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Prospects and Challenges of Going Green

4-5 August 2017, Dhaka, Bangladesh

Conference Proceedings

Prof. Dr. Zebun Nasreen Ahmed
Dr. Md. Ashikur Rahman Joarder
Editors

Kazi Fahriba Mustafa
Editorial Associate

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Sustainable and Renewable Energy Development Authority

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Prospects and Challenges of
GOING GREEN

Conference Proceedings
of the ***1st International Conference on Green Architecture (ICGrA 2017)***
Prospects and Challenges of Going Green
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EDITORIAL

It is a matter of great pleasure that the Green Architecture Cell (GrACe), Department of Architecture, Bangladesh University of Engineering and Technology (BUET), Dhaka in collaboration with the Institute of Architects, Bangladesh (IAB) and the Sustainable and Renewable Energy Development Authority (SREDA) are going to organize the 1st International Conference on Green Architecture (ICGrA, 2017): Prospects and Challenges of Going Green on 04 - 05 August 2017 at BUET.

Sustainable development is one of the key goals of Bangladesh as the country is going through a rapid development in construction industry. Now-a-days, innovation in green architecture is wide and a platform is needed to promote research and developments in green architecture and also to challenge a global technology before accept it locally. The concept of green architecture is not new in Bangladesh; however application of green features in building design is not common. Research and further innovation is required for sensible implementation of green technology. To develop this culture, arrangement of international conference on green architecture to share and exchange technological ideas is vital.

As the first conference on Green Architecture in Bangladesh, it is hoped that the event will engender large-scale awareness in the professions related to the Building Industry and Architecture. The prospects and challenges faced by the profession itself, the Industry, the education system, the related professionals, and so on and so forth, cannot be overemphasised, in the paradigm shift that is entailed by going Green.

The conference has been organized around 10 themes or tracks: Community and Lifestyle; Context and Vernacular; Design and Retrofitting; Ecology and Life Cycle Assessments; Energy Efficiency and Sustainability; Innovation and Policy; Materials and Methods; Renewable Energy and Architecture; Research and Pedagogy; and Resilience and Climate Change. The aim of addressing the prospects of Greening the environment, and the challenges faced by such initiatives, is the key motivation for this Conference. The papers in this set of Proceedings are directly or indirectly focussed on this aim. It is hoped that the experience of the past two decades in the Green movement, and the learning from the practice of Green architecture by learned professionals, will pave the way forward, towards a more doable plan of action for the future.

We take this opportunity to thank all the participants who have contributed to the knowledge sharing in this Conference. It has been a difficult effort, as demonstrated by the fact that, only approximately 30% of the original papers sent in for review, actually stood the test and are included in this Proceedings. Since then through double-blind reviews, the papers have seen some modifications, and are presented here in their final forms. Although the editors of these proceedings have made every effort to ensure that the work presented in this Proceedings is correct and absent of errors, the contents and opinions of the papers are the sole responsibility of the authors.

The Reviewers for ICGrA 2017 have also worked extremely hard, painstakingly going through the manuscripts and coming up with very pertinent suggestions that aimed to minimise any discrepancies or gaps that they perceived in the contributions. We are extremely grateful to all for this support, without which it would have been almost impossible to come up with this collection. The Technical Committee of the ICGrA2017 have also been very diligent in their support of screening and processing these papers, and deserve our gratitude.

We wish the ICGrA 2017 success and hope that it will encourage the profession and its multi-disciplinary team to go Green.

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Dr. Md. Ashikur Rahman Joarder
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PERFORMANCE EVALUATION OF DIFFERENT WINDOW CONFIGURATIONS TO ENHANCE EFFECTIVE DAYLIGHTING IN ARCHITECTURE DESIGN STUDIOS IN DHAKA

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Abstract: *Despite the fact that students work and perform better under natural lighting condition, observation shows that most of the architecture design studios in Dhaka are often lit by artificial means and the condition of daylighting is not satisfactory. Artificial light can satisfy visual needs of the students and studio guides, however it may cause tiresome and exhausting after a time period, also at the same time can create pressure on the overall energy demand. As daylighting is beneficial to psychological, physiological and aesthetic order of a place, the architectural features might be explored by ensuring adequate daylight as a prime source of light during learning sessions inside design studios. This research aims to identify window features of existing architectural design studios, located in Dhaka, that affect the studio lighting and analyse the effectiveness of different window configurations to enhance the quality of luminous environment of design studios. Trials have been done to emphasize the procedure of achieving better window design strategies for improved daylighting in architecture design studios. The 3D model of case studio was first generated in the ECOTECT to study the distribution of daylight in the interior space with static daylight performance metrics. Then, the decisions were refined with DAYSIM simulation program to compare the decisions with dynamic annual climate-based daylight performance metrics. It is expected that the outcome of this research will help architects and designers to generate some guidelines for window configurations to improve the luminous environment of architecture design studios in Dhaka as well as in the other cities of Bangladesh.*

Keywords*: Architecture design studios, Dhaka, simulation, window configurations.*

1. INTRODUCTION

It is the light that can make a building bright and airy or dull and gloomy. The use of daylight as the principle light source is an integral part of sustainable building design because daylighting has been recognized as a useful source of energy savings and visual comfort in buildings (Sharmin, 2011). Designers now tend to rely on electric lighting due to lack of daylighting in buildings. Design studios are primarily used as a workspace for the students to do assigned project works and present the outcome in front of the course teachers, jurors and visitors, where everyone in the room rightfully expects to get the clear vision of the desired output. Observation shows that, architectural design studios located in different universities of Dhaka function mostly under artificial means. This not only fails to provide a stimulating environment for better learning but also at the same time creates pressure on the overall energy demand. Recent studies have shown that daylight has a significant impact on human productivity, health and behaviour (Bakke and Nersveen, 2013). In most of the cases, buildings placed in compact urban context of Dhaka fail to provide proper daylighting during daytime into the studios (Figure 1). For that reason, artificial lighting becomes necessary in the room to do the assigned projects. Therefore, strategies for increasing the quality of luminous environment in the architectural studios should be established to support the design process.

Figure 1: Lighting conditions of different architectural studios located in Dhaka.

This paper analyses various categories of window configurations for different architectural studios, located in Dhaka to identify the best configuration available for daylighting purpose.

The paper consists of three major parts. The importance of daylight and simulation tools for architectural studios is described in the first part. The second part elaborates the steps of research methodology. Finally, the third part presents the findings of simulation results with conclusion. It is expected that, the examples of daylight simulation presented in this paper will help designers to comprehend the significance of daylighting in architectural studios.

2. LITERATURE SYNTHESIS

The minimum illuminance on desks for regular work is recommended as 500 lux (CIE, 2004), however lower values are recommended in some countries e.g. India (300 lux), Denmark (300 lux) and Australia (320 lux) (CIE, 2004). Acceptable illumination level, mentioned in IESNA for space with both computer task and regular paper tasks is 300 lux to 500 lux (IESNA, 2000). According to Bangladesh National Building Code (BNBC, 2006), the recommended illumination levels for desks and black boards in class rooms are 300 lux and 250 lux respectively. In addition to that, Shimu (2015) shows, in Bangladesh, architecture students have a range of preference of daylight for studio works which varies from 200 lux to 500 lux.

3. METHODOLOGY

3.1. Case Studio Selection

In Bangladesh, there are 22 universities with an Architecture Department and among these universities, 14 are located in Dhaka (UGC, 2016). Table 1 shows the list of universities with Architecture Department in Dhaka.

Table 1: List of universities with Architecture Department in Dhaka

No.	Name of the Universities	Design Status
01	Bangladesh University of Engineering and Technology (BUET)	Designed
02	Ahsanullah University of Science and Technology (AUST)	Designed
03	University of Asia Pacific, Bangladesh (UAP)	Designed
04	BRAC University (BRACU)	Renovated
05	American International University, Bangladesh (AIUB)	Renovated
06	North South University (NSU)	Designed
07	Stamford University	Renovated
08	State University of Bangladesh (SUB)	Designed
09	Bangladesh University (BU)	Renovated
10	Primeasia University (PU)	Renovated
11	Daffodil International University (DIU)	Renovated
12	South East University (SEU)	Designed
13	Sonargaon University (SU)	Renovated
14	Military Institute of Science and Technology (MIST)	Designed

Window configurations for simulation study were set, based on the physical survey results of 14 studios from 14 universities in Dhaka. One studio was selected as 'Case Studio' on which performance of different window configurations were tested. The criteria for selecting case studio were based on the following factors (Sharmin, 2011):

- Location would be in the urban context of Dhaka.
- The studio must be located on designed and planned campus.
- Year of completion of the

building/architectural studios should be within last 10 years (i.e. 2005-2015).

- The studio space should have designed for minimum 30 students.
- The room should have the provision of openings on exterior walls at south.
- The activity pattern and internal layout of the case studio should represent current practice of architectural studios of Bangladesh.

Considering the mentioned criteria, the design studio designated for first year first semester students located on the second floor in the Department of Architecture, Ahsanullah University of Science and Technology (AUST) (Figure 2) was chosen as case studio (Figure 3).

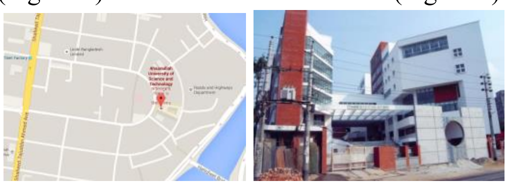

Figure 2: AUST with surrounding context.

Permanent campus building of AUST was built in 2008. It is a 10 storied academic building, located at Tejgaon industrial area, Dhaka. Among four main blocks of the building, architecture department is located at 1st to 4th floor of south block. The case studio is rectangular 147m^2 (14.9m x 9.9m), designed for 40 students which consists of window openings on south (Figure 4) with following charecteristics.

- **South facade:** Four 2400mm x 1650mm windows; material: Transparent glass with aluminium frame.
- **West facade:** Solid; material: White painted wall with particle board.
- **East facade:** Solid; material: white painted wall with particle board.
- **North facade:** Two doors (2100mm x 1000mm, each) with two high windows (600mm x 1000mm, each); material: wood, transparent glass.
- **Floor:** 600mm x 600mm glazed tiles.
- **Ceiling:** Solid; material: white painted.
- **Corridor (North):** 3.2m wide.
- **Height of the studio:** 3.45m (from finished floor to ceiling).

Figure 3: 2nd floor Plan of AUST showing location of case studio (shaded).

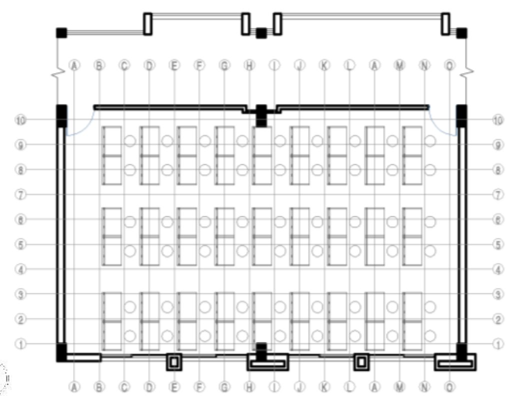

Figure 4: AUST Design studio plan

Figure 5: Case design studio showing south and east façade (left upper panel), east façade and ceiling (left lower panel), corridor in front of the case studio (right panel).

3.2. Evaluation Process

Indoor and outdoor conditions were kept constant, as found during physical survey. The interior space was modelled as vacant, devoid of any partitions or furniture, to avoid the effects of such surfaces, which both block and reflect daylight, and may hide the actual effect of window configurations (Joarder et al., 2009). Case studio was divided into 160 grid points to analyse the daylight levels on horizontal surface, at 0.75m above floor level, represents the work plane height (Figure 6).

For evaluation, sensor points coded as 1E to 10E were considered as core work plane sensors.

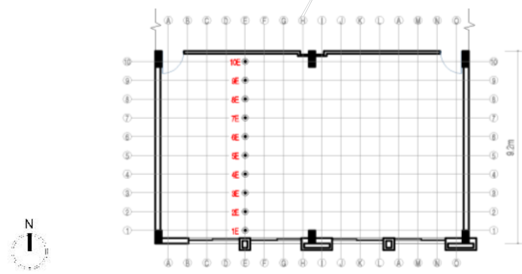

Figure 6: Plan of existing case studio showing core work plane sensors on work plane.

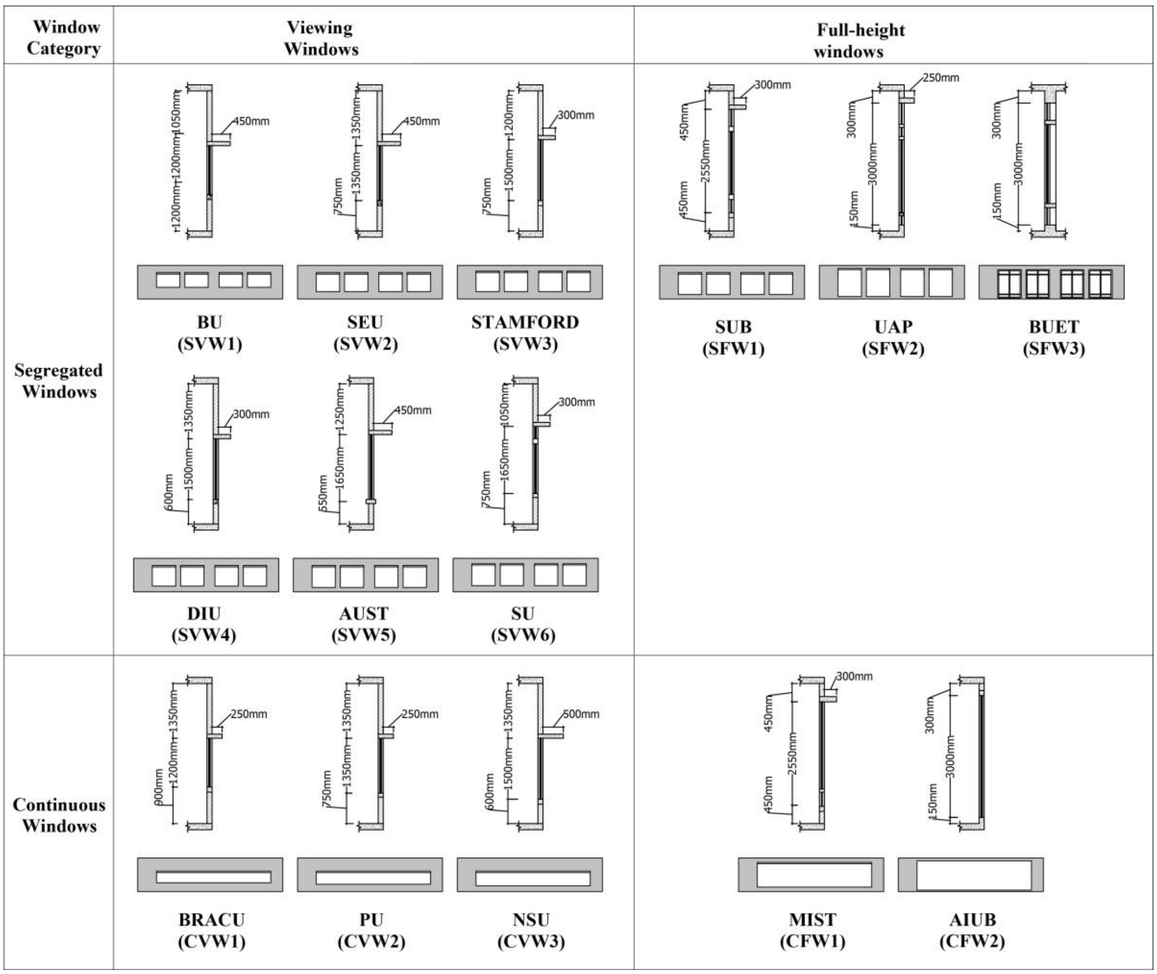

Figure 7: Window configurations on south facade of 14 studios for the simulation study.

The configurations were organized in four categories and coded as following (Figure 7):

- Segregated Viewing Windows (SVW),
- Segregated Full Height Windows (SFW),
- Continuous Viewing Windows (CVW),
- Continuous Full Height Windows (CFW).

Different window configurations were placed on south façade of case studio model and were evaluated based on the following criteria.

- Indoor average daylight level on the work-plane height.

- Number of points below 300 lux (BNBC, 2006), number of points within acceptable illumination levels (300 lux–500 lux) (IESNA, 2011) and number of points exceeding 500 lux.
- Performance evaluation through annual Climate Based Daylight Modelling (CBDM) simulation.

3.3. Climatic Parameters

- Location: Dhaka, Bangladesh (90.40 E; 23.80 N).
- Time: 4 September, 12.30 pm.
- Calculation settings: Full Daylight Analysis.
- Precision: High
- Local terrain: Urban.
- Window (dirt on glass): Average,
- Sky illumination model: CIE Overcast.
- Design sky luminance: 16,500 lux for static simulation (Khan, 2005).
- Illumination threshold: 300 lux (BNBC, 2006).

3.4. Simulation Tools

Two simulation programs were used: ECOTECT V5.20 and DAYSIM 2.1.P4. ECOTECT, developed by Square One Research Pvt. Ltd. is an environmental design tool which features a user- friendly 3D modelling interface fully integrated with a wide range of performance analysis and simulation functions (Marsh, 2003). Taylor showed in his research that the mean error of the estimated results of ECOTECT is less than 2%, indicating a reasonable degree of accuracy (Taylor, 2002). On the other hand, DAYSIM allows users to model dynamic facades systems ranging from standard venetian blinds to state-of-the-art light redirecting elements, switchable glazing and combinations thereof (Reinhart, 2014). Several criteria such as Daylight Factor (DF), Daylight Autonomy (DA), Useful Daylight illuminance (UDI) can be measured by the software.

4. RESULTS

4.1. Simulation Output for Case Situation

Present situation: Four 2400mm x 1650mm windows on south façade.

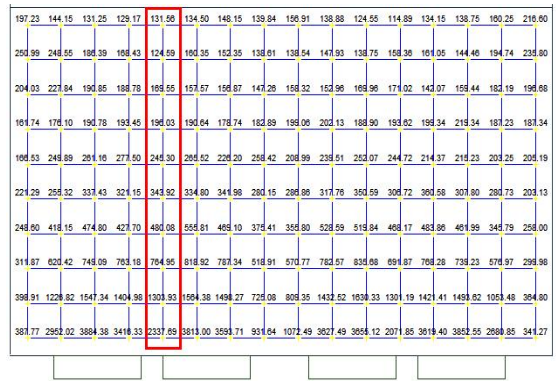

Figure 8: Daylight distribution on sensor points at case design studio in AUST (ECOTECT analysis)

Simulation shows average daylight on core sensor points (1E to 10E) at case design studio in AUST is 610 lux; and the average of all 160 sensor points is 615 lux (Figure 8).

The average daylight level of specified points exceed the range of acceptable daylight illumination level (300 lux), while only 2 points among 10 core work plane sensors have values within recommended level (300-500 lux). If the deeper parts of the studio interior are supplied with the recommended illumination level by supplementary light, the peripheral points will create glare.

Table 2: Dynamic performance of present daylighting situation.

Sensor points (lux)	DA [%]	$UDI_{<100}$ [%]	$UDI_{100-2000}$ [%]	$UDI_{>2000}$ [%]
1E	98	1	14	85
2E	98	1	22	77
3E	97	1	38	60
4E	95	2	55	43
5E	94	2	72	26
6E	93	2	79	19
7E	91	2	86	12
8E	90	3	90	8
9E	90	3	92	5
10E	90	3	93	4

Table 2 presents a summary of CBDM simulation results for core work plane sensors (1E-10E) of present situation in Architecture studio. Analysis indicates that, the result may cause glare near windows in the case studio and a major portion of the space remains darker due to poor daylighting distribution.

4.2. Simulation findings for different categories

4.2.1. Static analysis

Comparison of illumination level between four categories provided with 14 conditions for the case studio shows that (Table 3 and Figure 9). Full height windows offer better daylight penetration and distribution than the other options. The number of points getting acceptable illumination level of 300-500 lux is the highest here, while the average illumination level for the case is significantly higher than the other models.

Table 3: Static performance of different categories - ECOTECT

	Code of Window Configurations	Average illumination level (lux)	Points getting below 300 lux	Points getting 300-500 lux	Points getting above 500 lux
SVW	SVW1	444	115	19	26
	SVW2	491	104	17	39
	SVW3	561	101	15	44
	SVW4	551	102	16	42
	SVW5	615	100	15	45
	SVW6	645	95	19	46
SFW	SFW1	839	67	25	68
	SFW2	812	69	32	59
	SFW3	857	66	23	71
CVW	CVW1	615	90	25	45
	CVW2	636	102	20	28
	CVW3	615	88	22	50
CFW	CFW1	926	58	33	69
	CFW2	1158	33	39	88

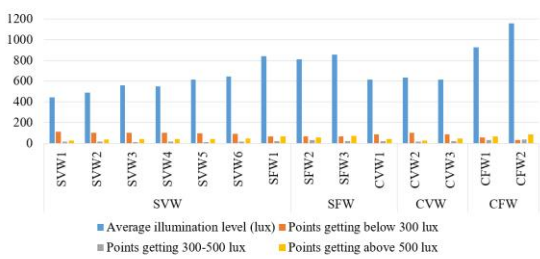

Figure 9: Performance analysis for different categories of windows based on ECOTECT

By allowing excessive daylight through large openings, both Segregated and Continuous Full Height Windows allows higher illumination at the deeper part of the room, though increased illumination level creates glare near windows. On the other hand, considering points below 300 lux, the illuminance level reached through the small openings of viewing windows are lower, particularly in deeper parts of the studio.

