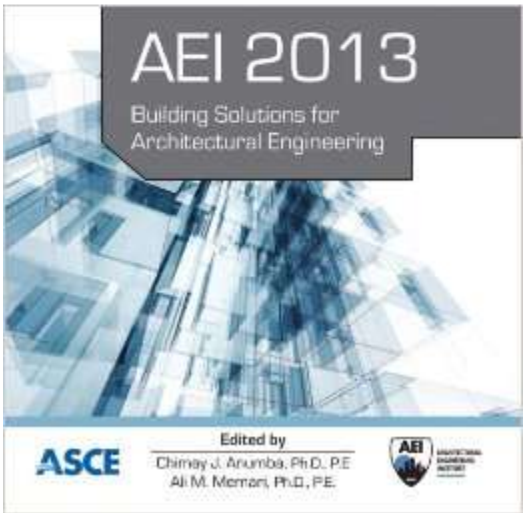
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MAXIMIZING DAYLIGHT USE POTENTIAL IN RETAIL SHOPPING ENVIRONMENTS IN THE CONTEXT OF DHAKA, BANGLADESH

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ABTRACT

In the recent times with the increase in the population, the number of retail shopping environments has increased significantly in Dhaka city. But these shopping environments are developing into high consumption areas of electricity resulting from artificially light design approach. In this study, it was found that the energy consumption is rising because of the minimal or no use of daylight and natural ventilation.

A field based case study was conducted to review the daylight inclusion in the design of retail shopping environments representing the historical periods of 1950-70, 1971-80, 1981-90, 1991-2000, 2001-2011. In this research in addition to field work, parametric study was done to identify the effect of design factors/parameters relating to daylight. The main focus was to develop a causal relation between the parameters of the shopping environments to maximize the use of daylight. The parameters which were considered in this study were- width, height and depth of the shops; the depth of the corridor between two rows of shops; the height and width of the light wells. All the parametric relations were derived to the width of the shop. Daylight level were measured and compared with the given level in the Bangladesh National Building Code (BNBC) code.

It was found that shopping environments play an important role in energy consumption in urban areas and little or no utilization of daylight contribute to this energy demand. This is of particular significance in an environment where dwindling fossil sources of energy and an increasing energy demand created by positive economic growth pose a challenge for the building industry stake holders.

Keywords: Daylight, Parametric Study, Retail Shopping Environments

1. INTRODUCTION

Dhaka city has an approximate 400 year old history where trading and commerce played an important role in its growth. The retail shopping environments of Dhaka city evolved over the whole time period. Before 1950 ‘Chawk Bazar’, ‘Babu bazar’ to name but a few were the major places for retail shopping activities in Dhaka city. Between 1950- 1960, ‘New Market’ was established as a retail shopping market to serve Dhanmondi, an planned residential area (Fig. 01). In 1981- 1990 some multistoried markets started to emerge. ‘Sharif Market’ and ‘Century Arcade’ (Fig. 02) are the examples of that period.

Between 1990- 2000 more multistoried retail markets were established with the amenities like escalator and air conditioning. ‘Eastern Plaza’, ‘Karnaphuli garden city shopping complex’, ‘Russel Square’ is some of the examples of that period. After 2000 the construction of retail markets expanded, between 2001-2010 lot of markets of similar typology were established throughout the Dhaka city. ‘Plaza A R’, ‘Bosundhara City’(Fig. 03)., ‘Anam Rangs Plaza’ etc are some of the example of this time. . These shopping environments are developing as introvert high energy consuming, mechanically controlled areas leading to poor utilization of daylight and natural ventilation.

Fig. 01: New Market (2012)

Fig.2: Century Arcade (2012)

Fig.3: Basundhara City (2012)

The utilization of daylight will lead to a decrease of energy use during daytime in retail shopping environment. As the shopping facilities are open until 8pm the use of electricity for the lighting would be necessary for only 3-4 hours. This amount of energy necessary for this service can be provided by the use of renewable energy, partially or entirely. The utilization of natural ventilation would render the opportunity to use passive cooling mechanisms in the shopping facilities. This will also decrease the use of energy for air conditioning and air circulation. In residences or commercial office spaces it is more expensive to cool a building than to light a building. But the amount of energy used for lighting in the shopping areas is almost 50% of the total energy consumption of the facility (Debnath, K. B, 2012).

