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

By

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A THESIS

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DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

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The undersigned certify that they have read and recommended to the institute of engineering for acceptance, a thesis entitled **'Energy Performance Analysis: A Case Study on Domestic Departure Hall Tribhuvan International Airport of Nepal'** submitted by Ritu Shrestha, in partial fulfillment of the requirements for the degree of Master of Science in Engineering in Energy System Planning and Management.

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ABSTRACT

The study summarizes design parameters for effective building envelope design from simulation results to reduce dependence on active means of mechanical systems, which turn helps improve thermal comfort. Tribhuvan International Airport is first international airport in Nepal which is in 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. Domestic and international terminal buildings are approximately 1 km apart. This research is about the electricity consumption by the heating and cooling at domestic departure hall at Tribhuvan International Airport, it should be maintained smooth operation of air condition system at multiple zones of the airport to keep comfortable to the passengers. Most part of the energy consumption is occupied by heating and cooling system and this consumption needs to be optimized to reduce whole energy consumption of the buildings. This research focuses on the energy performance of the building envelope of an Airport Terminal Building in Kathmandu, Nepal. This study explores how to improve thermal comfort energy analysis through a quantitative analysis of the effect of thermal characteristics of the building envelope. This analysis is based on the energy analysis in Revit Autodesk and energy optimization in Insight 360. Development of base model is in Revit and duplicated in Autodesk Insight. Based on the building energy analysis the energy use intensity (EUI) of departure hall is 298 kWh/m^2/yr. comparing with ASHRAE 90.1 that building figures seems lesser, reflecting high energy efficiency. From the building energy analysis report cooling load is 243.249kW and heating load is 35.848kW. In this building peak load, heating load is 9129W and cooling load is 10065W due to roof construction. while the infiltration rate reaches 0.4 ACH from 2 ACH, The EUI decreases from 298kWh/m^2/yr to 294kWh/m^2/yr. When R19 insulation placed over existing roof construction, The EUI 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.

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LIST OF ABBREVIATIONS

AC	Air Condition
CAAN	Civil Aviation Authority of Nepal
TIA	Tribhuvan International Airport
TIACAO	Tribhuvan International Airport Civil Aviation Office
ICAO	International Civil Aviation Organization
TDO	Terminal duty Officers
VRF	Variable Refrigerant Flow
VRV	Variable Refrigerant Volume
DG	Diesel Generator
DB	Distribution Box
GF	Ground Floor
HVAC	Heating Ventilation and Air Conditioning
DTB	Domestic Terminal Building
kVA	Kilo Volt Ampere
kVAR	Kilo Volt Ampere Reactive
kWh	Kilo Watt Hour
km	Kilo Meter
MVA	Mega Volt Ampere
NEA	Nepal Electricity Authority
NRs	Nepali Rupees

VIP	Very Important Person
HT	High Tension
LT	Low Tension
COP	coefficient of performance
SEER	Seasonal energy efficiency ratio
ACH	Air change per hour
BIM	Building Information Model

CHAPTER ONE: INTRODUCTION

1.1 Background

Tribhuvan International Airport (TIA), located at Gaucher-Kathmandu, established in 1949 A.D, is situated 5.56 km east of the central Kathmandu. The TIA has operational land area is about 2,320,000m^2 and total building area is about 31,000 m^2 including International Terminal Building (ITB), Domestic Terminal Building (DTB), 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 7,000 m^2 of international terminal and about 5,000 m^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 passenger's travels through Tribhuvan international airport come from a variety of climate fears. If 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 airport 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. The VRF Air condition installation in the domestic departure has just been completed and is now in operation. Single storey building from where thousands of passengers leave from Kathmandu to various airports of Nepal every day. Air-conditions have been installed in this departure hall for the comfort of the passengers waiting for the airplane.

Determining the actual electricity consumption and energy efficiency of the variable refrigerant flow (VRF) system in buildings is difficult. The procedure can take high costs associated with the complex measurements required. The performance of the VRF system is influenced by several factors, such as operating mode, set point temperature and climate(Qian *et al.*, 2020).

Efficiency of the electrical system and the electricity consumption, that can be considered as the main indicator to measure and evaluation of the performance of any electrical power systems. In building electrical system, it is quite hard to determine actual power consumption and system efficiency because the procedure requires complex measurements and it takes high cost.(Liu *et al.*, 2015a) .

One of the main methods to assess the performance of VRF system is to use of physical and data-driven models. Data-driven model, more data is needed for training this model. However, it is difficult to determine the actual electricity consumption and energy efficiency of the HVAC system in buildings. The procedure requires complex measurements and it takes a high cost to associate. The performance of the system has been affected by a number of factors, such as operating mode, set point temperature and climate Performance testing in the lab can illustrate the performance of the system in all conditions(Qian *et al.*, 2020).

However, representing the main situation is challenging of the systems. It is impossible to get real performance of the system in actual field. Actual testing of the actual performance of the system is quite difficult and challenging with compare to the laboratory testing and it can only test. It will be conducted on normal samples instead of large-scale samples (Liu *et al.*, 2015a).

Common fragments are not sufficient to reflect the performance of large-scale VRF system samples. Therefore, A simple method to evaluate is needed large scale VRF practice. Occupant behavior of the residential building could be important to determine the performance of the VRF system. The occupant behavior is important to determined complex operating mode of the VRF system possessive behavior marked it difficult to get real VRF system performance(Qian *et al.*, 2020).

Heating, ventilation and air conditioning systems account for about 50% of total building energy consumption(Liu *et al.*, 2015b). Unlike split AC equipment allows single indoor and outdoor unit, Variable Refrigerant Flow (VRF) system allows multiple indoor units to run the single system. VRF system is designed differently depending on its application. VRF system is considered either heat pump systems or heat recovery systems, VRF system can also heat and cool simultaneously. It can also joint by three pipe system to use refrigerant for both cooling and heating. A VRF is a ductless, large-scale system for high-performance HVAC. HVAC system of TIA domestic departure hall considered as nonessential load. This study is about the operational electricity consumption, Peak Heating/cooling load and Energy use intensity of the building at domestic departure hall at Tribhuvan International Airport. Proper building envelops systems can reduce the energy consumption and it also improves the building energy efficiency. It have huge potential of energy saving (Zhao *et al.*, 2021). This research is concern with reduction of operational electricity consumption on HVAC system.

1.2 Problem statement

The pilot energy audit at Tribhuvan International Airport was conducted during 26 December 2013 to 9 January 2014. This audit report suggests replacing old HVAC plant to reduce heating and cooling load, using LED instead of old lighting system, using occupancy sensor, reduce reactive load, using star rated equipment, and balance load to minimize cu loss.

It should be maintained smooth operation of air condition system at multiple zones of the airport to keep comfortable temperature and humidity to the passengers. Most part of the energy consumption is occupied by HVAC system and it needs to be optimized to reduce whole energy consumption of the buildings. Electricity consumption in airport can be improved by optimizing HVAC system.

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 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. According to weather record of the Kathmandu maximum and minimum outdoor temperature reached up to 2.3 degree centigrade in winter and 34 degrees centigrade in summer. This study is about the operational electricity consumption analysis of heating and cooling in domestic airport departure hall, Tribhuvan International Airport Kathmandu.

1.3 Objectives

Main Objective

To study and analysis, the energy performance of the domestic airport departure hall in Kathmandu, Nepal and the scope to reduce energy consumption

Specific Objective

- To develop Building energy model in Revit Autodesk
- To study heating and cooling load of domestic airport departure hall in Kathmandu, Nepal
- To find the parameters of the major energy consumption of the domestic airport departure hall Kathmandu, Nepal
- To quantify the annual energy saving from the infiltration rate, roof construction, glass windows at the domestic airport departure hall Kathmandu, Nepal

1.4 Limitations

In this building energy analysis, it has been done only to analyze how much Heating and Cooling load can be reduced. This study has been done to analysis how much difference windows glass, roof construction and infiltration rate make to increase the energy efficiency of the building.

CHAPTER TWO: LITERATURE REVIEW

The specific energy consumption of TIA (both international and domestic terminals) per square meter was comes out 173kWh/m^2/year or 14.48kWh/m^2/month during the fiscal year 2013/2014. This data obtained from Pilot energy audit report of the Tribhuvan international Airport. Tribhuvan international airport is one of the first international airport in Nepal. Which is 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.

Terminal buildings use large amounts of energy for lighting, heating, ventilation, air conditioning, and transportation systems. They are characterized by large volumes of spaces, often with non-uniform heat gains and extensive glazing areas (such as glass curtain walls) intended to provide natural light and aesthetically appealing features. Energy consumed by HVAC systems can exceed 40% of total electrical energy(Kotopouleas and Nikolopoulou, 2019).

Nepal energy efficiency program focus on installation of energy efficient appliances, improving HVAC system in Tribhuvan International Airport(GIZ, 2015).

Most of the energy analysts use the concept of Energy Use Intensity (EUI: kWh/m^2/yr. or kBtu/sf/yr.) to perform quantitative analysis of the energy performance. This unit can be used to measure the energy consumption level relative to the building's total area (Kim, Shin and Ahn, 2020).

The CBECS report indicates the Energy Use Intensity of 14 types of buildings. It had been taken 5000 measured data. For example, the report presents the survey results that the EUI of office buildings is 293.1 kWh/m^2/yr, and Healthcare is 592.2 kWh/m^2/yr, respectively. However, Transportation building such as airport terminal, bus stope, train stations and ship berthing facilities are very different in terms of functionality and other operational characteristics. They are not properly classified in detail(Kim, Shin and Ahn, 2020).

2.1 Electricity Supply and share of electrical energy consumption in TIA

Electricity used for TIA is received mainly through a 11 kV dedicated Chabahil feeder. Another 11 kV feeder from Baneshwor serves as an emergency standby. The total NEA approved demand of TIA is 2,362.5 kVA on 11 kV HT side and 141.25 kVA on LT side. The maximum demand recorded in the NEA Chabahil dedicated feeder in the year 2013 was 1,336 kVA (out of the contract demand of 2,000 kVA). In addition to the NEA power supply, TIA has also installed 7 units of Diesel Generator (DG) Sets with total capacity of 1,600 kVA.

The air conditioning loads consume highest amount of electricity and during the fiscal year 2013/2014 the air conditioning loads are assessed to account for 2.569 million kwh consumption, amounting to 48% 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% 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% share in the TIA annual energy consumption. The pumps, conveyors and others equipment are assessed to consume 0.45 million kWh annually, accounting for 9% share of the total electricity consumption of TIA (CAAN, 2014)

2.2 Building location and Monthly temperature record

For the weather data and temperature profile of the building, location setting is important.

Figure 2.1 TIA domestic terminal building from google map

This airport terminal building is in north side of Kathmandu Latitude 27.6969 and longitude 85.3592 and elevation 4370ft.AMSL. Closest address (KTM), Ring Road, Kathmandu 44600, Nepal. It is in the middle of the confluence of three ancient cities namely Kathmandu, Bhaktapur and Lalitpur. The airport is connected to most parts of The Kathmandu Valley by the ring road. Maximum temperature of Kathmandu is recorded 34˚c in summer season and the minimum temperature of Kathmandu is recorded 2.3˚c in winter season. This temperature profile is records of the Kathmandu weather station. Monthly temperature variation of the Kathmandu is illustrated in Figure 2.2.