Use of rating system for the simulated performance, presented in Table 4 shows the ratings of 14 window configurations of four categories. From 1st to 14th place ratings, points were considered as '13' to '0' points respectively.

Table 4: Rating of the options provided with different window configurations - ECOTECT.

Category of Windows	Code of Window Configurations	Points below 300 lux	Points between 300-500 lux	Points above 500 lux	Total points
SVW	SVW1	0	5	13	**18**
	SVW2	1	3	11	**15**
	SVW3	4	1	9	**14**
	SVW4	3	2	10	**15**
	SVW5	5	1	8	**14**
	SVW6	6	5	6	**17**
SFW	SFW1	10	10	3	**23**
	SFW2	9	11	4	**24**
	SFW3	11	8	1	**19**
CVW	CVW1	7	10	8	**25**
	CVW2	3	6	12	**21**
	CVW3	8	7	5	**20**
CFW	CFW1	12	12	2	**26**
	CFW2	13	13	0	**26**

Table 5: Ranking between four categories.

	Points below 300 lux	Points between 300 to 500 lux	Points above 500 lux
1st place	CFW	CFW	SVW
2nd place	SFW	SFW	CVW
3rd place	CVW	CVW	SFW
4th place	SVW	SVW	CFW

Table 5 shows that continuous full height windows scored highest in two metrics: points below 300 lux and points between 300 to 500 lux, while segregated viewing windows scored considerably lower in these sections. On the contrary, viewing windows are superior to full height windows according to the points above 500 lux. From static daylight performance evaluation process and ratings, it is evident that, continuous full height window category is the most feasible option for daylight provision in architectural studios in Dhaka considering a single sky condition, i.e. overcast sky. As daylight varies over days and changes rapidly over seasons, a dynamic CBDM simulation is necessary to comprehend the true performance, analysed below.

4.2.2. Dynamic analysis

Table 6 and Figure 10 show the evaluation of dynamic daylighting performance process, while Table 7 and Table 8 describe the ratings between the four categories provided with available window configurations.

Table 6: Dynamic performance of the options - DAYSIM.

Category of Window	Code of Windows	DA (%)	DA_{con} (%)	DA_{max} (%)	$UDI_{<100}$ (%)	UDI $_{100-200}$ (%)	$UDI_{>2000}$ (%)
SVW	SVW1	87	94	7	4	81	15
	SVW2	90	95	12	3	76	21
	SVW3	92	96	17	2	69	29
	SVW4	92	96	15	3	72	25
	SVW5	94	97	19	2	64	34
	SVW6	94	97	19	2	59	39
SFW	SFW1	97	98	40	1	39	60
	SFW2	97	98	43	1	35	64
	SFW3	97	98	44	1	34	65
CVW	CVW1	93	96	19	2	67	31
	CVW2	93	97	20	2	64	34
	CVW3	94	97	22	2	61	38
CFW	CFW1	97	98	47	1	32	67
	CFW2	98	99	63	1	21	78

Figure 10: Performance analysis for different categories of windows based on DAYSIM analysis.

Table 7: Rating points distribution for different dynamic metrics of four categories.

Category of Window	Code of Windows	DA	DA_{con}	DA_{max}	UDI $_{100-200}$	$UDI_{>2000}$	Points
SVW	SVW1	0	0	13	13	13	**39**
	SVW2	1	1	12	12	12	**38**
	SVW3	3	4	10	10	10	**37**
	SVW4	3	4	11	11	11	**40**
	SVW5	8	8	9	8	8	**41**
	SVW6	8	8	9	5	5	**35**
SFW	SFW1	12	12	4	4	4	**36**
	SFW2	12	12	3	3	3	**33**
	SFW3	12	12	2	2	2	**30**
CVW	CVW1	5	4	9	9	9	**36**
	CVW2	5	8	6	8	8	**35**
	CVW3	8	8	5	6	6	**33**
CFW	CFW1	12	12	1	1	1	**27**
	CFW2	13	13	0	0	0	**26**

The results for architecture studio provided with window configurations of four categories (SVW, SFW, CVW and CFW) compared in Table 8. According to DA and DA_{con}, continuous full height windows category is superior to the other window categories. However, it scored considerably lower than the other three categories in DA_{max}, $UDI_{100-2000}$ and $UDI_{>2000}$ metrics. $UDI_{100-2000}$ shows that, viewing windows provided with lintel height of 2100mm effectively produce larger amount of useful daylight into the studio compared to the full height windows. Increase of lintel height i.e. full height window indicates excessive daylighting through large openings which may create glare, particularly in the workspace near windows. On the other hand, $UDI_{>2000}$ of minimum 60 percentage and DA_{max} of minimum 40 percentage suggest that, the case space for both segregated full height and continous full height windows is over daylit.

Table 8: Ranking between four categories (Reinhart, 2006).

	DA & DA_{con}	DA_{max}	UDI $_{100-200}$	$UDI_{>2000}$
1st place	CFW	SVW	SVW	SVW
2nd place	SFW	CVW	CVW	CVW
3rd place	CVW	SFW	SFW	SFW
4th place	SVW	CFW	CFW	CFW

After summing the ranking system, it can be stated that, viewing windows perform better than full height windows for architectural studios in Dhaka.

5. CONCLUSION

Due to dynamic change of daylighting during daytime, south facade is relatively critical to design for proper daylight distribution in the room in the climatic context of Bangladesh. To improve the luminous environment in the architecture design studios by changing window configurations, a series of options, divided into categories were compared in this study followed by static and dynamic simulation guided decisions. For a specific time frame (overcast condition), 'full height windows' were found efficient, while 'segregated viewing windows' were the most feasible option considering the most types of sky conditions available over the year. Full height windows admit more light deep in the studio while having other drawbacks, such as glare near windows, larger uniformity ratio between the daylight level in the front and back of the room. On the other hand, viewing windows have potentiality to control glare and maintain smaller uniformity ratio. Under the studied options it is difficult to specify one category as the best, as individual categories have their own shortcomings, however, better daylight distribution may be possible with viewing windows in the studio, especially in the deeper parts by changing lintel and/or sill heights and length of shading devices, which may create difference in daylighting performance.

To validate the simulation results and to compare the actual measured daylight levels with illumination values of the present situation, measurements of daylight level were taken by 'DIGITAL LIGHT METER- LX1330P' in the case space on September 04, 2016 at 12.30 pm. The deviation between actual and simulation point illumination was found to be on average 2.93%. Given the limited time and scope of this research, this study has concentrated solely on lighting issues, through the thermal aspects of a space may also be affected by these options.

A well daylit architectural studio should host a stimulating interplay of light and satisfies occupant needs by keeping them comfortable. It is expected that the research will contribute to daylighting practice by helping architects and designers in improving design for proper daylight distribution in architectural studios.

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DAYLIGHT PERFORMANCE IN CLASSROOMS OF GOVERNMENT HIGH SCHOOLS:
STUDY OF A CASE AT DHAKA, BANGLADESH

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Abstract: *Daylight has a profound impact on human performance and psychology. As one of the first learning environments, designing the schools get ample importance to consider proper daylight in the classrooms. A study in this paper intends to analyze the existing daylight performance in class rooms through field survey and simulation software. After conducting a field survey on randomly selected three Govt. high schools in Dhaka, one school was selected representing the typical prototype of schools and was fixed as the example space for detailed field survey and daylight simulation for the purpose of the study. Measurement of spaces, illumination values on work plane height, exterior and interior photographs, different spaces and their component which affect the luminous environment, like details of windows (type, material, sill, lintel, shading etc), heights of different objects in classroom interior (work plane, ceiling height etc) and other such related survey activities were conducted. For simulation study, the simulation software 'ECOTECT ANALYSIS 2010' was used to analyze the existing condition and the impact of proposed retrofitting. Based on the simulation study, a possible retrofitting was proposed for better daylight performance in the learning environment in the Govt. school's prototypal design in Bangladesh.*

Keywords*: Daylight Performance, Daylight simulation, Government High Schools, Retro fitting*

1. INTRODUCTION

Daylight is one of the most important natural features available to architects to enhance the visual quality of interior spaces. It is a resource in the tropics, indispensable both as a primary source of illumination as well as aesthetics of interior spaces. According to the Bangladesh Bureau of Educational Information Statistics (BANBEIS) Ministry of Education (Nov. 1983), there were 56 enlisted Govt. High schools. By next thirty years, several more Govt. High Schools were commissioned and established. In the decade of 60's and 70's, numbers of Govt. high schools were established in Dhaka city following a prototype of school design, e.g. Motijheel Govt. Boys' High School (est.1957), Govt. Laboratory High School (est.1961), Dhanmondi Govt. Boys' High School (est.1965) etc. It is a matter of regret that, the indoor environment of these prototype school buildings designed as spaces with an inattentive architecture lacking health and comfort conditions in Bangladesh. As visual tasks such as reading and writing are of great importance during the educational period, providing visual comfort conditions in these buildings is essential.

As majority of the school environments depend entirely on natural daylight, the design of daylight gets ample importance in schools in a developing country like Bangladesh. Study in this paper intends to analyze the existing daylight performance in class rooms through field survey and simulation analysis. A possible modification through retro-fitting has also been proposed for better daylight performance in the learning environment of the Govt. school's prototypal design.

2. OBJECTIVES

The study focuses on the existing daylight performance, due to various sizes and positions of openings in class rooms. Particular emphasis was given to increasing daylight inclusion to the classrooms. The objectives of the study are as follows:

1. To explore the nature of the luminous environment of Government High school buildings in Dhaka through field survey and simulation analysis.
2. To identify parameters that can help to improve the luminous environment by daylight inclusion in the classrooms of Government High Schools.
3. To recommend some opening configuration to increase daylight inclusion in classrooms through simulation study and considering minimum intervention of existing situation with proposed retrofitting which can be materialized with minimum cost.

3. METHODOLOGY

The general classrooms where educational facilities of various subjects are performed are fundamentally chosen as a topic for this study considering their long time usage by the pupils according to other spaces in the school buildings and their repetition in quantity. Although in the tropics, with the daylight may enter unwanted heat and too much or unguided daylight may cause glare, this study is limited to evaluating the amount of daylight inclusion into classrooms only. A short literature study was conducted to provide a knowledge base for the study and information about related climatic issues and daylight requirement in the given context.

A field survey was conducted on 3 schools randomly selected from different locations in Dhaka. Month of March was selected, as, it has maximum amount of days of clear sky among the Pre-monsoon and monsoon seasons (Table 01). Measurement of spaces, illumination values on work plane height, exterior and interior photographs, different spaces and their component which effect the luminous environment, like details of windows (type, material, sill, lintel, shading etc), heights of different objects in classroom interior (work plane, ceiling height etc) and other such related survey activities were conducted. Based on the survey, one school was selected representing the typical prototype school and was fixed as the example space for detailed daylight simulation for the purpose of the study. A Digital Lux meter was used (model – AR813A) which is manufactured by "Smart Sensor" to measure the existing Daylight performance in the sample area. For simulation study, the simulation software 'ECOTECT ANALYSIS 2010' was used to propose the retrofit or possible modification of the openings through simulation analysis and weather data of Dhaka was used for simulation purpose.

4. DAYLIGHT IN THE CONTEXT OF BANGLADESH

4.1. Climate and Context

The climate of Bangladesh is categorized as warm-humid based on the widely used classification by Atkinson (Koenigsberger et al, 1973). There are mainly three distinct seasons, e.g., the hot dry (March-May), the hot humid (June- November) and the cool dry season (December- February) (Joarder, A.R, 2007). Generally the cool dry season is short while the summer is long and wet. April is the hottest month with 30.3°C to 34.8°C and January is the coldest month with average temperature ranging from 9°C to 15.2°C. Dhaka is located in central Bangladesh at 23º 42'0"N 90º 22'30"E. The city has a distinct monsoonal season, with an annual average temperature of 25ºC and monthly means varying between 18ºC in January and 32ºC in May. Approximately 87% of annual average rainfall of 2,123 millimeters occurs between May and October. The sky condition for a year is shown in the following table,

Table 1: Sky condition in respect of cloud cover for a year

Type of Sky	Hot-Dry	Warm-Humid		Cool-Dry (Dec-Feb)	Total (Day)
	Pre-Monsoon	Monsoon	Post-Monsoon		
Clear sky	62	38	39	77	215
Overcast sky	30	84	22	14	150
Total Days	92	122	61	91	365

4.2. Recommended Values of illumination for educational buildings

As per Bangladesh National Building Code (BNBC) recommendations regarding luminance for different area of activity are as follows (Bangladesh National Building Code, 1993) (part-8, chapter-1)

Table 2: Recommended illumination level

Area of Activity		Luminance (lux)
Class & lecture rooms	desk	300
	Black board	250
Art rooms		400
Corridor		70

Table 3: Recommended brightness ratios

For high task brightness (above 100 cd/m2)	Ratio
Maximum ratio between task brightness and the adjacent sources like table tops	3 to 1
Maximum ratio between task brightness and illumination of the remote areas of the room not being used as work areas	10 to 1

5. OBSERVATION AND FINDINGS

5.1 Site and Surroundings

The selected school is Motijheel Govt. Boys' High School, one of the most renowned schools in Dhaka. The school was founded in 1957 to provide the facility of higher education in the community of Dhaka city. The main school block is 'L' shaped where the elongated arm is stretched from east to west and occupied by the rows of class rooms in three floors. The shorter arm of 'L' is stretched from north to south and the Laboratories and other ancillary facilities occupy this block. A large play ground is located at the western part of the site and the 'L' shaped form at south encloses a smaller field. The enclosed court at south is also used as an assembly court in the morning. The classrooms are accessed by the corridor of 3.0m wide which is open on one side towards the assembly court. All the classrooms are the same size of 7.92m x 6.40m having the ceiling height of 3.35m.

Figure 01: Entrance of the school

Figure 02: openings at north in classrooms

Figure 03: open corridor at south.

5.2 The study of the unit

One class room was selected at each floor located in the middle of the class room block. The numbers of the class rooms are 108, 208 and 308 in three consecutive floors. The daylight illumination was measured with a Daylight measuring device from 11 A.M. to 12 P.M. to get the day light illumination at the middle of the working hour. All the measurements have been taken at nine points [figure-2] in the level of working plane (table surface) which is 0.76m from the floor level. Point 1, 4 and 7 was taken at a 0.60m distance from the south wall to get the daylight illumination at the southern part of the class room. Point 2, 5 and 8 was taken in the middle of the class room to measure the daylight illumination at that point. Point 3, 6 and 9 was taken at a 0.60m distance from the north wall to get the daylight illumination at the northern part of the room. All the measured data was analyzed along with the furniture layout, opening position and opening sizes.

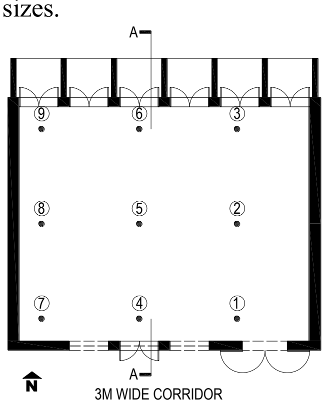

Figure 4: Plan of class room 108 with daylight illumination measuring points

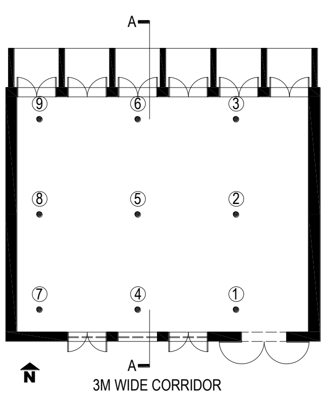

Figure 5: Plan of class room 208 with daylight illumination measuring points

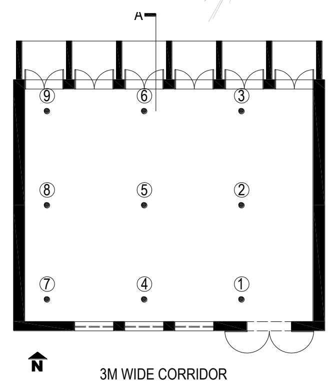

Figure 6: plan of class room 308 with daylight illumination measuring points

Windows at north wall measuring 1.06m in width and 1.52m in height have two parts. The lower part measuring 1.21m is operable window and the upper part measuring 0.30m is operable ventilator. The whole window unit is made of 5mm glass with 2.54cm wooden frame. The windows at north are same in all class rooms, where the opening at south (corridor-side) varies in size and character.

At ground floor in room no. 108, there are two operable ventilators measuring 1.06m x 1.52m and a window with two parts measuring 1.06m x 1.67m. The lower part measuring 1.21m is operable window and the upper part measuring 0.45m is fixed glass. The whole window unit is made of 5mm glass with 2.54cm metal frame. Initially the class rooms at ground floor had three operable ventilators at south wall, but school authority converted the middle ventilator to a large window in the year 2002 for better ventilation and daylight illumination. At first floor in room no. 208, there is one ventilator measuring 1.06m x 0.45m and two windows with two parts measuring 1.06m x 1.67m in south wall. The lower part measuring 1.21m is operable window and the upper part measuring 0.45m is operable ventilator. The whole window unit is made of 5mm glass with 2.54cm wooden frame. At second floor in room no. 308, there are three ventilators measuring 1.06m x 0.45m in height at south wall. The ventilators are made of 5mm glass with 2.54cm wooden frame. All the windows start at sill level (0.76m high) and the ventilators are at 1.82m height from the floor level. The tables and benches are made of wooden planks with metal frame having dark natural polish on the surface.

5.3 Comparison of Daylight performance among the samples

The illumination levels in different classrooms at different points are as follows

Table 4: Illumination levels in different classrooms at different points

	Room 108	Room 208	Room 308
1	60	125	203
2	72	176	137
3	590	709	525
4	290	112	75
5	84	157	102
6	565	709	445
7	39	100	70
8	65	145	80
9	360	646	323

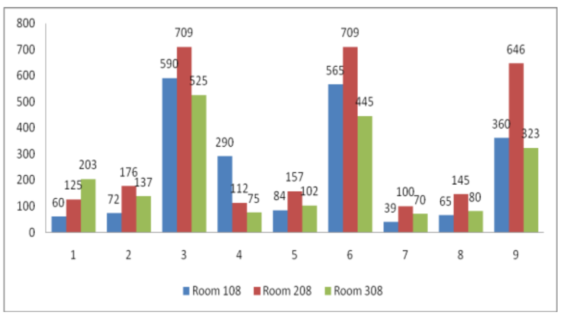

Figure 7: illumination level at different rooms

From the data analysis, it is found that the day light illumination is well above required 300 lux at points 3, 6 and 9 which are close to the openings at north. The middle row shows a radical decline in daylight illumination ranging from 65 lux to 176 lux. The data at points 1, 4 and 7 varies according to the size and position of the openings. At classroom no 108, there is a large window close to the point 4 and 290 lux was measured at that point. 157 lux was found in room no 208 which is highest daylight illumination among all three rooms at point 5. The southern part is opened by two windows and a ventilator in this room. Therefore, the larger openings at southern part allow more daylight penetration to the middle row of the classroom. It is also found that room no. 208 has better daylight illumination level among all three rooms as it has two larger openings at corridor side unlike other rooms (Figure 7).

From the field survey, it is found that school authority is not comfortable with the openings which open at corridors. It makes visual distraction and creates physical obstruction at rush hours. The authority having no other option for better ventilation and day light illumination is allowing large openings in ground and first floor at corridor side considering visual distraction and other complains.

6. DAYLIGHT SIMULATION AND RESULT

The proposal was made by studying on the existing condition of daylight illumination. To simulate the daylight, room no 108 was selected for the simulation model as it has comparatively poor daylight performance and the openings have variety in corridor-side wall. The simulation software 'ECOTECT ANALYSIS 2010' was used and weather data of Dhaka was loaded for weather information in simulation study.

Table 5: simulation parameters

Location: Dhaka
Longitude: 90.7 deg
Latitude: 23.9 deg
Local terrain: urban
Time: 12:00 pm
Date: March 08
Calculation settings: Full Daylight Analysis
Precision: High
Window (dirt on glass): Dirty
Sky Conditions: Sky Illumination Model: CIE Overcast
Design Sky Illuminance: 11000 lux (1 lux = 1 cd/m2)
Model dimension: 7.92m x 6.40m
Model height: 3.35m

Large opening at south receives more daylight and natural ventilation but does not create glare as there is the approach corridor. The use of horizontal and vertical shading devices might be unnecessary at north elevation; in fact, it might reduce the amount of diffused light from north. Although, the opening sizes and the shading devices were kept unchanged at north wall in the simulation study as there was adequate light was found in field survey and that elevation is the front elevation of the school.

