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Energy Performance Analysis: A Case Study on Domestic Departure Hall Tribhuvan International Airport of Nepal

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Abstract

This analysis is based on the energy simulation in Revit Autodesk, and Insight. This study is about the operational electricity consumption, Heating load, cooling load and Energy use intensity of the building at domestic departure hall at Tribhuvan International Airport, Tribhuvan International Airport is first international airport in Nepal, It is located in Kathmandu, capital city of Nepal. There is one runway and separate terminal building. The domestic terminal building is located in North side of the international terminal building. Domestic and international passenger go through the separate terminal building. Based on the building energy analysis the energy use intensity of domestic departure hall is $298kWh/m^2/yr$. From the building energy analysis report total cooling load is $243.247KW$ and total heating load is $35.848KW$. While the infiltration rate reaches 0.4 Air Change per Hour from 2 Air change per year, The energy use intensity decreases from $298kWh/m^2/yr$ to $294kWh/m^2/yr$. When roof insulation R19 placed over existing roof construction, The energy use intensity decreases from $298kWh/m^2/yr$ to $294kWh/m^2/yr$. Maximum load of the building is occupied by the passenger movements that is occupancy load then the building infiltration, roof and windows material.

Keywords

Tribhuvan International Airport, Building energy analysis, Airport Terminal Building, Heating load, cooling load

1. Introduction

Tribhuvan International Airport (TIA), located at Gauchar-Kathmandu, established in 1949 A.D, is situated 5.56 km east of the central Kathmandu. The TIA has an operational land area of about $2,320,000m^2$ and total built up area is about $31,000m^2$ including International Terminal Building, Domestic Terminal Building, Operations and Airlines building, Cargo, VVIP, and other associated buildings. The single 3.2 Km long airport runway caters to both international and domestic flights and, along with taxiway, covers about $230,000m^2$ of land. The Apron area covers about $7,000m^2$ of international terminal and about $5,000m^2$ of domestic terminal. The capacity of international terminal apron is 11 medium and wide body category aircrafts and that of domestic terminal apron being 17 small aircraft and 13 Helicopters. The TIA services also include air traffic control services (aerodrome control, approach control and area control), aeronautical communication service and aeronautical Information services. TIA received International Civil Aviation Organization (ICAO) compliance. Every year millions of passengers travel through Tribhuvan international airport come from a variety of climate fears. As long as passengers are waiting at the airport, it is necessary to create a comfortable atmosphere. To provide comfortable interior spaces and precise air control of multiple zones, these buildings need a strong air conditioning system and should be able to ensure a high comfort throughout the year. An air conditioner is required in airport to maintain the passengers comfort zone as well as to prevent the overheating of various machines and equipment connected to the airport. Passengers are coming and going throughout the operation hour. Since there are passengers coming and going, all the doors should be kept open during the operation hour. There is a runway on the north side of this building and a ticket counter on the south side. The ticket counter is not air conditioned. In the northern part, 5 doors are used for passenger boarding to the aircrafts, while on the south side, through 2 large doors, passengers enter to hand baggage checking after ticket

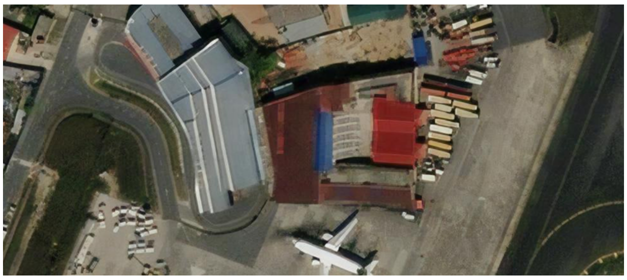

Figure 1: TIA Domestic terminal building on google map

counter and the cargo comes from other side. These doors remain open until the airport opens. Proper insulation is not used in windows. Fall ceiling is placed on the zinc roof. The maximum and minimum outdoor temperature here reaches -3.5 degree centigrade in winter and 40 degrees centigrade in summer. This study is about the operational electricity consumption analysis of HVAC system in domestic airport departure hall, Tribhuvan International Airport Kathmandu. Building envelops systems has a great scope to reduce the building energy consumption and consequently improve building efficiency.

