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IMPROVING THE ENERGY EFFICIENCY OF EXISTING COMMERCIAL BUILDINGS IN LAHORE THROUGH RETROFITTING TECHNIQUE

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Abstract

Pakistan is facing sever energy crises which has adversely affected its economy. Retrofitting of existing buildings though energy efficient building material can possibly help reduce the energy consumption. This study involves analysis of energy consumption pattern of an existing commercial building in Lahore and its retrofitting. A computer programme named Ecotect has been used to simulate and determine the heating and cooling load of the building and testing the efficacy of retrofitting measures in terms of energy saving. Our results suggests that significant amount of energy can be saved by making slight modifications in the building using energy efficient material available in the market. The cost of retrofitting can be recovered within a few years. The findings of this study also serve as a guide for owners/tenants of other existing commercial buildings on how to move towards sustainable practices and gain enormous amount of energy savings.

Keywords: Energy efficiency, retrofitting, commercial buildings, Lahore.

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1. Introduction

Energy efficiency is "using less energy to provide the same service" [1]. For instance, insulating allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. “Energy efficient buildings (also known as green buildings or sustainable buildings) refer to a structure and using process that is environmentally responsible and resource-efficient throughout a building's life-cycle” [2]. It calls for slight modification in the conventional and predominantly linear process of designing a building by Architects with meagre or even no consideration of energy efficiency of the building orientation and materials [3]. It also involves use of energy efficient lights as well as air conditioning and heating systems.

However, it should be made clear that “energy efficiency does not mean energy conservation”. The latter is “reducing or going without a service to save energy. Turning off a light is energy conservation, whereas replacing an incandescent lamp with a compact fluorescent lamp (which uses much less energy to produce the same amount of light) is energy efficiency” [1].

The electricity consumption in commercial sector of Pakistan was 5,754 Giga watt hours in 2011-2012. It is increasing at a rate of 11.6%, one of the highest as compared with other sectors of electricity consumption. Growing demand of electricity in commercial sector and recent downfall of economy due to short supply of electricity to commercial sector has encouraged the architects, designers, planners and policy makers to think about strategies to enhance energy efficiency of building [4].

Much of the commercial building stock of Pakistan has been constructed without keeping in view the energy efficiency measures, thereby involving huge consumption of electricity the number of newly constructed commercial buildings with some concept of energy efficiency is very small as compare to existing/old buildings. Such buildings were constructed without incorporating energy conservation measures. Thus, there is a need to find solutions that can possibly help turning them into energy efficient buildings. In this regard, Evonne and Laurie [5] argue that

“Whilst there is increasing recognition that green buildings outperform conventional buildings in terms of a variety of environmental, economic and social indicators, much less is known about how green-building initiatives might be incorporated into existing buildings, which make up the bulk of the market. If the challenge of climate change is to be successfully addressed, therefore, this vast stock of older buildings (developed decades ago when sustainability was not a consideration) needs to be retrofitted.” (p.4)

Retrofitting can facilitate reducing the operating costs of the building, enhancing attendance and productivity of the employees due to improved quality of environment and promoting sustainable energy use in commercial buildings [6]. However, it is less clear how to retrofit the existing commercial buildings [5]. This study attempts to explore possible ways to improve energy efficiency of existing buildings in Lahore by taking a case study approach. The next section presents the methodology adopted for this study. This is followed by case study introduction. The results and discussions are presented in the next section. The final section provides the conclusions.

2. Methods and Data

This research involves several but challenging tasks. Firstly, the literature on energy efficiency and retrofit techniques was reviewed. The next task was to identify computer based program capable of simulating energy performance of existing buildings. After going through various programs/softwares, ECOTECT was selected for this research [7]. The ECOTECT is a highly visual architectural design and analysis tool that links a comprehensive 3D modeller with a wide range of performance analysis functions covering thermal, energy, lighting, shading, acoustics and cost aspects. Whilst its modelling and analysis capabilities can handle geometry of any size and complexity, its main advantage is a focus on feedback at the earliest stages of the building design process as well as the existing buildings. In addition to standard graph and table-based reports, analysis results can be mapped over building surfaces or displayed directly within the spaces. This includes visualization of volumetric and spatial analysis results, including imported 3D

Computational Fluid Dynamic (CFD) data. Real-time animation features are provided along with interactive acoustic and solar ray tracing that updates in real time with changes to building geometry and material properties [8].