2. EVOLUTION OF RETAIL COMMERCIAL GROWTH IN DHAKA

Cities are products of the changing circumstances, culture, societies, politics and economy of their origin and growth. The commercial activities in a city are as old as the city. (Hossain, N. 2002) Dhaka, the capital city of a Bangladesh, is situated on the northern bank of river Buriganga. The antiquity of Dhaka as a settlement can be dated 7th century AD when it was part of the Buddhist kingdom of Kamrup and an image of Harissankara dated 11-12th century AD. (Islam, N. 1996) These relics suggest that human habitation started from approximately 1400 years ago. Dhaka was established as a town approximately 400 years ago. In different periods of history the city expanded due to significant developments in trade and commerce. This time period can be divided into six stages. They are - Pre-mughal hindu Period (Before 1608), Mughal Period (1608-1764), The rule of the East India Company (1764-1857), British Colonization (1858-1947), Pakistan Period (1947-1971) and Bangladesh Period (1971-2011). It seems that the shopping environments are evolving towards the multistoried development. But the energy consumption of these buildings are increasing due to the less or no use of daylight and natural ventilation and increase in the use of artificial ventilation and lighting. (Debnath, K. B, 2012).

3. METHODOLOGY

In this study, from literature review and the field study the evolution of the retail shopping environments of Dhaka city was analyzed. From this evolution study the problems of the retail developments regarding the day light utilization and natural ventilation was investigated. In the later stage parametric studies were conducted to find out the parametric solutions for maximizing the utilization of day light in shopping environments.

4. MICROCLIMATE OF DHAKA CITY

Dhaka experiences a hot, wet and humid tropical climate. The city has a distinct monsoonal season, with an annual average temperature of 27.5 °C (81.5 °F) and monthly means varying between 19.5 °C (67 °F) in January and 32 °C (90 °F) in April. Approximately 87% of the annual average rainfall of 2,121 millimeters (83.5 in) occurs between May and October. Increasing air and water pollution emanating from traffic congestion and industrial waste are serious problems affecting public health and the quality of life in the city (Mondal, M. Abdul Latif, 2006). Water bodies and wetlands around Dhaka are facing destruction as these are being filled up to construct multi-storied buildings and other real estate developments. ‘Coupled with pollution, such erosion of natural habitats threatens to destroy much of the regional biodiversity’ (Mondal, M. Abdul Latif, 2006).

Throughout the year the availability of daylight is a major environmental asset for Dhaka. Solar direct and diffuse radiations during these months are the major sources of daylight in buildings. In case of shopping environments BNBC made standards of light level is minimum 300 lux in the shop at work top level and minimum 500 lux in display area. Since solar radiation is a major source of light in the energy saving approach in spite of its heat and glare, the maximum use of daylight and natural ventilation is a major consideration to achieve environmentally responsiveness in shopping environment.

5. METHODS AND TOOL FOR PERFORMATIVE EVALUATION

Daylight analysis means using a manual calculation or computer program to model, mathematically the interplay of lighting level within a building. There are wide range of mathematical models used for this purpose, all of which vary significantly in both case of implementation and comprehensiveness. ECOTECT is such type of environmental design tool, which couples an intuitive 3D modeling interface with extensive solar, thermal, lighting, acoustics and cost analysis functions. Nicky Taylor validated ECOTECT as part of his research work for the degree of Bachelor of Engineering (Hors.) form Department of Environmental Engineering at University of Western Australia in 2002. He showed in his research that the mean errors of the estimated results are less than 2%, indicating a reasonable degree of accuracy (Hossain.S. 2007).

For the software the input data were- In 3D model for the ray tracing precision 4096 spherical rays per sample point, design sky illuminance was 11000 lux.sky luminance distribution model was CIE overcast sky condition, the window cleanliness was average (x 0.90), the orientation were North, South, East, West, Weather file for Dhaka city (prepared by the U.S. Department of Energy) and the context was urban, fully natural ventilated building, operating time 12:30PM at 1st April.