2. Methodology

This research focuses on the energy performance of the domestic airport departure hall in Kathmandu, Nepal. It explores how to improve thermal comfort through quantitative analysis of the effect of thermal characteristics of the departure hall. The base model was develop in Revit and building annual energy simulations done in Audesk Insight 360. The study summarizes the potential energy saving by air infiltration rate, windows glass material and roof construction of the buildings. This study will define annual saving of building electricity from the simulation results which turn helps to improve thermal comfort. Figure 2 address the flow of creation of building energy model and building energy simulation.

3. Literature Review

The specific energy consumption of TIA (both international and domestic terminals) per square meter was comes out $173kWh/m^2/yr.$ or $14.48kWh/m^2/month$ during the year 2014. comparing with other international airports, the TIA figures seem lesser, reflecting high energy efficiency.

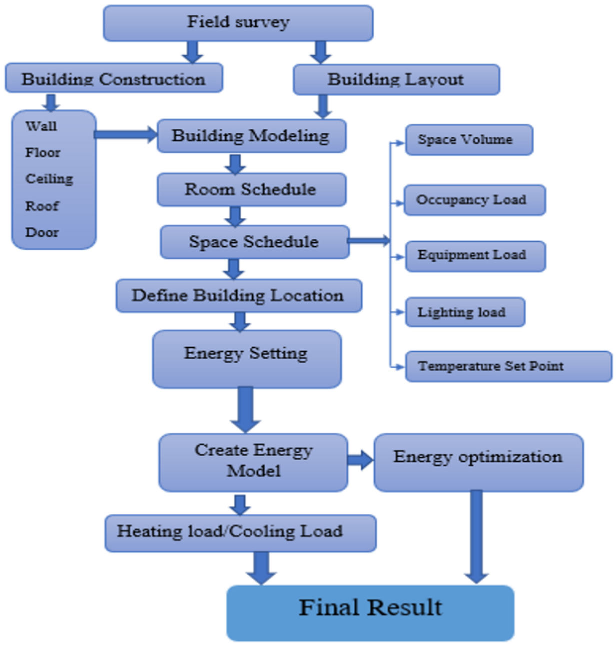

Figure 2: Building Energy Simulation Flowchart

it would be important to consider several defining factors influencing energy consumption like number of runways (TIA having just one runway), favorable weather conditions with low AC needs, facilitation and commercial activity extent and nature inside airport. Tribhuvan international airport is first international airport in Nepal. Which is located in Kathmandu, the capital city of Nepal. There are several machines and equipment are installed to make smooth operation of the airport. All the lighting system, machines and equipment's are operated by the electricity. Air conditioning systems, in-door and out-door lighting system, airfield lighting system, lifts, escalators, conveyor belts, water pumps, aviation and IT related equipment's are the major electrical loads of the TIA. According to the Pilot energy audit report 2014 the annual cost of electricity paid by TIA to NEA during fiscal year 2012/2013 is NRs 56,185,992 against the consumption of 5,388,009 kWh, which relates as NRs 10.42 cost per kWh (or Unit). Nepal energy efficiency program focus on installation of energy efficient appliances, improving HVAC system in Tribhuvan International Airport. The energy performance benchmark model for Airport terminal Building was tested for the effectiveness of evaluating the energy performance of existing and future Airport terminal Building, and is discussed here.[5] Autodesk Revit and Autodesk Insight 360 can also be used to create superior energy and environmental performance inside the building. Insight 360 carries current workflows like Revit Energy Analysis and Lighting Analysis for Revit model, which now extended customization options Insight360 facilitates to visualize solar radiation on building element surfaces with new solar analysis workflows as well as understanding PV energy production. It also controls and makes use of the power of EnergyPlus to produce dynamic thermal heating and cooling loads in Revit. [4] Designers and contractors may use BIM services to generate 3D models that could assist owners in making informed decisions [3] The overall process flow of energy analysis includes the following activities: initial contact, start-up meeting, data collection, field work, analysis, report and final meeting. The current work aims is to analysis phase by providing a comprehensive process for building energy modelling, energy performance assessment, identification of energy losses area and technically feasible energy efficiency measures to reduce the energy use intensity. [2] The type of roofing material will affect the thermal conditions in the roof space. Another result of this study was the effect of roof materials on reducing solar radiation on roof surface temperature[7]