For simulation model, the opening size was changed in south wall (corridor-side). A large opening of 5.34m width and 2.13m high from sill level was proposed. This opening is divided into three parts. The lower part is fixed window with frosted glass to avoid visual distraction and operability towards the corridor. The middle and upper part is operable ventilator with clear glass to receive externally reflected daylight and natural air flow from south.

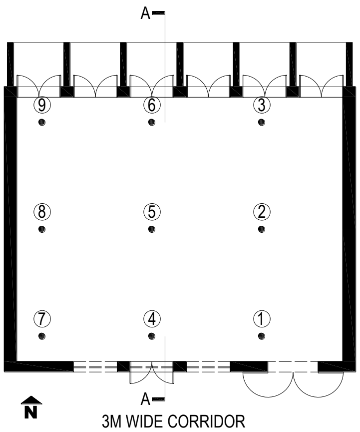

Figure 8: Existing plan of room 108

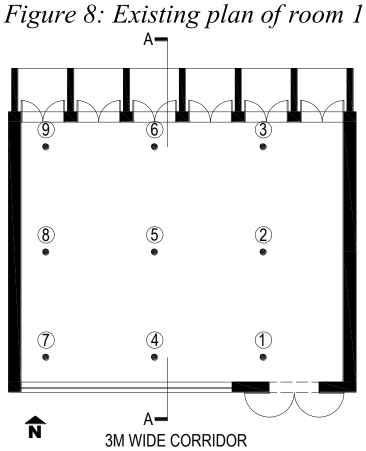

Figure 9: proposed plan of room 108

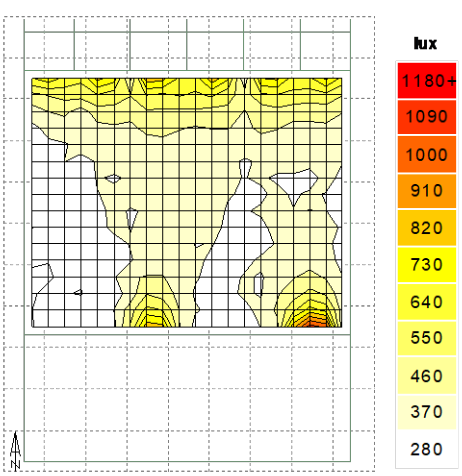

Figure 10: Simulation study showing contour lines of daylight illumination levels in existing plan of class room 108.

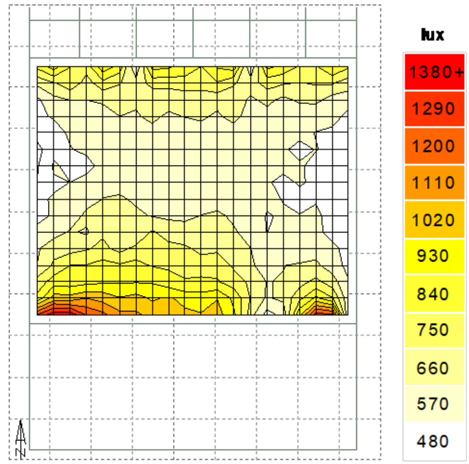

Figure 11: Simulation study showing contour lines of daylight illumination levels in proposed plan of class room 108.

Table 6: illumination levels in existing and proposed condition at classroom 108

ROOM 108		
Points	Existing	After proposed modification
1	60	650
2	72	578
3	590	788
4	290	974
5	84	613
6	565	791
7	39	871
8	65	556
9	360	743

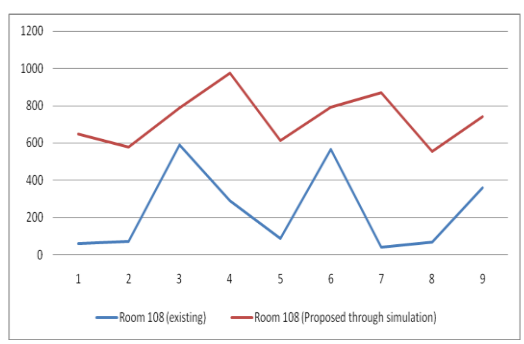

Figure 12: existing and proposed Illumination levels at different points in classroom 108

Though the change in opening size has an impact in overall daylight situation, the simulation result shows much higher output than the expected value in reality. In reality, the value of design sky illumination varies according to several external factors like topography, atmosphere, cloud condition etc. Therefore, to analyze the change in daylight performance with the change of opening size and position, the qualitative outcome of the graph can be considered rather than the quantitative.

According to the graph (figure 12), unlike the existing condition the daylight illumination level do not show any radical decline at the middle row points like 2, 5 and 8. In simulation study the contour lines of daylight levels in existing and proposed condition at classroom 108 also shows that daylight is well distributed in proposed condition than existing. The basic requirement of 300 lux in reading environment is also fulfilled in the proposed condition of classroom 108. A similar modification can also be applied in room no 208 and 308 for better daylight inclusion. Thermal condition in the classroom might have minor or no change, as south façade is protected by approach corridor, and always remain under shade. Therefore, south façade of the classroom never get direct solar exposure to increase indoor temperature. Further studies might find out the indoor temperature change due to proposed window modification.

RECOMMENDATION

Based on the simulation results and considering the Daylight levels, some recommendations can be drawn for classroom design in the context of Dhaka, Bangladesh to improve the luminous environment in the classrooms of the Government high Schools.

a) Sill level of window from work plane height will increase the daylight inclusion.
b) Fixed frosted glass at eye level (from 0.76m to 1.82m) at corridor side will solve visual distraction from the movement there.
c) Introduce high window with clear glass above the fixed glass level. The high window can be up to the ceiling and composed of operable ventilators for proper ventilation.
d) Increasing window breadth has a significant impact on the daylight level of the room

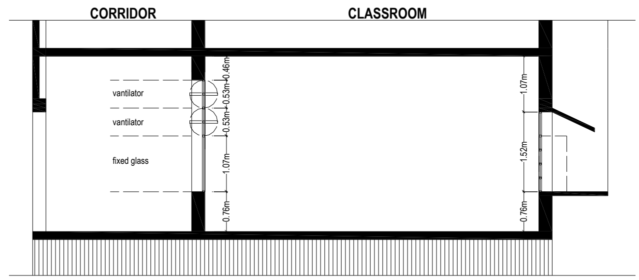

Figure 13: Proposed section of class room 108

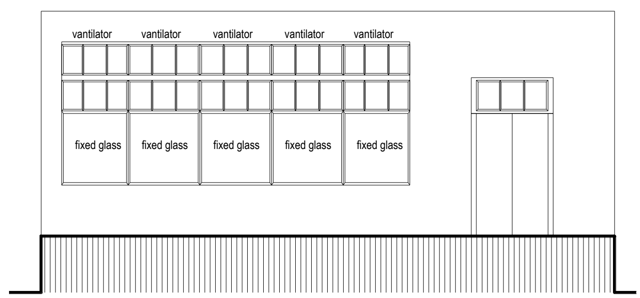

Figure 14: Proposed south elevation of class room 108

CONCLUSION

In this research, only those basic strategies have been discussed which can easily be implemented in Bangladesh if designers are aware of the issues. Guidelines suggested may be applied during construction of the schools (window configuration, sill height, high window etc) as well as after construction or during general renovation works with less intervention for increased inclusion of daylight for better performance of students. Only the ways of greater daylight inclusion are discussed here as this study is conducted within limited scope. The limitations in govt. high school in terms of fund and other technical issues have also been kept in account. Therefore, only possible modification is proposed in this paper which may work in reality without massive alternation in the external surface or external elevation which represents the classic façade of the Govt. high schools in Dhaka.

ACKNOWLEDGMENTS

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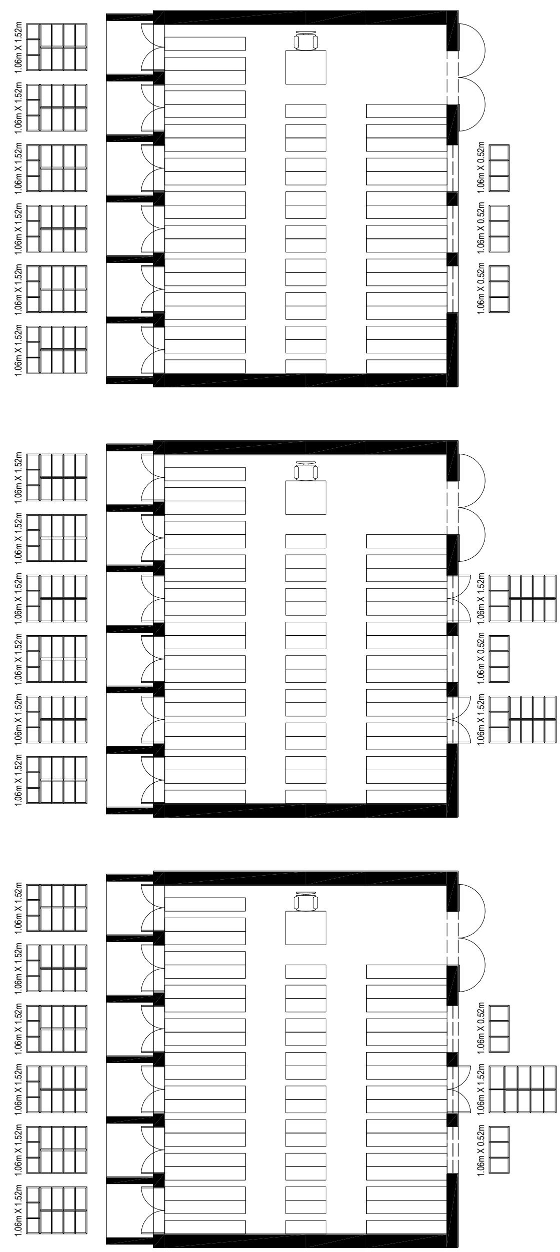
APPENDIX

1. **Plan of class rooms 108, 208 and 308 with furniture layout and opening sizes.**



A Review of the Daylight Rule of Thumb:
Assessing window head height to daylit zone depth for shading devices in commercial buildings

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Abstract: *This paper reviews the validity of the ubiquitous daylighting rule of thumb (DRT) that relates window-head-height to the depth of the daylit area adjacent to a façade, in the specific context of the tropical conditions found in Dhaka. The spatial depth in a room, up to which penetration of daylight ensures adequate daylight for a specific task, is defined as the depth of daylit zone. According to DRT, the daylit zone is considered, to be a depth of two and a half times the window head height. Deeper parts of a space are considered in 'dark zone', having inadequate daylight, and requiring artificial light. However, in the Tropics, parts of the daylit zone, may be over-lit, adversely affecting both visual and thermal comfort, thus influencing consequent energy consumption. This paper presents a simulation study evaluating DRT in recent tall office buildings of Dhaka, with the most commonly used shading devices, for the south, east and west orientations. Six selected fixed external shading devices, found from a field survey, have been assessed through the simulation study, during the overheated period of summer, considering related daylit zone depth and their resulting lighting/luminous efficiency. The simulation results support predictions made by DRT for specific shading devices. However, they also demonstrate the limitations of the rule, with differing relationships between window head height and daylit zone depth all day long, based on facade orientation, as well as on the geometrical, and the material characteristics of the studied shading devices. The results clearly indicate that, modification of the dimensional relations of light zone, by proper selection of shading devices, can enhance luminous efficiency in offices of Dhaka and similar Tropical areas.*

Keywords*: Daylight thumb rule(DRT), Daylit zone depth, window head height, shading device.*

1. INTRODUCTION

Daylight Rule of Thumb (DRT) is often considered inviolable in sustainable building design, thus providing the sole quantitative justification for room proportions and orientation of facade openings. Its strong appeal stems from its simplicity (no calculations required), its relevance for key design decisions, and the lack of competing design rules for daylighting. Different versions of DRT are cited in daylighting design guidelines and norms for Canada (Enermodal, 2002; Robertson K., 2005), Europe (Cofaigh et al., 1999), Germany (DIN V 18599, 2005), North America (IESNA, 2000), and the United States (US-DOE, 2005; O'Connor et al., 1997). Despite the worldwide acceptance of DRT, no documented scientific evidence is found to support the rule in the context of Bangladesh.

At present daylight is being encouraged in office/commercial buildings all around the world, as a fundamental means of health, comfort and energy benefits (Dubois and Blomsterberg, 2011) – and Dhaka, where this study is based, is no exception. The recent trend is seen to be high-rise, deep plan, open offices, with extensive use of curtain glass envelopes, having large apertures (Rahman and Ahmed, 2008). However, the extent of shading devices for these commercial buildings have not yet been investigated for Dhaka (RAJUK, 2008), which has the highest consumption of electricity in Bangladesh. Studies show that improper distribution of illumination or light zones within interior spaces may cause harm, rather than any targeted benefit (Joarder, Price and Mourshed, 2010). Over-lit areas of daylit zone may cause glare, and also increase the HVAC load. Under-lit zones may enhance dependency on artificial light (Mayhoub, 2012). Therefore, an informed balance among light zonal depths must be struck, through proper investigation of DRT, for shading devices, ensuring effective/usable depth of acceptable/comfortable daylit areas.

In a recent study, luminous vs. thermal conflicts of tall air conditioned office buildings of Dhaka, with fenestrations, using the most common, external fixed shading devices, for south orientation (Trisha and Ahmed, 2016) have been evaluated. This research paper is based only on comparative luminous distribution for those shading devices, in south, east and west orientations, using the computer simulation program, 'Ecotect' (version 5.50), with ray trace based software 'Radiance'. The aim of the study was to scientifically review DRT for differing shading devices, with respect to spatial depth of light zones and their corresponding lighting efficiency.

2. DAYLIT ZONE DEPTH

Analytically, light zone (Merete, 2007) can be regarded, as spatial groupings of the lighting variables (intensity, direction, distribution and colour), which are significant in a space. In any space, a light zone may consist of both direct sun light and diffuse light, or only diffuse light. Variation in their illumination levels, create a) over-lit areas, b) acceptable areas of daylit zone and c) under-lit or dark zone (Figure 1)

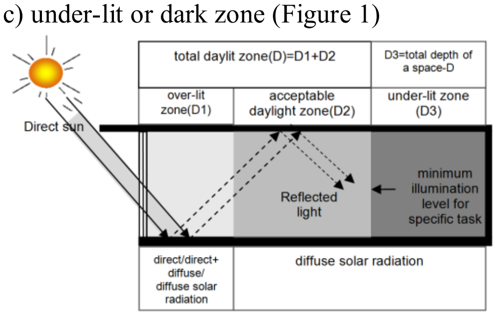


Figure 1: Distribution of light zones in section

3. ASSESSMENT CRITERIA OF DRT

According to the International Energy Agency (IEA, 2000), ideally within the visual field the luminance ratio should be 5:2:1(Central field: background: environment). Whenever this ratio exceeds 10:3:1, glare problems occur, due to over-lit zone. The minimum standard illumination level for general office is considered to be 300lux (CIBSE, 2002) (BNBC, 1993).Therefore, on the basis of distribution of the illumination level(Joarder et. al., 2009) in deep plan open office spaces, luminous efficiency of shading devices can be evaluated, under fulfilment of the luminous criteria of Table 1.

Table 1: luminous variables for daylit zone depth

maximum depth of total daylit zone(D)=D1+D2	maximum depth of over-lit zone(D1)	effective depth of acceptable daylit zone(D2)
≥300lux	≥900lux	≤900-≥300lux

Maximizing effective depth of accepted daylit zone (D2) to increase usable area is the prime criteria for good quality for daylighting (BNBC, 1993). Both depth of glare prone over-lit (D1) and under-lit or artificial light zone(total depth of a space-D), are considered under-efficient, in daylit buildings for office tasks, and should be minimized, while increasing effective acceptable zonal depth(D2) of daylit area. However, the depth of over-lit zone(D1) is given preference, compared to that of under-lit zone (D3=total depth of a space-D), as it requires no energy consumption for artificial lighting. Moreover, D1 may be converted into usable area, merely by changing the direction of seating in the interior layout (Jakubiec and Reinhart, 2012). In this paper, for a constant window head height, various daylit zone depths and their lighting efficiency for shading devices have been assessed, comparing with the conventional DRT, to review its applicability.

4. METHODOLOGY

Quantitative determination of average luminous variables was used, to review DRT in this research. The adopted methodology of this study is shown in Figure 2.

5. SELECTION OF SHADING DEVICES

For the simulation models, parameters of shading devices were derived from a field survey of tall office buildings of Dhaka (Trisha, 2015). As there is no defined aspect of tallness (CTBUH, 2014), buildings above six stories were regarded as tall buildings, considering walk up limit and fire escape provision (RAJUK, 2008). After a pilot survey, involving 106 buildings, six were finally selected, based on the most commonly found parameters of shading devices (Figure 3).

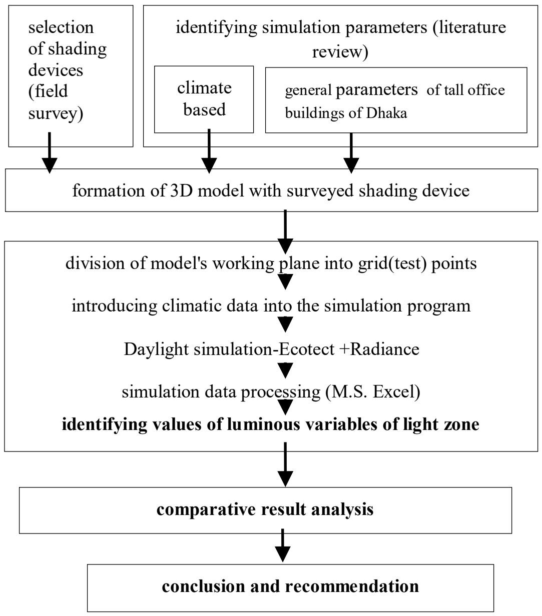


Figure 2: Flow diagram of simulation process

Table 2: parameters for simulation

Climatic parameters		
Simulation day	15 April	extreme climatic features (U.S. dept. of Energy) of the hottest month of the year, for the study region of Dhaka.
Time (office hrs.)	9.00-17.00hrs	
Sky condition	Sunny with sun	
Model dimension from General parameter of tall office building of Dhaka (Rahman and Ahmed, 2008)		
Model Width	6000mm	typical column grid
Floor height	3000mm	typical clear height
Aperture Width	5750mm	the whole span between two columns up to full floor height
window head height	2875mm	
Working plane height	760mm	ergonomics standard
Model depth (Trisha and Ahmed, 2016)		
Model Depth	13750mm	2x 2.5x window or aperture head height
Material specification(default material specification, considered by the chosen software)		
Ceiling	white painted on 12.5mm plaster, 150mm RCC (reflectance:0.7, U value:2.05w/m^{2}k)	
Wall	150mm brick work with 18.5mm plaster (reflectance:0.5, U value:2.602w/m^{2}k)	
Floor	200mm thick concrete slab plus tiles finishes (reflectance:0.3, U value:2.9w/m^{2}k)	
Glazing	Single glazed clear with aluminum frame for maximum visual transmittance with thermal gain. (reflectance:0.89, U value:6w/m^{2}k)	
Shading device	White paint on concrete, reflectance:0.55, U value:1.8w/m2k. grey silver polyester powder coated aluminum louvers, reflectance:0.796, U value:1.7w/m2k\	

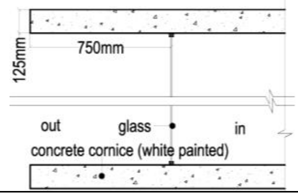
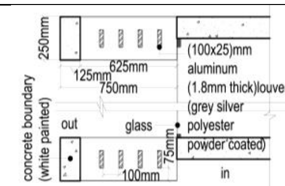
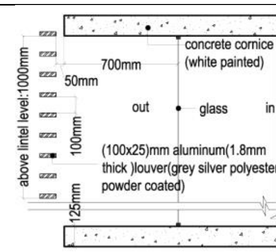
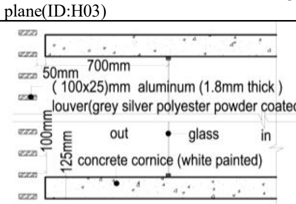
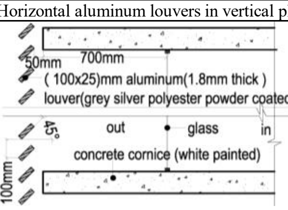
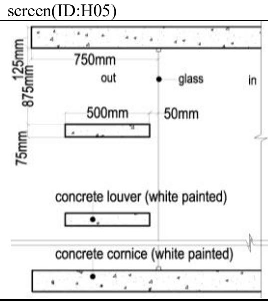
Selected building	Section of the case shading device	parameters
 Nuruzzaman Biswas Tower, Gulshan	 Horizontal concrete cornice(ID:H01)	cornice depth:750mm, thickness:125mm
 I-Center, Dhanmondi	 Horizontal aluminum louvers with concrete boundary(ID:H02)	cornice depth:750mm, Boundary depth:625mm, thickness:250mm, louver:100mmx25 mm, spacing:100mm, thickness:1.8mm
 The Alliance Building, Baridhara	 Horizontal aluminum louvers in overhang of vertical plane(ID:H03)	Cornice depth:700mm, thickness:125mm, offset from overhang:50mm , overhang depth:1000mm, louver:100mmx25 mm, spacing:100mm, thickness:1.8mm
 Uday Tower, Gulshan	 Horizontal aluminum louvers in vertical plane-screen(ID:H04)	Cornice depth:700mm, thickness:125mm, offset from screen:50mm, louver:100mmx25 mm, spacing:100mm, thickness:1.8mm ,
 Mika-Cornerstone, Uttara	 Horizontal angled aluminum louvers in vertical plane - screen(ID:H05)	cornice depth:700mm, thickness:125mm, offset from screen:50mm louver:100mmx25 mm,spacing:100m m, angle:45˚,thicknes s:1.8mm
 NCC-Bank, Head office, Motijheel	 Horizontal concrete louvers (ID:H06)	cornice depth:750mm, thickness:125mm louver depth:500mm, thickness:75mm offset from glass:50mm,spacin g:875mm

Figure 3: case shading devices from field survey (Trisha and Ahmed, 2016)

6. SIMULATION PARAMETERS

The climatic parameters and general dimensions for simulation model (Table 2) were identified from literature review. The depth of the model was derived through parametric study of DRT under considered climatic parameters, for a ‘model without shading’, regardless of orientation, from maximum reachable depth of 300lux.