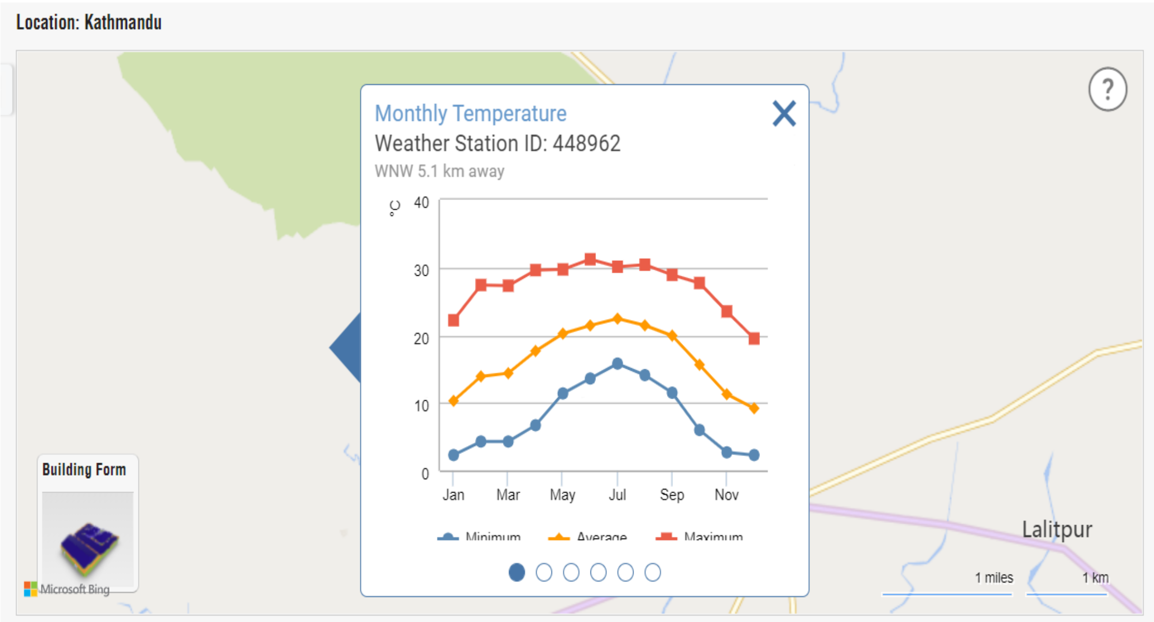

Figure 2.2 Temperature variation of Kathmandu recorded by Kathmandu weather station

2.3 Human comfort zone

The boundaries for different passive and active designs will be determined using bioclimatic techniques chart. From the simplified psychrometric chart at 1 atm total pressure human Comfort zone is between temperature is 22˚C to 27˚C and Relative humidity is 40% to 60%. 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 (Uprety, 2021).

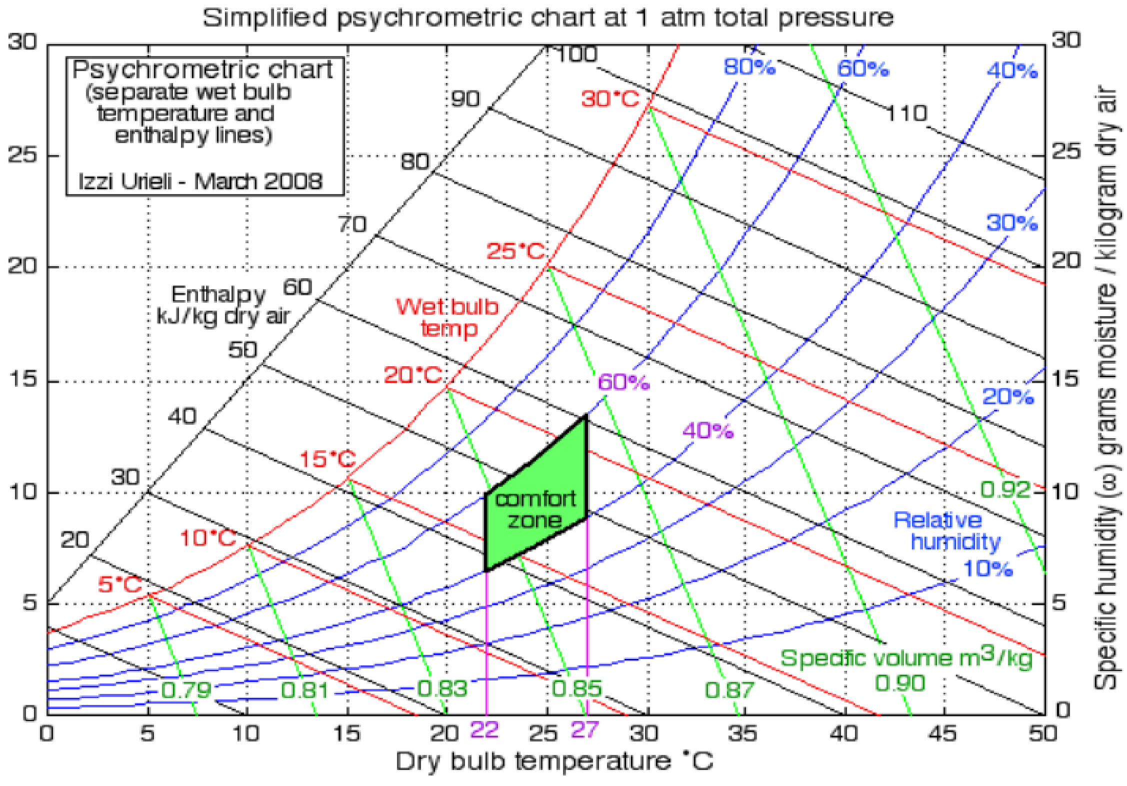

Figure 2.3 psychometric chart defines the comfortable zone

Table 2.1 Recommended comfort criteria for airport terminal spaces

	Summer	Winter
	Operative temperature	
Baggage reclaims	21-25	12-19
Check in area	21-23	18-20
Departure lounge	21-25	19-24
Concourse (no seat)	21-23	18-20
Customs area	22-24	19-21

(Kotopouleas and Nikolopoulou, 2019)

Table 2.1 illustrate the recommended comfort criteria for airport terminal spaces. Airport terminal buildings which include the different services and the individual service type need different comfort criteria. This temperature ranges are recommended by the (Anon., 2010). This report recommend the clothing insulation of 0.65 in summer and 1.15 in winter (Kotopouleas and Nikolopoulou, 2019).

2.4 Building Envelope materials and profile

All the sheets and design documents have been made available by the airport technical office; thus, the characterization of building envelope has been made.

Table 2.2 Building Envelop materials

Component	Description
wall	Brick wall with cement mortar
Roof	Corrugated galvanized iron CGI sheet with gypsum false celling/ partial slab casting
Floor	Plane cement Concrete (PCC) flooring with ceramics marble tile
Entrance/ exit	Metal frame with single transparent glass
windows	Metal frame with single transparent glass

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.

In order to simulate reliable building energy performance, the numerical value has been characterized by data acquired by means of field surveys, interviews with managers and occupants and in-field measurements. Building envelops, construction material as shown in Table 2.2. wall is made of brick wall with cement mortar. The roof is constructed by corrugated galvanized iron CGI sheet with gypsum false ceiling and partial slab casting. Building floor is made of plane cement concrete (PCC) flooring with ceramics marble tile. Building entrance and exit is made of aluminum frame with single transparent glass and windows are made of aluminum frame with single transparent glass.

Table 2.3 Domestic airport departure hall profile

Facing	East facing
Operation period	➢ 18 hours ➢ 7 days ➢ 12 months
Area of thermal performance	➢ Window glass ➢ Roof construction ➢ Infiltration ➢ Passenger movement

Tribhuvan International Airport, domestic terminal building profile is as shown in Table 2.3. building have different space and service type. The airport operation period is 12 months, 7 days and 18 hours. 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, 6 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.

2.5 VRF system Air-Condition in Airport Terminal Building

VRF refers to the variable refrigerant flow. The technology of the VRF system allow to circulate only the minimum amount required during a single heating or cooling period. The mechanism of VRF system provided end users with the opportunity to individually control multiple air conditioning zones at the same time. VRF system takes long way to explain how the system uses refrigerant for both cooling and heating purpose. It is a ductless, large-scale system for high-performance HVAC. Unlike split type AC equipment has single indoor and single outdoor unit, VRF allows multiple indoor units to run in the single system. VRF system designed differently depending on the different application. VRF systems are considered either heat pump systems or heat recovery systems. VRF system can be operate in heating and cooling simultaneously.

VRF system can achieve high efficiency by using their inverter compressors. Inverter system can allow the compressor to run up or down depending on the demand the needs within each space. A non-inverter system always allows the compressor to run in full capacity. As like inverter systems operate at lower speeds and at lower capacities, the efficiency gains can be substantial.

The mechanism of the VRF system allows to connect multiple indoor units with single system and each indoor unit are connected by combining same refrigerant pipe networks. The system can adjust multiple indoor to operate in different indoor criteria and varying load on each indoor to meet their different comfort demand. The VRF system can adjust the operation of each indoor units in different rooms and different zone to meet their varying loads and different comfort demand(Liu *et al.*, 2019).

2.6 Autodesk Revit and INSIGHT 360 in Building energy analysis

Autodesk Revit and Autodesk Insight 360 can be used to create the energy model and to perform energy performance analysis of the domestic departure hall Tribhuvan International Airport Kathmandu, Nepal. Revit Autodesk can be used to generate the base model of the building with their physical and thermal properties and it can also used to analysis the building heating and cooling load and the area of energy consumption. Annual energy consumption of the building can be obtained from the Revit. Insight 360 could use to perform Energy Use Intensity (EUI) of the building. Insight 360 can also used to optimize the energy performance of the building and it assists to retrofit the exiting building to optimize building energy performance. Insight 360 facilitate visualization of the solar radiation on the surface to create new solar analysis workflow as well as PV energy generation. The analysis could use the power of the energy plus to produce the thermal heating and cooling loads in Revit Autodesk(Alba and Manana, 2016).

BIM software has been used to create building model and to generate the building energy model. Two software programs has been considered for design the building model, Autodesk Revit and the Insight360. BIM software could assist user to make wise decision. BIM software make easy and can assist to make construction safer. It can simplify the procedure of designing and construction of new building. It has also facilities to retrofit the existing construction.

The Insight platform could be used to investigate roof, windows material and infiltration rate and efficiencies of building thermal properties. Insight optimization option could use to minimize the building energy consumption. Other variables were maintained constant over the selected models to perform the energy performance analysis of the relative energy model.

2.7 Psychometry and psychometrics

It is not possible to find dry air in practice. Air always contains some part of water vapor that is called moisture. The moisture contains in air effect on the human comfortable. Psychometry is name as an art to measure the moisture content in air. It plays most important part in human comfort factor and it has significant effects on many other materials. Psychometrics, the science which studies the effect of moisture on material and human comfort, it is a science to investigate the thermal properties of moist air ans control the moisture content of air. Dry bulb temperature generally refers to the ambient temperature. It is the temperature of air measured by ordinary thermometer. The air temperature which is indicated by a dry bulb thermometer not affected by the moisture of the air. Wet bulb temperature, it is the temperature measured by a thermometer when the bulb is covered by a wetted cotton and is exposed to a current of rapidly moving air. It combines dry air temperature with humidity.

Humidity is the amount of water vapor contain in the air. It is the presence of water molecules in the air. High humidity levels are more likely in warm air, because air can hold more water at higher temperature. If the temperature of air is high, it has also more capacity to hold more water molecules on it.

2.8 Roof construction and energy consumption

Zinc is an excellent roofing and cladding material that provides long and almost maintenance-free service. Proper installation is not only the correct fixing of zinc, but also the correct design and installation of the support structure. 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 (Ratih Widiastuti∗, 2018).

It is indicated that with the use of green roofs, the annual baseline electricity consumption for heating and cooling loads in Tehran, Tabriz and Bandar Abbas was reduced by 16.3%, 12.5% and 23%, respectively. The use of green roofs in tropical regions (Bandar Abbas) is more efficient than in cold regions (Tabriz) (Ehyaei, 2020).

The report indicate that the green roofs in the humid tropics had significant thermal insulation capabilities, with a decline in thermal conductivity, of up to 57.1%from 1.99 to 0.85 W/(m K) in the concrete roofs, and 90% from 5.87 to 0.59 W(m K) in the corrugated zinc roofs. As opposed to non-green roofs, green roofs could reduce heat flow by up to 56% from 19.3 to 8.5 W/m2 in concrete and could reach 50.8% from 39.6 to 19.5 W/m2 in corrugated zinc. Green roofs over humid tropical dwellings are therefore useful for improving environmental microclimates, particularly in dense urban contexts(Yuliani *et al.*, 2021).

2.9 Infiltration and energy performance

Infiltration is a natural phenomenon that occurs when the outside of a building is higher than the inside, causing air to leak from the outside to the inside of the building envelope. This can increase peak heating and cooling loads and potential indoor air quality concerns because the infiltrating air is unfiltered and unconditioned. This differential pressure is created by three elements: stack effect, wind and mechanical building pressure. Each of these three elements varies from building to building and moment to moment, resulting in a heating and cooling variable that is challenging to calculate, measure and control(Kevin Ricart, Rosemary Hwang, 2020).

Infiltration is the cause of 15-30% space heating energy use with ventilation in a two-story detached house when the building leakage rate is n50 is typical (3.9 ACH), while the corresponding ratio is About 30-50% (10 ACH) in leaky houses. Correlation of the airtightness of the building envelope and Infiltration rate is almost linear with heat energy use of houses at the same time increases almost linearly(Jokisalo *et al.*, 2009).

2.10 Air curtain performance to improve energy efficiency

It keeps the environment clean from insects and vermin, dust, airborne, pollution, smells, odors and drafts and entry of cold or hot air. The operation of the air curtain is based on a high-speed jet of air that covers all openings. Air curtains are an effective way to separate the environment of two areas. They serve as a virtual barrier for many applications, preventing heat and cooling losses and eliminating the flow of pollutants.