In the modeling the ceiling material was 10mm suspended white plaster board ceiling, plus 50mm insulation, with remainder (150mm) joists as air gap. The partition walls were of 80mm framed wall as air gap, with 10mm white plaster board either side. In the model the apertures are containing single glazed glass with aluminum frame, All the shops are in a row layout, The floors are 100mm thick suspended concrete floor plus ceramic tiles and plaster ceiling underneath., Only three type of floor to floor height is considered- 8’, 10’, 12’, The shops are maintaining the U shaped display counter, In the corridors the material of railing is Stainless steel with circular section.

6. COMPARISON OF ENVIRONMENTAL RESPONSIVENESS

6.1 Utilization of daylight

In Shakhari bazaar during the pre-mughal hindu period (Before 1608) people mainly depended on the daylight. The Chawk bazaar was depended on daylights from Mughal Period (1608-1764) to British Colonization (1858-1947). But after the establishment of New Market in Pakistan period artificial lighting was introduced in retail shopping areas. But the design of the New Market enabled it to use the daylight. In Bangladesh time period, the Polton Super Market was also following the footsteps of the New Market. A simulation study was conducted on existing built spaces to evaluate percentage of daylight received in terms of area (Fig. 04). It was found that in the case of Polton Super Market the circulation corridor was not spacious as in the case of New Market hence the amount of area receiving daylight is less. Centaury Arcade has also utilized daylight. But they had to depend on artificial lighting due to the greater depth of the building. The Eastern plaza was a completely artificially light shopping environment. (Fig. 04) There are some apertures in the building but they are not sufficient. Basundhara city uses little daylight due to planning approach where shops on the front side create s a barrier. The atrium mostly lights the circulation around it. But most of the shops are depended on artificial lighting even in day time. So the daylight use is higher than Eastern plaza but not significant (Showed in Fig. 04).

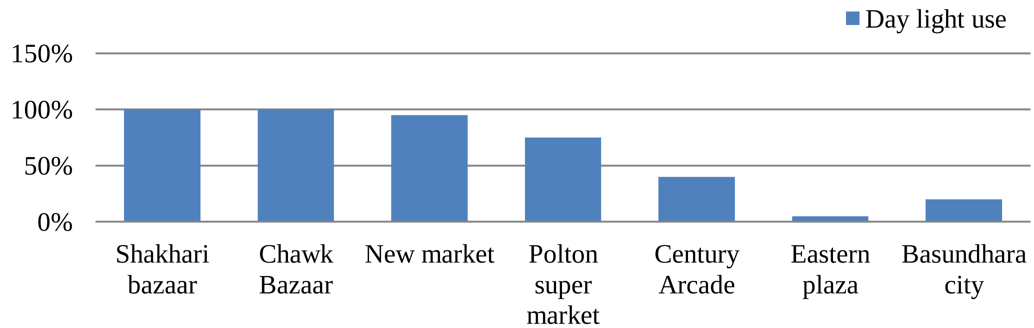


Fig. 04: Simulated Day light Use in Retail Shopping Environments expressed in Percentage of Floor Area

6.2 Energy Consumption

From pre-mughal hindu period (Before 1608) to British Colonization (1858-1947) all the shopping environments were not using any electricity.