7. SIMULATION RESULTS AND ANALYSIS

The simulation models with selected shading devices (H01 to H06), were generated, using shading device parameters of Figure 3, with model parameters from Table 2. The simulation process was carried out considering all other variables constant, except shading devices, using the grid points code as shown in Figure 4.

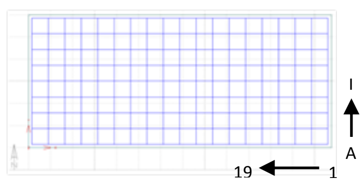


Figure 4: Coding grid points on working plane of simulation model

In daylight simulation results for south, east and west orientation of Figure 5, grey, black and white denote the day long changes of spatial depth of over-lit(D1), accepted daylight(D2) and under-lit zone(total depth of a space -D) respectively. In the southern orientation, D reaches the maximum depth (5x aperture head height) at mid day for H02, while for east H01 as well as H02 show that value at early hours. For west orientation, the value of D reaches its ultimate limit (5x aperture head height) at the end of the day for H01 and H02. All the tested devices yield similar trend with time of day, though with lower values. H05 shows maximum consistency all day long, especially for south orientation.

The comparative efficiency analysis of the shading devices are assessed below, under the average spatial depths calculated from simulation results (Figures 6, 7 and 8), to explore its relation to DRT, while Table 3 gives a comparison between the lighting efficiency of the tested shading devices of the three orientations.

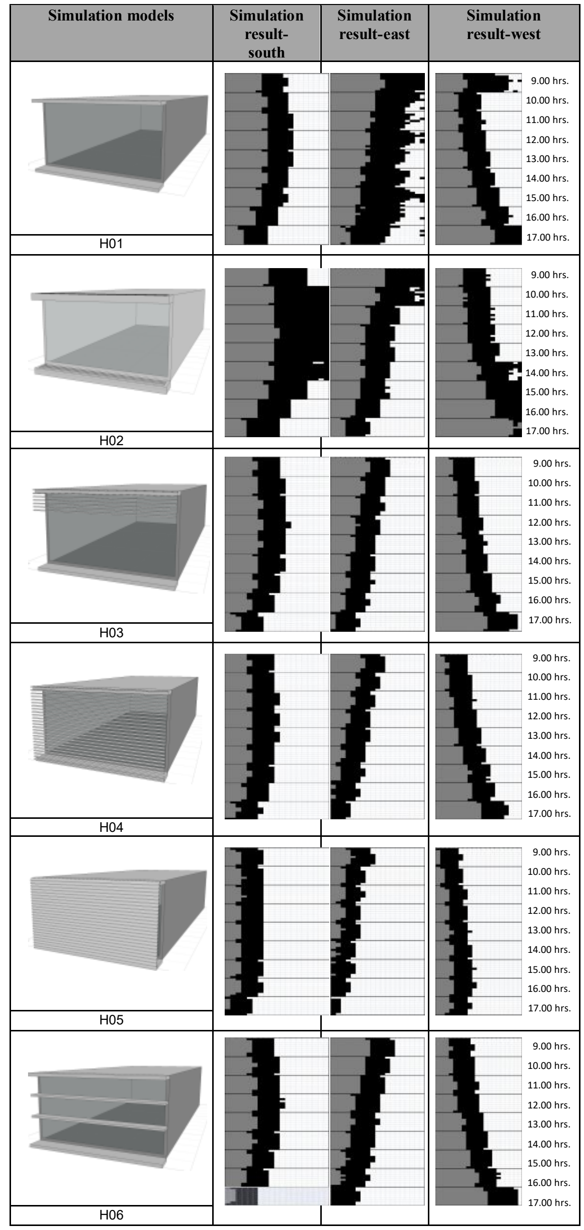


Figure 5: Daylight simulation results for tested shading devices in south, east and west orientation

7.1. South orientation

According to Figure 6 shows that, H02 (Horizontal aluminium louvers with concrete boundary in cornice type horizontal plane) yields markedly greater average values of total daylit zone (D), as well as acceptable daylit zone (D2). D has a value 4.5 times the aperture head height. This is almost twice compared to that calculated from

DRT. D2 for this shading is approximately twice that of the other shading devices investigated. However, the device also yields the highest depth of glare prone over-lit zone (D1), though its depth is half of the corresponding D. From Figure 6, it is also clear that the worst performance is shown by H05 (Horizontal angled aluminium louvers in vertical plane-screen type).D1 depth is the lowest - only 0.8 times of the window head height, which is only one third of D. The Maximum depth of D for H05, found from the study is only 1.9 times of the aperture head height, i.e. 76% of depth when considering DRT. For the rest of the shading devices, the glare prone over-lit zone (D1) values are higher than their corresponding D2 (acceptable daylit zone) area. H01 (Horizontal concrete cornice) occupies the second highest values, i.e.3 for D,1.7 for D1 and 1.3 times for D2 of the aperture head height, respectively. H03, H06and H04 have similar variations, though the values are much smaller than that of H01.

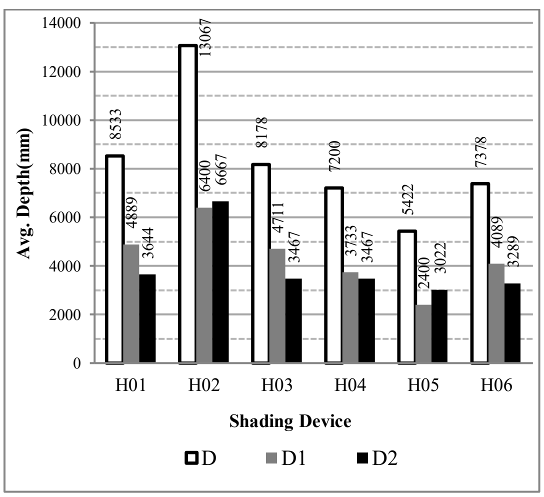


Figure 6: Comparative analysis of average maximum depth of total daylit zone(D),overlit zone(D1) and effective depth of acceptable daylit zone(D2) for the tested shading devices in the south orientation

Among them H04 (Horizontal aluminium louvers in vertical plane-screen type) yields a greater value of D2 compared to H06(Horizontal concrete louvers). The value of D2 for H04 is similar to that of H03(Horizontal aluminium louvers in overhang of vertical plane), which is 1.2 times of the window head height. Of all the shading studied, H04 yields closest value to DRT, i.e. 2.5 times of the aperture head height for D. It however performs worse than H06, as it has a deeper under-lit zone(D3). Considering the above discussion on light zone distribution, the identified selection order of the south oriented shading devices for lighting/luminous energy efficiency is specified in Table 3. Thus it is clear that for this orientation, most of the shading studied, yield greater depth of total daylit zone than the 2.5 times of window head height, as predicted by DRT, with HO2 allowing the greatest depth.

7.2. East orientation

Among the tested shading devices, in Figure 7 average values of D and D2 for H01 (Horizontal concrete cornice), are markedly greater than the other tested devices in the east orientation. For H01, value of D is 4.8 times of the aperture head height, which is almost twice compared to that calculated from DRT. D2value for H01 is also 1.6 to 3 times greater, compared to the different tested shading devices. Though H01 yields the highest value of D1, it is almost half of its corresponding D and much lower compared to its D2 value. H04 (Horizontal aluminium louvers in vertical plane-screen type), H05 (Horizontal angled aluminium louvers in vertical plane-screen type) and H06 (Horizontal concrete louvers), yield similar variations among D, D1 and D2, though with much lower values than those of H01 and H02.

H05 yields the least depth (0.6 times of the window head height) of D1, which is only one third of its D value. However, H05 also presents the least values of D and D2. D for H05 is only 1.6 times of the aperture head height, which is only 64% of that generated from DRT. Among the rest of the shading devices, both H02 (Horizontal aluminium louvers with concrete boundary in cornice type horizontal plane) and H03(Horizontal aluminium louvers in overhang of vertical plane) yield greater values of D1 (overlit zone), compared to their corresponding D2 (acceptable daylit zone). Nevertheless, H02 yields the second highest values, i.e. 3.7 times for D, twice for D1 and 1.7 times for D2, of the aperture head height, respectively. H03, yields lower values compared to that of H02, for all the light zones. The values of D and D2 for H03, are also smaller compared to that of H06, though they are very close.

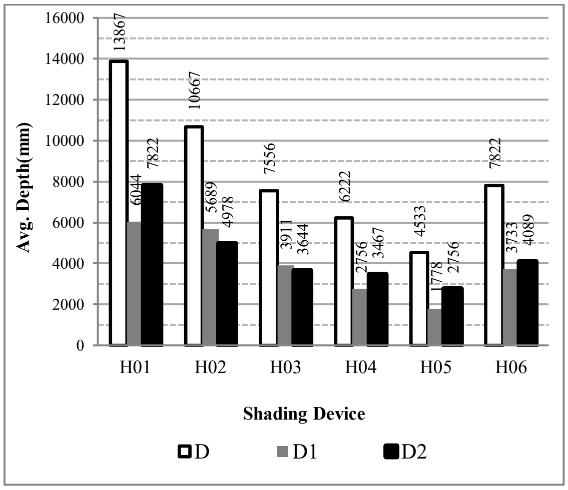


Figure 7: Comparative analysis of average maximum depth of total daylit zone(D),overlit zone(D1) and effective depth of acceptable daylit zone(D2) for the tested shading devices in the east orientation

Considering the above discussion on spatial depth of light zones, the identified selection order of the east oriented shading devices for lighting energy efficiency, is specified in Table 3.Like the South orientation, in the East too, it is seen that Daylight penetrates much further than the 2.5 of window head height prediction of DRT for most of the six tested shading devices.

7.3. West orientation

Among the tested shading devices in Figure 8, H02 (Horizontal aluminium louvers with concrete boundary in cornice type horizontal plane) yields the highest average value of D and D2 in the western orientation. For H02, value of D is 4.3 times of the aperture head height, which is almost twice compared to that calculated from DRT. However, its D2 value is very close to that of the other tested shading devices, while it is equal to that of H01 (Horizontal concrete cornice). H02 also yields the highest depth of glare prone D1, which is more than half the corresponding D value. Moreover, this D1is double of its D2 value. The rest of the tested shading devices yield lower values than for H02. With the exception of H05 (Horizontal angled aluminium louvers in vertical plane-screen type), they also present similar variations among the variables, D, D1 and D2. Only H05 yields a lower value of D1 compared to its D2 value. H05 also occupies the least value under all considered criteria, i.e. 3 times for D, 1.7 for D1and 1.3 for D2, of the aperture head height, respectively.

Considering the above discussion on spatial depth of light zones, the identified selection order of the west oriented shading devices for luminous energy efficiency is specified in Table 3. It is clear from the results that DRT does not hold true for windows with the shading devices tested for the West orientation.

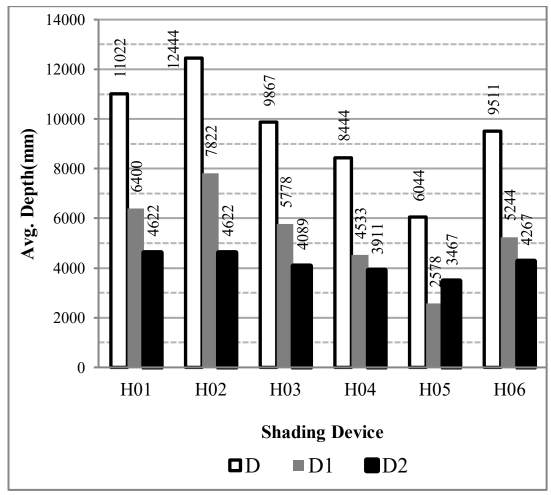


Figure 8: Comparative analysis of average maximum depth of total daylit zone(D),overlit zone(D1) and effective depth of acceptable daylit zone(D2) for the tested shading devices in the west orientation

Table 3: lighting efficiency order of Shading device in south, east and west orientation(Lower number means more efficient)

order	1	2	3	4	5	6
south	H02	H01	H03	H06	H04	H05
east	H01	H02	H06	H03	H04	H05
west	H02	H01	H03	H06	H04	H05

8. SUMMARY OF RESULTS

The results reported in the above sub-section (7.1,7.2 and 7.3) make it clear that the Daylit Zone Depth (D) for windows with the various tested shading devices differ significantly from the DRT prediction of 2.5 times the window head height, in most of the cases. The greater the depth of daylit zone, the lower is the need for artificial lighting, and hence this value has significant impact on lighting energy efficiency. In all the three considered orientations (south, east and west), a screen type device - H04 (horizontal aluminium louvers in vertical plane) yielded depth D closest to DRT, though the value was much lower, compared to the other tested shading devices, with the exception of H05. Under these considerations, H05 (angled aluminium louvered screen) is the least energy efficient shading device, as it presents the lowest value of D among the tested shading devices, a value lower than the DRT prediction.

The results suggest a modification of the DRT, by a factor of M, based on the daylight zone depths, using the equation: Daylit zone depth(D)= M X window head height.

Values of M, derived from the study are given in Table 4. In this paper, M was derived from the equation: M= D / 2875

where window head height=2875mm (Table 2) and D=Daylit zone depth for each tested shading device of Figure 3 in the south, east and west orientation (Figure 6,7 and 8).

Table 4: Recommended Value of M for tested shading device type in south , east and west orientation

Shading device type	Value of M		
	south	east	west
Horizontal concrete cornice(H01)	3	4.8	3.8
Horizontal aluminum louvers with concrete boundary in cornice (H02)	4.5	3.7	4.3
Horizontal aluminum louvers in overhang of vertical plane(H03)	2.8	2.6	3.4
Horizontal aluminum louvers in vertical plane/screen(H04)	2.5	2.2	2.9
Horizontal angled aluminum louvers in vertical plane/screen(H05)	1.9	1.6	2.1
Horizontal concrete louvers(H06)	2.6	2.7	3.3

No doubt that these figures of M are based on a limited survey and simulations on a particular day and more extensive work is required to establish them into set rules. However, this study points to a method, which can be elaborated for actual adoption into any codes.

9. CONCLUSION

The study cited in this paper, examined the luminous distribution and different spatial depth of daylight zones, for windows with various surveyed shading devices, and how much they differ from the Daylight Rule of Thumb (DRT) predictions. DRT predicts a daylit zone depth (D) of 2.5 times the window head height.

The research tested spatial depth of daylit zones of various office interiors, depending on the parameters and typology of shading devices used. Since the results clearly show that D differs significantly from the 2.5 times window head height prediction for the different devices, a modified DRT has been suggested, which reveals more realistic daylight penetration prediction for windows with the various tested shading devices. In conclusion, it may be emphasized that while the study is limited in nature due to the choice of shading devices, and restrictions of simulation time, it is clear that the Daylight Rule of Thumb is not a reliable indicator of daylight penetration in the climate of Dhaka.

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INCORPORATION OF ATRIUM SPACES TO IMPROVE LUMINOUS ENVIRONMENT OF RMG FACTORY BUILDINGS IN THE CONTEXT OF DHAKA

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Abstract: *The production space is a part and parcel of ready-made garments (RMG) factories where workers are engaged in different type of works such as sewing, ironing and operating machinery. Due to the poor visual environment quality, workers often feel discomfort and suffer health problems that sometimes result in direct negative impacts on their health and productivity. The aim of this research is to study different locations and shapes of atrium spaces in RMG buildings to improve luminous environment of factories in the context of Dhaka. Simulation analysis was done to refine design parameter i.e; location of atrium in the RMG building with combination of basic geometrical shapes of an atrium. In this research DAYSIM, that use dynamic Climate-Based Daylight Modelling (CBDM) method was used to calculate DA, UDI>2000 and annual illumination profile for the selected case RMG building. DAYSIM use RADIANCE (backward) raytracer combined with a daylight coefficient approach considering Perez all weather sky luminance models. ECOTECT was used as the modelling interface to launch DAYSIM program. The findings show that the semi-enclosed square type atrium located north sides of an RMG building, perform better to enhance visual quality into the interior space compared to other atrium configurations and locations. It is expected that the outcome of this research will help architects and designers to incorporate atrium space to enhance the lighting quality of RMG factories in the context of Dhaka that will also help to improve the productivity of workers.*

Keywords*: Atrium, Daylighting, Dynamic Performance, RMG Building, Simulation analysis.*

1. INTRODUCTION

Over 30 years, atrium becomes a significantly architectural design form, especially in case of deep planned office or commercial buildings to bring daylight into dark deep areas of buildings (Rezwan, 2015). In addition to daylight, as the atria are made of large glassed surface in spaces, atria also allows to access different positive aspects inside buildings such as natural ventilation and space sterling under extreme outdoor climatic environment (Yunus et al., 2011; Fahmawee, 2013). Now-a-days, atrium is quite popular in the design of green buildings. It also adds qualitative value to interior spaces and connects the adjoining space with the outside world. An atrium also creates impressive internal spaces, maximizes the benefit to access direct solar heat gain into the internal space during winter, and increases interaction of socialization of building occupants. Key important parameters for daylighting of atrium buildings are the volume of atrium, its orientation to the sun, transmittance of roof, reflectivity of atrium surfaces and glazed area which affect the daylight conditions in the adjoining space and on the atrium floor (Fahmawee, 2013). Shallow atrium is better for daylighting to reach at maximum floor levels and adjacent space rather than high storied atriums (Figure 1).

In modern architecture, atria play a prime role in enhancing amenity of congested urban areas. It has been reported that buildings designed by atrium spaces have higher rental rates and often increase the productivity of the building occupants which in turn add value to the buildings (Song et al., 1997). There are hardly any atrium seen in RMG factories located in Bangladesh; however, incorporation of atrium can be effective to admit daylight into the interior spaces and to meet the visual and psychological needs of the workers to support increasing productivity as well as decreasing energy consumption by reducing artificial lighting use.

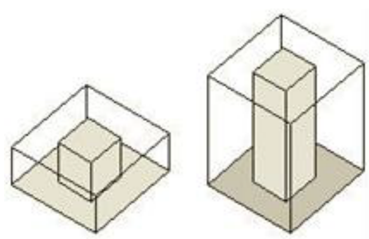


Figure 1: A low atrium base is brighter than a high atrium which has a same plane (Fahmawee, 2013).

The aim of this research is to develop architectural design strategies to incorporate atrium spaces in RMG factory buildings to improve luminous environment under tropical sky conditions in the context of Dhaka. This paper consists of two major parts. The first part presents an application method to evaluate the performance of different configurations of atria to increase useful daylight for RMG factory buildings in context of Dhaka. The second part presents the results to identify the best possible location and shape of atrium spaces to improve indoor luminous environment of RMG buildings.

2. METHODOLOGY

2.1. Selection of RMG building for simulation study

The criteria for RMG building selection were based on the following aspects (Joarder and Nahid, 2015).

a) The RMG factory should have to be located within greater Dhaka region (e.g. Dhaka, Savar, Gazipur and Narayanganj)

b) The RMG building should be designed as a RMG (e.g. not converted or located in mixed used building) and built in accordance with the Building Construction Regulations of the concerned authority.

c) RMG building should have to be regular in shape and minimum complexity of design for effective daylight simulation.

d) Width of the building has to be more than 20m, which will be difficult to be illuminated by vertical façade windows only and should have enough depth to incorporate atrium.

e) The building should not exceed six story in height and frame structured building is preferred.

f) The RMG building should have typical floor plan and should be designed with an atrium or light well.

g) The RMG factory should be enlisted with Bangladesh Garment Manufacturers and Exporters Association (BGMEA).