3.1 Share of Electrical Energy Consumption in Various Segments

The air conditioning loads consume highest amount of electricity and during the year the air conditioning loads are assessed to account for 2.569 million kWh consumption, amounting to 48 percent out of TIA total annual energy consumption. The Lighting loads are assessed to account for 1.718 million kWh annual energy consumption, which amounts to 32 percent share in the total energy consumption of TIA. The segment of local sub-consumers inside TIA account for 0.6 million kWh annually, which relates as 11 percent share in the TIA annual energy consumption. The pumps, conveyors and others equipment are assessed to consume 0.45 million kWh annually, accounting for 9percent share of the total electricity consumption of TIA. [1]

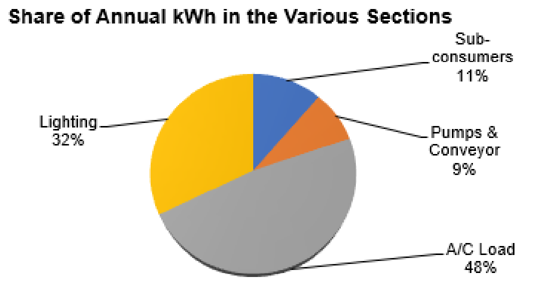

Figure 3: Share of Electrical Energy Consumption in Various Segments

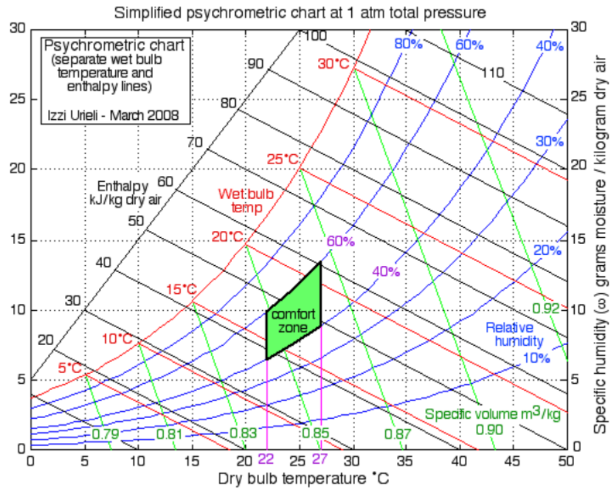

Figure 4: Comfortable temperature and relative humidity

4. Site Documentation

4.1 Airport location

TIA situated 5.56 km east of Kathmandu city is in the heart of Kathmandu Valley. TIA is at the confluence of three ancient cities namely Kathmandu, Bhaktapur and Lalitpur, vibrantly rich in art and culture, with breathtaking temples and pagodas, inhabited by smiling men and women, the pride of the nation. TIA has flourished not only as the main hub for ever expanding business interests of Nepal but also has opened up windows to various domestic and international destinations and airlines.

4.2 Comfort zone

The boundaries for different passive and active designs will be determined using bio climatic techniques chart. From the simplified psychometric chart at 1 ATM total pressure human Comfort zone is 22°c to 27°C and Relative humidity is 40 percent to 60 percent[6]. It reveals That passive measures such as thermal mass effect and can be an effective way to provide air movement Comfortable area inside. In humid climates, Air circulation seems more important. Summer Heat requires active cooling. during winter, can be beneficial due to passive solar heating Available solar radiation.

4.3 Domestic passenger flow through Tribhuvan International Airport

Passenger movement is affected by various things directly and indirectly. Such as climate, occasional, Festival and other uncertainties affect the passenger's movement. That's why only the compartment security check-in area of the building and the seat capacity of the passenger waiting hall have been considered during the simulation. A total seat capacity of 200 people including passengers and airport staff in the security check in area and a total of 470 seat in the passenger waiting hall and 30 different airlines and airport operation staff have been considered for a total of 500 people.