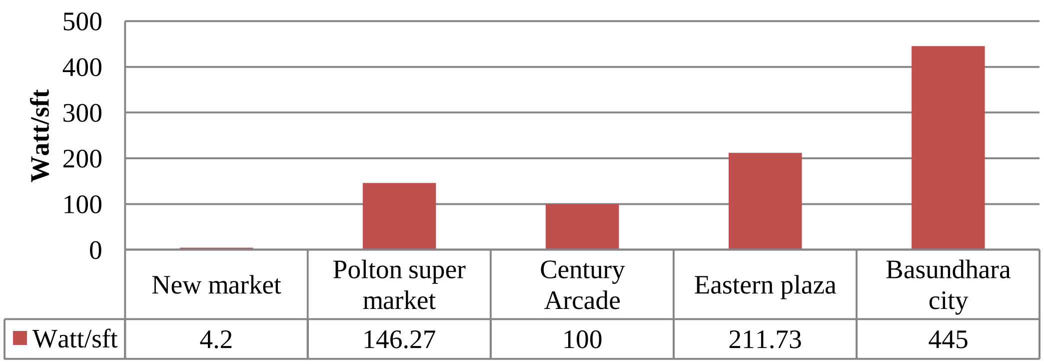


Fig. 05:Electricity Use per square feet in Retail Shopping Environments Expressed in Watt per sft Floor Area

From New Market to Basundhara City, the energy consumption is rising (Showed in Fig. 05). The use of electricity in per square feet is rising with the increase in the use of artificial lighting and the reduced daylight. The energy consumption was measured from the monthly electric bills. This data is showing the maximum energy consumption as it was measured in the month of April after the Eid festival. Because of the festival the number of occupants reaches to the top causing high energy consumption. It was found that these types of mechanically controlled multistoried shopping environments are increasing the use of energy in a high rate. These are not environmentally responsive design solutions.

7. PARAMETRIC STUDY

7.1 Introduction

During the study two distinctive type of shop layouts were found. One type of shop has one side which comes with the contact with the outer surface. This can be used as an aperture for daylight. The circulation corridor is on the opposite side of the aperture surface (Showed in Fig. 06). Other than this aperture all other surface is surface is closed. The second type of shop has the circulation corridor in on one side and this corridor is the source of daylight (Showed in Fig. 07).

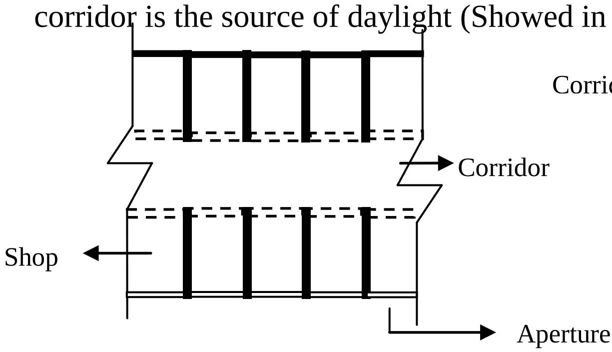


Fig. 06: Shops with apertures in one side

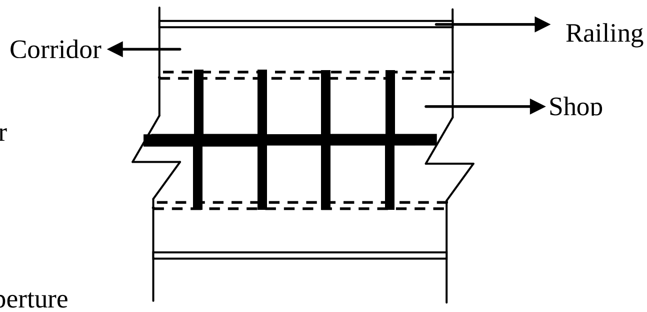


Fig. 07: Shops with corridor in one side

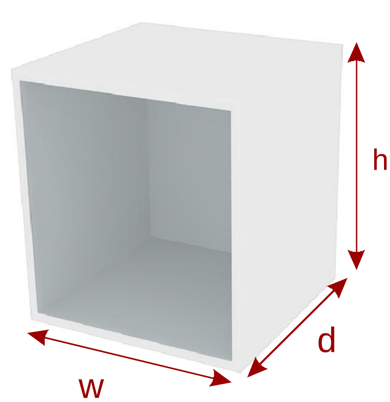
For this reason, the total study is divided into 4 stages. Firstly the single shop, where two types of organization can be found. One is the shop facing inward with an exposed surface towards the exterior and other is the shop facing outward with a corridor in front. Second is the organization of the multiple shops. Here the relation between the lengths of the multiple shop organization can be analyzed. Thirdly the relation of the parameters in case of horizontal expansion is going to be simulated. And fourthly in case of the vertical expansion the parametric relation is going to be analyzed. In the tables- Green is the acceptable value (If the light level at last end of shop is greater than 300 lux) and blue is unacceptable value (If the light level at last end of shop is less than 300 lux).

