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Simulation of Energy Conservation in a Building: A Case Study

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P A P E R I N F O

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A B S T R A C T

This study used a simulate based approach for calculating building energy consumption using monitoring data. This calibration was carried out on a building situated in Gurgaon, Delhi. Software used for dynamic simulation was E-Quest 3.65. The objective function was set to minimize the difference between calculated data and simulated data. The evaluation of the model accuracy, the mean bias error (MBE) and the Coefficient of Variation (Cv RMSE) were calculated. Through this paper show the real behavior of people in a building simulation, there may be differences up to 30% [1]. This paper shows the possibility of energy, money and time saving. The schedule of simulated building is same as per actual building.

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INTRODUCTION

The worldwide energy consumption in the residential sector is 16-50% of total energy used [10]. In recent years. Most of the country concern of building energy improvement and developed rules and regulation based on energy efficiency improvement to achieve reduction of energy consumption and improved human life, the example of such country is Portugal [11], Brazil [12] and Australia [13]. In the northern region of India requirement of energy 44,949MW at peak load, but the availability were 44.447 MW in 2017. The deficient of energy was about 1.1%. [2].Energy consumption in Delhi increase rapidly, so tried to resolve this problem. TheGovernment chooses options to increase the uses of renewable resources. Through this paper the author tried to reduce the energy consumption and provide better comfort in buildings. For simulation of building differenttypes of software isavailablelike this paper reduces the disagreement between simulated and monitored data [3]. In building simulation not only concern building construction material, but also building orientation, blinds, window glazing,etc. Occupancy pattern will be considered as per ASHRAE90.1 2007. Some assumption will be taken for building simulation performances. A system that produces the building simulation data about the occupancy of people worked in building can significantly improve the performance of building simulation tool. [4-6]. Basically energy consumption can be improved in the stage of building design planning and construction.Building energy performance mainly depends on four factors (1) Occupancy (2) Building Envelope (3) Heating, ventilation and air conditioning and (4) Lighting. For the best result finds out uncertainty in the calculation of energy analysis of buildings. The first one is denominated uncertainty parameters and relates to a lack of information on the exact characteristics of the building. The second one is the modeling uncertainty that arises from simplifications and assumptions that have been introduced in the development of the model [7]
Through a literature survey found that a maximum of 40% energy can be saved at the stage of architectural design periods. So plan shape and design strategy should be chosen to fully reduceenergy consumption for air conditioning, heating and lighting in high-rise office buildings, according to local climatic conditions in construction sites [8].
So through this article evaluate the effect on load by changing the value of these four terms which described above. A test building was chosen for a case study which is situated in Delhi, Gurgaon. This is a commercial type building.one year period was investigated on hourly basis results [3].

MATERIAL AND METHODS

Software description

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Building performance for all measures was evaluated using Visual DOE software program. This program uses the DOE-2.1 simulation engine for evaluating energy-use and peak demand on an hourly basis.A proposed building model minimally complying with ECBC-2007 was developed and simulated in Visual DOE. A Proposed building with energy efficiency measures for HVAC, Lighting and Envelope features is modeled and EPI compared with the GRIHA benchmark.DOE-2 is a US department of energy funded software.DOE-2 engine simulated all type of building energy and cost.in this software have a description of building layout, construction, operating schedule, window, conditioning system(lighting, HVAC, etc.) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility .

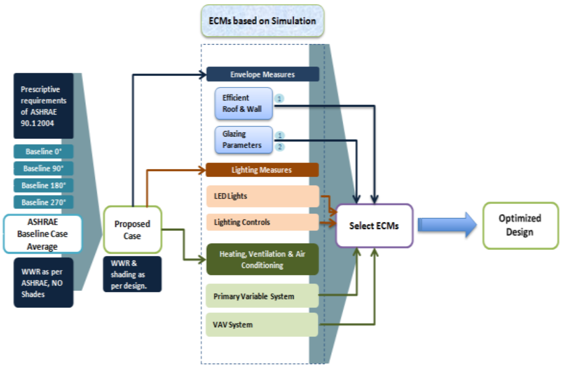

Figure 1. simulation methodology flow chart

Data collection strategy

The first process is to analysis the building input parameters without knowing the actual buildings. Through this to build up model based on collected information so that estimates the building energy use. Sometimes there is a distance between analyst and actual building site. These are some important input for building simulation.