Considering the mentioned selection criteria, the six storied Global Attire Ltd., Pathalia, Nolambaghbari, Mirjanagar, Savar, was selected as case RMG building for simulation study (Figures 2-4). The case building has a 9m wide road as site access on the east side of the building which is the main access for the RMG building. The site is surrounded by cultivated lands on its three sides. Some single storied service buildings are situated at the southwest corner and south side on the site (Figure 5). As the three sides are surrounded by cultivated lands, there is no obstruction and have ample opportunity of daylight exposure through sides of the building as well. For the simulation study, production space (92m x 52m) was selected, which is located on the 2nd floor of the building (8.4m high from ground level) with 4.2m clear height. The dynamic simulation was done considering the actual building with surroundings, found during physical survey (Table 1).

Figure 2: Front side of the case RMG building

Figure 3: South elevation of the case RMG building

Figure 4: Present scenarios of RMG factories

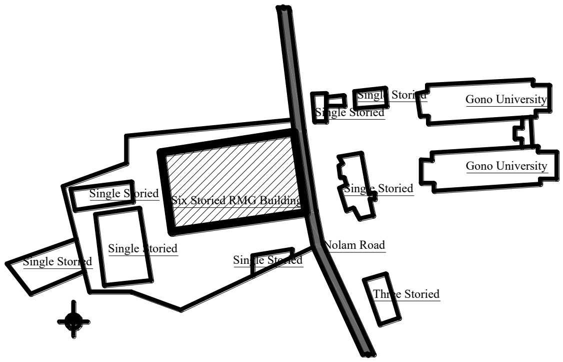


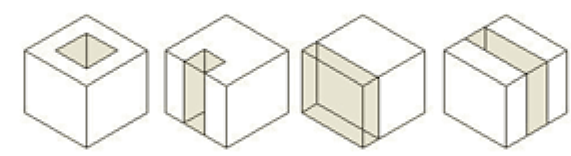
Figure 5: RMG building site and surrounding

Table 1: Field survey data

Parameters	Specifications
Total floor area	28,704m^2
Ceiling height	4.2m
Average height of interior partition walls	4.2m
Average height of work plane	0.76m
Total no of viewing windows	84 no of windows at each floor
Total no of high windows	37 no of high windows at each floor
Window size	7.25sqm, 025sqm, 3.17sqm
High window size	0.9sqm, 2sqm
Sill level	0.7m
Lintel level	2.65m
Effective window position	North and south direction
External shading	No Shading

2.2 Decide on different configured atrium variant

Atrium configurations can be defined by its number of sides that are enclosed by building mass, that often determine the building form and shape. The atrium form is the crucial factor in the initial phase when deciding the daylight performance attribution. Centralized, semi-enclosed, attached and linear shapes (Figure 6) are generally used as basic typological configurations of atrium (Yunus et al, 2010).



a) Centralized b) Semi-enclosed c) Attached d) Linear

Figure 6: Basic typological configuration of atrium (Yunus et al, 2010)

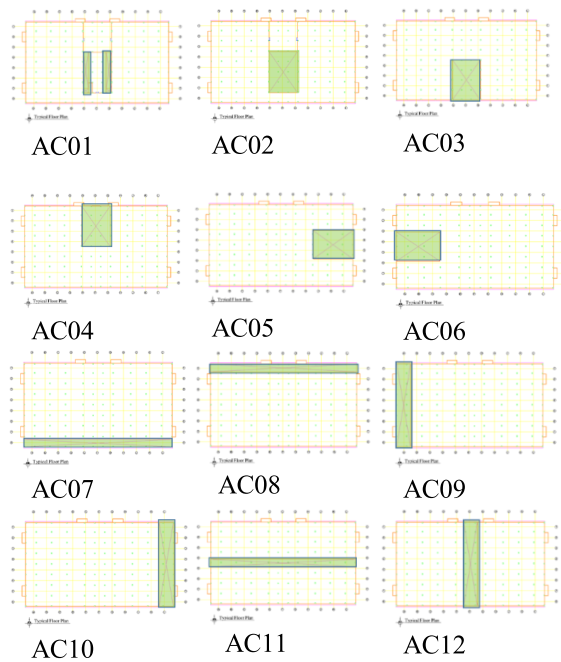


Figure 7: The schematic plans considering studied 12 atrium configurations with codes (AC01-AC12) assigned for this study.

The general use of atrium is to allow the accessibility of daylighting into the center of the buildings which enhance more even distribution of daylight (Kim et al., 2009). Considering the basic typological configurations (Figure 6), eleven types of atrium were found suitable to accommodate with case RMG building for simulation analysis. Figure 7 shows the schematic plans of existing and proposed eleven typical atrium configurations with assigned codes (AC01-AC12) for comparison purpose under this study, where AC01 represents the present condition with two light wells, AC02 combines the two light wells into a single atrium and AC3 – AC12 presents different atrium configurations accommodating basic types and location keeping the area of individual atrium same.

2.3 Sky conditions of Dhaka city

Dhaka city lies between longitude 90º20'E – 90º30'E, and between latitudes 23º40'N-23º55'N. The climate of Dhaka is tropical and has mainly three seasons - the hot dry (March-May), the hot humid (June-November) and the cool dry season (December-February) (Ahmed, 1994). The sky can be both clear and overcast at different times of the various seasons. The sky remains both clear (sunny with sun) and overcast during summer (Hot Dry). Yet, during the warm-humid (March-November) period, which includes the monsoons, the sky remains overcast most of the time. The sky remains mostly clear only during the winter (December-February). In winter, Dhaka remains sunny more than eight hours per day. In monsoon period, due to cloud cover, this comes down to four hours per day. After June–July this again increases progressively. Although overheating is the major problem of Dhaka city, it is due to some related factors. For example, from March to May high air temperature with high solar radiation remains. From June to October high humidity with high air temperature are observed. From March to May moderately overheated situation prevailed, minimizing the impact of solar radiation, while from June to October contributes to minimize the over-heating condition, maximizing wind flow (Joarder and Ahmed, 2015). Sky condition of Dhaka with respect to cloud cover for test reference years (TRYs) is shown in Figure 8.

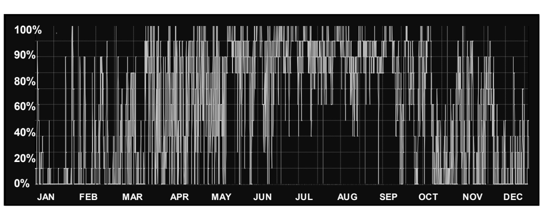


Figure 8: Cloud cover for TRYs, Dhaka (Source: U.S. Department of Energy, 2008).

In composite climates, such as Dhaka, where both overcast as well as clear conditions are observed during the course of each year, designers face difficulties to select the condition, based on which they should take the design decisions. Only overcast sky condition is the assumed characteristic of Dhaka's skies during much of the year (Joarder et al. 2015).

2.4 Selection of simulation tools and simulation parameters

In this research, a comprehensive and innovative building analysis software ECOTECT V5.20 which is a highly visual, architectural and analysis tool (Crawley et al, 2005) is used as the modelling interface to launch DAYSIM program, a dynamic annual Climate-Based Daylight Modelling (CBDM) simulation program. DAYSIM 2.1.P4 was used to investigate and analyse the impacts of the 12 atrium configurations on indoor daylighting (Figure 7). DAYSIM uses RADIANCE 1.02 (backward) raytracer combined with a daylight coefficient (DC) approach (Tregenza and waters, 1983) considering Perez all weather sky luminance model (Perez, 1993). Both RADIANCE and DAYSIM have been validated comprehensively and successfully for daylighting analysis (Reinhart and Walkenhorst, 2001). Table 2 summarizes the non-default RADIANCE simulation parameters for the simulation analysis recommended by Reinhart (2010) for complex geometry.

Table 2: Utilized RADIANCE simulation parameters in DAYSIM (Reinhart, 2010)

Ambient bounce	Ambient division	Ambient sampling	Ambient accuracy	Ambient resolution	Specular threshold	Direct sampling
5	1000	20	0.1	300	0.15	0.2

2.5 Generate the 3D model

The shape of the case building is rectangular with typical floor plans. There are 37 nos. of windows with 37 nos. of high windows located in north and south directions; and 10 nos. of windows located in east and west directions (Figure 9) at each floor. There are two nos. of light wells which are elongated towards north-south direction having 28 nos. of windows with 28 nos. of high windows located in east and west directions at each floor (Figure 9 and 10). Section XX' (Figure 11) through north-south direction is shown in Figure 9. The simulation was done using same nos. and size of windows, sill height, lintel height, work plane height, materials and surroundings which were found during field survey shown in Table 3.

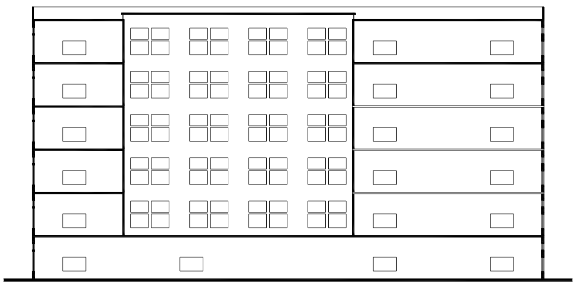


Figure 9: Building section through north-south direction (Section XX').

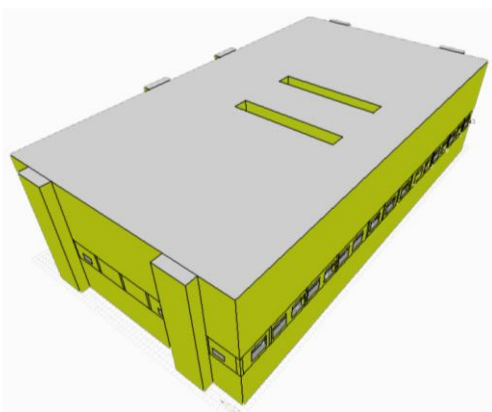


Figure 10: 3-dimensional exterior view of the case RMG building

Table 3: Material properties from field survey.

Building element	Material description	Material properties
Ceiling	Metal insulated with aluminum fuel paper	80% diffuse reflectance
Walls	Brick with plaster, either side	70% diffuse reflectance
Floor	Net cement finishing	40% diffuse reflectance
Window	single glazed low-e aluminum frame	90% visual transmittance
Furniture	Plywood	60% diffuse reflectance
Mullions	Aluminum	50% diffuse reflectance
External ground	Grass	25% diffuse reflectance
Light well/ Atrium	Single glazed low-e aluminum frame	Transmission: 90% Pollution factor: 0.70 Framing factor: 0.90 Maintenance factor: 0.85

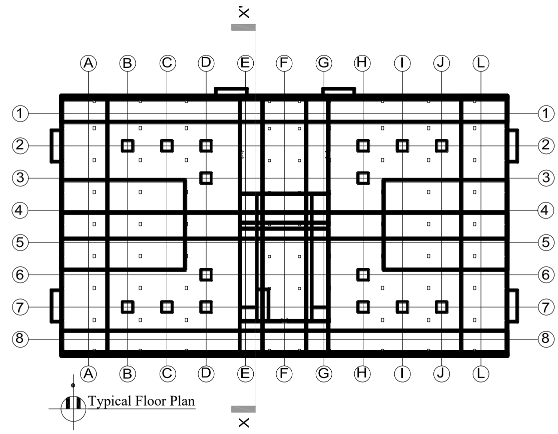


Figure 11: Location of sensor points in the plan of case building

The entire floor was divided into grids, with reference to the structural grids, for simulation purposes. Through the middle of column grids, eleven axes in XX' direction (east-west) and eight axes in YY' (north-south) are intersected into 88 points. Sensors were placed in the 88 intersection points, at work plane height (0.76m from floor level). Each intersection point of the grid was coded according to the number-letter system shown in Figure 11.

Sixteen sensor points were found commonly capable to show the daylight level that is not affected after placing different configurations of atrium in different locations in the case building (Figure 11). These sixteen points (2B, 2C, 2D, 2H, 2I, 2J, 3D, 3H, 6D, 6H, 7B, 7C, 7D, 7H, 7I and 7J) were considered as core work plane sensor points.

2.6 Identify the metrics for performance evaluation

The simulation program was used to make comparison between different atrium configurations. At first twelve available atrium configurations were created to calculate the lighting level. Indoor and outdoor conditions and other physical parameters were considered constant as found during the field survey. Simulation parameters were kept constant, described in Table 1. Dynamic simulation was done to calculate Daylight Autonomy (DA), Maximum Daylight Autonomy (DAmax) and

Useful Daylight Index (UDI).

The target of the dynamic simulation analysis was to keep min 300 lux daylight illumination at each sensor points at work plane height, in the time of nine hours from 8:00 am to 5:00 pm (working hours from Field Survey). The maximum level of work plane illumination should not exceed 2000 lux to avoid glare (Nabil and Mardaljevic, 2005). The daylighting illumination levels were analysed based on 16 core work plane sensors mentioned earlier.

3. SIMULATION RESULT

In this research, dynamic performance metrics were calculated for the 16 sensor points in the space of recommended 12 atrium configurations and the results are presented in Table 4. From the rating system (Table 5), the suitable configuration of atrium was selected.

Daylight Simulation Result

Table 4 presents summary result of annual CBDM simulation for building with studied configurations of atrium for RMG building. According to the DAmax, UDI <100, AC04 performed best among the studied options.

According to DAmax, UDI100-2000 and UDI>2000, AC12 was found considerably better than rest of other atrium configurations.

Among the studied atrium configurations based on dynamic matrix simulation results, rating has been done to identify the most suitable atrium configuration considering the average value of DA, DAmax, UDI<100, UDI 100-2000 and UDI>2000. The rating is done considering the highest value of "11" and lowest value of "0". The atrium configuration AC04 (semi-enclosed type atrium in north location of building mass), was found best for the daylighting performance among the studied configurations (Table 5).

According to Meyersson (2014), the illumination condition of indoor space also depends on the shape of the atrium. With the changing of the shape of an atrium, the reflectivity of light within the atrium is affected (Meyersson, 2014). Further, simulation was done to identify the shape of atrium that will ensure uniform distribution of daylight in the adjacent area of atrium. To compare this, atrium with three basic shapes (i.e. square, circular and triangular) and rectangular shape in two orientations were selected for next phase of simulation analysis.

Table 4: Summary results of dynamic simulation for available atrium configurations.

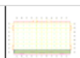
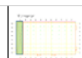
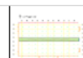
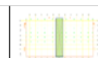
												
Different strategies	**AC01**	**AC02**	**AC03**	**AC04**	**AC05**	**AC06**	**AC07**	**AC08**	**AC09**	**AC10**	**AC11**	**AC12**
DA	60	64	71	84	75	79	63	87	68	78	67	74
DAmax	0.1	0	2	0	2	5	4	0.1	3	2	0.1	0
UDI<100	13	8	6	3	6	5	10	3	8	4	7	5
UDI 100-2000	82	88	84	91	84	81	80	91	82	92	87	95
UDI>2000	5	3	10	6	10	14	10	6	11	3	6	0

Table 5: Rating system of the simulation results

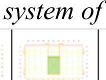
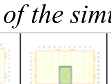
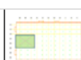
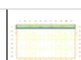
												
Different Strategies	**AC01**	**AC02**	**AC03**	**AC04**	**AC05**	**AC06**	**AC07**	**AC08**	**AC09**	**AC10**	**AC11**	**AC12**
DA	0	2	5	10	7	9	1	11	4	8	3	6
DAmax	8	11	5	11	5	0	1	8	2	5	8	11
UDI<100	0	3	6	11	6	8	1	11	3	9	4	8
UDI 100-2000	3	7	5	9	5	1	0	9	3	10	6	11
UDI>2000	8	10	4	7	4	0	4	7	1	10	7	11
Total Rating	19	33	25	48	27	18	7	46	13	42	28	47
Place	9th	5th	8th	1st	7th	10th	12th	3rd	11th	4th	6th	2nd

Table 6: Summery results of dynamic simulation for different atrium shape

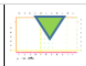
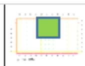
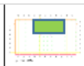
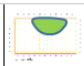
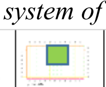
					
Different strategies	**AC13**	**AC14**	**AC15**	**AC16**	**AC017**
DA	85	84	85	87	84
DAmax	0	0	0.4	1	0
UDI<100	3	3	3	3	3
UDI 100-2000	90	91	90	88	91
UDI>2000	7	5	7	9	6

Table 6 shows the result of annual CBDM simulation with 5 atrium configurations with different shapes within the semi attached type atrium. The same performance evaluation process was followed, as before, and analysis shows, according to the DA, DAmax, UDI<100, UDI 100-2000 and UDI>2000, AC14 performed the best among the available shape of atrium (Table 7).

Table 7: Rating system of the simulation results

					
Different strategies	**AC13**	**AC14**	**AC15**	**AC16**	**AC017**
DA	3	1	3	4	1
DAmax	4	4	1	1	4
UDI<100	4	4	4	4	4
UDI 100-2000	2	4	2	0	4
UDI>2000	2	4	2	0	3
Total Rating	15	17	12	9	16
Place	3rd	1st	4th	5th	2nd

4. CONCLUSION

Daylighting is one of the most significant parameters which can enhance the visual quality of interior space of RMG buildings for better performance of workers in addition to save the energy consumption and make a building sustainable.

The simulation study of this paper found the effectiveness of interior space of RMG buildings by incorporation of atrium to improve the luminous environment. The findings demonstrate that the semi-enclosed atrium located at north side of a building, perform better to enhance visual quality into the interior space compared to other configurations and its location. At the same time, this paper also found that the square shape of atrium performs better than other shapes (i.e. circular, triangular and rectangular shape in two orientations). In this research, impact of different atrium configurations on the daylight of 2nd floor has been studied, considering the significance of impact will be similar (or proportional) for other floors. Further analysis could be done to identify the volume ratio of atrium space with respect to the building volume to ensure effective daylight inside RMG buildings. It is expected that the study and findings of this paper, will help architects to maximize the penetration of useful daylight at indoor space of RMG buildings by effective use of atrium that will also help to reduce energy consumption for lighting purpose.

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AN ENERGY USE STUDY OF NORTH SOUTH UNIVERSITY CAMPUS

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Abstract: *The North South University permanent campus completed in Bashundhara residential area of Dhaka in 2009 provided a model for large urban institutional facility development within the city's dense urban fabric. A number of private university campuses have closely followed this model in later times; however, the emerging concern of this type of infrastructure design is their overall large operating cost. This has called for a need to address energy efficiency of such complex designs. This paper is based on the research study using a mathematical simulation model of the North South University permanent campus to assess the primary contributors towards energy inefficiency in such complexes that have large potentials for improvement. The model was developed in a DOE-2 software environment to facilitate a building energy performance assessment and this was validated with the actual energy use data obtained from the utility billing companies as well as, from the results obtained from a physical energy audit. The base case so defined, allowed selected building parameters to be evaluated with regards to performance and possible mitigation strategies to come up with overall energy efficiency. These have been described briefly in this paper. The objective of the study was to provide some degree of quantitative measure of energy performance improvement strategies by modifying specific building parameters. These provide a reference for architects and electro-mechanical designers for more informed green campus designs in the future, as well as, for the North South University and similar university campus owners and utility managers to assess financial benefits of possible energy retrofitting measures and their required intervention areas.*

Keywords*: Sustainable Architecture, Simulation, North South University*

1. INTRODUCTION

The annual utility bills of the North South University (NSU) campus indicated that with a gross floor area of 1,250 thousand square feet (Ahmed, 2016) the campus had an energy use intensity of 8 KW-Hr per square foot in 2015 and 6.75 KW-Hr per square foot in 2014 varying significantly from the earlier figures of 2 KW-Hr and 2.3 KW-Hr as recorded in 2012 and 2011 respectively. The amount spent in utility bills had grown from BDT 2.5 crores during the years 2011 and 2012 to about BDT 4.1 crores in 2014 and 3.4 crores in 2015. This indicates that the gradual growth of building types, like the NSU campus, which are heavily reliant on mechanical heating, cooling and artificially lit environments in dense urban fabric is a growing concern due to their large operating costs. The NSU campus design was obtained through an international design competition mediated by the country's Institute of Architects (IAB) that received nineteen (19) entries. Three leading architects of the region judged to select the winning project. The criteria used in the selection were primarily aesthetic and functional (Ahmed, 2016), operational energy use and sustainability did not have any bearing as a result its huge operational cost today is a severe setback.