4.4 Building Envelope materials

All the sheets and design documents have been made available by the airport technical office; thus, the characterization of building envelope has been made. The building has reinforced concrete structure; the vertical opaque envelope has made brick-concrete composition. There is a fall ceiling with zinc sheet roof. Main characteristics of building envelope is listed in table. The floor of the ground level is made of Cement and ceramic tiles. There is a runway on the north side of this building and a ticket counter on the south side. The ticket counter is not air conditioned. In the northern part, 5 doors are used for passenger boarding to the aircrafts, while on the south side, through 2 large doors, passengers enter to hand baggage checking after ticket counter and the cargo comes from other side. These doors remain open until the airport opens.

4.5 Building ground layout modeling

Airport Terminal Building have multiple building (space) types, such as Security check-in area, café, Airlines shop, breast feeding room, VIP waiting room, smoking zone, toilet, restroom and other support areas. Types, operations, and different business models Each Airport terminal building. In addition, the structure of Building (space) type Airport terminal building should be analyzed to define characteristics. Information about the construction of the building is taken from the field survey. All the information about the wall, windows, doors, floor, ceiling roof of the building is defined by the field visit of the airport and the information given by the airport officers.

Name	**Area**(m^2)	**Volume**(m^3)
Security check in area	543	4189.88
Passenger waiting hall	1276	5991.52
Café	34	154.85
Airlines Shop	30	133.55
Breast feeding room	30	137.06
VIP room	64	286.94
Smoking Zone	14	54.84
Toilet 1	44	199.7
Toilet 2	23	114.2

Table 1: Room area and volume

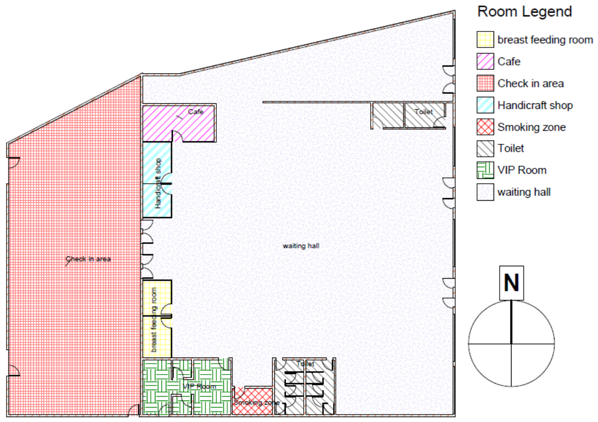

Figure 5: TIA domestic departure hall ground layout

5. Building Energy modeling and performance Analysis

This 3D Building model of TIA domestic departure hall build in Revit Autodesk platform. It includes 2 compartments. One is security check-in area and another is passenger waiting hall. It has 12" wall made with brick and cement mortar, corrugated galvanized iron (CGI) sheet with gypsum false ceilling and partial slab casting roof, Plane cement Concrete (PCC) flooring with ceramics marble tile, metal frame with single transparent glass windows and doors. This is an energy model created on Revit Autodesk after energy setting completion. Energy setting includes the site location, building construction material, building orientation and the

Figure 6: North face of domestic terminal building

Name	Sensible(W)	Latent(W)
Check in area	54,355	10,335
Waiting hall	136,026	26,050
café	3,712	536
Handicraft Shop	5,649	1,582
Breast feeding room	1,620	232
VIP room	2,748	402
Smoking Zone	unconditioned	
Toilet 1	unconditioned	
Toilet 2	unconditioned	
Total Cooling Load	**204,110**	**39,137**

Table 2: Building Cooling load

Name	Sensible(W)	Latent(W)
Check in area	-12,595	949
Waiting hall	-23,744	1,812
café	-537	37
Handicraft Shop	-469	32
Breast feeding room	-316	0
VIP room	-1,057	40
Smoking Zone	Unconditioned	
Toilet 1	Unconditioned	
Toilet 2	Unconditioned	
Total Heating Load	**-38,718**	**2,870**

Table 3: Building Heating load

analytical materials. It is a building energy model ready for the energy analyses.

