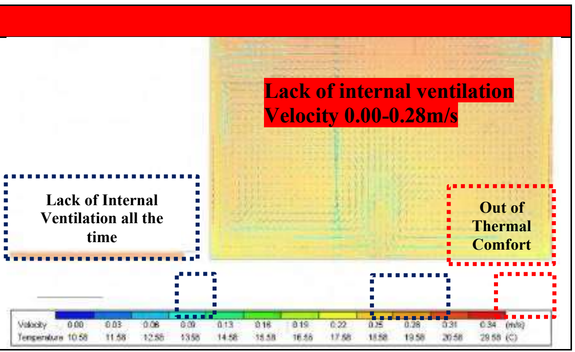
Total Site Power	594100.79	234.70	234.70
Net Site Power	594100.79	234.70	234.70
Total Source Power	1096947.45	433.35	433.35

Analysis:
It was recommended Combining the piezo units with floors, bumps, train rails, station waiting areas, pedestrian sidewalks, parking garages, and tunnels was recommended architects integrate energy conservation and production systems with environmental architectural treatments towards reducing energy consumption and preserving the environment. The total energy produced was approximately 27,166.75 KWh/day/1000 = 27.17 MWh/day[21].

Stage 3: Applying passive ventilation techniques, the importance of ventilation systems is to achieve both thermal comfort and air regeneration. There are many passive ventilation strategies, including the difference in air density creating buoyancy ventilation, also known as solar chimney system ventilation, as well as controlling window opening and closing systems and designing wind towers to renew the air and cool the interior space. The results of a design model simulation were simulated in Designer Builder on a hot summer day, August 15th, which is today the hottest month of the year.

CFD simulation (South-Front Facade)- Base Case



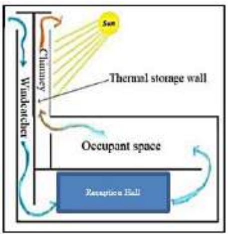


Front Facade: Although the reception hall is within the range of thermal comfort, the air is calm, and there is a lack of air renewal due to the southern orientation and openings closing all the time. Which requires the integration of passive ventilation techniques to renew the airflow.

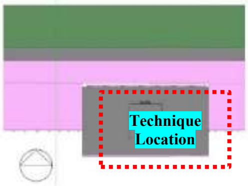
Left Facade: Although the internal spaces are within the range of thermal comfort, the feeling of discomfort is present due to the openings being closed all the time. Which requires the integration of passive ventilation techniques to renew the air.

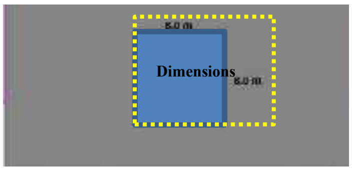
Analysis: CFD simulation showing the operative temperature and airflow of the base case (main entrance), where a single-directional airflow ventilation strategy produces indoor air temperatures of 29.45 °C (out of comfort levels). The airflow outside is faster in normal conditions on the north façade, but the station entrance and the reception hall are oriented to the south.

Modeling a wind catcher and a solar chimney as passive ventilation techniques



Accordingly, it is recommended to combine a wind catcher with a solar chimney mood [21].





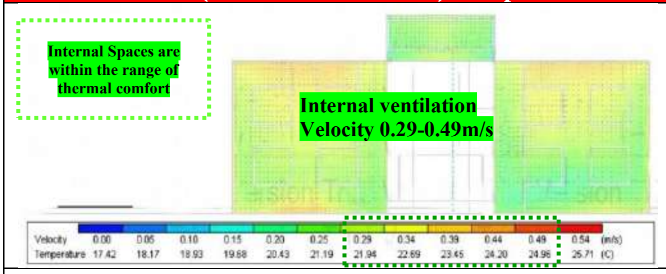
Ventilation Passive Technique:
Dimension: 8*8*12 m (3m above roof)

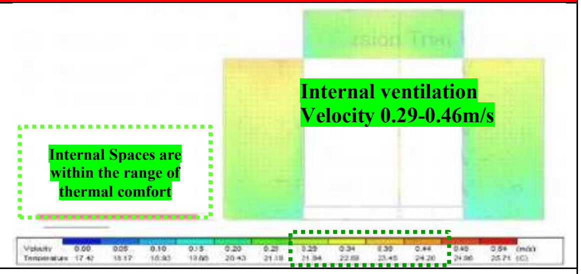
Windcatcher Mood- from 6 a.m. to 11 a.m.