- Architectural Plan: Through this construction geometry ,wall , roof area ,construction material, floor plan , elevation , door ,direction , glazing, facades , overhangs and shadings etc. obtained.
- Electric lighting system: In this blog find out the electric equipment uses and layout of electrical appliances like lamps, fan ballasts and luminaires required for buildings
- Air conditioning system: cooling, heating, thermal set point, supply and return air quality, chiller, cooling tower, fan power etc. included in this section.
- Occupancy: occupancy a real time depends data. Basically, many authors work on occupancy, but it has no systematic way to find out actual occupancy. Sometime it considers as a constant and optimized the building.
- Building schedule: Schedules for lights, air condition system and occupants.
- Equipment Inventory: Electrical equipment which uses energy considered and count for energy simulation.
- Monthly energy consumption for one year
- Hourly energy consumption detail, mainly available in large buildings
- Building component properties: in this catalogue building component property like a window to wall ratios, glazing, facades, etc. includes.
- Weather file for a particular region
- Any software through which building simulate.

Case study

The case study is the twelve story commercial building situated in Gurgaon, 28º 45' Latitude, Altitude: 721 feet Delhi. The building was chosen for the availability of monitoring data and considering a large floor area for calculation of energy consumption. Total gross floor area is 67734.3m^2.The building situate din Delhi climatic zone. According to ASHARAE Indian climatic zone is 1A. A 3D sketch view of building show in fig 2 below. In this study consider that building has no shade and blinds.

For the simulation there is uncertainty to calculate the results. Weather file was chosen from ISHRAE file. This is not accurate file. It is calculated from previous weather .The wall and roof construction are not exactly similar as actual building construction. The occupancy pattern is based on prediction, it is not accurate.In this research work with internal load is not considered. Window used in this construction is single pan with insulation layer.The window to wall ratio was no exact as actual building. This led to overstatement of materials used and, ultimately, the environmental impact [16].

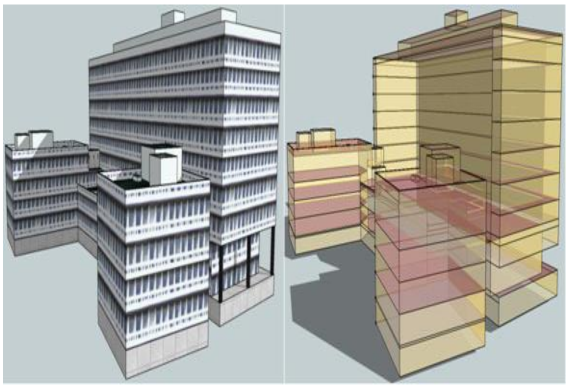

Figure 2. 3D sketch view of building

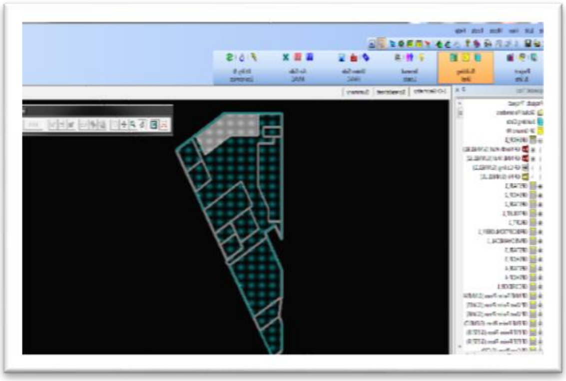

Figure 3. Screen shot of 2 d building in e- quest software

Typology

In Delhi most of the people residence in flat approximately 50-60%. In Delhi most of house natural ventilated. According to the ASHAREA 90.1 2007, Indian climatic zone number is 1 and zone name Very Hot–Humid (1A), Dry (1B)[14]. The building is situated in Gurgaon, Delhi India.