Then selection of case study building was another challenge. The city of Lahore has plenty of commercial centres at different locations, some of them are at the Mall Road, Anarkali, Ichra, Shah Alami, Mozang, Allama Iqbal Town, Liberty, and the Main Boulevard Gulberg. The city's posh residential area which has transformed into an important commercial hub is situated on Main Boulevard Gulberg. It has several offices, multi-storey shopping malls and commercial buildings [9]. For this research, a commercial building named "Fountain Avenue", situated on Main Boulevard Gulberg was randomly selected as a case study. The building was designed by an architectural consulting firm based in Lahore. The construction of building was completed in 1990. A detailed inventory of the structural characteristics of the building was prepared including its orientation, types and materials of windows, walls, floors, and the roof.

Following this, an interview schedule was designed to find out the status of energy efficiency in Fountain Avenue-our case study building. The shop keepers were interviewed to seek information about business timings, number of air conditioned installed and their thermostat position. Similarly, information about type and number of lighting bulbs, electricity charges in summer and winter was obtained. The information so obtained was utilized to simulate Fountain Avenue data on the ECOTECT program. The results were analysed before and after employing retrofitting techniques. It facilitated measuring the energy efficiency outcome, and calculating estimated cost and benefits of the proposed retrofitting measures. The owners/tenants of the shops were also asked about their willingness to improving the energy efficiency of the building and and bearing its cost.

3. Case study Introduction

It is a triple storey commercial building, built on a total area of four Kanals (18000 sq. m). There are roads on three sides and a building on the rear side. The building was constructed in two phases-first during 1980 and second in 1990. First part is called Fountain Avenue-I and the second one as Fountain Avenue-II. Its plan includes two basements and ground plus eight floors and a parking lot in front of the building. It has a ground floor and two upper floors accommodating 12 shops and 4 offices. All these 16 units were surveyed.

Figure 1: Facade of Fountain Avenue building I & II
Source: Photograph taken by the authors

3.1 Structural details

Orientation

Building is located at -110 degrees to north. The building has its front in North West direction; however its back is in South East direction. No uses are present on the north and south side expect dead walls.

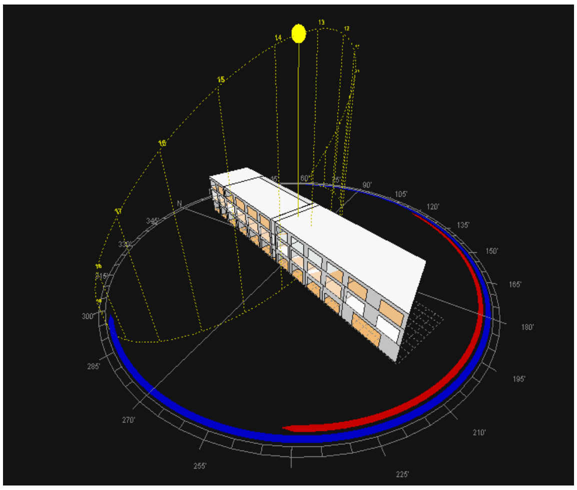


Figure 2: Sun path and position of the case study building during winter

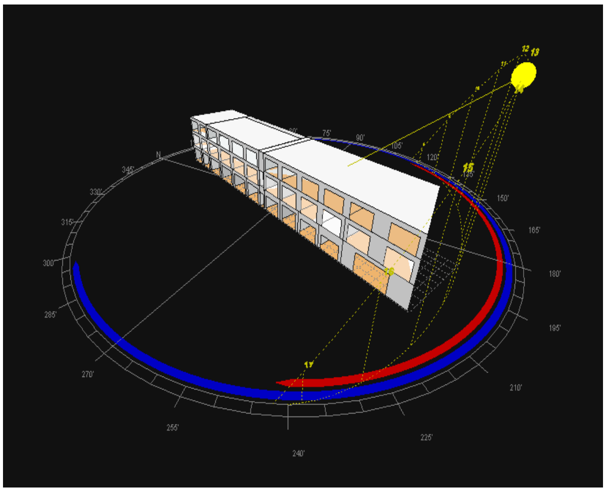


Figure 3: Sun path and position of the case study building during summer

Source: Images generated using Ecotect by the authors

Walls and windows

Walls of the case study building are made up of red brick tiles which have been used on the outer face of the walls (Figure 4). Each tile is 9" inch long and 3 inch wide. Thickness of the outer walls is 9 inches while that of the inner ones is 4.5 inches. These are made up of cement-sand mortar. Every shop and office occupant has the liberty to make any changes within his premises.