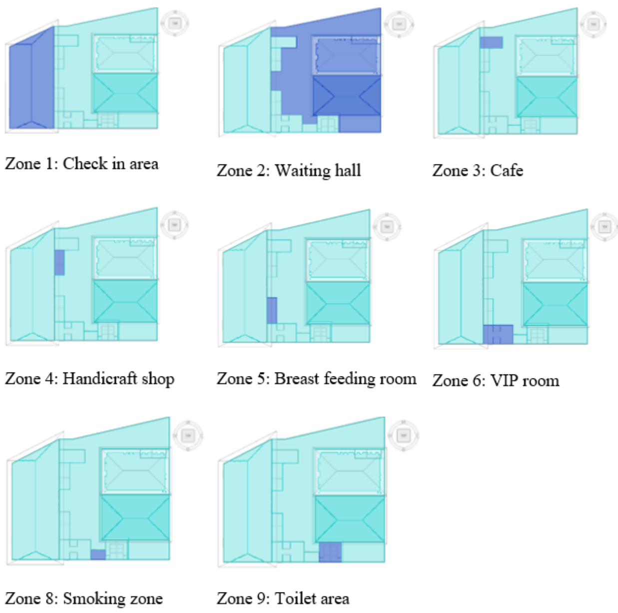

Figure 7: Energy model of domestic terminal building created in Revit Autodesk

6. Result and Discussion

6.1 Cooling and heating load

As shown in table 2 There is 204.110kW sensible load and 39.137kW latent heat load. The total peak cooling load of the building is 243.247kW. The smoking zone and toilet rooms has mechanical ventilation.

As shown in Table 3 there is -38.718kW sensible heat load and 2.870kW latent heat load. The smoking zone and toilet rooms has mechanical ventilation. The total peak heating load of the building is -35.848kW.

As shown in Figure 8 Total cooling load of the terminal building is 243.247kW and the total heating load of the terminal building is 35.848kW. according to simulation result the peak cooling load of the terminal building is more than the peak heating load of the terminal building.

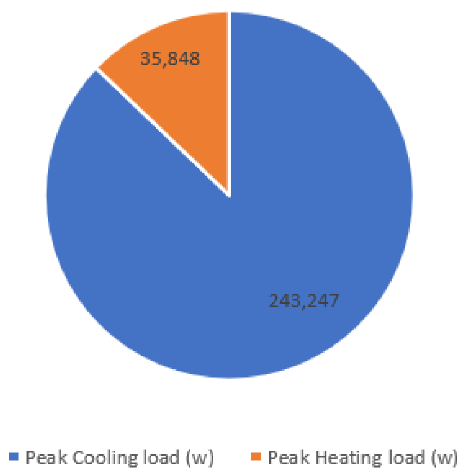

Figure 8: Peak Cooling and Heating Load

6.2 Energy Use Intensity and Building Energy Analysis

Based on the building energy analysis the energy use intensity of departure hall is $298kWh/m^2/yr$. comparing with ASHRAE 90.1 that building figures seems lesser, reflecting high energy efficiency.

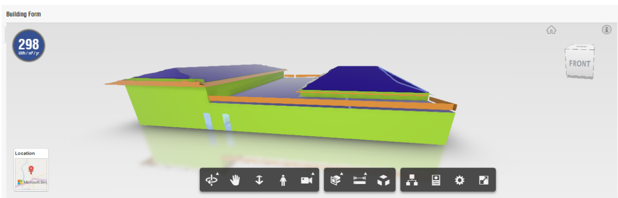

Figure 9: Autodesk Insight output

ASHRAE 90.1 -Benchmark comparison of energy standard for buildings.

6.3 Energy Saving Through Infiltration

Infiltration is in Air Change per hour (ACH). Hourly ventilation rate divided by the building volume. According to the Figure 10 Infiltration is greatly affecting the energy consumption of the building. When the infiltration rate reaches 0.17 ACH from 2 ACH, The EUI decreases from $298kWh/m^2/yr$ to $294kWh/m^2/yr$.