Assessing operational cost during the design phase is however, strongly emphasized in sustainable architecture and green building design – a movement that is a product of the 1970s after such events as the Earth Day (1970) and the

OPEC Oil Embargo (1973). They triggered an agenda for reducing per capita energy consumption to ease the demand on fossil fuel based resources (Borasi, 2008; Andrew, 2006; Madge, 1993). The building sector, which is roughly a 30 to 40 per cent consumer of total energy demand in the developed countries (UNEP, 2007) became a primary focus for energy efficiency drives. Our adoption of similar building designs in the country has created similar energy hungry infrastructure.

Modern planning and architecture in the Indian subcontinent were introduced in the 1960s. Their approach towards energy was largely confined within building forms. For warm-humid regions it emphasized orientation, shape and fenestration design to cut off solar radiation and reduce solar heat gain; as well as, facilitate prevailing wind flow through buildings to enhance cross-ventilation. These strategies were initially documented by authors Otto Koenigsberger, Maxwell Fry, Jane Drew, Victor Olgay and Aladar Olgay, amongst others, drawing heavily on broad based generalization of macro climatic features by regional trends, generalization of vernacular customs and advocating architectural forms to respond to them (Baweja, 2008). Suffice to say, their ideas have heavily influenced formal and functional aesthetics in the academia and institutional practice of architecture from the 1960s to the 1990s. Recently however, dense urbanization and loss of green vegetation and water bodies have resulted in the rise of the average ambient urban air temperature of Dhaka (Saifuddin, 2010). In addition, the city development authority has allowed an increase in the height of buildings which is beginning to offer greater physical barrier dampening wind velocity, particularly to spaces closer to the ground. Both of these have made delivery of indoor comfort with cross ventilation difficult with passive means. At the same time, the easy availability of mechanical air conditioners and assimilation of global culture has favoured energy intensive life style practices in the region; so there is an overall rise in the demand for building operational energy (Mohanty, Scherfler, & Devatha, 2012; Pachauri 2007). The assessment and efficiency drive for operational energy is therefore, an imperative for contemporary design. This in part, other than water-saving and occupant health, is at the core of the sustainable architecture and green building discourse. The World Business Council for Sustainable Development (2007) identified that a building consumes 80% of the total life-cycle energy during its operational phase; so efficient design to a large extent means optimized performance.

2. ASSESSMENT TOOL

Operational energy is addressed by whole building energy simulation. Simulation literature usually traces the adoption of this methodology to the needle experiment leading to the development of the Monte Carlo method by Buffoon in 1777, later augmented by Laplace in 1812 (Goldsman, Nance, & Wilson, 2010). Simulation gradually evolved as a recognized powerful problem solving technique since the 1950s and 1960s. Its application spread to multi-disciplines becoming user friendly since the 1970s and 1980s (Goldsman, Nance, & Wilson, 2010). Today, the globally recognized sustainable architecture benchmarking tools, LEED, HK-BEAM, BREEAM and Energy Star amongst others, recognize whole building energy simulation as a reliable measure in the determination of the projected energy performance of buildings (Haselbach, 2010; Lee & Burnett, 2007; USGBC, 2011).

The DOE 2 software environment is listed in both the US Department of Energy[1] published official list of sponsored software for development as well as the Lawrence Berkeley National Laboratory[2] listing of reliable software for accurate outputs. The comparative reliability of the results of DOE 2 has been discussed in

[1] US Department of Energy sponsored building energy simulation software list can be found at http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored.cfm

[2] The Lawrence Berkeley National Laboratory website claims reliability of the DOE 2 engine in accurately predicting building energy patterns with real case studies. For further details please see: http://gundog.lbl.gov/dirsoft/d2whatis.html

detail by Crawly et.al. (Crawley, Hand, Kummert, & Griffith, 2005) particularly validating it by several testing methods for reliability in traditional HVAC system sizing; while Maile et.al. (Maile, Fischer, & Bazjanac, 2007) has also shown that it is mostly reliable with the exception of some limitations with newer HVAC systems. Cho and Haberl (2006, p. 6) indicate that DOE2 has limited or no functionality only with Under Floor Air Distribution System, Dual Path System, Displacement Ventilation, and Natural Ventilation. The case described in this paper uses an HVAC system that does not belong to any of the above so it is assumed that the simulation results are reliable.

3. METHODOLOGY OF STUDY

The NSU campus is arranged in a U-shape configuration with the Administration Building (7 floors) on the west end; the North Academic Building (10 floors), the South Academic Building (10 floors), the Library & IT Centre (8 floors) on the south-east corner; the Lecture Theatre Block (5 floors) just west of the Library; and the Auditorium (capacity 1100) on the North-east corner. The building is constructed of reinforced concrete with peripheral 10" thick brick walls with exterior wall cladding of ceramic tiles and aluminium framed double glass windows. The building is centrally air-conditioned with five chillers located in the space below the auditorium. These have a total cooling capacity of 2,750 tons (5 numbers 550RT) and 123 Air Handling Units and 396 Fan Coil Units. In addition there are 133 ventilation fans for air circulation in the basements, toilets, and plant areas. Electric power is provided with a 4 MW (3 x 1.34MW) gas generators, backed with 3MW grid power from Dhaka Electric Supply Company (DESCO). In addition there are 3 stand-by diesel generators (Ahmed, 2016).

The two methods adopted in this study are – (1) physical energy audit and (2) whole building energy simulation. The physical audit of equipment and use data were dependent to some extent on general estimates. Due to wide variability of use and operation a sample year for the simulation was chosen and this was set at 2012. The data used in the simulation is mostly representative of the inventory available in 2012-2013. All the data was simplified for input in the simulation model. Fresh air supply fans (TFA) have been ignored to keep the HVAC systems assignment simpler. In short, given the large building size and complexity of the energy equipment and operations, significant simplifications were made and correction factors were applied to adjust and mimic the actual energy use pattern of the campus. Specific energy saving measures was then applied to the model to predict the impacts on total energy use.

4. VALIDATION OF RESULTS

A comparison of the simulated data with the DESCO and TITAS[3] utility bills for the baseline year of 2012 indicated when multiplied with a correction factor of 0.1 the former closely resembled the observed data. With this correction factor the energy usage value of the baseline year 2,480,786 Kilowatt-Hours (KWH) metered directly against the simulated model value 2,448,513 KWH gave a 1.3% deviation. On the other hand, applying a correction factor of 0.4081 yielded a +0.048% deviation from the total annual metered use of 2015. The simulated values with these factors of correction were used throughout this study.

The ASHRAE identifies three levels of energy audits: (1) walk through, (2) energy survey & analysis, and (3) detailed analysis of capital investment modifications (ASHRAE, 2003). The second category of audit as above was conducted to cross check the simulated results. An adjusted total audited energy amount of 9,992,028 KWH annually was recorded against a total metered amount of 9,989,179 KWH (2015) with an actual difference of 2,849 KWH or deviation of 0.028% which was a close fit to the observed value.

[3] TITAS: Bangladesh natural gas distribution company

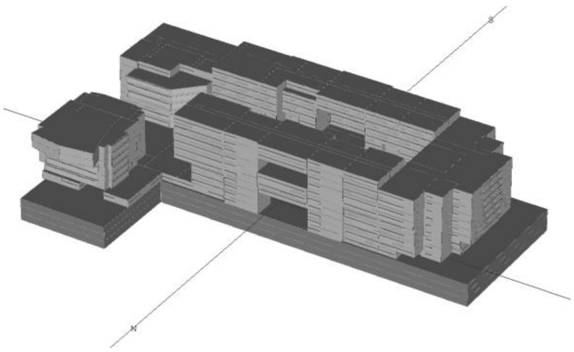

Figure 1: Simulation model of the NSU campus

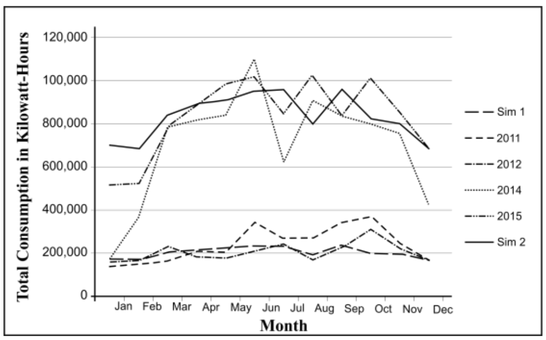

Figure 2: Plot of actual utility billing records and simulated data

Figure 2 above indicate simulated values compare closely with the total annual metered billing amount of the baseline year of 2012 with the correction factor, which is also comparable with the preceding year 2011. However, the energy usage figures drastically increase in the years of 2014 and 2015 (data for 2013 are not available due to a fire incident) due to the beginning of operation of the central auditorium, the addition of an increased number of classrooms and facilities in the basement, along with greater energy load due to increased number of student intake requiring extra operation hours for classroom, labs, offices and equipment. Unfortunately, conducting a new physical survey to take into account these changes for the years 2014-15 was not within the scope of this study and it was assumed that these would be a simple multiple of the energy use pattern. So an overall correction factor was applied.

5. OBSERVATIONS & DISCUSSION

Energy conserving opportunities by ASHRAE (ASHRAE, 2003) provides a number of possible energy saving measures, in addition to these, our own observations from both physical audit as well as, energy simulation has been combined in developing a number of strategies. However, due to limitations of space only a partial list is being discussed here.

5.1. Zonal distribution

Our study has indicated that physical zone based functional distribution is energy inefficient. Following traditional campus planning, departmental offices, associated circulation spaces and classrooms are distributed and stretched out across the building in different physical areas or zones. During the lean hours, such as after 4:10 pm not all the classrooms or studios in each zone are occupied, but the zones as a whole have to be kept operational. The same happens during weekly off-days for especially scheduled or make-up classes which take place only at partial occupancy of the whole zone. The situation can be improved at present with occupancy sensors and network controlled timing switches with manual overrides. Scheduling of classes at a single zone for different departments during off-peak periods could be another solution. From a design perspective shared classrooms and spaces are more energy efficient.

5.2. Stretched Out Form

To facilitate cross ventilation and access to daylight, the primary academic blocks with central double loaded corridors are stretched out in the east west direction. This requires extensive ducting and fan assisted air movement, and thereby, significant fan energy.

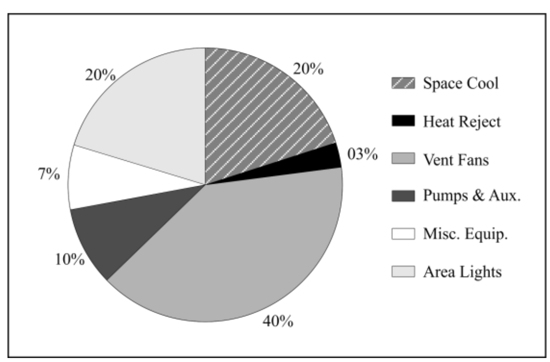

Figure 3: Due to extended building form & central HVAC system, fan energy is significantly high

The energy distribution chart from simulation is shown in Figure 3 above. The greatest energy expenditure or forty (40%) per cent is in the operation of the cooling and ventilation fans. Compact form and zone based mechanical systems design can alternatively improve performance. Unfortunately, the campus already exists, so an alternative strategy can be to change the fan efficiency by using variable speed drive motors. A study for the Green Building Code in Bangladesh sponsored by the International Finance Corporation (IFC) and executed by the Housing and Building Research Institute (HBRI) released in 2013 has also recommended this (International Finance Corporation, 2013). The simulation data of our study indicates that this measure saves 1,012,162 KWH annually, which is a 10% saving on the overall annual energy use.

5.3. Lighting & Equipment Load

The distribution of classrooms all across the campus leads to the common area lights in the corridors, toilets and lobby to be kept turned on throughout the daytime and through late evening hours. Evening and weekend classes may be clustered in assigned zones of the campus which can be kept powered on, while the rest can be kept under minimal lighting and ventilation loads. In addition, occupancy and daylight sensors in the common areas may be used with dimming ballasts to control the intensity of lighting after hours or when outside daylight is available. Based on the survey data of 2012 the campus is lit with less energy efficient compact fluorescent lamps. The power wattage of these lamps typically varies between general lights of 18 Watts (17,618 nos.), and 26 Watts (777 nos.) and special lights of 200 Watts (103 nos.). These lights can be replaced with more efficient LED lights, reducing total lighting energy consumption by 50%[4] and the total annual campus energy consumption by 4.5% (based on audit) to 10% (based on energy simulation).

Computers and lights in the offices and classrooms are kept turned on when these are not in use thereby, contributing to energy wastage. Installing occupancy sensors in classrooms and network timed classroom computers and overhead projectors may save energy. For general office and teachers' computers a late cut-off hour of 8:00 pm or similar based on reported use by faculty members and staff may be set at which point other than essential computers (such as servers) the power supply may be automatically and progressively turned off through network auto timing. According to the US Environmental Protection Agency (EPA) category A desktop computers consume 148 KWH compared to a category A laptop which consumes only 40 KWH (Baroudi, Hill, Reinhold, & Senxian, 2009). Therefore, switching to laptops from desktops by faculty members and administrative offices can contribute towards reducing office equipment energy demand by almost 75%. Water coolers, printers, photocopiers and personal office telephones may be turned off automatically after the cut-off hours to save energy. Administration offices close down after 5:00 pm and automatic or zonal power control switches may turn off the connection to printers, photocopiers, telephones and coolers at this time.

5.4. HVAC & Generator Load

NSU campus energy is primarily generated with gas turbines which fail to run at full capacity frequently due to low gas pressure particularly between 10:30 am and 4:30 pm. The energy demand is met partially with DESCO supplied electricity, and failing that, with diesel generators. In 2014, the share of the energy supplied by gas generators and DESCO were 63% versus 37% respectively. The price of energy supplied with gas generators was BDT 3.19 per unit-average compared to BDT 7.63 per unit-average for electricity supplied by DESCO. Clearly, it is much cheaper to produce electricity from gas generators. If all the power at the campus in 2014 were to be generated with its own gas generators the total annual energy saving would be about BDT 1.4 crores. Unfortunately the supply and regulation of gas pressure are outside the jurisdiction of building owners. Alternatively, therefore, the establishment of ice plants for air cooling can shift chiller

[4] *The relative wattage and equivalent lumen information of CFL versus LED light bulbs have been obtained from the website: http://www.ensyscobd.com/ledlightbd.html.*

operation time after 12:00 am at night which can provide cooling during the daytime allowing only the fans to be operational. This would require less operational energy during peak electricity rates and when the gas generators are less efficient due to significant drop in the supply pressure.

From the above discussion, it is clear that a number of these strategies with regards to design, layout planning, operation and equipment use can contribute to significant reduction in the operational energy demand of an urban campus of significantly large size such as that of NSU. Due to limitations of space, the economic benefits of these measures cannot be discussed here. Moreover, the discussions focus on add-ons and management only, since the building is already built and in occupation.

ACKNOWLEDGEMENTS

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A GEOGRAPHICAL DEMAND RESPONSE MANAGEMENT MODEL FOR ELECTRICITY IN DHAKA

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Abstract: *A recent study shows that in Bangladesh, about 25% of the total demand is unserved with the current generation. Dhaka, the capital of Bangladesh, as one of the fastest growing cities in the world, is the worst hit, which could never keep pace with its ever-growing population in providing services like electricity. Apart from physical constraint like less generation of power, management problem may be another issue here. Energy conservation as a sustainable option has not been explored much in this regard. Proper collection of data and systematic assessment of the problem through modelling of the factors affecting consumption nature and management practices can significantly reduce the inefficiency in the sector. A geographical mouza/mahalla based model has been developed for the study area of Dhaka Electric Supply Company Ltd (DESCO). The model was done through continuous geocoding of each location and relating it to each electricity connection. It records the distribution network, consumption nature, demand-supply cycle and thus helps in demand response management.*

Keywords*: Electricity demand response, demand side, energy conservation, distribution network, resources allocation, geographical information system*

1. INTRODUCTION

The economy of a country is largely dependent on electricity and it is a driving force for development. The energy access on percentage of city population with authorized electrical service, total electrical use per capita, number and duration of electrical interruptions per year per customer are again the sustainability indicators in urban area [1]. According to Bangladesh Bureau of Statistics (BBS) census 2011, in the study area authorized electrical service and access to electricity were varied from 13% to 100% in case of general households and union level population density were up to 22,556 per sq km. In Bangladesh, the demand of electricity is increasing at a rate of 10% every year [2]. It needs to ensure expansion of capacity where there are 40% people living without access to electricity.

In course of time in recent years, through some improvement in management practices, utilities could improve some performance in the city. At present, per consumer demand (maximum) in the area is around 1.2 kilowatt (kW) on an average. It has been reduced from 2.9 kW since year 2002, which could be achieved through improvement in both technical and non-technical management (see appendices) practices in electricity distribution [3]. It is really small and actual demand per electricity connection per household in the city. In larger and denser cities, high consumption patterns brand unsustainable lifestyles, and reducing consumption is a myth because of low incentives and no information. Like developed country and in the growing stage, it is crucial to reconsider the energy policy across the whole country in the mid-to-long term range to realize a sustainable electricity system considering constraints in technology and system integration from various perspectives [4].

Less research has been focused explicitly on helping individuals to manage resource consumption in the households using technology, awareness and best management practices. The relationship between consumption pattern and geographical regions were not studied for Dhaka city in a framework. The First Law of Geography, according [5] to Waldo Tobler, is "everything is related to everything else, but near things are more related than distant things." This integration can be introduced through comparing the consumption with nearest mouza/mahalla and guiding the communities (and thus individual) for the best possible solutions.

2. RESEARCH OBJECTIVES

Each mouza/mahalla community area covers every electricity connections inside it which is called node. There are few or more nodes within a ward/union boundary. The main objectives of this research are:

1) To develop the mouza/mahalla based geographically visible electricity communities in Dhaka city for demand response (see appendices) management and

2) To evaluate the demand-side diversity considering influencing factors to create a growth ecosystem. The parameters are types of electric appliances, availability of renewable power system, population density, climatic condition, time, tariff rate etc.

On the nodes, a qualitative analysis of average individual's current practices on electricity resource consumption and management will be studied.

3. THE INVESTIGATION PROCESS

An intelligent distribution market of the electricity utilities will play the crucial roles to manage whole things efficiently in the denser city. To develop the geographical demand response management model, the publicly visible market structure will be developed to record the technical distribution network in the cycle of electricity resources allocation.

Sources of data, for around 200 sqkm in the city, the data were collected and market was identified from the related consumers. The advancement in data collection and management can leverage geographic 2D and 3D information. In this study, the primary data of nodes was collected from Google Earth as vector coordinates. The secondary data related to electricity usages, standard area information and the base map were collected from the utility named Dhaka Electric Supply Company Ltd (DESCO), Bangladesh Bureau of Statistics (BBS) census 2011 and Dataset papers in Science – Hindawi alongside OpenStreetMap data respectively.

3.1. Market Development

There are different village/town, mouza/mahalla, ward/union and thana/upozila which are smaller to larger areas respectively under the distribution network in the study area of Dhaka city.

The market was identified by socially oriented geographical regions and named same as in the BBS area. Geocoding is the process of assigning the node using the vector coordinates. The following tasks were followed for a node:

i. Breaking down each consumer's address into BBS area and relating to its code.

ii. Plotting geo-location of each electricity connection by mapping each address with the code.

iii. Keeping consistency between them.

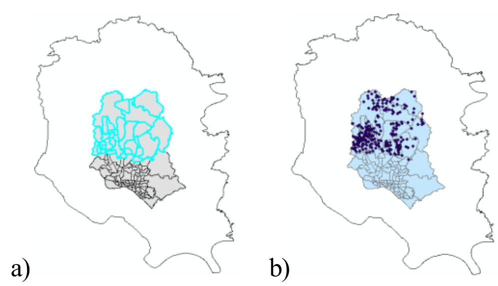


Figure 1: The Dhaka city within Dhaka boundary, a) highlighted ward/union of the study areas, b) Total 356 nodes are belonging to Fig. 1a

3.2. Demand Response Model

Practitioners need practical tools for evaluation and planning, given that the available information, time and budgets are often limited. Unlike conventional system, a network is developed to consider the demand factors that may influence the energy use pattern in near future. In the process of electricity meter connection – market development, transient hidden process and current observations states can fit in the proposed model of a geographical demand response management. The next potential impacts from the applied demand of consumers are strongly dependent on past development history in an area.

The steps outlined below are the requirements and it has the ability to guide and regulate professionally in the better way to fit new demand considering cumulative effects.

1. Electricity demand plan submission: Consumers will apply for required electricity line with corresponding necessary valid documents. It will be considered as the plan of electricity demand and readiness of consumers. So the node will be aligned or created from each consumer address as described in section 3.1.

2. Electricity network/ facilities plan: The utility will assess the demand and will fit efficient and energy-optimal shortest path using the existing demand response management model.

3. The demand plan confirmation: Actual resource allocation will be confirmed to consumers with additional conditions like alternative renewable energy source if any.