Building inlet orientation, building pressure, and door usage frequency all affect air infiltration/exfiltration. and energy performance resulting from air curtains compared to single doors and vestibules. In particular, the entrance orientation of the building and the balance of the HVAC system cannot be influenced were ignored and they were shown to be as important as door usage frequency(Tang, Tao and Zheng, 2022).

In addition to blocking the flow of cold and hot air, air curtains keep the indoor environment clean of insects, dust, particles, pollution and odors. Researchers proved that the use of highly efficient air curtains in shops means more than 30% energy savings (Gil-Lopez *et al.*, 2013).

Figure 2.4 Interior doors with Air curtain in domestic Airport departure hall, TIA, Kathmandu.

As shown in the Figure 2.4, air curtains have been installed at all doors of TIA domestic airport terminal buildings, but air curtains are not always kept in operation. As the staff of the airlines and security guards must sit at the door during the boarding pass check and security checking, the noise is high, the air curtains are often closed.

2.11 Windows type and energy performance

Many design features and technologies make windows more energy efficient and improve durability, aesthetics and functionality. Improving the thermal resistance of the frame can contribute to the overall energy efficiency of the window, particularly its heat loss rate or U-factor. All types of frame materials have advantages and disadvantages, but vinyl, wood, fiberglass, and some composite frame materials offer greater thermal resistance than metal. The most important decision regarding energy efficiency in many windows is the selection of glazing. Based on various window design factors such as window orientation, climate, building design, etc.

Energy efficient glazing covers both double and triple glazing. These are windows with two or more glass panes in a sealed unit. You can also improve the energy efficiency of your home by installing secondary glazing, or even by using heavy curtains. Having energy efficient windows could help to reduce your carbon footprint and your energy bills.

Energy efficient glazing covers both double and triple glazing. These two or more glass panes are windows in a sealed unit. By installing secondary glazing or using heavy curtains can also improve building's energy efficiency. Energy efficient windows can help reduce building's carbon footprint and building's energy bills.

Energy conservation in the construction sector is an essential issue to achieve a sustainable environment. However, buildings experience large amounts of heat gain or loss through windows and this will affect the thermal comfort of building occupants. Building without windows is able to save energy, but it is not recommended because of the benefits of natural light in visual comfort and the biological effect of natural light on humans(Latha, Darshana and Venugopal, 2015).

By design with optimal solar cell transmission in each area, the total electricity consumption of the building has decreased by 2.4 percent the best case of uniform transmittance design, which was a WWR of 50% and Transmission of 40%. The reduction resulted in 55% compared to the standard Model(Miyazaki, Akisawa and Kashiwagi, 2005).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Methodology for research

This chapter address the selection of quantitative analysis method used to evaluate data of the building energy analysis. Detailed methodology used in this research which includes research objective, data collection procedure, research strategy, research process, building geometry, building model creation, energy settings, result analysis is explained. Research process is as illustrate in Figure 3.1.

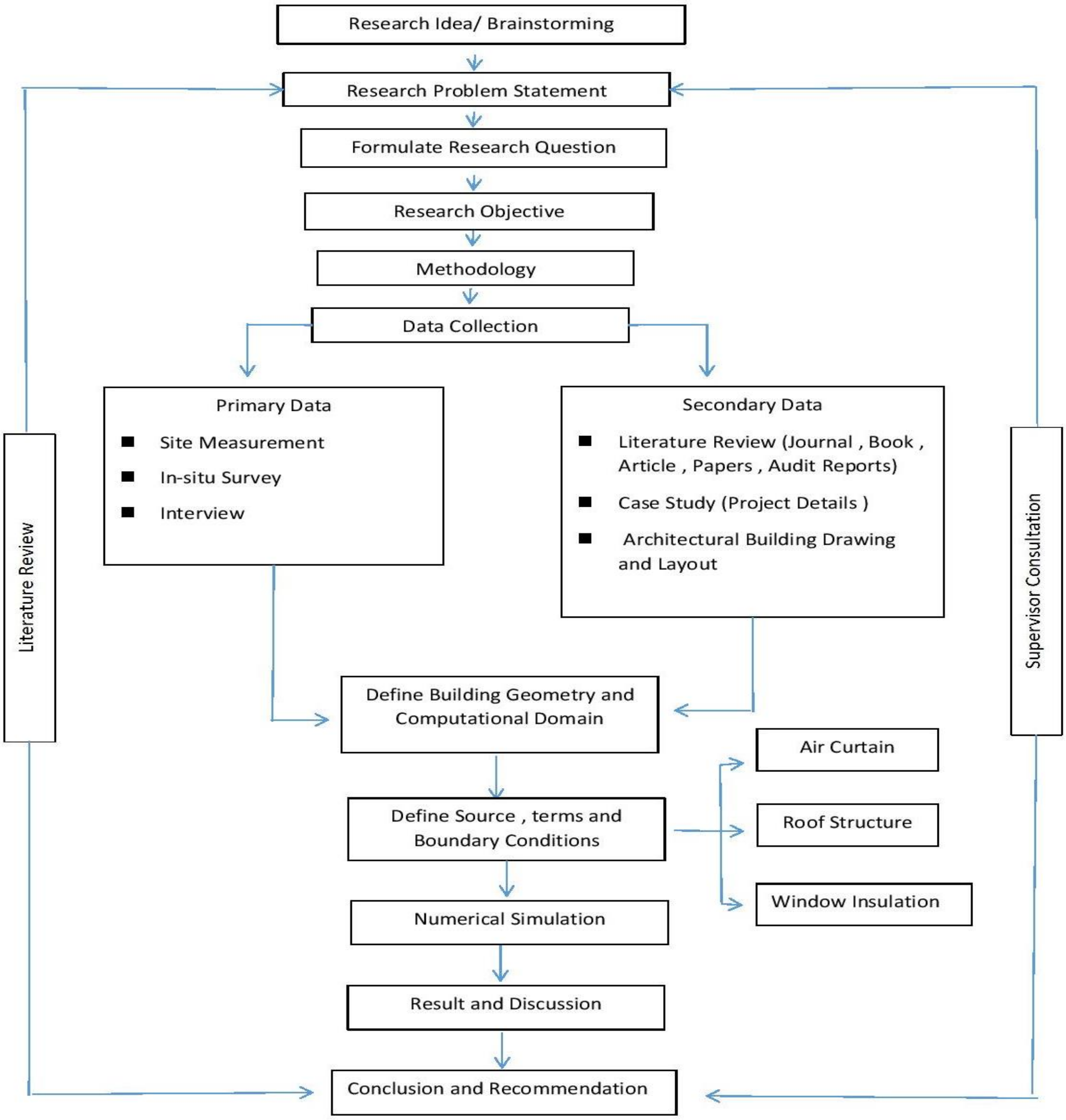

Figure 3.1 Research Methodology

3.2 Research framework

This research mainly focusses on the energy performance evaluation of the domestic departure hall Tribhuvan International Airport, Kathmandu, Nepal. It is a quantitative analysis and it explore the potential of energy saving through building envelope system. This research illustrates how to improve thermal comfort of the building through quantitative analysis of the energy performance of the effect of thermal characteristics of the departure hall. The building model and building annual energy simulation model has been generated in Revit Autodesk. The study summarizes the potential energy saving of air infiltration rate to the buildings. This study will define annual saving of building electricity from the simulation results which turn helps to improve thermal comfort. The overall process of the research includes various stages it includes the following activities: initial contact, start-up meeting, field survey, data collection, building modeling, energy performance analysis, documentation, report writing and final meeting. The current research work aims are to building energy modelling, energy performance assessment, identification of energy losses area and technically feasible energy efficiency measures to reduce the energy use intensity. A flowchart of the methodology is shown in Figure. The methodology that is following during the project is shown in the flowchart below.

3.3 Study site

This research has been conducted in domestic airport departure hall of Tribhuvan International Airport, Kathmandu, Nepal. Tribhuvan International Airport is one of the first international airport in Nepal which is in mid of the capital city Kathmandu, Nepal. It is operating with different domestic terminal building and an international terminal building with single runway. This domestic airport, it connects Kathmandu to another domestic airport in Nepal.

3.4 Data Collection

This research work has been collected different data requirements. Primary data were collected from in-situ field survey and interviews with airport officers. Building location and envelope material were analyze via in-situ field survey. Passenger movement of the domestic airport were obtained from the spreadsheet shared by TIACAO “daily flight & passenger movement list”.

3.5 The study instruments

Primary data has been collected through field survey and the secondary data has been collected through research paper, journal articles, government report, TIA data records and interviews with the airport officers. These data were used to construct the building modeling in Revit model. The Revit building model was copied to Autodesk INSIGHT 360 in order to further annual energy simulation of the building.

3.6 Building energy simulation

The building base model has been developed in Revit and simulated in Autodesk Insight.

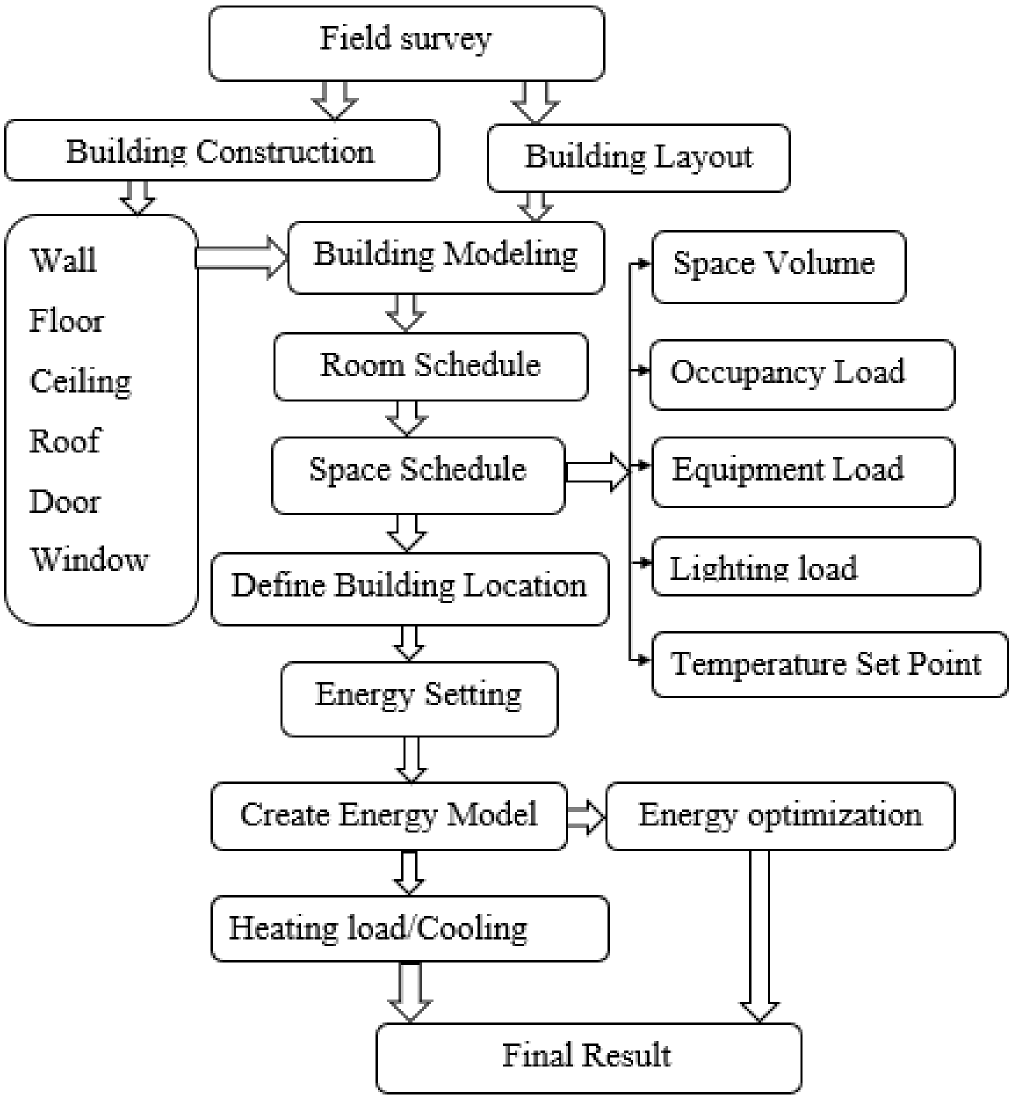

Figure 3.2 Building Energy Simulation Flowchart

These building energy simulation tools have been used to study the energy performance of the existing building and thermal comfort to reduce energy consumption of the building's mechanical systems through retrofitting strategies. This tool helps to illustrate the potential area of the energy losses. Figure 3.2 address the flow of creation of building energy model and building energy simulation.