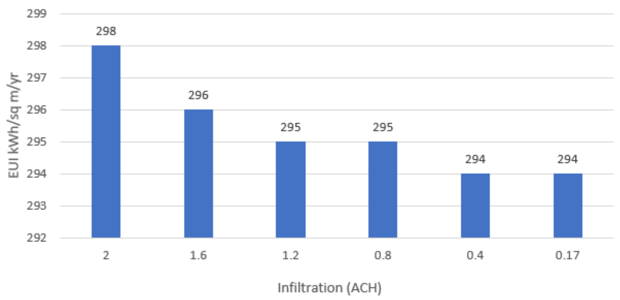

Figure 10: Variation of EUI with respect to infiltration (ACH)

6.4 Energy Saving Through Roof construction

Roof is constructed by corrugated galvanized iron CGI sheet with gypsum false ceiling and partial slab casting. As shown in Figure 11 Roof construction has great potential to reduce heating and cooling. When R19 insulation placed in Un-insulated roof construction, The EUI decreases from $298kWh/m^2/yr$ to $294kWh/m^2/yr$.

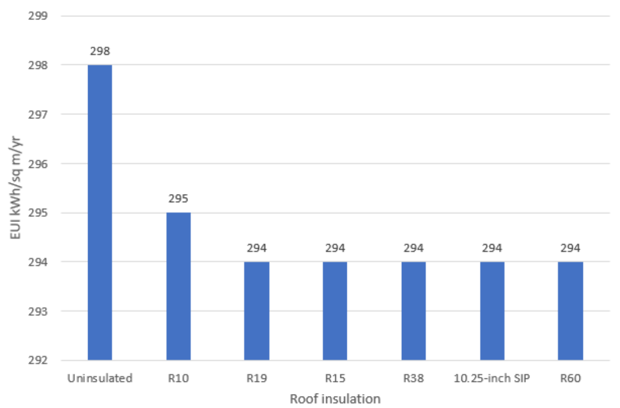

Figure 11: Variation of EUI with respect to Roof construction

6.5 Energy Saving Through Window glass

Windows are only on the east side and Windows Wall Ratio is 25 percent. In this building model windows glass material has slightly less energy saving potential. In case of single clear glass, it will add $1kWh/m^2/yr$ more energy on building energy intensity then double low-E glazing. In case of triple Low-E Glazing it will reduce $1kWh/m^2/yr$ energy on building energy intensity. Using Triple-E glazing than when keeping single clear glass, building EUI decreases to 297 $kWh/m^2/yr$ from $298kWh/m^2/yr$.

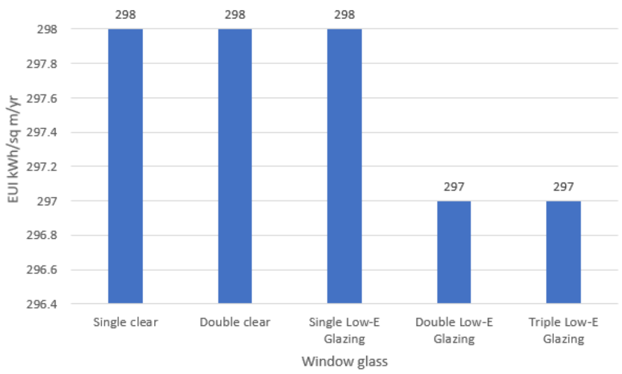

Figure 12: Variation of EUI with respect to window glass

7. Conclusion

In this study building energy simulation of TIA domestic departure hall has been taken. According to the simulation result of Autodesk Revit and Insight 360. building heating peak load is less then building cooling peak load. Due to the transportation building, there is a lot of passenger movement, so the cooling peak load is high. Based on this building energy Simulation the energy use intensity (EUI) of departure hall is $298kWh/m^2/yr$. From this study, the role of roof construction, windows glass and infiltration rate has been studied to minimize energy consumption and building energy use intensity. According to the Figure 10. Figure 11 and Figure 12 when the infiltration rate reaches 0.4 ACH from 2 ACH, The EUI decreases from $298kWh/m^2/yr$ to $294kkWh/m^2/yr$. When R19 placed over existing roof construction, The EUI decreases from $298kWh/m^2/yr$ to $294kWh/m^2/yr$. comparing with other national and international airport terminal buildings, TIA domestic terminal building figures seem lesser, reflecting high energy efficiency. it would be important to consider several defining factors influencing energy consumption like favorable weather conditions with low AC needs, facilitation and commercial activity extent and nature inside airport terminal building.

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