Figure 4: Northeast wall of Fountain Avenue building

Figure 5: Windows on the left wall of first floor

Source: Photographs taken by the authors

The ground floor shops have no windows. The front wall of these shops is made up of float glass panels which function both as doors and windows. These are fixed glass panels having an average size of 9 ft x 12 ft. At the first floor, there are 11 windows (Figure 5). The average size of these windows is 8 ft x 12 ft. These windows are not transparent, but have glass of dark brown color. The second floor consists of three offices. The windows at this floor are made up of the same material as that of the ground floor but these are 12 in numbers with an average size of 7ft x 12 ft. There is no shade on windows throughout the building.

Floors and the roof

Marble and ceramics tiles are the most favourite materials for floors in this building. Some shops and offices preferred off-white marble floor. Others have used light brown or off-white ceramic tiles. There is nothing special with the roof of this plaza. It is a common flat concrete slab suspended roof. The lining of brick tiles on the upper most exposed surface of the roof is worn out exacerbating further decay of the roof.

4. RESULTS AND DISCUSSION

4.1 Analysis of the Existing Energy Consumption Pattern

The types and number of electricity equipment being used for lightening and air conditioning of various shops and office in the building as well as monthly electricity bills are presented in Table 1. Most of the shops are using energy saver bulbs, however, the average thermostat position of the AC's in the shops ranges from 20.44 degree Celsius to 23.87 degree Celsius. Majority of the shop owners keep it to a maximum of 26 degree Celsius. The average monthly electricity bill is Rs. 18562/- in winter and Rs. 34125/- in summer with a minimum of Rs. 8000/- and a maximum of Rs. 100000/- per month respectively. This shows that there is sharp variation in the bills during summer reflecting a diversified consumption pattern.

Table 1: Types and number of lights and air conditioners being used in the case study building

Name of Shop/Office	Type of Shop/Office	Business Timings	No of Lights	AC's	Thermostat Position		Electricity Bill (x1000 Rs.)	
					Min.	Max.	Win.	Sum.
Levi's	Garments	11-22	40	2	17	18	10	21
Nike	Garments & Shoes	10-22	230	12	22	24	40	100
Dockers	Garments	11-22	44	2	17	26	12	20
Charles & Keith	Handbags & Shoes	11-22	40	2	22	24	12	20
Cambridge	Garments	11-22	31[1]	2	24	26	8	17
Asghar Ali	Perfumes and Deodorants	10-22	80	2	22	26	43	70
Karma	Garments	11-22	36[2]	1	16	18	20	36
Nishat Linen	Garments	10:30-22	36	2	21	26	9	20
Sarah's	Garments	10-22	36	1	20	26	8	12
Marie Claire	Handbags & Shoes	10:30-22	30	1	22	26	16	24
Bonanza	Garments	10-22	90[3]	4	22	26	40	60
Shirt & Tie Shop	Garments	11-22	100	1	20	22	12	28
Ali & Ali Law Associates	Law firm	9-18	12	3	18	20	9	12
Chevron	Energy	9-18	60[4]	6	18	22	20	40
KSAB Securities	Security firm	9-18	20[5]	5	24	26	30	50
The Princeton View	Office	9-18	18	2	22	26	8	16

Note: All the shops and have energy saver lights except few variations described as **1:** 23 LED lights, **2:** All fluorescent lights, **3:** 60 LED lights, **4 & 5:** each has 20 tube lights. The thermostat position is in degree Celsius.
Source: Output obtained from field data collected by the authors