7.2 Shops with Single Side Aperture

7.2.1 Relation between Height, Width, Depth for a single shop with aperture on external side

	h=8’			h=10’			h=12’		
w:d	1:1	1:2	1:3	1:1	1:2	1:3	1:1	1:2	1:3
100%									
50%									
25%									

Fig. 08: Relation between Height (h), Width (w) and Depth (d) for a single shop with aperture on external side



For h=8', 10', 12' and 50-100% opening, **d= [1-2] w**

For h=8', 10', 12' and 25% opening, **d= w**

If the floor to floor height is 8', 10' or 12' and the shops has a exterior surface with a 50-100% aperture with clear glass the depth of the shop should be equal or maximum double to the width of the shop (Fig. 08). In case of exterior surface with a 25% aperture with clear glass the depth of the shop should be equal to the width of the shop. The greater amount of depth than the above mentioned proportion will create less than 300 lux of light.

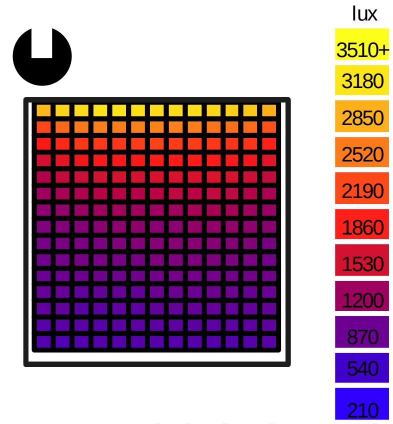
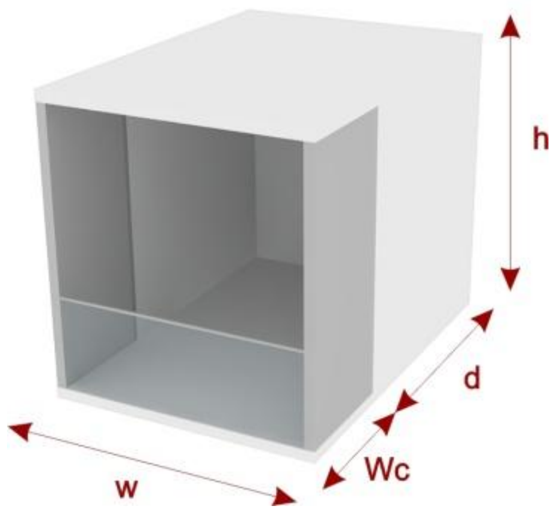


Fig. 09: Daylight level at work top (h=8', w:d=1:1 and Aperture 100%)

7.2.2 Relation between Height, Width, Depth for a single shop with peripheral corridor on one side



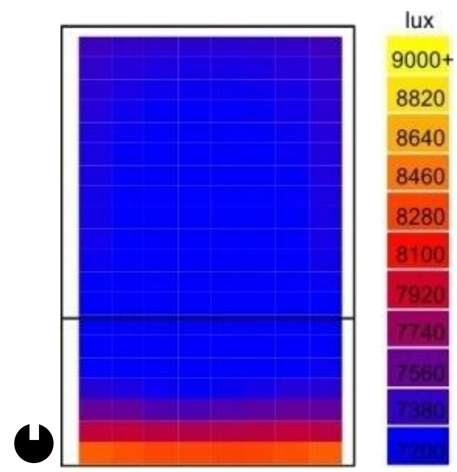


Fig. 10: Daylight level at work top (h=8', w:d=1:1 and Wc= 0.5w)