3.6.1 Field survey

Field survey is one of the most widely used methods and one of the reliable methods to collect sufficient information of the site. It is the most widely used by researchers for the primary data collection process. In some cases where secondary sources of data do not provide sufficient information field surveys allow researchers to better monitor and evaluate the impact of field experiments.

3.6.2 Building layout

Domestic airport terminal building layout has been provided by TIACAO. From the building layout, the measurement the building, length, width, and orientation of the building were obtained. The layout of that building has been illustrated in the la appendices 2 of the report.

3.6.3 Building construction

Information about the construction of the building has been taken from the field survey. All the information about the wall, windows, doors, floor, ceiling roof of the building has been defined by the field visit of the airport and the information given by the airport officers.

3.6.4 Building modeling

The 3D Building model of TIA domestic departure hall has been built 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 celling and partial slab casting roof, Plane cement Concrete (PCC) flooring with ceramics marble tile, metal frame with single transparent glass windows and doors. After collecting of primary and secondary data of the building construction of the building modeling has been done in Autodesk Revit platform, TIA Domestic Departure Hall Building Model built in Revit Autodesk.

3.6.5 Room schedule

Airport terminal Building includes different service type like, check in area, waiting hall, VIP waiting hall, café, smoking zone, baby breast feeding room and toilet. Different room has different service type and carry individual load pattern. Area and volume of the different room has been set in Revit Autodesk. Different room has been set up individually.

3.6.6 Space schedule

When simulating a building's heating and cooling loads, accurate modeling and accounting for space utilization should be done. Often, design loads must be revised due to incorrect or incomplete accounting of space utilization, components, internal loading, or design. Change of space use. Creating a work schedule of building space properties in Revit MEP will help the model and coordinate the factors. Condition Type Describe the type of space conditioning (e.g., heating and cooling, hot, cold, or unconditioned). These things are included.

Table 3.1 Space load scheduling

Heating set point temperature	22˚c
Cooling set point temperature	24˚c
Lighting load	Default- By space type
Equipment load	Default- By space type
Occupancy load	As per passenger movement

3.6.7 Define building location

In order to provide the weather data and variation of temperature profile of the site, the building location should be in Revit Autodesk. There is an option to setting the site location in Revit.

3.6.8 Energy setting

It uses the information generated by the energy model to specify that Revit to perform energy simulations for walls, doors, ceilings, windows, and floors. Energy settings governs the behavior of the energy model, thermal characteristics, physical properties, and thermal space properties. Energy settings control the behavior of the energy model creation. It also allows to be setting up the optional additional parameters of the model which is specified by the Revit. The building energy model has been created on Revit Autodesk and it has been based on the thermal input values for various building components such as building's wall, ceilings, roofs, floors, and glass, this affects the heating and cooling loads on the building.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Building energy analysis

Building energy model has been generated on Revit Autodesk based on the input provided by the users. The information which has been set by the users such as site location, weather data, thermal characteristics and building envelopes. the energy model has been generated as color codes with various HVAC zone in order to be simulated by Insight.

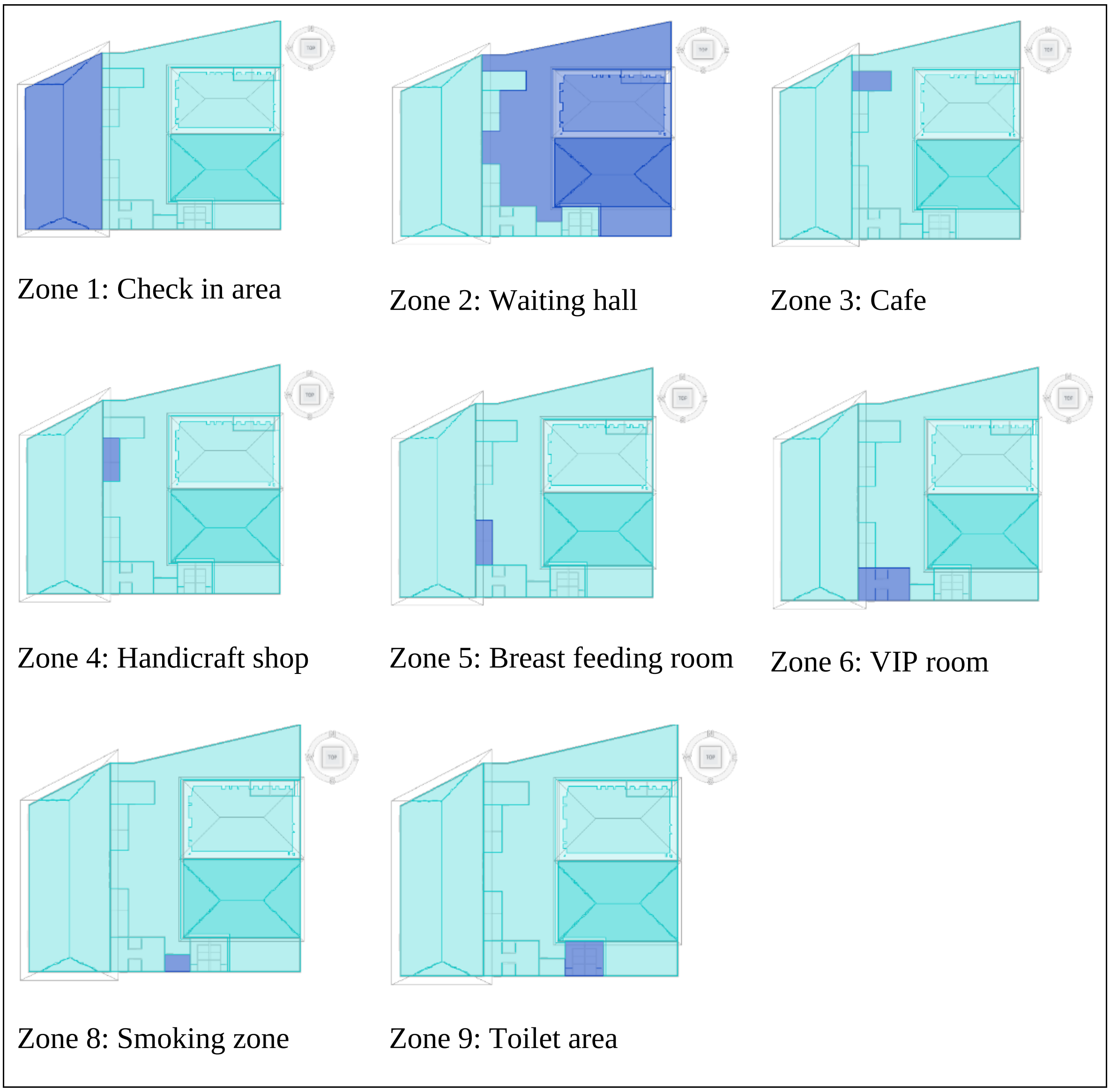

Figure 4.1 Revit Autodesk energy model with different HVAC Zones

Figure 4.1 shows the energy model created on Revit Autodesk after energy setting completion. Energy setting includes the site location, building construction material, building orientation and the analytical materials. It is a building energy model ready to the energy analyses. Building energy model includes the different space type and service of the airport terminal building. Figure 4.1 illustrates the different HVAC zones. Each HVAC zones represent individual room. This energy model includes the lighting load, equipment load, occupancy load of each HVAC zone. After creating the energy analytical model energy optimization on the building were perform.

4.1.1 Thermal resistance and heat transfer coefficient value

While creating the 3D model in Revit it has been selected materials from the thermal properties option available. Energy setting available are used for controlling the conduct of energy model creation. Thermal resistance and heat transfer coefficient value for each material is available on the software and is selected on the type of material used in the construction of the building.

Table 4.1 U-Value of the window glass.

Window Glass Types		
Name	Construction	U-Value(W/m^2K)
Single clear	Single Clear 6mm	6.17
Double clear	Double Clear 6/13 Air	2.74
Triple Low-E	Triple Low-E (e2=e5=0.1) Clear 3mm/6mm Air	1.55
Double Low-E	Double Low-E (e3=0.2) Clear 3/13 Air	1.99
Quad Low-E	Quadruple Low-E Films (88) 3mm/8mmKrypton	0.66

4.1.2 Airport location and profile

Figure 4.2 illustrate the building location setting in Revit. It allow to determine the weather of the location. Temperature profile of the location has been used to evaluate heating and cooling load of the building. After completion of the building 3D model, building location has been selected with the help of internal mapping service feature which is built in Revit, and geographical conditions were entered. It provided the weather detail and weather station of the building which was going to be analyzed. 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, 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 windows to various domestic and international destinations and airlines. It has Coordination 274150N-0852128E and Elevation 4390 ft. AMSL (Average Mean Sea Level).

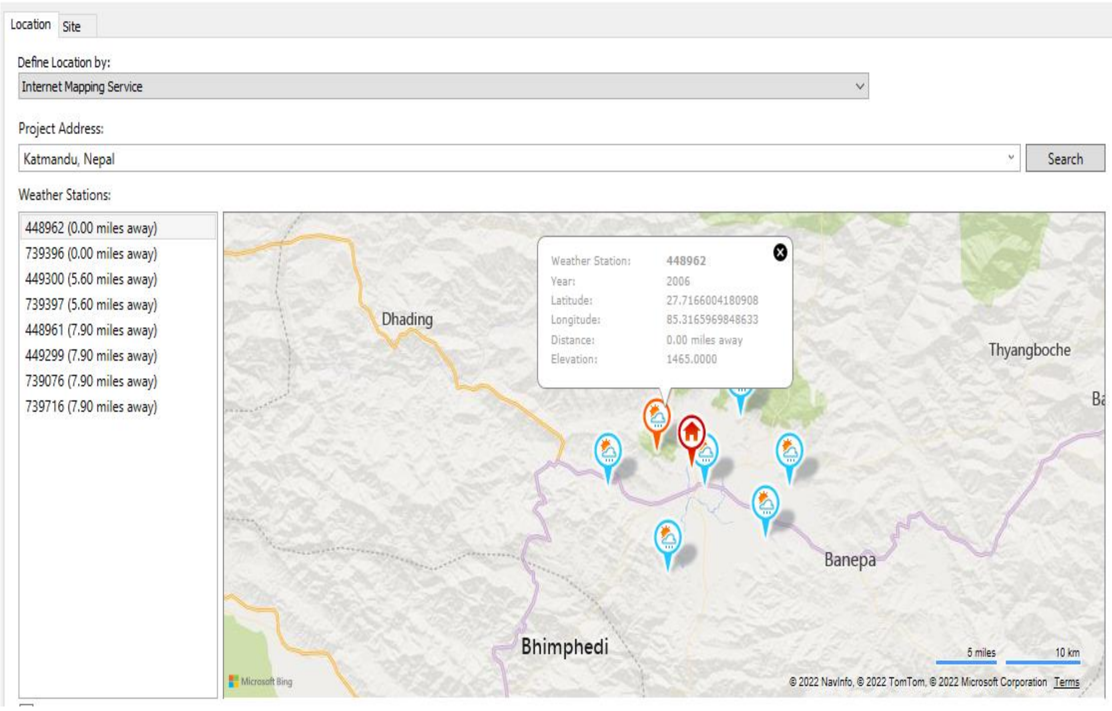

Figure 4.2 Building location setting in Revit

4.1.3 Domestic passenger flow through Tribhuvan International Airport

Figure 4.3 shows the Daily domestic passenger departed through TIA domestic Airport. (Data 15-Jun to 30-Jun) and Figure 4.4 shows the Daily domestic passenger departed through TIA domestic Airport. (Data 15-Jul to 30-Jul). According to data compiled by Civil Aviation Authority of Nepal (CAAN), Total of 2.8 million domestic passenger traveled through TIA in 2018. This passenger movement data is provided by TIACAO domestic TDO. In this data, passenger movement is given from 15-June 2022 to 29-June 2022 and from 6-July 2022 to 27-July 2022. Passenger movement is affected by various things directly and indirectly. Such as climate, occasional, Festival and other uncertainties affect the passenger's movement.