Solar Chimney Mood - from 12 am to 6 pm

Close/Open Windows Mood

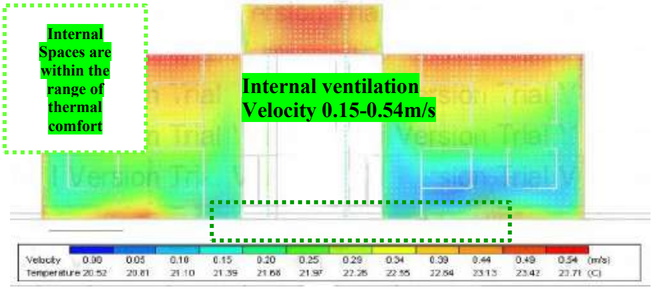
CFD simulation(South-Front Facade)- Proposed Windcatcher Mood- from 6 a.m. to 11 a.m.

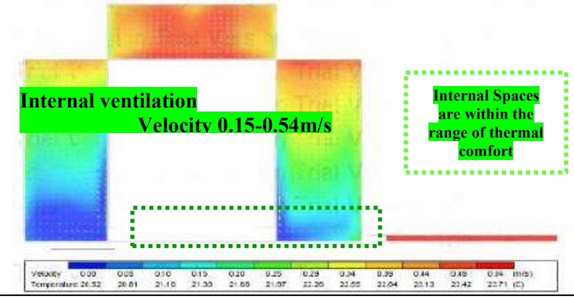




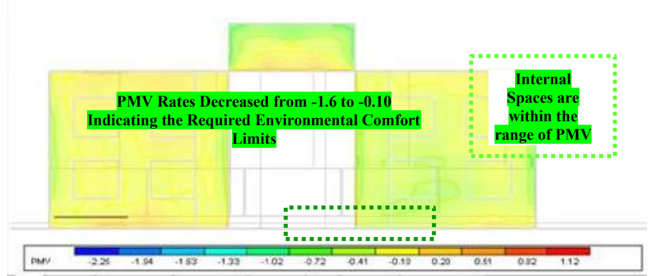
Analysis: CFD simulation results of the proposed design of the wind catcher, the air temperature decreases more than 3 °C after adapting the wind catcher from 6 a.m. to 11 a.m. at the South Front Façade (cold air). Internal ventilation velocity is around (0.29 to 0.46) m/s The variation in ventilation rates allows the possibilities of air regeneration and self-cooling.

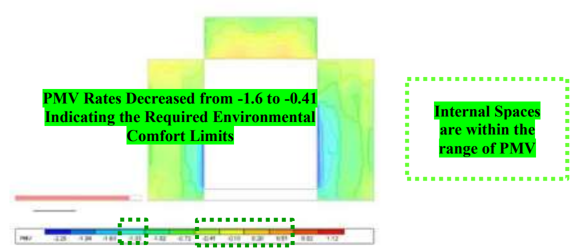
CFD simulation(South-Front Facade)- Proposed Solar Chimney Mood - from 12 am to 6 pm





Analysis: CFD simulation results of the proposed Design of the solar chimney, the air temperature decreases more than 3 °C after adapting the wind catcher from 12 am to 6 pm (absorb time). Internal ventilation velocity is around (0.15 to 0.54) m/s The variation in ventilation rates allows the possibilities of air regeneration and self-cooling.





Analysis: Internal Spaces are within the range of PMV, PMV rates decreased from -1.6 to -0.10 indicating the required environmental comfort limits.

The airflow is controlled during the hours of cold air availability, and the solar chimney is at noon. Which causes air renewal, and therefore it is also necessary to control the opening and closing of windows. On a single side, the wind catch is integrated with a solar chimney, The wind catcher and solar chimney are connected to the main hall by multiple separate pathways. A small void connects the double-height reception hall as well. A wind capture and a solar chimney allocate the south-facing entrance facade. Additionally, the entrance facade serves as a Thermal mass integrated into thesolar chimney. At noon, solar radiation is absorbed through the solar chimney wall, while fresh air enters through wind traps when cold air is available, as well as controlling the opening and closing of windows to create an air current that reduces heat and renews the air as well. The variation in ventilation rates allows the possibility of air regeneration and self-cooling.

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