For h=8'
d= [1-2] w
Wc= [.5-1] w

For h=10', 12'
d= [1-2] w
Wc= [.5-1.5] w

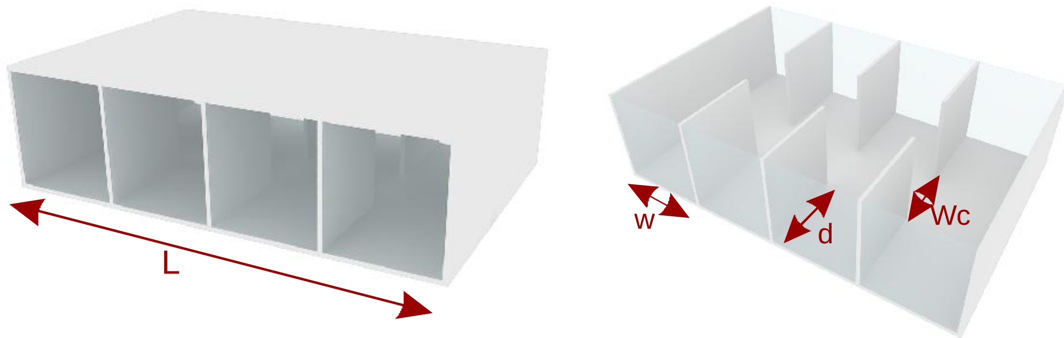
	h=8'			h=10'			h=12'		
w:d / Wc	1:1	1:2	1:3	1:1	1:2	1:3	1:1	1:2	1:3
0.5w									
w									
1.5w									
2w									
2.5w									

Fig. 11: Relation between Height (h), Width (w) and Depth (d) for a single shop with peripheral corridor on one side

If the floor to floor height is 8', 10'or 12' and a corridor in front of the shop, then the depth of the shop should be equal or maximum double to the width of the shop (Fig. 11). In this case the width of the corridor should be 0.5 to equal (for 8') or 1.5 times (for 10' and 12') than that of the width of the shop.

7.3 Multiple shops

7.3.1 Relation between Height, Width, Depth and Width of the corridor with aperture on one side of the shop for daylight



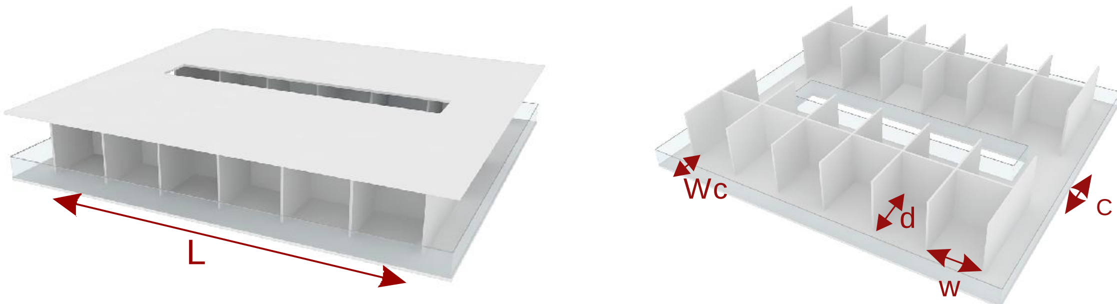
Height		h=8'			h=10'			h=12'		
Aperture	w:d / Wc	1:1	1:2	1:3	1:1	1:2	1:3	1:1	1:2	1:3
100%	0.5w									
	w									
	1.5w									
	2w									
	2.5w									
50%	0.5w									
	w									
	1.5w									
	2w									
	2.5w									

Fig. 12: Relation between Height (h), Width (w), Depth (d) and Width of the corridor (Wc) with aperture on one side of the shop for daylight

For h=8', 10', 12' and 100% opening, **d= [1-2] w, Wc= [0.5-1.5] w**
For h=8', 10', 12' and 50% opening, **d= [1-2] w, Wc= [0.5-1] w**
For h=8', 10', 12' multiple shops with 25% opening not acceptable
In case of the floor to floor height is 8', 10' or 12' and the shops has a exterior surface with a 50-100% aperture with clear glass, the depth of the shop should be equal or maximum double to the width of the shop. Exterior surface with a 25% or less aperture is not acceptable. If the shops have an exterior surface with a 100% aperture with clear glass the width of the corridor should be 0.5 to 1.5 times of the width of the shop. In case of 50% aperture the width of the corridor should be 0.5 to 1 times of the width of the shop. (Fig. 12)