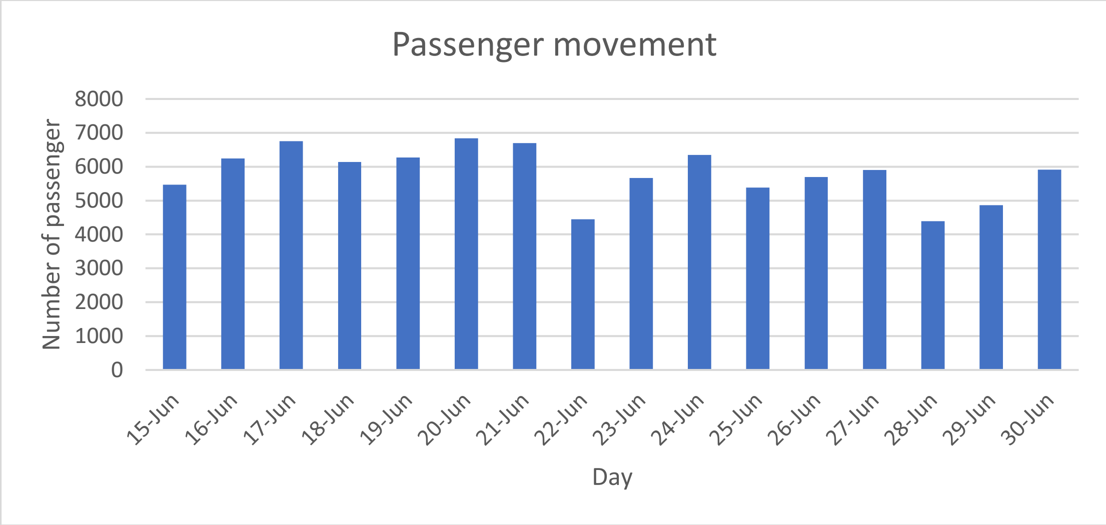

Figure 4.3 Daily domestic passenger departed through TIA domestic Airport. (Data 15-Jun to 30-Jun)

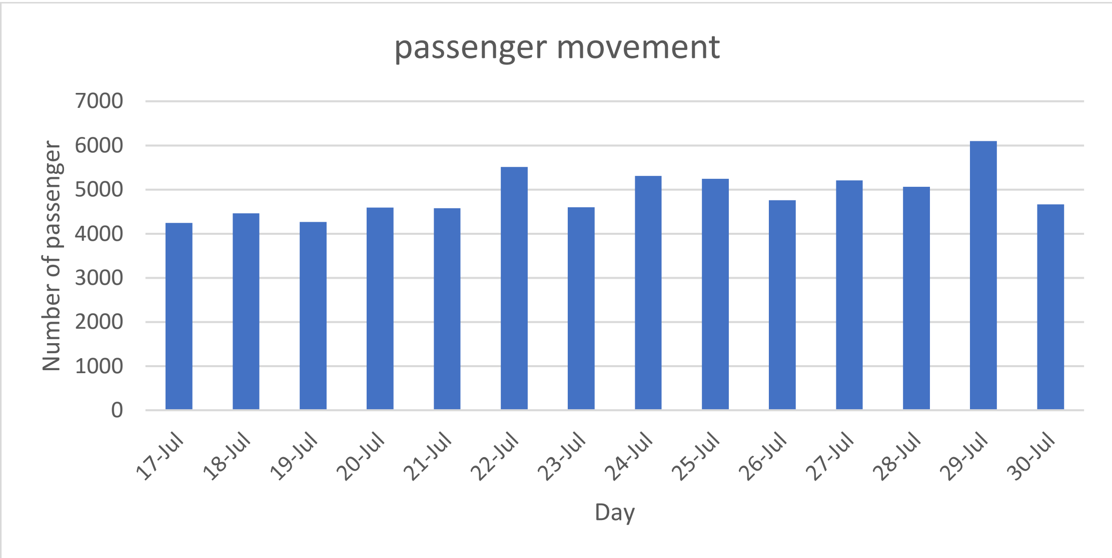

Figure 4.4 Daily domestic passenger departed through TIA domestic Airport. (Data 15-Jul to 30-Jul)

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.

4.1.4 Room and Space scheduling

After completion of building modeling in Revit Autodesk room scheduling were done. Color code in Figure 4.5 and Figure 4.6 represents the different space of the terminal buildings.

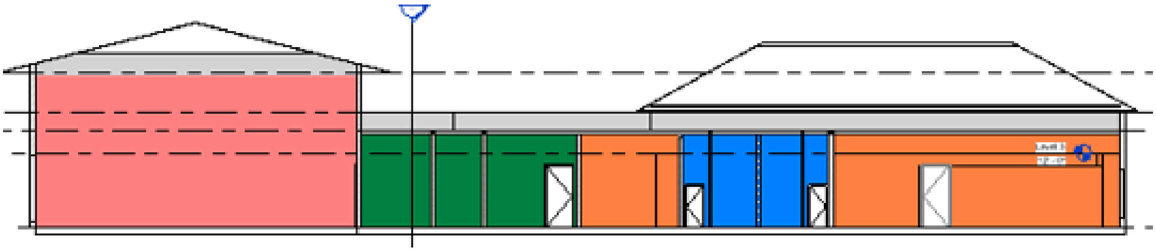

Figure 4.5 Building space scheduling Autodesk Revit model section view

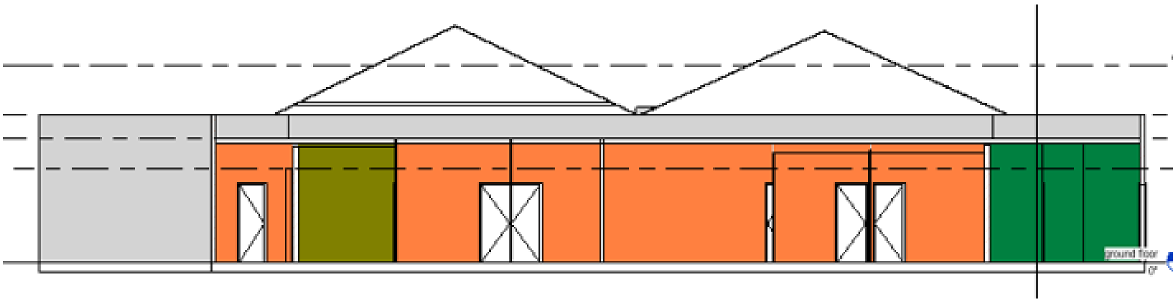

Figure 4.6 Building space Autodesk Revit model section view

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. It is complicated to evaluate energy consumption pattern of the Airport terminal building because it has complexity of space type and operational characteristics. We can conclude that EUI the differences are due to factors such as Building geometry, characteristics of building (space). 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. Airport terminal building includes different categories as define below.

Figure 4.7 is building model created in Revit Autodesk. Figure 4.8 is the North face of the Domestic airport terminal Building. Different spaces are categorized into different service type. Each space represents the individual room. Each room has individual name and the service type and individual load categories. Name of the room. Room area, volume, number of occupancies and service type are illustrated into Table 4.2.

There are 9 spaces which represents the individual room. Each space is indicated as a HVAC zone. There are 6 rooms which is Air-conditioned and other 3 rooms which includes Toilet and smoking zones have mechanical ventilation.

Figure 4.7 Building 3D modeling build in Revit Autodesk

Figure 4.8 North face of the Domestic airport terminal Building

Figure 4.9 ground floor plan illustrates the building ground layout which includes the different room and their service type. Passenger checking area, passenger waiting hall, café, VIP waiting room, breast feeding room, toilets are the room categories by the domestic airport terminal building.

Table 4.2 Room Scheduling and service type

S.N.	Name	Area (m^2)	Volume (m^3)	Number of occupancies	Defined Service type in Revit
1	Check in area	543	4189.88	200	Airport ticket counter
2	Waiting hall	1276	5991.52	500	Airport - Concourse
3	café	34	154.85	19	Hotel
4	Handicraft Shop	30	133.55	32	Sales area- retail
5	Breast feeding room	30	137.06	4	Lobby
6	VIP room	64	286.94	7	Lobby
8	Smoking Zone	14	54.84	Unconditioned	Restroom
9	Toilet 1	44	199.7	Unconditioned	Restroom
10	Toilet 2	23	114.2	Unconditioned	Restroom

It has main two compartments and the different compartments are parted by the interior building partition. Each room and spaces have their own properties in Revit Autodesk. There are 6 air-conditioned room and another partition has their own mechanical ventilation. The passenger waiting hall has 470 seat capacity the security check in area has 200 and another room has default set up according to the space type.

Figure 4.9 Ground floor plan Autodesk Revi

4.2 Cooling load and Heating load

As shown in Figure 4.10 Total cooling load of the terminal building is 243.249kW 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.

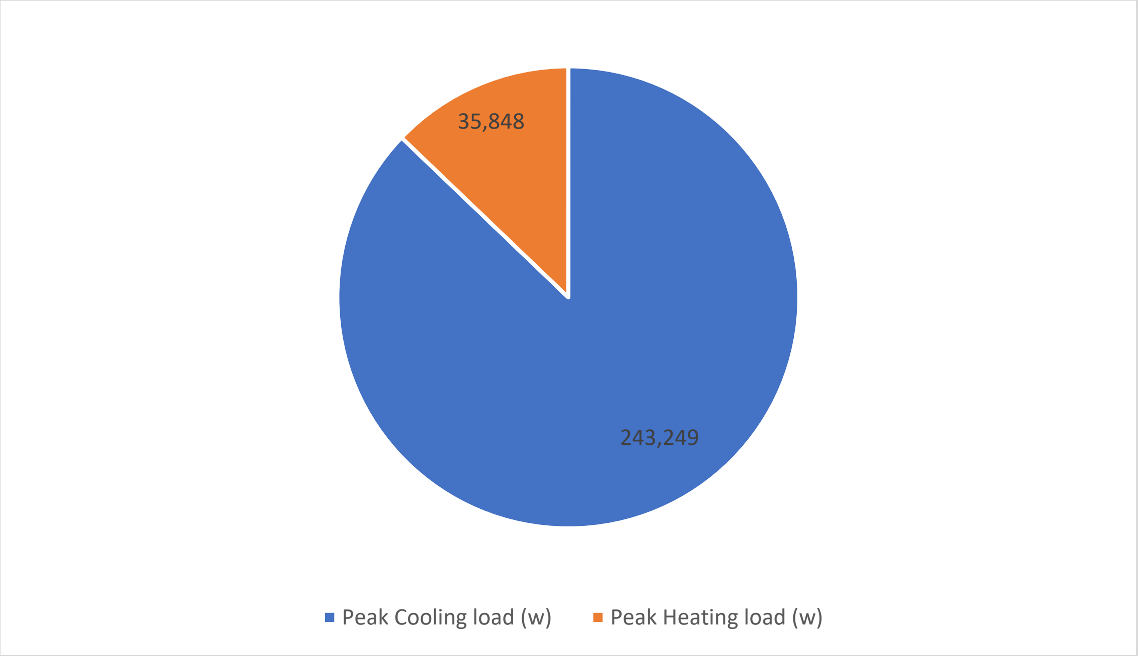

Figure 4.10 Peak Cooling and Heating Load of Departure Hall, TIA

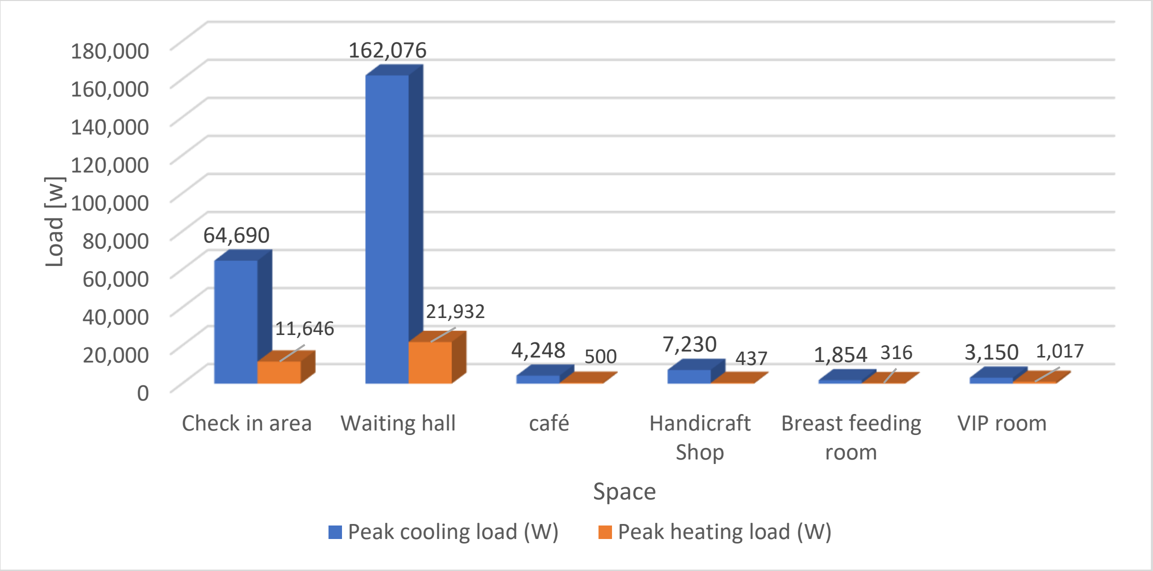

Figure 4.11 Peak Cooling and Heating Load of the spaces

According to Figure 4.11 peak cooling and heating load of the spaces all room's cooling load is more than the heating load. Due to the passenger movement and the internal equipment's and lighting heat gain cooling load is more than heating load. Passenger check in area it has cooling load 64.690kW and heating load 11.646kW. passenger waiting hall cooling load 162.076kW and heating load 21.932kW. Café cooling load 4248 and heating load 500W. handicraft shop cooling load 7230W and heating load 437W. breast feeding room cooling load 1854W and heating load 316W. VIP room cooling load 3150W and heating load 1017W.