4.2 Retrofitting of the Building

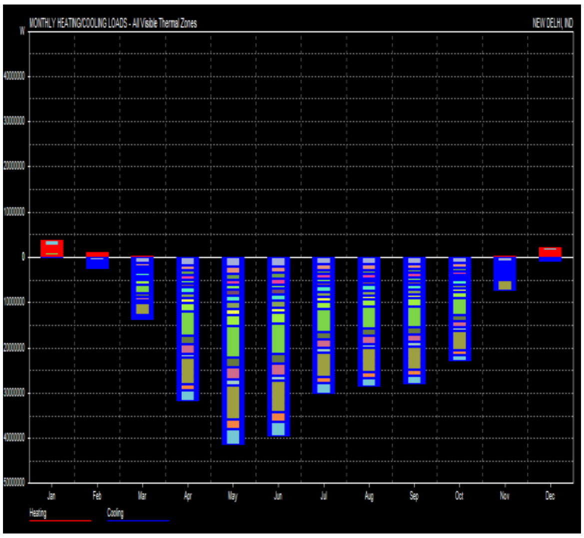
After determining the existing energy consumption pattern, the structural elements of the case study buildings were critically analysed with respect to their vulnerability of direct solar heat. Since the building is not exactly facing the north, therefore, its southwest and northwest sides are more vulnerable to direct solar heat. The glass used in the doors and windows allows 97% of the heat to enter the building.

Our field survey suggests that construction of cavity walls with insulation material placed inside and above the concrete roof slab are necessary to minimize the direct solar heat gain. Low energy insulated glass for doors and windows is required to minimize entry of the heat through these sources. Furthermore, LED lights can help reduce energy consumption within the building. All the aforementioned materials and techniques were used to retrofit the building. The quantities and cost of materials required for this purpose are presented in the section 4.5. A comparative analysis of the monthly heating and cooling loads before and after retrofitting the building is presented in the next section.

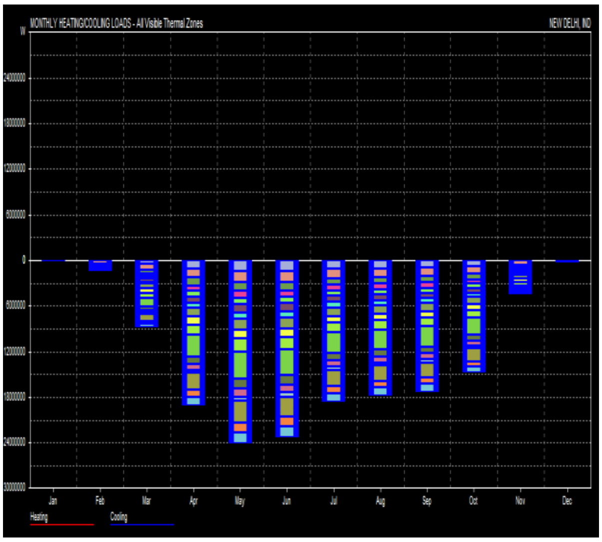
4.3 Monthly heating and cooling loads before and after retrofitting

The analysis of monthly heating and cooling loads using Ecotect software revealed that the maximum heating was required during the month of January and it used 3748130 Wh. (apporx. 3748 KWh) energy. After the application of energy efficiency techniques (retrofitting) the required heating load dramatically reduced to 23418 Wh (approx. 24 KWh). The maximum cooling was required in May and it used 41544508 Wh (41544 KWh) energy (Figure 6). The cooling load reduced to 24190632 Wh (24190 KWh) after retrofitting (Figure 7).

The average monthly heating and cooling load of the existing building reached up to 21394138 Wh (approx. 21394 KWh), but reduced to 12555345 Wh (approx. 12555 KWh) after retrofitting. This implies that nearly 41% of the energy being used in the existing building can possibly be saved through the retrofitting techniques applied in this case.