7.4 Multiple shops with horizontal layers

7.4.1 Relation between Floor height, Width of the corridor and width of the light well for shops with aperture on one side



Height	h=8′					h=10′					h=12′				
Wc / C	.5w	w	1.5 w	2w	2.5 w	.5w	w	1.5w	2w	2.5 w	.5 w	w	1.5w	2 w	2.5 w
0.25w															
0.5w															
w															
1.5w															
2w															
2.5w															
3w															

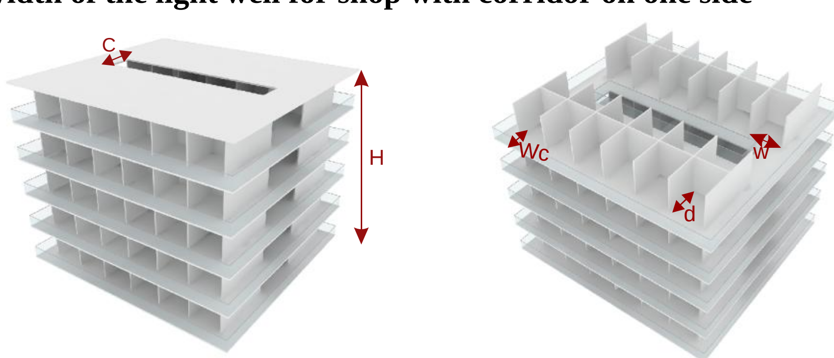
Fig. 13: Relation between Floor height (h), Width of the corridor (Wc) and width of the light well (c) for shops with aperture on one side

For h= 8′ **C= [1-2] w** when **Wc = [0.5-1] w**
For h= 12′ **C= [1-2] w** when **Wc = [0.5-2] w**
For h= 10′ **C= [1-2] w** when **Wc = [0.5-2] w**

When the shops develop multiple layers horizontally, a light well is needed for the utilization of daylight and natural ventilation features. The width of the light well should be equal or maximum double to the width of the shop when the floor to floor height is 8′, 10′or 12′. But when the floor to floor height is 8′, the width of corridor should be 0.5 to 1 times of the width of the shop. If the floor to floor height is 10′or 12′, the width of corridor should be 0.5 to 2 times of the width of the shop. (Fig. 13)

7.5 Multiple shops with Vertical layers

7.5.1 Relation between Building height, Floor to floor height, width of the corridor and width of the light well for shop with corridor on one side



Height	h=8′					h=10′					h=12′				
h / C	2h	3h	4h	5h	6h	2h	3h	4h	5h	6h	2h	3h	4h	5h	6h
w															
2w															
3w															
4w															
5w															
6w															

Fig. 14: Relation between Building height (H), Floor to floor height (h), width of the corridor (Wc) and width of the light well (C) for shop with corridor on one side

For h= 8′, 10′, 12′ **c=nw** when **H=nh** Here, n>1 and when Wc= 0.5w

When the shops develop multiple layers horizontally and vertically, the width of the light well should be ‘n’ times of the width of the shop in all cases of the floor to floor height is 8′, 10′ or 12′ (Fig. 14). The height of the light well should be ‘n’ times of the floor to floor height. The number of floor should be more than 1.

8. CONCLUSION

The issue presented in this paper can be regarded as the beginning of this complex but important relation between building morphology and daylight in the local context. The findings illustrates that it is greater clarity in design is required retail shopping areas in a Hot-humid climate like Bangladesh. From these parametric relations the architects can find possible indications in designing a retail shopping environment optimizing daylight availability. Although there is other factors like urban density or impact of adjacent buildings can affect the daylight availability. The scope of this research allowed the study in an simplified situation omitting the effect of adjacent buildings. But detail study and research can be undertaken to observe the above effects. This study provides an initial but important step for finding out the basic parametric relation between the building morphology and its environmental responsiveness.

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