4.2.1 Cooling load

This data is obtained from the Revit Autodesk Heating and Cooling load analysis. The maximum cooling load is recorded in 5/21 14:45:00. As shown in Table 4.3 there is 155.957kW instant sensible heat load, 48.153kW delayed sensible heat load and 39.139kW latent heat load. The total peak cooling load of the building is 243.249kW. The smoking zone and toilet rooms has mechanical ventilation. According to the data illustrated in Table 4.3 maximum heat to be removed is 162.076kW in passenger waiting hall and minimum heat to be removed in VIP waiting hall is 3150W.

4.2.2 Heating load

The maximum Heating load is recorded in 1/21 24:00:00. As shown in Table 4.4 there is 17980w instant sensible heat load, 20738W delayed sensible heat load and 3870W latent heat load. The smoking zone and toilet rooms has mechanical ventilation. The total peak heating load of the building is 35848W. According to the data illustrated in Table 4.4 maximum heat to be add is 21932W in passenger waiting hall and minimum at breast feeding room is 316W.

Table 4.3 peak cooling load in each space of the departure hall

S.N.	Name	Area $[m^2]$	Volume $[m^3]$	Number of people	Instant Sensible [W]	Delayed Sensible [W]	Latent [W]	Total [W]
1	Check in area	543	4189.88	200	40,383	13,972	10,335	64,690
2	Waiting hall	1276	5991.52	500	105,270	30,756	26,050	162,076
3	Cafe	34	154.85	19	2,971	741	536	4,248
4	Handicraft Shop	30	133.55	32	4,799	850	1,582	7,230
5	Breast feeding room	30	137.06	4	1,074	546	234	1,854
6	VIP room	64	286.94	7	1,460	1,288	402	3,150
8	Smoking Zone	14	54.84	Unconditioned				
9	Toilet 1	44	199.7	Unconditioned				
10	Toilet 2	23	114.2	Unconditioned				
	Total Cooling Load	2,058			155,957	48,153	39,139	243,249

Table 4.4 Peak heating load in each space of the departure hall

S.N.	Name	Area $[m^2]$	Volume $[m^3]$	Number of people	Instant Sensible [W]	Delayed Sensible [W]	Latent [W]	Total [W]
1	Check in area	543	4189.88	200	-5,310	-7,285	949	-11,646
2	Waiting hall	1276	5991.52	500	-12,122	-11,622	1,812	-21,932
3	Cafe	34	154.85	19	-200	-337	37	-500
4	Handicraft Shop	30	133.55	32	-171	-298	32	-437
5	Breast feeding room	30	137.06	4	0	-316	0	-316
6	VIP room	64	286.94	7	-177	-880	40	-1,017
8	Smoking Zone	14	54.84	Unconditioned				
9	Toilet 1	44	199.7	Unconditioned				
10	Toilet 2	23	114.2	Unconditioned				
	Total Heating Load	2,058			-17,980	-20,738	2,870	-35,848

4.2.3 Building load heat addition and remove by the different parameter

Following results are obtained from Revit annual heating and cooling load report. Revit has been generated the summery of the thermal load of the building using the input parameters. Building energy model has been created on the Revit platform after completion of the building thermal and physical properties.

Table 4.5 Peak Heating and Cooling load due to infiltration

Infiltration	Instant Sensible [W]	Delayed Sensible [W]	Latent [W]	Total [W]
Cooling load	5,111	0	-182	4,929
Heating load	-4,387	0	791	-3,596

As shown in Table 4.5 Peak Heating and Cooling load of infiltration there is cooling and heating load due to infiltration of the buildings. There is 5111W instant sensible and 0182W latent heat in cooling. Instant sensible heat -4387W and 791W latent heat due to infiltration.

Table 4.6 Peak Heating and Cooling load due to Roof construction

Roof	Instant Sensible [W]	Delayed Sensible [W]	Latent [W]	Total [W]
Cooling load	0	10,065	0	10,065
Heating load	0	-9,192	0	-9,192

As shown in Table 4.6 Peak Heating and Cooling load of Roof construction there is 10.065kW delayed sensible heat to be removed in cooling mode and 9192W delayed sensible heat to be added in heating mode due to current roof construction

Table 4.7 Peak Heating and Cooling load due to window glass

Window glass	Instant Sensible [W]	Delayed Sensible [W]	Latent [W]	Total [W]
Cooling load	2,679	0	0	2,679
Heating load	-1,924	0	0	-1,924

As shown in Table 4.7 Peak Heating and Cooling load of windows glass there is 2679W instant sensible heat to be removed in cooling mode and 1924W instant sensible heat to be added in heating mode due to current windows glass.

Table 4.8 Peak Heating and Cooling load due to Passengers

Passenger	Instant Sensible [W]	Delayed Sensible [W]	Latent [W]	Total [W]
Cooling load	39,136	6,770	44,309	90,215
Heating load	0	0	0	0

As shown in Table 4.8 Peak Heating and Cooling load of passenger movement there is 39.136kW instant sensible heat and 6.770kW delayed sensible heat to be removed in cooling mode and no heat to be added in heating mode due to passenger movement.

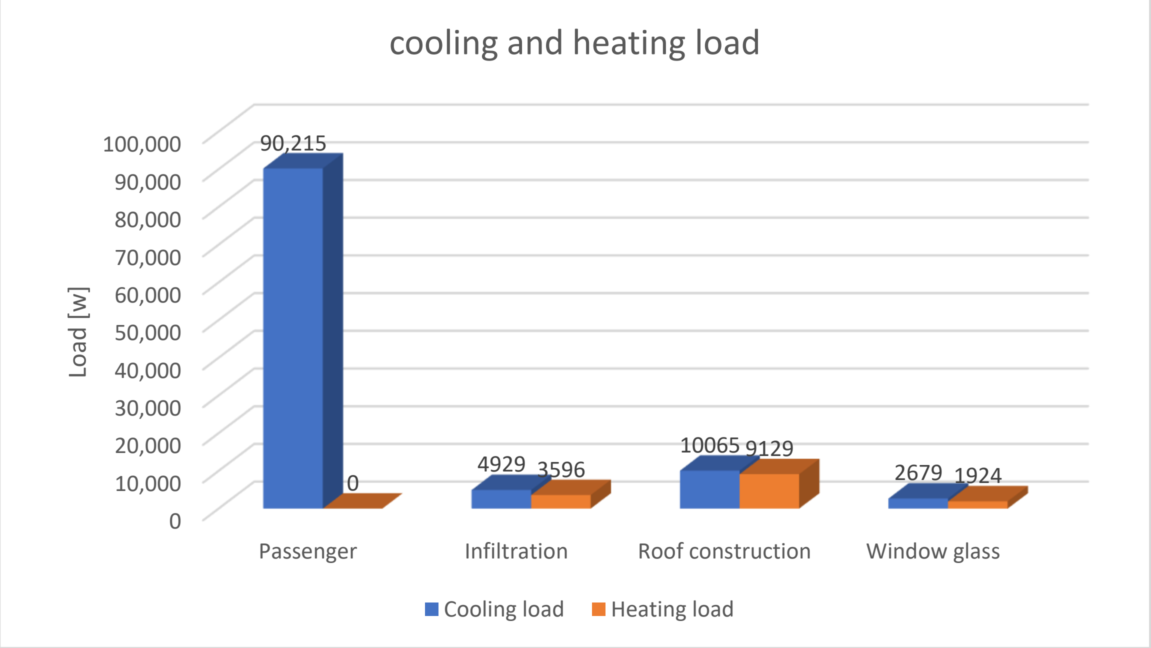

Figure 4.12 Peak Heating and Cooling load due to different parameters

As shown in Figure 4.12 Peak Heating and Cooling load due to different parameters the maximum heat to be removed is 90.215kW and no heating load due to passenger movements that is no occupancies load in heating mode. Total load due to infiltration is in cooling 4.929kW and heating 3.596kW. Total cooling load 10.065kW and heating load 9.129kW due to roof construction. Total 2.679kW cooling load and 1.924kW heating load due to window's glass.

4.3 Energy use intensity

From the simulation results, the building energy consumes approx. 298kwh/m^2/yr. After completion of building energy analysis with mention building properties on Insight Autodesk, the results can be output as shown in Figure 4.13. Figure 4.13 illustrates Autodesk Insight output.

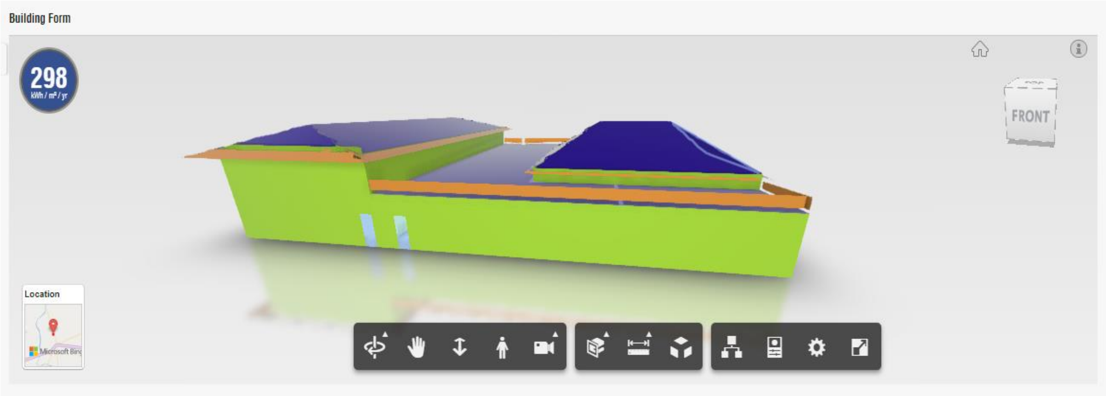

Figure 4.13 Autodesk Insight output

Based on the building energy analysis the energy use intensity (EUI) of departure hall is 298 kwh/m^2/yr.

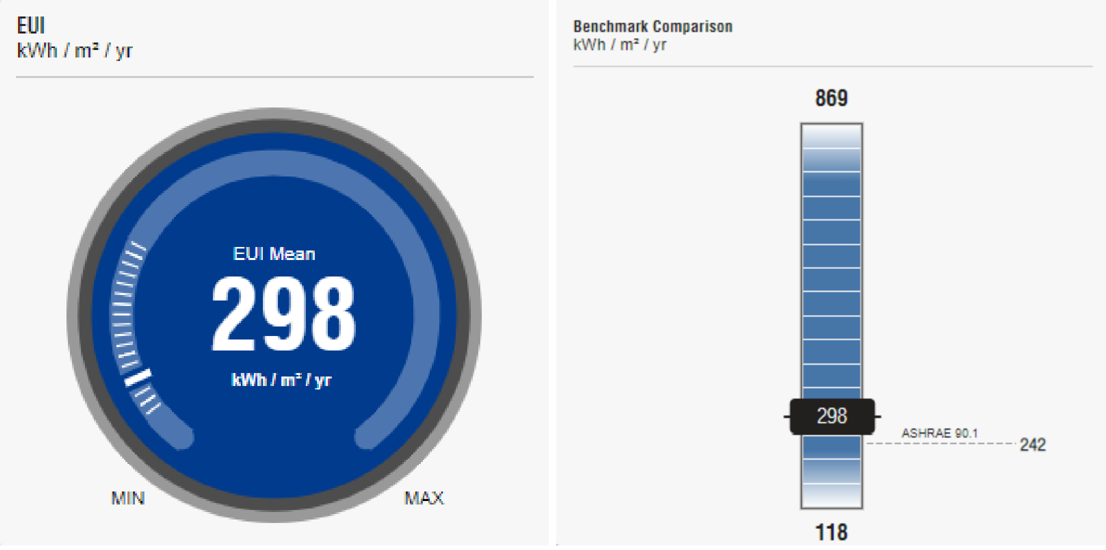

Figure 4.14 Initial value of Energy use Intensity of the Airport terminal building.

comparing with ASHRAE 90.1 that building figures seems lesser, reflecting high energy efficiency. ASHRAE 90.1 -Benchmark comparison of energy standard for buildings.