Figures 6: Monthly heating and cooling loads on building before retrofitting

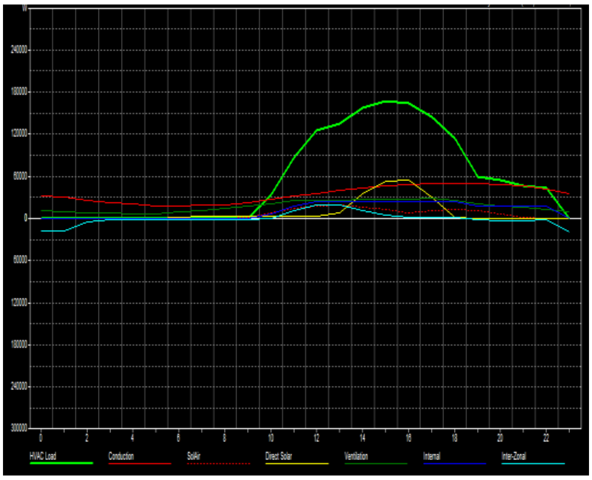


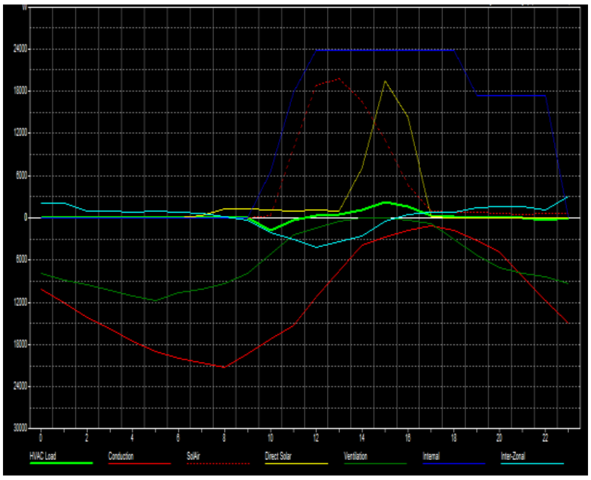
Figures 7: Monthly heating and cooling loads on building after retrofitting

Source: Output obtained from Ecotect through analysis done by the authors

4.4 Hourly heat gains before and after retrofitting

Hourly heat gains have also reduced after the application of energy conserving techniques. Before the modifications in building, the maximum load 334328 Wh (334KWh) was experienced in the 15th hour, i.e. from 2: 00 pm to 3: 00 pm. Out of this, the HVAC (heating, ventilation, and air conditioning) system of the building was bearing most of the heat gains i.e. 167157 Wh (167KWh) see Figure 8. This is because in the simple HVAC system the air is circulated at much higher rate than what is actually needed for ventilation [3].





Figures 8: Hourly load of various factors before retrofitting

Figures 9: Hourly load of various factors after retrofitting

Source: Output obtained from Ecotect through analysis done by the authors

Figure 9 shows a very diversifying result. The HVAC load is very less and only increases in the 15th hour i.e. up to 2283 Wh (2.28KWh) only. However, the peak of direct solar gains is quiet high in the 15th hour i.e. 19504 Wh (19.5 KWh), showing that in this hour the sun rays are allowed to enter the building without any hurdle. The highest peak is of internal loads, and it remains constant from 12^{th} hour to 18^{th} hour.

4.5 Cost Benefit Analysis

The Table 2 presents the breakup of required materials and the costs of constructing the two cavity walls and insulating the roof.

Table 2: Cost of Constructing Cavity Walls and Insulating the Walls and Roof

	Unit Price	**Northwest Wall**	**Southwest Wall**	**Roof Insulation**
Type of Element/ Dimensions		**30'X205'X4.5"**	**30'x40'x4.5"**	**79000sft**
	Cost (Rs.)			
Bricks	8.5/brick	119000	54400	-
Cement	515/bag	12875	6180	-
Sand	700/m^3	2450	1050	-
Insulation	94/sft.	246750	112800	742600
Labour	5250/day	37800	25200	474000*
Miscellaneous	10% of total	41888	19963	-
Cost of each element		**460763 (A)**	**219593 (B)**	**1216600 (C)**
Total cost of cavity walls & insulation		**A+B+C= 1896956 Rs. (Sub-total M)**		

*In case of roof insulation, the labor cost is Rs. 60/sft.
Source: Market survey, 2014

The Table 3 presents the required quantities and cost of low energy glass for windows and doors as well as for the LED light.