Window area, natural ventilation and shadings

in India most of the time in residential building used a single open type window and in commercial building used single glass with insulation type window. Blinds, shading etc. are used to protect the sun lights enter into buildings. Minimum of window to wall ratio used is 30%.It will be changed depends on the geometry, location and weather of city.According to the local building code for the city of Delhi, the minimum room window area should be defined in relation toits floor area and its type of used [15]. In this research paper there are two type of scenario used , one is based of ASHRAE base line case and other one is based on proposal case. Through this find the optimum value of building construction property.

Thermal property of construction material

The thermal properties of the components of the building envelope were chosen based on the typical building components for residential buildings in India [14]. Two different building components were simulated. The absorbance of material is 0.7.The wall amd roof property show in Table 1 for both base case and proposed case.

Different scenario of building component

The building is simulated using e quest software described above. In this research work two type of scenario is used. One is based on ASHRAE 90.7-2007 and another is proposed. Property of cases is described below.

TABLE 1. Properties of building envelope and lighting base case

	Component	Thickness(ft.)	Conductivity (Btu/h ft-°F)	Density (lb./ft^3)	Sensible heat (Btu/lb.°F)
Wall	Com brick bin(BK02)	0.667	0.4167	120	0.20
	Polystyrene1.25in(IN34)	0.234	0.020	1.8	0.29
	Cement mortar	0.083	0.4167	116	0.20
Roof	Conc LW 80lb 6in(CC25)	0.500	0.2083	80	0.2
	Polystyrene Material	0.25	0.02	1.8	0.29
Window		Single glazing			
	Shading coefficient	0.29			
	VLT%	30%			
	U value (Btu/hr.ft2.°F)	1.57			
Slab	Material	4 inch thick RCC Slab	ASHRAE Steel Joist Floor		
	U value (Btu/hr.ft2.°F)	0.32	0.32		

TABLE 2. Proposed case

	Component	Thickness(ft.)	Conductivity (Btu/h ft-°F)	Density (lb./ft^3)	Sensible heat (Btu/lb.°F)
Wall	Com brick bin(BK02)	0.667	0.4167	120	0.20
	Polystyrene1.25in(IN34)	0.234	0.020	1.8	0.29
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Roof	Conc LW 80lb 6in(CC25)	0.500	0.2083	80	0.2
	Polystyrene Material	0.25	0.02	1.8	0.29
Window		Single glazing			
	Shading coefficient	0.29			
	VLT%	30%			
	U value (Btu/hr.ft2.°F)	0.4			
Slab	Material	4 inch thick RCC Slab	ASHRAE Steel Joist Floor		
	U value (Btu/hr.ft2.°F)	0.32	0.32		

TABLE 3. Lighting, Equipment and Occupant densities

	ASHRAE Baseline Case
Interior Lighting Power Density(W/sqft)	Office: 1.0 Lobby: 1.0 Service: 1.0 Parking: 0.3 Shop: 1.7 Mechanical: 0.4 Light : 0.6
Day lighting controls	NA
Other Lighting Control Credits	NA
Exterior Lighting Power (kW)	11.47

RESULTS AND DISCUSSION

Simulation based results have great potential to reduce trial and error problem [18]. In this study chosen a large floor area, type commercial building ,because in a large building energy consumption is more .So through this simulation to find the optimum value and save carbon , sulphur emission. Delhi air quality day by day worst. So this is challenging for Delhi government to control air quality degradation. Through this study provide information to improve human life and reduce energy consumption. Operation cost shows in dollar form.The results show below