4. Advance security: Advance security bill along with others required items will have to be paid by consumers.

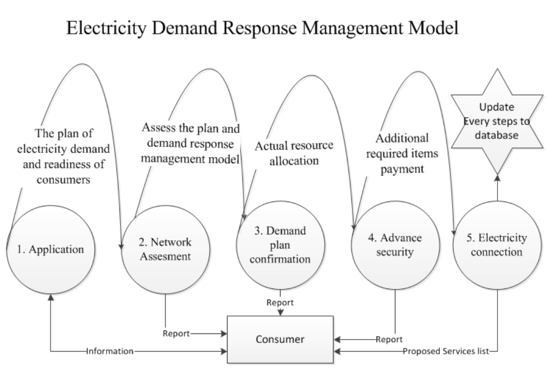


Figure 2: The proposed model of electricity resource allocation and demand response management

5. Electricity connection: After full payment electricity connection will be provided to consumer along with promised services list.

4. ANALYSIS AND FACTORS

The 2nd smallest area is the node and a node based classification and their change detection framework was developed. The different classification results are embedded in a topologically enabled hierarchy (topological relationships between the node in vertical and horizontal direction). In which they are aggregated and compared to a change detection layer (e.g. a user defined regular node based layer). Existing multi-temporal (technical and non-technical management) classification results (vector or raster data) are integrated into the hierarchical knowledge framework, which is parameter based and flexible in terms of

1) Number of classes

2) Flexible combination/aggregation of classes and

3) Number of time slots to be visual.

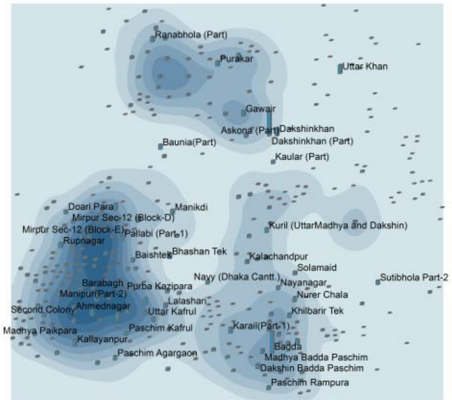
Geographical information system (GIS) software, ESRI ArcGIS tools were used to display different geographical areas. It measures the spatial distribution pattern to determine the various forms on sensing the need to tap demand flexibility.

A sample but recent dataset of 1,43,533 consumers were analyzed among total 356 nodes to simplify computation scale. It provides access and responsive to users across the 200 sqkm sample area in city. It really helps with the knowledge from the solid datasets, information and tools to improve work for collaborating, sharing, and publishing on map-based information as below.

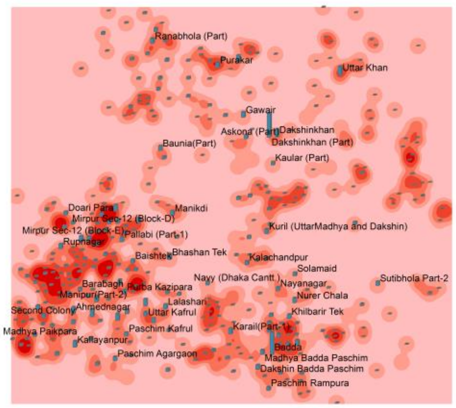
4.1. Change Management

A couple of parameters can create density maps and the hotspots. The distance value in the neighbourhood sites which tells the software how much area around each density feature to be considered in the calculations. Selecting the distance can have a big impact on getting the results. A density map was created using radius of an eighth-mile neighbourhood (Fig. 3a).

Another map was created using radius of one-mile around (Fig. 3b). Using same data and just changing the radius value, the model can generate a different picture of concentrations and greater consumer density hotspots. In those hotspots BBS census 2011 data was also plotted in bar to show the households in that time and the expansion of electricity distribution based on recently developed households.



a) Density based on larger distance and the extensive households location



b) Density based on smaller distance (hotspots)

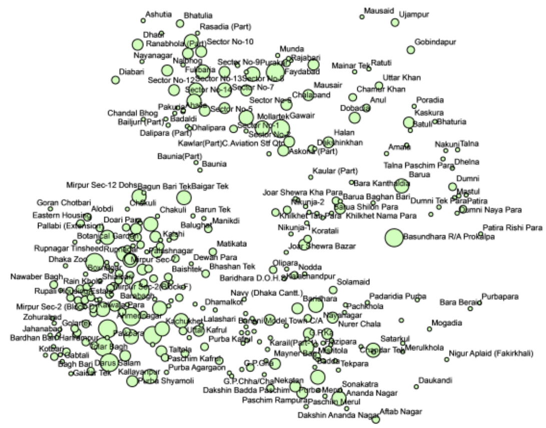
Figure 3: Kernel density pattern of total consumers (6,43,376) till 2015 in the total 356 nodes to find the classes and households (hh) pattern (bar) of BBS census 2011, where above 5000 hh have label

In the Fig. 3, it is indicating higher electricity connection penetrated in market where it has deeper color in blue or red. It is indicating lower electricity connection penetrated in market where it has lighter color in blue or red.

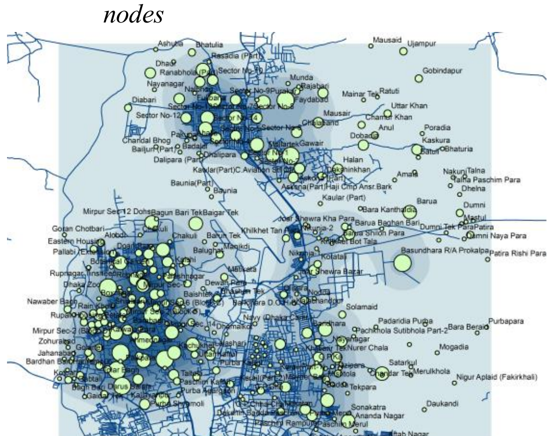
It can generate many other variations and can accept different parameters to evaluate the desired relations on area basis divergence and convergence.

4.1.1. End-Consumer Feedback

Psychologists have already shown that with proper feedback, real time-information at salient times, and goal setting abilities [6, and 7], households can have up to 10% energy savings with small changes in behaviour. Since householders need real-time feedback to alter their consumption, regular communication with consumer is highly required to improve the situation. It will be the integral part of the proposed model in *step 1* of section 3.2.



a) A map of feedback frequency of years 2014-2015 in the study area and 319 nodes



b) The density pattern of Fig. 3a (partly) and Fig. 4a with roads

Figure 4: Feedback and the consumers with road infrastructure relations

Moreover, the feedback form can be developed to manage the online feedback by consumer account. The utility already has complaint system to receive the feedback from consumer and the information can be extracted easily. In the data, 73,947 feedbacks of 57,884 consumers were received between 2014 and 2015.

Almost 26% of the cases it has meter and metering related problem.

In the Fig. 4a, the larger circle indicates there are frequent end-consumer feedbacks and utility has to respond accordingly.

It is fully visible to utility for the node areas by aggregated consumers or even by individual consumer. It will also be easy to decide where the utilities need to have the patrol cars and offices for the shortest possible path. There is moderate roads network based consumer density shown in the Fig. 4b. The change can be made to manage the distribution network for the node. End-consumer behaviour and preferences have such importance. The characteristics can be accounted for more practical plan.

4.1.2. Technological Change

End-consumer characteristics can be accounted for like data of appliances have influence in demand response. Utilities can jointly participate into interactive reporting to end-consumer for building the awareness. To reconsider the energy policy (particularly in the densely populated city) in the mid-to-long term to realize a future clean and safe electricity system [4], it can guide the local appliances market in the communities. This is the sensitive technological factors in the electricity consumption reduction purposes but can be costly and have some overhead and maintenance over the years.

Data was collected to find the utilization of appliances in energy flow and usage in households. Appliances items can be collected online and displayed by summary at website like the feedback mentioned in section 4.1.1. It'll be effective because utility bill is not checked up to find the message by the many households. It can be compared in term of monetary values between a household load profile for conventional appliances and for high rating smart appliances. The difference in electricity usage for these two types of appliances and the analysis will certainly help end-consumer. It can be easily an integral part of the model for better demand response in the study area.

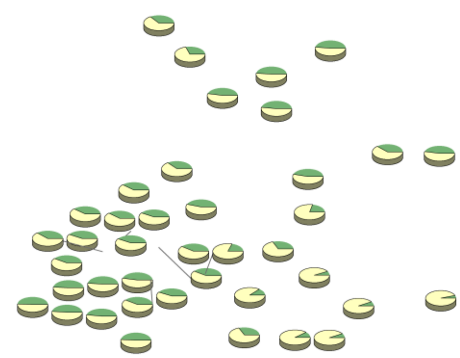


Figure 5: Among 92,486 consumers upto 2015 using appliances profile having higher load (yellow) and lower load (green) by consumers per union/word

Overall, the existing consumer's awareness is around 68% in the use of energy efficient (CFL, LED etc.) lights till 2015. There was a finding that increase of average one kW capacity of electric appliances beside each consumer groups between 2kW to 7kW, at household level significantly increases the electricity consumption up to 47% for residential usage and up to 177% for commercial usage. So node based same end-consumer behaviour and preferences of energy appliances can have the significant impacts to be reconsidered.

4.2. Demand Management

The variables can be off-peak and peak electricity consumption separately. It can help to relate things with the modeling and visible understanding. The effect will be in unit or kWh per day at peak, off-peak hours of electricity in the households per consumer as usual for the nodes.

The selected spatial scale was created for Fig. 6 and it helps on the decision-making process. The observation and visualization were displayed to detect patterns three-dimensionally and how patterns developed over areas in time period like 2013-2014.

Historical and future growth rate can be shown for understanding and modeling by changing and adding layers parameters in all kind of the scale (e.g. Fig. 3). Spatial analysis is an umbrella term covering a wide variety of analytical techniques associated with the study location. It can be applied to the information resources to transform demand-side for desired growth ecosystem development. It is possible to add the expected value to the original data and create new dimension in the model to support decision-maker. The actual anomalies were not immediately obvious in the conventional data which will be revealed in various dimensions.

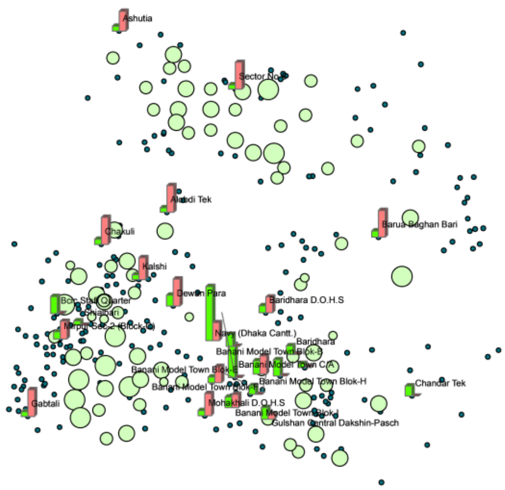


Figure 6: Daily consumption pattern on off-peak (green bar) above 15 kWh relating peak (red bar) per consumer in 2013-2014, and more than 300 feedbacks per areas (bigger circle)

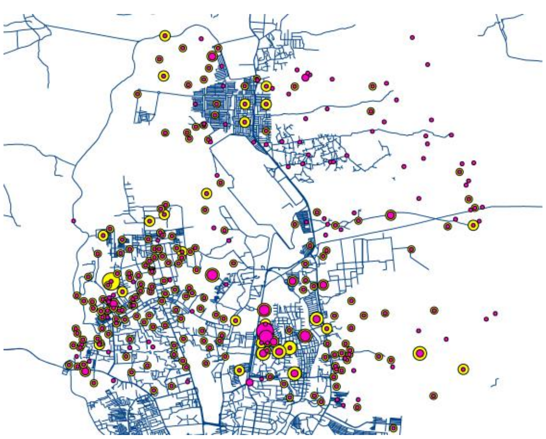


Figure 7: Daily consumption pattern (average) at the time of peak hours in pink and off-peak hours in yellow color

For example, a spatial analysis was used to discover the map features related to consumption patterns (Fig. 7) for same node on peak and off-peak hours. Peak hours in Dhaka city is 5 PM to 11 PM and off-peak hours is 11 PM to next day 5 AM. Higher load profile like air conditioner/cooler can rapidly increase the peak demand and always need to adjust the load. In case of ideal equipment peak and off-peak tariff rate may need to reverse or if a consumer has mostly same load all the day, can be considered to declare ideal tariff based consumer. The analysis also can help to electricity generation to develop its investment environment and infrastructure.

There are more options to evaluate each node for each set of parameters. The utilities can get a much different and more widespread picture of electricity consumption because of this model. In future, the model can help individuals to proceed towards zero-energy housing in households.

4.3. Environmental Factors

The model is designed to find energy efficient and optimal power consumption path in term of unit and costs for energy scheduling, accounting and budgeting. The economy demonstrated in generation capacity from the fossil fuel based expansion has role on oil import. It can link up to evaluate ecological footprints what are related to the utility business process, technology and the interest.

4.3.1. Seasonal Effect and Tariff Monitoring

Bangladesh struggled to meet demand, even during off-peak winter season [8]. For the short term seasonal electricity consumption trend, visual analyses of demand profiles were needed for meeting the burgeoning growth in demand in denser city area.

Seasonal effects, weather information, and historical electricity load patterns are three important factors that affect load forecasting technologies. Among weather information factors, temperature has the greatest effect on load forecasting [9]. In the life-cycle, the consumption patterns are widely varying on the different seasonal weather each year (Fig. 8).

Per capita electricity consumption of Bangladesh increased a little to 293 kWh in 2013 (Source: World Bank).

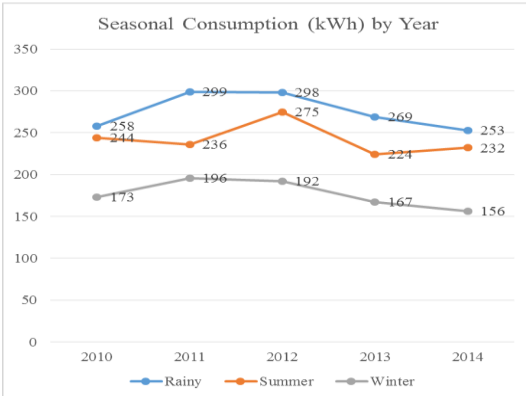


Figure 8: Consumption pattern (average in kWh, year 2010 to 2014) in different seasons

In Dhaka city, monthly electricity consumption varies in different seasons between 156 to 299 kWh by years. In years within 2010 and 2014, tariff rates increased several times and consumptions decreased relations are noticeable.

4.3.2. Solar Panel and Procedure

This research can help to develop environment friendly fuel consumption mechanism. It is responsive in renewables integration studies in Dhaka. Solar panels and solar home system (SHS) are very popular now a day. Its acceptance is growing in households and small industries as substitute with green energy to provide electricity. Other small scale use is already been noticed. So in term of solar variability, how much flexible capacity will be really needed is a question. In Dhaka, according to recent government strategy 10% renewable energy (RE) supply for new flexible capacity needed by 2020.

Contribution of solar photo voltaic (PV) system by capacity installed 78,38,368 Wp till 2015 (Fig. 9) as per existing policy in the study area. And it is growing as per the demand of electricity new connection and conditions in the policy.

The monitoring system is missing link with the govt. policy of RE program to ensure the use of the installed system. The use of solar power can be matched according to the node wise decision. The following procedure can link up the policy with the proposed model in the corresponding steps of section 3.2 –

In step 2, assess if the roof has adequate space and sunlight and determine what upgrades would be necessary to have a solar PV installation by having an engineering inspection. And match some quotes from installers and perform a financial assessment for the project.

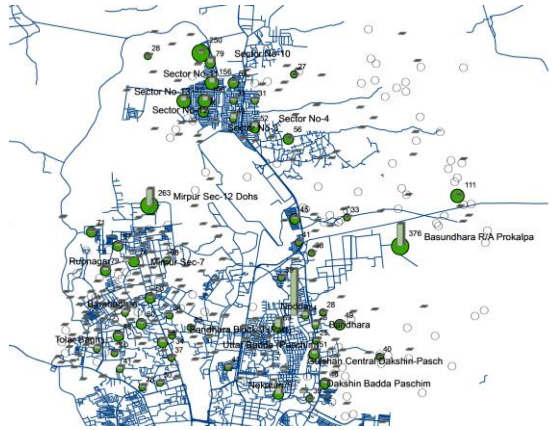


Figure 9: Solar system map in 243 mouza/mahalla on new connection between year 2011 and 2015, selected node based solar panels (green circle with total systems) and in bar area mentioned has more than 75,000 Wp among total 4,930 system were installed, and 113 mouza/ mahalla had no solar (white circle)

In step 3, decide to install the system, and arrange for metering along with utility metering. And *in step 5*, register the metering part with the utility authority.

5. CONCLUSION

Communication with the end-consumer is very important to balance the demand side variability. By monitoring and sharing electricity resource consumption since the beginning, the model can be powerful to determine, evaluate, and quantify up to the economic impacts for households. It is the facilities to provide enough electricity and its dependent resources to mass people level for ecological economic network development.

The node based classification and their change detection framework have the ability to improve the classification, manipulate and detect the required change. New features can be integrated to improve the framework results with the existing constraints. The change and the interchange in the layers are online and automated using ArcGIS software. But the accuracy in all the things on digital maps depends on the geocoding system and it was difficult to maintain for indirect and discrete addresses.

It will be interesting to both energy researchers and policy makers to build the capacity of such regulatory frameworks and governance structure of importance for the welfare of developing nation. Their response and interest on it will be appreciated for further development in the actual dynamic system.

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APPENDICES

There are **technical management** like metering system with total meters in the consumer premises, replacing non-useable old meter by new advanced meter, reducing long distanced distribution line of consumers, quality based electricity distribution management and modernization (New/Renovation), load balancing of distribution transformer (3 Phase), over load management of distribution transformer and 11 kV feeder, for standard connection manage loop of distribution transformer, avoiding interruption on distribution line, improve the non-standard or sub-standard distribution line to standard [3].

There are also **non-technical management** like ensuring the billing of 100% consumers, examining meter connection and seal 100% meters, illegal connection disconnection using by vigilance, sudden inspection in internal or external suspected area, building public awareness using national media or by local announcement [3].

Demand response is a change in the power consumption of an electric utility customer to better match the demand for power with the supply [10].

ENERGY EFFICIENCY
INSIDE AND OUTSIDE THE BUILDINGS

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Abstract: *Energy efficiency is an approach to design buildings with minimum energy requirement during the time building operates. It is necessary and unavoidable as today world is facing real energy crisis. The buildings which we as architects built either residential or commercial, it consumes 52% of total energy in terms of construction, use and maintenance. On the other hand, transport sector consumes 33%; industry 14% and agriculture 1%. The fossil fuel which is required to generate this energy is also at its height of vanishing. So, there is an urgent need to conserve energy by using energy efficient design techniques and materials to build buildings environment friendly. The concept of energy efficient design is related to Green Buildings and involves the use of principles that are in conformity with nature, rather than against it.*

This paper gives emphasis on the dynamic change from the last two decades that took place especially in India. The new approach of energy efficient architecture helps us to ensure the sustainability of the resources and the eco-system. Well-designed buildings go a long way in reducing operational costs by avoiding resource wastage. Environment - friendly buildings offer new opportunities to the struggling construction industry. The buildings should be designed in such a way that they conform to the particular climatic type.

This paper shares real experiences in design of energy efficient buildings by "Saakaar Foundation" in different climatic types especially with reference to Indian sub–continent. Another great experience was to design "Energy Conservation Building Code for Punjab" which laid out strategy to conserve energy at building and its component scale. The objective of this paper is to make people understand that with their little contribution and sensitivity towards climate, we can save a lot amount of energy that is being wasted today.

Keywords: *Climate, Energy, Renewable Energy*

1. INTRODUCTION

The buildings built earlier all over the world had characteristics of its own time and place. The buildings even stand out today in different seasons of the year with desired thermal comfort for the human being. These buildings use passive measures to cool or heat the indoor air. Like the buildings built by Plato and Socrates (and other Greeks) recognized the ability of the sun to warm their homes. The Roman Baths: The south-facing portico and windows of buildings were covered with sheets of mica or glass supported on wooden frames, the solar energy passing into the building would be trapped inside causing the internal temperature to stay more or less constant into the night. The Indian houses with different climates, like for hot and dry climate the buildings were more compact and introverted to keep out harsh summer sun and induce water body to cool the ambient environment. In humid climate the building is opened up in wind direction for excess amount of cross ventilation. These strategies use no external source of active energy which simultaneously saves our environment from pollution.

After the World War II, the construction industry was moving at the faster speed to serve the need for shelter for the growing population all over the world. This tremendous growth has somehow laid to haphazard construction and buildings without being climate responsive and environment friendly. Talking about India, the buildings which are built now-a-days gives a look of copying the western trend of developed countries. This has resulted into the huge amount of energy wastage at the time of construction, operation and maintenance of the infrastructure. These new materials will require the labour quality of desired standard to execute it correctly. And then the machines to maintain that executed materials. This all false practice in the field has given rise to the word "Sustainability". That means to utilise the available resources such that it can be saved for our future generation.