Table 3: Glass and lights required for different uses in building

Insulated Glass Elements	Quantity sft.	Unit Price	Cost of Glass	Labour Cost*	Total
Glass for Windows	1036	193/sft.	199948	18648	D+E= 730271
Panels	1216		234688	21888	
Glass for Doors	1209		233337	21762	
Total Quantity and Cost of Glass Work	**3461**		**667973 (D)**	**62298 (E)**	
LED Lights	**Nos.**	**Unite Price**	**Cost of Lights**	**Labour Cost****	
Ceiling lights	507	1850	937950	30420	F+G= **2534850**
Spotlights	304	3275	995600	18240	
Panel lights	44	12500	550000	2640	
Total Quantity and Cost of LED Lights	**855**		**2483550 (F)**	**51300 (G)**	
Total cost of glass and LED lights	**D+E+F+G= 3265121 Rs. (Sub-total N)**				

*The unit labour cost of glass installation is rupees 18/ft
** The unit labour cost for installing LED lights is rupees 60/item
Source: Market survey, 2014

Total cost of retrofitting = Subtotal M+ Subtotal N = 1896956+3265121= 5162077 Rs. Thus, an approximate amount of 5.2 million rupees would be needed to retrofit the building using energy efficient material/techniques.

4.6 Revenue from the Sale of Old Glass and Lights

Used glass and lights of the building will not go waste. During the market survey, resale value of old lights and glass panels were also enquired. The following Table 4 presents the detail of resale value of each item and the expected revenue to be generated.

Table 4: Revenue to be generated by selling old lights and glass

Type of Light	Quantity	Resale Rate of 1 Light	Total Amount
Energy savers	744	45	33480
Tube lights	40	50	2000
CFL lights	36	35	1260
Total	**820**		**36740 (H)**
Resale value of Glass			
Type of Glass	**Quantity (sft)**	**Resale Rate of 1 sft of Glass**	
Float Glass	**3461**	**30**	**103830 (J)**
Total revenue to be generated		**H+J = 140570 Rs. (Subtotal P)**	

Source: Market survey, 2014

4.7 Total Investment Required and Payback Period

To find out the total amount required, we must look at the total cost of retrofitting which is Rs. 5162077 and total existing revenue we have is Rs. 140570. It means the investment is needed of amount Rs. 5021507 (Say 5.2 Million).

To calculate the time needed to recoup the investment, we must look at the reduction in energy consumption and monthly electricity charges/bills. Estimation of total energy savings is made because decrease in power consumption is directly proportional to the decrease on electricity charges.

Table 5: Average monthly energy consumption, electricity bill and saving

Building Status	Avg Monthly Energy Consumption (Wh)	Avg Monthly Electricity Bill (Rs.)
Existing	21394138	421500
Modified	12555345	247357*
Total reduction	8838793	174143
Energy Saving	~41 %	

Source: Authors

*Reducing the average annual electricity bill proportionate to reduction in annual energy consumption, assuming a flat unit rate of electricity although electricity rate per unit increases after certain number of units. Thus, actual saving on the monthly electricity bill would be higher than the calculated amount.

The total monthly savings indicate how much time would be needed to recover the cost of retrofitting the building. If everything goes normal and the saving remain Rs. 174142 per month continuously, approximately 29 months are required to regain the total amount of investment.

4.8 Willingness of the owners/tenants for retrofitting the building

Willingness and participation of the owners/tenants is of essential for successful retrofitting of the building for improving its energy efficiency [5]. Our survey revealed that 90 % of the owners/tenants of shops and offices are willing to support the retrofitting of the building and bear its cost. However, only 10% of them showed their unwillingness. Hence, a vast majority of them is ready to take the initiative. However, someone will have to play a lead role and coordinate the retrofitting and cost sharing process.

5. Conclusion

Energy efficiency of existing commercial buildings is a global concern. Most of such buildings were constructed keeping in view the conventional process of design in which minimizing the cost of construction has been the driving force. The energy efficiency measures were given least consideration. Retrofitting has evolved as a technique to modifying existing buildings using heat resistant low energy materials. It can help save energy consumption in existing buildings and hence contribute to sustainable development practices.

The analysis of existing energy consumption pattern of our case study building and the simulation results of retrofitting obtained using Ecotect demonstrates that significant reduction in heating and cooling load on the HVAC system of the building can possibly be achieved (i.e., saving of nearly 41 percent of energy). The retrofitting measures and materials identified in this study are not much costly and cost recovery is possible in less than three years' time.

Our survey of tenants of case study building shows their willingness to switch towards energy efficiency and gain financial benefits. The findings of this study also serve as a guide for owners/tenants of other existing buildings how to move towards excellence and sustainable practices by retrofitting their buildings. Development authorities like the LDA may modify bylaws for new and present commercial buildings to set a way forward for future sustainable development.

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