The result has been covered as much features, such as benchmark comparison, EUI, and model history. Autodesk Insight consider many different factors to obtain the energy performance result. It considered the HVAC system, Windows material, glazing properties, lighting power, equipment load, roof construction and wall construction. After completion of the different input parameter that determine the annual energy in practice. It obtained the result in Energy Use Intensity (EUI). Energy Use Intensity (EUI) kwh/m^2/yr it determines the total annual energy in practice divided by the total area of building by square meter. It obtained the result on the maximum, average and minimum EUI.

4.3.1 Energy Saving Potential Through Infiltration

Infiltration (ACH) is Air Change per hour. Hourly ventilation rate divided by the building volume. All doors and window kept closed during the analysis.

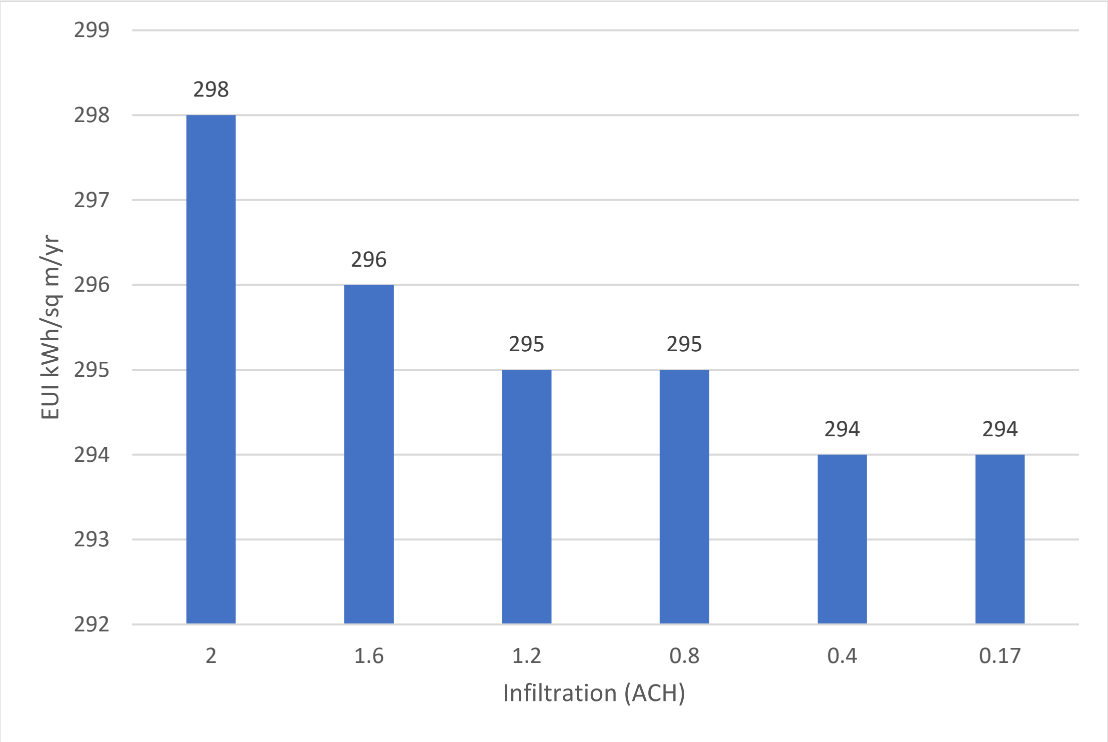

Figure 4.15 Area of energy saving through infiltration rate

According to the Figure 4.15 Infiltration is greatly affecting the energy consumption of the building.

Table 4.9 Amount of Energy Saving Through Infiltration

Infiltration (ACH)	EUI kWh/m^2/yr.
2	298
1.6	296
1.2	295
0.8	295
0.4	294
0.17	294

According to the Table 4.9 mentioned below, when the infiltration rate reaches 0.17 ACH from 2 ACH, The EUI decreases from 298kWh/m2/yr to 294kWh/m2/yr.

4.3.2 Energy Saving Potential Through Roof Construction

Roof is constructed by corrugated galvanized iron CGI sheet with gypsum false celling and partial slab casting.

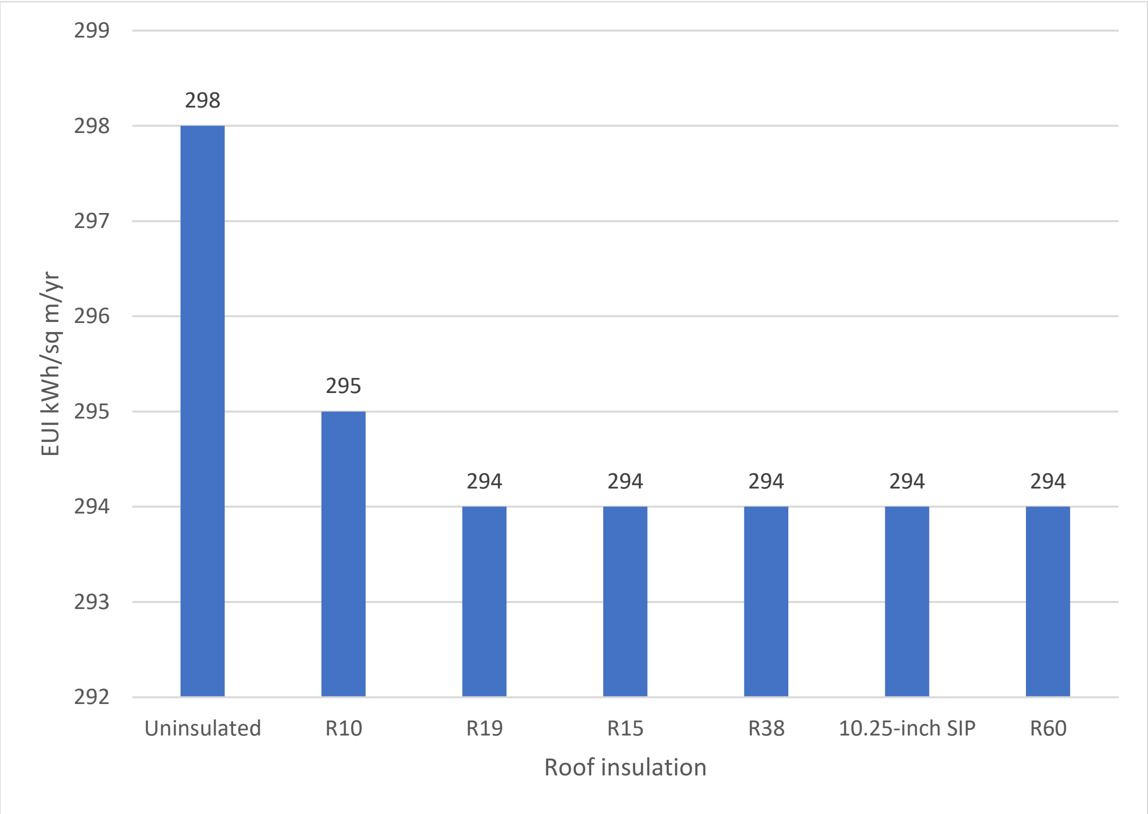

Figure 4.16 Amount of energy saving through roof construction

As shown in Figure 4.16 Roof construction has great potential to reduce energy load. When R19 insulation placed in Uninsulated roof construction, The EUI decreases from 298 to 294 kWh/m2/yr. as shown in Table 4.10.

Table 4.10 Amount of energy saving through roof construction

Roof construction	EUI kWh/m^2/yr.
Uninsulated	298
R10	295
R19	294
R15	294
R38	294
10.25-inch SIP	294
R60	294

4.3.3 Energy Saving Potential Through Window glass

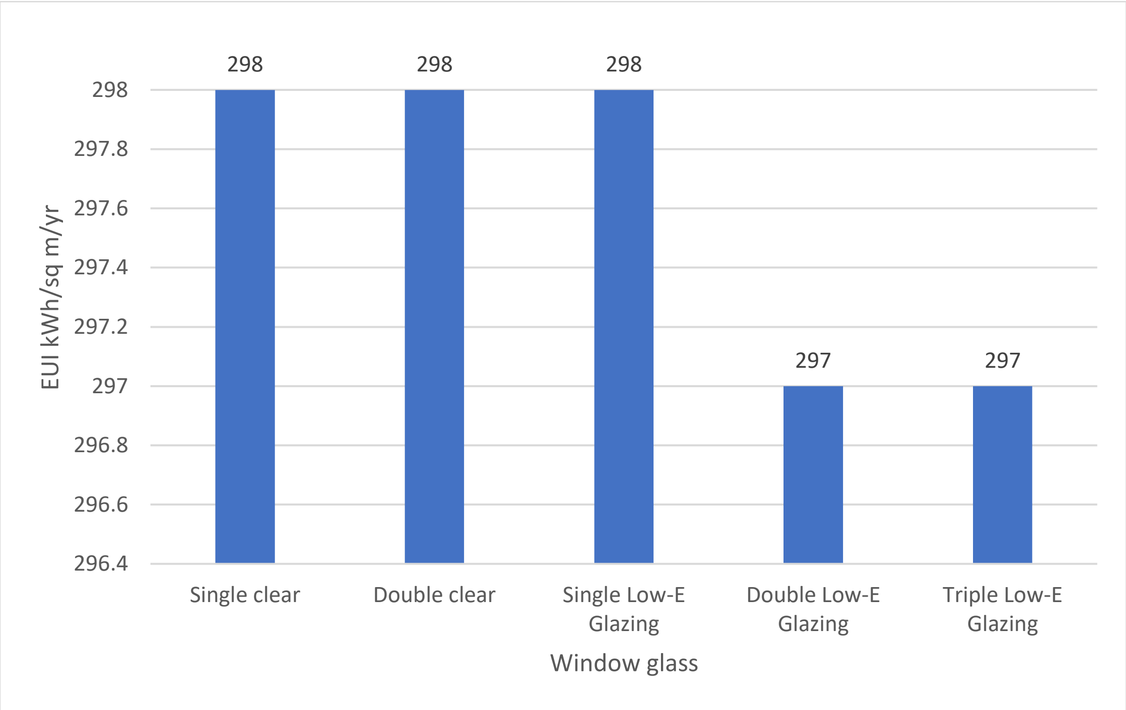

Figure 4.17 Amount of energy saving through window glass types

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 297kWh/m^2/yr from 298kWh/m^2/yr. As shown in Table 4.11 Amount of energy saving through window glass types.

Table 4.11 Amount of energy saving through window glass types

Windows glass East	EUI kWh/m^2/yr.
Single clear	298
Double clear	298
Single Low-E Glazing	298
Double Low-E Glazing	297
Triple Low-E Glazing	297

According to the studies and analysis there are so many factors that effect on the energy performance of the buildings. The factors which contributes to energy consumption of the buildings such as building orientation, windows shades, windows wall ratio, wall material, roof construction, infiltration, lighting efficiency, windows glass materials and floor structure. This analysis has been carried out to highlights importance of reducing the energy losses and importance of reducing heat gain from the building envelope and improve the thermal comfort of the building. This research has been done to improve the thermal characteristic of the domestic airport terminal building in Tribhuvan International Airport Kathmandu, Nepal. The nature of the building assists the thermal characteristics of the building which determine the amount of heat gain and loss from the building therefore building envelop system needs to be optimize to reduces energy losses and improve the energy performance of the buildings.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the building energy analysis report peak cooling load of the building is 243.249kW and peak heating load is 35.848kW. Building peak heating load is 9.129kW and cooling load is 10.065kW due to roof construction. Infiltration of the building consumes total 4.928kW peak cooling load and 3.596kW peak heating load. Windows glass consume 2.679kW sensible cooling and 1.924kW sensible heating peak load. Building occupancy load is 39.136kW instant sensible, 6.770kW delayed sensible, 44.309kW latent heat has been recorded. It consumes total 90.214kW cooling load.

34.73% of the building cooling load is due to the passengers that is occupancy load. 1.89% of the building cooling load is due to infiltration. 3.87% of the building cooling load is due to roof construction. 1.03% of the building cooling load is due to window.

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

when the infiltration rate reaches 0.4 ACH from 2 ACH, The EUI decreases from 298kWh/m^2/yr to 294kWh/m^2/yr. When R19 insulation placed over existing roof construction, The EUI decreases from 298kWh/m^2/yr to 294kWh/m^2/yr. In this building model windows glass material has slightly less energy saving potential. Windows are only on the east side and Windows Wall Ratio is 25%.