- Electricity consumption in both base case and proposed case show through the table below. The MBE value is 0.35% and CVRMSE(s) is 0.952% for electricity.
- Sulphur dioxide emission mitigation show in table for both cases below. The percentage of sulphur dioxide saved in this study is 0.35% and CVRMS is 0.951%.
- Carbon dioxide emission mitigation show in Table. The percentage of carbon dioxide savings is 0.36%, the CVRMSE is 0.952%.
- Carbon mono oxide MBE value is 0.356%, the sample mean of measurement data is 2971.2kg and the value of CVRMSE is 0.943%.
- Nitrogen oxide MBE value is 0.36%, the sample mean of measurement data is 2119.13kg, and the value of CVRMSE is 0.956%.
- Operational cases for the base is 337, 134, 3.5$ and the proposed case value is 3359, 211.9$ .The saving through this research work is 0.4%.
- MBE $=\sum_{i=1}^{Ns}(yi - y2)/\sum_{i=1}^{Ns} yi$ ……….. (1)
- Y=$\sum_{i=1}^{Ns} yi$ / Ns … … (2)
- where, yi is the measured data;y2 is the simulated data; Ns is the sample size; and Y is the sample mean of measured data[17].

TABLE 4. Base case

	Electricity (kWh)	SO_2 (Kg)	CO_2 Emission (Kg)	CO emission (Kg)	NO_x emission (Kg)	Operational Cost ($) ($0.55/kWh) (1 GJ = 26.13m3) ($0.15/m3)
Heating	23737	206.4	14,004.8	80.5	57.44	13055.35
Cooling	2109371	18343.1	1,244,528.89	7157.09	5105	1160154.05
Interior Lighting	2440463	21222.26	1,439,873.17	8280.49	5905.9	1342,254.65
Fans	338594	2944.41	199,770.46	1148.849	819.4	186226.7
Pumps	813770	7076.5	480,124.3	2761.121	1969.32	447573.5
Misc. equipment	60290	524.28	35,571.1	204.56	145.9	33159.5
Heat rejection	343489	2986.9	202,658.51	1165.458	831.24	188918.95
Total	6129717	53303.4	6117457.57	20798.12	14833.91	3371344.35

TABLE 5. Proposed case

	Electricity (kWh)	SO_2 (kg)	CO_2 Emission (kg)	CO emission (kg)	NO_x emission (kg)	Operational Cost ($)
Heating	23737	206.4	23689.53	80.5	57.45	13055.35
Cooling	1984405	17256.38	1980436.19	6733.09	4802.26	1091422.75
Interior Lighting	2440463	21,222.2	2435582.07	8280.5	5905.92	1342254.65
Fans	320965	2791.11	320323.07	1089.034	776.74	176,530.75
Pumps	1090469	9482.718	1088,288.06	3699.96	2638.94	599,757.95
Misc. Equipment	60290	524.281	60169.42	102.77	145.9	33159.5
Heat rejection	178226	1549.85	177,869.55	604.72	431.3	98025.95
Total	6107658.	53112.194	6095442.68	20723.28	14780.53	3359,211.9

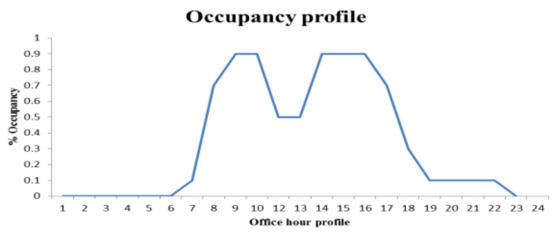

Figure 4. Occupancy profile schedule

TABLE 6. Summary of annually results

Alternative	Annual Energy Use (kWh)	Annual Energy Use (kWh/ Sqft-gross area)
ASHRAE 90.1 2007 Baseline Building	6129717	7.137
Proposed Building	6107658	7.112

HVAC load summary:

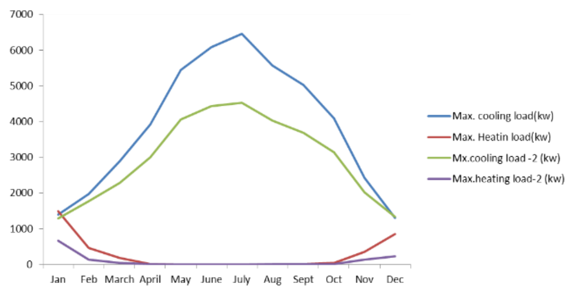

Figure 5. Load summary for two differnet scenario

TABLE 7. Heating Ventilation and Air Conditioning:

Parameter	Proposed Design
Primary HVAC system type	Central cooling plant with variable air volume AHU in each zone
Fan Power (kW/CFM)	0.0006
Ventilation Rates (CFM)	15 CFM/person
Chiller type & Efficiency	Electric hermetic centrifugal & 6.3
Chiller Size	190TR
Cooling Set Point (F)	75°F

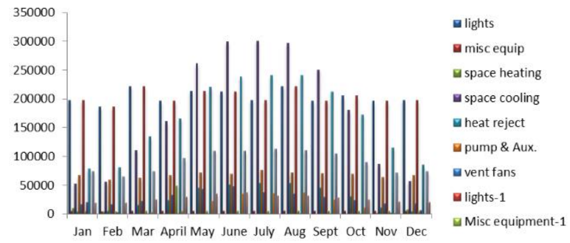

Figure 6. Monthly loads and usage in kW

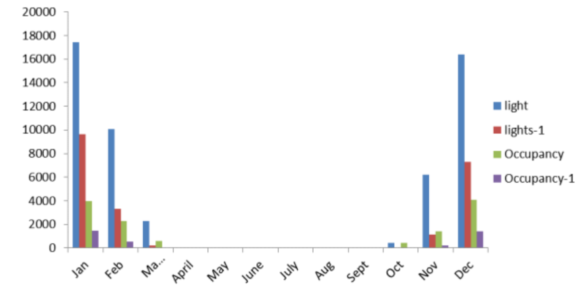

Figure 7. Light pattern in buildings

TABLE 8. Characteristics considered for the HVAC system.

Input data	Conditions
Cooling Thermostat	75°F
Heating Thermostat	72°F
Outdoor air flow rate per person	0.0075 (m^3/s)
Fan operating mode Conditions	By User
Elec. Input ratio	0.1587
Fan pressure	20 ft
Heating capacity	Autosize
Cooling capacity	Auto size
COP	6.3 Btu/Btu

CONCLUSION

The focus point of this paper is to reduce energy consumption and provides better human comfort life. Through this paper highlight the different level of resolution, input into building energy simulation improved the early stage of basic information of building .If Improved the early stage of architecture design improved the energy conservation in building.Differnet energy scenario are purposed in this research work .With the help of these scenario compare the different level of resolution and choose better one. The major disadvantage of building simulation perform is that we cannot found with the help of scenarios, how the building is running better. The results of this paper based on assumption because of lack of actual data. So it is impossible to find accurate results on behalf of predict data. But the author tried to find optimum results. In this research work used ASHRAE 90.1-2007 for base case. It is very helpful the review available information in quality and quantity wise for purposes cases. In this research work only basic needs are provided for building people so reduce the initial cost. Moderate quality is provided in this building. Window blinds, shading etc. are not provided. Occupancy pattern is based on building type and survey of authors.The concept of simplified energy analysis remains a valuable tool even in the age of hi-tech computers. Computer based simulation is a good techniques through this save money, time and hard labor work. For a computer based calculation need more accurate data and results also fine.

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Persian Abstract

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چکیده

این مطالعه از یک روش مبتنی بر شبیه سازی برای محاسبه مصرف انرژی ساختمان با استفاده از داده های نظارت استفاده کرد. این کالیبراسیون بر روی یک ساختمان واقع در گورگان، دهلی نو انجام شد. نرم افزار مورد استفاده برای شبیه سازی دینامیکی E-Quest 3.65 بود. تابع هدف برای به حداقل رساندن تفاوت بین داده های محاسبه شده و داده های شبیه سازی شده تنظیم شده است. ارزیابی دقت مدل، خطای میانگین خطای (MBE) و ضریب تغییر (Cv RMSE) محاسبه شد. از طریق این مقاله رفتار واقعی افراد در یک شبیه سازی ساختمان را نشان می دهد، ممکن است تفاوت ها تا ۳۰٪ وجود داشته باشد. این مقاله امکان صرفه جویی در انرژی، پول و زمان را نشان می دهد. برنامه ساختمان سازی شبیه سازی شده مشابه همان ساختمان واقعی است.