According to the study, while analyzing the peak load of the domestic departure hall inside TIA, infiltration heating 1730W and cooling 4928W, Windows glass heating 1924W and cooling 2679W, Roof construction heating 5639W and cooling 10065W, and passenger occupancies heating load zero and cooling load 90214W. TIA domestic Airport terminal buildings show the majority load of passengers. It is analyzing the daily passenger movement seen more than the seat capacity of the hall during the field survey.

The CBECS report indicates the EUIs of 14 types of buildings. This research has been used 5000 measured data, it presents the survey results that the EUI of office buildings is 293.1kWh/m^2/yr, and Healthcare is 592.2kWh/m^2/yr, respectively.

However, Transportation buildings such as airports terminal, bus stations, train stations, subway stations, and ship berthing facilities are very different in terms of functionality and operational characteristics(Kim, Shin and Ahn, 2020).

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.

According to simulation building peak cooling load has been 243.249kw, when external temperature 34-degree Celsius and set point, temperature was 24-degree Celsius. Field data has been recorded into power analyzer. During 1:30 pm to 1:45 pm when external temperature 27-degree Celsius and set point temperature 24-degree Celsius, cooling load has been recorded 105.9 kVA and 110.7 kvar.

5.2 Recommendations

The energy consumption factor of the building can be minimized by using the proper technology to build the building envelopes. The energy consumption of the buildings can be reduced by using proper design of the building. Proper selection of the building material can play important role in energy consumption of the buildings. According to the simulation results it can be concluded that proper use of Roof and infiltration rate helps in reducing energy consumption where windows glass has shown low energy benefit.

Air curtain can be placed on the door to reduce infiltration through the door. The annual energy consumption of the building can be reduced using air curtains.

At a broader policy level, uniform codes need to be developed to be incorporated into the Building Code and the National Building Code. It is essential to the new Terminal building must be made in Nepal have to be comply to minimum requirements of thermal comfort and energy efficiency.

TIA domestic Airport terminal buildings show the majority load of passengers. The daily passenger movement is more than the seat capacity of the departure hall.

REFERENCES

Alba, S.O. and Manana, M. (2016) ‘Energy research in airports: A review’, Energies, 9(5), pp. 1–19. Available at: https://doi.org/10.3390/en9050349.

Attou, N. et al. (2021) ‘Energy management system for hybrid microgrids’, EEA - Electrotehnica, Electronica, Automatica, 69(2), pp. 21–30. Available at: https://doi.org/10.46904/EEA.21.69.2.1108003.

Bhandari, S., Acharya, D. and Lamsal, K. (2022) ‘Comparative study of Variable Air Volume and Variable Refrigerant Volume for Automotive Workshop’, 8914, pp. 179–184.

Celina, F. (2022) ‘Energy Analysis with Revit Insight and Green Building Studio’, pp. 1–24.

Cho, H., Gowri, K. and Liu, B. (2010) ‘Energy Saving Impact of ASHRAE 90.1 Vestibule Requirements : Modeling of Air Infiltration through Door Openings’, PNNL Report: PNNL-20026 [Preprint], (November). Available at: https://doi.org/10.2172/1017117.

Corrado, V. et al. (2017) ‘A new procedure of energy audit and cost analysis for the transformation of a school into a nearly zero-energy building’, Energy Procedia, 140, pp. 325–338. Available at: https://doi.org/10.1016/j.egypro.2017.11.146.

Gil-Lopez, T. et al. (2013) ‘Experimental analysis of energy savings and hygrothermal conditions improvement by means of air curtains in stores with intensive pedestrian traffic’, Energy and Buildings, 67, pp. 608–615. Available at: https://doi.org/10.1016/j.enbuild.2013.08.058.

GIZ (2015) Integrated Company Report. Available at: https://www.giz.de/en/downloads/giz2015-en-Integrated-Company-Report.pdf.

Iakovou, I. et al. (2005) ‘Incidence, predictors and outcome of thrombosis after succesful implantation of drug-eluting stents’, Journal of the American Medical Association, 293(17), pp. 2126–2130. Available at: https://doi.org/10.1001/jama.293.17.2126.

Jokisalo, J. et al. (2009) ‘Building leakage, infiltration, and energy performance analyses for Finnish detached houses’, Building and Environment, 44(2), pp. 377–387. Available at: https://doi.org/10.1016/j.buildenv.2008.03.014.

Jonghoon Ahn , Soolyeon Cho (2015) ENERGY PERFORMANCE BENCHMARK MODEL North Carolina State University , Raleigh , NC , USA Building Simulation Conference, pp. 2515–2522.

Kevin Ricart, Rosemary Hwang, A.C.H. (2020) No Title, Best practices for infiltration and building pressurization. Available at: https://www.csemag.com/articles/best-practices-for-infiltration-and-building-pressurization/.

Kim, S.C., Shin, H.I. and Ahn, J. (2020) 'Energy performance analysis of airport terminal buildings by use of architectural, operational information and benchmark metrics', Journal of Air Transport Management, 83(December 2019), p. 101762. Available at: https://doi.org/10.1016/j.jairtraman.2020.101762.

Kindangen, J.I. and Umboh, M.K. (2017) 'Design of evaporative-cooling roof for decreasing air temperatures in buildings in the humid tropics', AIP Conference Proceedings, 1818(March 2017). Available at: https://doi.org/10.1063/1.4976887.

Kotopouleas, A. and Nikolopoulou, M. (2019) 'Understanding thermal comfort conditions in airport terminal buildings', Proceedings - Windsor Conference 2014: Counting the Cost of Comfort in a Changing World, (April 2014), pp. 234–252.

Latha, P.K., Darshana, Y. and Venugopal, V. (2015) 'Role of building material in thermal comfort in tropical climates - A review', Journal of Building Engineering, 3, pp. 104–113. Available at: https://doi.org/10.1016/j.jobe.2015.06.003.

Lee, C.Y., Kaneko, S. and Sharifi, A. (2020) 'Effects of building types and materials on household electricity consumption in Indonesia', Sustainable Cities and Society, 54(June 2019), pp. 1–3. Available at: https://doi.org/10.1016/j.scs.2019.101999.

Li, C. et al. (2015) 'Experimental and theoretical study on the effect of window films on building energy consumption', Energy and Buildings, 102, pp. 129–138. Available at: https://doi.org/10.1016/j.enbuild.2015.04.025.

Liu, C. et al. (2015a) 'Operational Electricity Consumption Analyze of VRF Air Conditioning Sys-tem and Centralized Air Conditioning System Based on Building Energy Monitoring and Management System', Procedia Engineering, 121, pp. 1856–1863. Available at: https://doi.org/10.1016/j.proeng.2015.09.167.

Liu, C. et al. (2015b) 'Operational Electricity Consumption Analyze of VRF Air Conditioning Sys-tem and Centralized Air Conditioning System Based on Building Energy Monitoring and Management System', in Procedia Engineering. Elsevier Ltd, pp. 1856–1863.

Available at: https://doi.org/10.1016/j.proeng.2015.09.167.

Liu, H. et al. (2019) ‘Performance of VRF systems based on large scale monitoring’. Available at: https://doi.org/10.1088/1757-899X/609/5/052012.

Maghiar, M. et al. (2022) ‘Roof Design Efficiency for Energy Consumption in Residential Units’, 3, pp. 767–757. Available at: https://doi.org/10.29007/swb4.

Mellek, Y. and Kaya, A. (2020) ‘การตรวจสอบแอพพลิเคชั่นถ่ายโอนพลังงานแบบไร้สายโดยมุ่งเน้นไปที่พลังงานทดแทน Elsevier Enhanced Reader.pdf’.

Mero, T., Fee, S. and Branch, B. (2020) ‘Payment Transaction Details’, p. 4222939.

Miyazaki, T., Akisawa, A. and Kashiwagi, T. (2005) ‘Energy savings of office buildings by the use of semi-transparent solar cells for windows’, Renewable Energy, 30(3), pp. 281–304. Available at: https://doi.org/10.1016/j.renene.2004.05.010.

Nakarmi, G., Shah, B. and Uprety, S. (2020) ‘Impact of Floor Area Ratio (FAR) on Energy Load in Kathmandu : Case of Sinamangal Town Planning’, 8914, pp. 437–443.

Nuclear, I. (2009) ‘50 + years of INIS’, pp. 164–165.

Polater, A. (2020) ‘Airports’ role as logistics centers in humanitarian supply chains: A surge capacity management perspective’, Journal of Air Transport Management, 83(November 2019), p. 101765. Available at: https://doi.org/10.1016/j.jairtraman.2020.101765.

Pyakurel, S., Prasad, R. and Karki, M. (2021) ‘A Case Study of Pokhara Industrial Estate to Estimate Cost of EENS and Perform Reliability Worth Analysis’, 8914, pp. 88–96.

Qian, M. et al. (2020) ‘Power consumption and energy efficiency of VRF system based on large scale monitoring virtual sensors’, Building Simulation, 13(5), pp. 1145–1156. Available at: https://doi.org/10.1007/s12273-020-0670-x.

Tang, Y., Tao, Q. and Zheng, J. (2022) ‘Performance analysis of air curtains on indoor environment and dehumidification energy consumption in a low humidity plant’, Journal of Asian Architecture and Building Engineering, pp. 1–16. Available at: https://doi.org/10.1080/13467581.2022.2097240.

The, E.S. ‘1.0 environmental design criteria for project engineering 1.1.’, pp. 1–6.

Time, F. et al. (2022) ‘No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title’, Material Safety Data Sheet, 33(1), pp. 1–12. Available at: http://www2.warwick.ac.uk/fac/sci/whri/research/mushroomresearch/mushroomquality/fungienvironment%0Ahttps://us.vwr.com/assetsvc/asset/en_US/id/16490607/contents%0Ahttp://www.hse.gov.uk/pubns/indg373hp.pdf.

U.S. Department of Energy (2012) ‘2011 Buildings Energy Data Book’, Office of Energy Efficiency and Renewable Energy, pp. 1–81. Available at: http://buildingsdatabook.eren.doe.gov/ChapterIntro2.aspx%5Cnhttp://buildingsdatabook.eren.doe.gov/docs/DataBooks/2011_BEDB.pdf.

Uprety, P., Uprety, S. and Shrestha, B. (2021) ‘Energy Performance Evaluation of Rammed Earth Construction’, Proceedings of 10th IOE Graduate Conference, 8914, pp. 440–445.

Widiastuti, R. et al. (2018) ‘Comparative Effect of Roof Material Toward Thermal Condition on the Roof Space. Case Study: High Density Settlement in Semarang City’, Advanced Science Letters, 24(12), pp. 9761–9763. Available at: https://doi.org/10.1166/asl.2018.13133.

Wong, N.H. et al. (2003) ‘The effects of rooftop garden on energy consumption of a commercial building in Singapore’, Energy and Buildings, 35(4), pp. 353–364. Available at: https://doi.org/10.1016/S0378-7788(02)00108-1.

Work, R. (2017) ‘Lawrence Berkeley National Laboratory’. Available at: https://doi.org/10.1016/j.enbuild.2017.09.084.

Yu, X. et al. (2016) ‘Comparative study of the cooling energy performance of variable refrigerant flow systems and variable air volume systems in office buildings’, Applied Energy, 183(April 2018), pp. 725–736. Available at: https://doi.org/10.1016/j.apenergy.2016.09.033.

Yuliani, S. et al. (2021) ‘Thermal behaviour of concrete and corrugated zinc green roofs on low-rise housing in the humid tropics’, Architectural Science Review, 64(3), pp. 247–261. Available at: https://doi.org/10.1080/00038628.2020.1751054.

Zhao, T. et al. (2021) ‘BIM-based analysis of energy efficiency design of building thermal system and HVAC system based on GB50189-2015 in China’, International Journal of Low-

Carbon Technologies, 16(4), pp. 1277–1289. Available at: https://doi.org/10.1093/ijlct/ctab051.

APPENDIX I: SPACE SCHEDULE OF BUILDING

A	B	C	D
Name	Number of People	Occupancy Unit	Condition Type
Check in area	200	Number of people	Heated and cooled
VIP Room	10	Number of people	Heated and cooled
Smoking zone	1.436084	By Space Type	Unconditioned
Toilet	4.423359	By Space Type	Unconditioned
breast feeding roo	3.035811	By Space Type	Heated and cooled
Handicraft shop	29.581443	By Space Type	Heated and cooled
Cafe	17.148961	By Space Type	Heated and cooled
waiting hall	500	Number of people	Heated and cooled

APPENDIX II: LAYOUT OF THE BUILDING