Seeing the depletion of fossil fuels and degrading quality of the environment, need of conserving energy has arrived. It can be achieved through different avenues- generation

1. Reduce the demand by building Climate-responsive structures,
2. Fulfil the demand with the help of renewable energies.

2. ENERGY EFFICIENCY AND CLIMATE

Climatically India is divided into five different types of zones. Each zone has its own guidelines for designing buildings in that particular region. Building green from the start could enable efficient structures, rather than using 20th century building practices & then retrofit for efficiency down the line. This helps companies & the country to make more rapid progress towards their sustainable goals. For designing any green building, climate of a place plays a very important role. A building is climatically responsive when the building uses less or no energy for cooling and heating in different months of the year. Also the building uses natural light during morning and noon hours to reduce energy consumption in the building. This practice will not only save huge amount of fossil fuels to produce that energy but also saves environment.

3. CLIMATE RESPONSIVE STRUCTURE

The concept of climate-responsive design is related to Green Buildings and involves the use of principles that are in conformity with nature, rather than against it. Design for a place not only reduce the energy consumption in the building but also accomplish need of the occupants inside the building during all period of the year without using much of active means. Strategies that should be considered by architect, designers while designing the buildings.

3.1 Building Envelope

Use appropriate Orientation of the built form and the Openings and Windows, Vertical and Horizontal Zoning of different spaces. Form; which highly affect the incoming pattern of sun and wind inside the building. Materials of Opaque surfaces like walls and roofs and their U-values which play a major role while for insulating the building for summer and winter months. Shading devices to cut the higher altitude sun during summers and let in lower altitude sun during winters if required.

3.2 Passive Heating & Cooling Techniques

Passive system means it harness environmental conditions such as solar radiation, cool night air and air pressure differences to drive the internal environment. Passive measures do not involve mechanical or electrical systems. The plan, section, materials selection and siting create a positive energy flow through the building and "save energy". Passive maximises the use of 'natural' sources of heating, cooling and ventilation to create comfortable condition inside buildings.

3.2.1 Passive Cooling Techniques

Cross ventilation, Wind towers, Passive down draft towers, Evaporative cooling towers, Earth Air tunnel and many other passive features are introduced to make indoor environment air cooler in hotter times of the month. These towers can be supported with water bowls to increase the humidity level if the air is too dry.

3.2.2 Passive Heating Techniques

Direct solar gain, Trombe wall, Rock bed, Stack towers, Glass towers and many other measures can be introduced to heat up the air and circulate it inside the structure. These strategies are commonly used in the cold climate where the internal temperature is lower than the external temperature.

3.3 Natural Lighting

Light shelves can be provided to get glare free light inside the structure. Light colours should be used in interiors so that it reflects the light back to create desired lux levels in the space. Courtyards and Skylights can be provided to light the structure from centre zone so that no corner would be dark in day time.

Being a nature sensitive architect, the knowledge about all the aspects like effect on human health, environmental impact, loss of resources, energy consumption and waste going to landfill is must. In a way it's the architect's responsibility to protect the environment by promoting sustainable buildings.

4. LIVE PROJECTS-

Some projects done by Saakaar Foundation are briefly discussed here:

4.1 Baptist Church, Chandigarh- Composite Climate

The Baptist Church, established by the North-West India Baptist Association (NWIBA), is located in Sector 44, Chandigarh. This religious building represents an environment-responsive design attitude specific to the region and local culture. It is one of the 41 energy-efficient buildings in India chosen by The Energy Research Institute (TERI) and Ministry of Nonconventional Energy Sources Government of India.

Concept- Fenestrations for admitting light and ventilation are either below or above eye level, so that activities outside do not distract the worshippers within. The apse and baptism tank which form the background, are finished with grit and a coat of blue paint which symbolizes the heavenly and spiritual setting.

Reduce heat penetration- The minimum use of glass, provision of cavity walls, and white painted barrel vaults which reflect sun rays, contribute a lot to keeping the interiors cool and comfortable in summer. Approximately summer temperature of Chandigarh goes high up to 42-

Figure 1 Exterior Facade of Baptist Church, Chandigarh

44ºC. Provision of cavity walls had considerably reduced heat gain in building. Glass has been used minimally and light colours have been used on exteriors and rooftop. As a result, inner temperature remains nearly 31ºC which is comfortable.

Maximize cooling- Fenestrations are recessed in the walls to provide adequate shading from direct sun and are planned to ensure good cross-ventilation, which reduces the load on cooling devices in the summer. The cool air enters from the lower windows, becomes warm and exits from top, maintaining air flow. No active means of air-conditioning is required inside the building. Thereby there is saving in operational cost.

To induce natural lighting- Provision of natural lighting has been done for energy conservation. Well-lit (light color) reflective interior walls eliminate the use of artificial lighting during day-time.

4.2 Lopon Public Library, Moga- Composite Climate

The 'Green Library' is situated on ancestral land of Dhaliwal village, Lopan in Moga district of Punjab where summer temperature goes up to 43ºC. Being a low-budget single-storeyed sustainable building, planning is done to orient the wind direction in such a way that the building neither uses air-conditioners nor even fans for keeping interiors cooler throughout hot periods of the year. The building is naturally ventilated for maximum time period of the year.

Reduce heat penetration- Cavity walls are provided on east and west side and openings are totally avoided. This helped in overall heat gain inside the structure.

Ventilation technique- A blower fixed on the roof draws fresh air from the atmosphere and sends it down the route. An outlet for hot air has been provided on the wall on south side of the building. The blower that gushes out the hot air consumes much less energy in comparison to a fan.

Figure 2 Front Facade of Lopon Library, Moga

Figure 3 Plan of Library, Moga

This Passive Ventilation technique works all throughout the year, since the place experiences hot sunny days for eight to nine months of the year. The payback period for installing such system was just about two years. And after that the building starts saving in electric bills.

4.3 Housing, Jaipur- Hot and Dry Climate

This housing project has been built at Jaipur in Rajasthan State of India which falls in Hot and Dry Climatic zone.
Temperature touches 45ºC in the month of June.

Figure 4 MAP Housing, Jaipur

Reduce heat penetration- Building blocks are oriented in north-south direction to complement the weather of this state. The houses have been designed for hot and dry climate. The windows have been kept very minimal. The buildings have light coloured exterior finish which reflects solar heat.

Ventilation technique- A series of courtyards/open spaces help in inducing ventilation and thus ameliorating the climate.

4.4 Composite Regional Centre, Srinagar- Cold and Cloudy Climate

It is a Centre built for persons with disabilities. The centre is located in Srinagar City where temperature varies between -2ºC to 30ºC. It is a modern eco-friendly structure. The sloping roofs made up of multi-wall polycarbonate are provided to cope with the climatic conditions of the valley.

Figure 5 Exterior View of CRC, Srinagar

Resist heat loss- The cavity walls improve thermal mass, thus ensuring heat trapping. Unlike other glazing materials, multi-wall poly-carbonate is virtually unbreakable and provides as much as 60% more thermal insulation than glass.

4.5 Youth Hostel, Burdwan, West Bengal- Warm & Humid Climate

The plan-form has been evolved to the irregular shape of the site. Existing trees on the site have been retained. Each function is reflected in the external expression of the building. Hence, the building is truthful to the dictum of "form follows function." The building with 930 square metres built-up area is located in Burdwan where temperature varies between 13ºC - 35ºC and humidity range from 71% - 88%.

Figure 6 Exterior View of Youth Hostel, Burdwan

Reduce heat penetration- The windows are well shaded with projections. The light coloured finish on the outer side reflects solar radiation. To provide view of the greenery around the site and suit the orientation, windows are provided on mainly north and south sides.

Ventilation technique- The linear plan ensures cross ventilation in the rooms. The arrangement of openings increases ventilation and air exchange rate.

Special feature- To insulate the residential area from the noise of public-movement in the corridor, cut-outs is provided. These cut-outs provide light to the corridor at ground level, besides visual communication between both the floors. These cut-outs have added visual variety in experience while walking in corridor, and ensured cross-ventilation.

These above examples have elaborated how the buildings should be built responding to different climates and locally available materials and techniques. Another technique to solve the problem of energy crisis is Renewable Energies.

4.6 Youth Hostel, Joshipur, Orissa- Warm & Humid Climate

The hostel is situated at Joshipur where temperature ranges from 13ºC - 43ºC and maximum humidity noted is 86%. The inspiration for evolving suitable design was derived from the words of Mahatma Gandhi, "we should make the hostels like homes, and create in them ideal conditions for growth and development; such as do not obtain even in real homes. Therefore, the thing to do would be to turn the hostels into *Gurukulas*" To achieve this objective the plan form incorporates hexagonal modules which are joined together like beehive. Some units are omitted to create courtyards. The natural rocky boulders are incorporated in the landscape.

Figure 7 Exterior view of Youth hostel, Joshipur

Reduce heat penetration- Thickness of walls has been kept to suit the local size of bricks. RCC columns are incorporated at strategic points to take concentrated loads. External surfaces are stucco finished and painted in off-white cement based paint. Interiors are plastered and white-washed. RCC flat roofs are finished with lime terracing.

5. RENEWABLE ENERGIES

Reducing energy consumption in a building has solved the task to a larger extent. Alternate to the active energy is need of the hour. The active measure of generating electricity by burning fossil fuels should now be substituted by renewable energy wherever possible is now in trend. Recent trends suggest that the demand for appliances which use renewable energies will continue to grow rapidly, particularly when supported by favourable government policies. Solar Photo Voltaic (PV) panels, Solar Water Heaters (SWH), Rain Water Harvesting system, Biomass production, etc. are some of the examples of available renewable resources feasible with respect to the Indian context.

5.1 Building Integrated Photovoltaic Panels

The available Sun's energy in daytime is being captured in these panels which convert them into the electrical energy. This kind of practice is favourable especially for countries lying in range of tropics of the Equator. The government is supporting such initiative by providing subsidies and tax benefits to the individual.

5.2 Solar Water Heaters

Solar water heaters (SWH) are the transformation of Sun's heat energy for water heating using a solar thermal collector. They are also available with an insulated storage tank so that heated water can be stored for next day usage.

5.3 Biomass Production

Increasing amount of wet waste if treated regularly can solve a large problem of our garbage disposing in landfills. Generated wet waste on site should be collected and treated so that it turns into compost and can be used as manure for landscaping. It is natural compost and beneficial for both plants and environment. Even the gases produced from it can be used to produce green fuel which can be filled in cylinders as used for cooking.

5.4 Rain Water Harvesting

Tank consists of simple systems to collect, conveys, and store rainwater. Rainwater captured is accomplished primarily from roof-top, surface runoff, and other surfaces. The quality of this collected water is much better and with just a primary treatment the water can be reused for flushing and landscaping.

6. CONCLUSION

The projects elaborated above have shown how the architect has to think of energy efficiency from concept stage to completion. Different passive measures like cavity wall, proper ventilation in tropical climate and right orientation can save huge amount of energy in buildings. India has five climatic zones. Studies have indicated that buildings should be designed keeping in view the particular requirements of each zone. Since buildings consume a major share of energy in their construction, use and maintenance, so it is the foremost duty of all architects to design their projects to save energy. It will help us in saving our environment and thereby mother earth for future generations.

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IMPACT OF GREEN FACADES ON ENERGY SAVINGS IN DHAKA CITY

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Abstract: *Dhaka is predicted to be the 6th largest city of the world by 2030 with a population of about 27 million. The unplanned and often unauthorized urbanization of the city has caused a significant increase in the built-up area with serious repercussions on city's microclimate, especially temperature. The introduction of green in building design through roof and vertical greening can be an effective way to mitigate the deteriorating microclimate. Although the studies on green facades have positively asserted their role in energy conservation, they have generally been conducted in the developed countries and also in the temperate climate. It is necessary to re-affirm the role of green facades in a developing country i.e. Bangladesh with a subtropical climate where the built environment, building materials and the green facade (plant species and the agronomic characteristics) are also different. It is in these contexts that this research was taken up to attest the technical feasibility of green facades in partially mitigating the urban heat. The possible impacts of green facades on energy savings during the summer was analysed by using Penman-Monteith method and is based on the principle of absorption of heat by a green space from the surrounding air through plant evapotranspiration. The energy savings in a typical six storied building in a typical canopy of Dhaka city was estimated by Penman-Monteith method based 'CropWat' model considering devil's ivy (Epipremnum aureum) as the green façade. The results of the model study show that the average energy savings with a green façade during the summer months would be about 31% of the building's total energy consumption.*

Keywords: *Green facade, Energy savings, Dhaka City*

1.0 INTRODUCTION

Dhaka is one of the fastest growing cities in the world and is ranked as the 11th largest city with a population of about 17 million. The city is predicted to be the 6th largest city in the world by 2030 with a population of about 27 million (United Nations, 2014). Dhaka city's unprecedented urbanization during the last three decades along with the high population density had serious repercussions on the environment (land, water, vegetation and the microclimate). Poor and uncoordinated planning and development along with high pressure on land for urbanization have exacerbated the problem. During the 1989-2010 period, the city's water bodies and the vegetation decreased by 53.7% and 16.5%, respectively (Raja and Neema, 2013). At the same time, the built up area has increased dramatically by 118.7%. If the present trend of urbanization continues into the future, then it is estimated that the built up area would increase to 49% and 57% of the city area by 2019 and 2029, respectively (Ahmed et. al., 2013).

The change is land cover, especially the dramatic increase in built up area by converting the water bodies and vegetation, has advertently affected the microclimate, especially temperature. The increase in temperature over different land covers of the city during the 1989-2009 period was studied by Ahmed et. al., (2013). The study shows that the city area did not experience any average temperature above 30^0C before 2009. In 2009, about 5% of the city area experienced average temperatures above 30^0C. If the present trend of urbanization continues into the future, then it is estimated that the area experiencing temperatures above 30^0C would increase to 56% and 87% of the city area by 2019 and 2029, respectively (Ahmed et. al., 2013). In a recent study on thermal comfort condition of the city, Sharmin et. al., (2015) observed that 79% of the people reported the thermal condition to be uncomfortable.

Because of scarcity of land and also to accommodate more people per unit area, the recent trend in urban construction is to go vertical rather than horizontal. Although such expansion would minimize the use of land, it would not alleviate the deterioration of the microclimate, especially temperature. The introduction of green in building design through roof and vertical greening can be an effective way to mitigate the deteriorating microclimate.

Although the studies on green facades have positively asserted their role in energy conservation, they have generally been conducted in the developed countries and also in the temperate climate. It is necessary to explore the role of green facades in a developing country i.e. Bangladesh which is located in a subtropical climate (with hot and humid summer, mild and dry winter and heavy monsoon rain in between).The focus of this research was to study the effects of green walls on urban dwellings in the subtropical environment of Dhaka city. Broadly, the research examines how green facades are going to work on a pre-existing building and what impacts they would have on the microclimate and energy savings.

2.0 GREEN WALLS

Green spaces in a building refer to all the vegetated surfaces of a building and can be broadly classified into two categories: ‘horizontal green’ or ‘green roof’ and ‘vertical green’ or ‘green walls’. Leaving aside ‘green roofs’, in which a roof is fully or partly covered with a layer of vegetation, the ‘green wall’ is a wall that is partially or completely covered with vegetation, that are either freestanding or stand with support, with their root system either in soil or in some other inorganic or organic growing medium. The potential of walls as green space is much higher than the roof because the extent of surface greening area can be much higher for the walls than the roof. Green walls can be subdivided into two major groups: green façade and living wall. Green facades are walls where the climbing plants grow either directly clinging to wall with their roots in the ground (called direct façade) or are supported by vertical structure (cables or mesh) for plant development (called indirect façade). Living walls are a comparatively new technology, where pre-fabricated vegetated walls or modules are fixed on the building’s façades or walls. As pre-planted vegetation may be used for cladding the walls, living walls allow faster coverage of the walls with a more uniform growth.

3.0 IMPACTS OF GREEN WALLS

Through an extensive review of literature, Perez et al., (2011) have classified the effects of green walls into four groups: shade effect, cooling effect, wind barrier effect and insulation effect. Green walls reduce the façade temperature due to shading and cooling through evapotranspiration. The shading effect results from the interception of the solar radiation by the plants. The cooling results due to evaporation of water from the substrata and from the leaves in addition to the shading by the plants. The wind barrier effect or the reduction in air velocity by the foliage helps reduce the heat flux and air infiltration between the interior and exterior of a building and helps reduce the energy consumption. The insulation effect refers to the insulation characteristics of different substrata used in living walls to hold the moisture or retain the basal temperature.

3.1EnergySavings

Perez et al., (2014) have carried out an extensive review of published literature on energy savings by green walls by different researchers at different countries of the world and have concluded that the reduction in summer temperature varied from 1.7^0 C to 13^0 C, in warm temperate climate. It was also observed that east and west orientations had big impacts on the reduction in temperature but there were no differences in impacts between species used (deciduous and evergreen). Studies on green walls in Hong Kong (sub-tropical climate) by Chu (2014), observed that the temperature reduction by 13 vine species of green facades varied from 0.5^0 to 2.5^0 C during a sunny day. In a summary the effects of green wall on energy savings with respect to location, Raji et. al., (2015) have concluded that green walls would be more effective at high latitudes than at low latitudes.

4.0 METHODOLOGY

4.1 *Assessment of Impact Through Energy Conservation by Green Facades*

During the process of plant evapotranspiration, a green space absorbs heat from the surrounding air. The heat absorbed by the plants is the latent heat of vaporization. The evapotranspiration from the plants can be calculated by the Penman-Monteith equation as follows:

$$ET = (\Delta (R_n - G) + \rho_a c_p (\delta_e) g_a) / (\Delta + \gamma(1 + g_a/g_s))L \quad (1)$$

Where:

ET = Water volume evapotranspired (mm s^{-1})
Δ = Rate of change of saturation specific humidity with air temperature. (Pa K^{-1})
R_n = Net irradiance (W m^{-2}), the external source of energy flux
G = Ground heat flux (W m^{-2}), usually difficult to measure
c_p = Specific heat capacity of air (J kg^{-1} K^{-1})
ρ_a = dry air density (kg m^{-3})
δe = Vapor pressure deficit, or specific humidity (Pa)
g_a = Conductivity of air, atmospheric conductance (m s^{-1})
g_s = Conductivity of stoma, surface conductance (m s^{-1})
γ = Psychrometric constant ($\gamma \approx 66$ Pa K^{-1})
L_v = Volumetric latent heat of vaporization. Energy required per water volume vaporized. ($L_v = 2453$ MJ m^{-3})

The use of Penman-Monteith equation for the calculation of evapotranspiration has been suggested by Malys et. al., (2014). The method was tested with experimental data from Geneva, Switzerland and the results showed good correlation. Although the Penmen-Monteith equation requires a lot of climatic data to calculate the evapotranspiration (which are generally not available from the local weather stations), FAO has developed a software called 'CropWat', which is based on the equation. The 'CropWat' software (FAO, 2016) is widely used worldwide by the hydrologists and engineers for estimating the evapotranspiration of crops. The advantage of using the software is that it does not require all the data as shown in Equation 1, as they are in-built into the software, provided the location of the place (latitude and longitude), altitude and some basic climatic data (i.e. temperature, humidity and wind speed) of where evapotranspiration rate is to be calculated, is provided as inputs into the software. In this study, the 'CropWat' software was used for the computation of evapotranspiration.

If the evapotranspiration rate can be determined from the model, then the energy saving can be calculated by multiplying the rate of evapotranspiration with the latent heat of vaporization, λ_v (also known as enthalpy of vaporization) which has value of 2257 kJ/m^3 (Allen et. al., 1998). Thus, the energy saving from 1 m^2 of green façade can be calculated as:

$$E = \text{Evapotranspiration (m/day)} \times \text{Area } (1\ m^2) \times 2257 (\text{in kJ}/m^3) \quad (2)$$

Where: E is the energy saving in kJ/day for 1 m^2 of green façade.

4.2 Selection of Study Site

The study was carried out in a typical building of a typical canopy of Dhaka city. The urban dwellings of Dhaka city generally belong to three groups: planned, unplanned and mixed use (residential and commercial). Most of dwellings belong to unplanned areas and one such area is Shiddeshwari Ward. A photo of a canopy in the ward is shown in Figure 1. Buildings in the Shiddeshwari Ward canopy have been developed without following any planning standard and regulation. The façade of the building is placed near the street and did not follow the set-back rule. The development trend in the canopy is characterized by high density units without provisions for open space and greenery. High urban density (high ratio of height of buildings to the distance between them: H/W) means less view of the sky. As a result, the buildings are deprived of natural light and air flow and have high demand for ventilation and air conditioning. Most of the buildings are medium rises (5-6 storied), with the façade of the building very near to street line and constructed ignoring the setback rule. The canopy street is narrow (4 to 6 m) and congested and without any sidewalk.

Figure 1: Photo of a typical canopy in Shiddeshwari Ward.

4.3 Plant Selection for Green Facade

The most common plant that can be used for green façade in Bangladesh is the Devil's ivy, locally known as money plant, (*Epipremnum aureum*). It is a robust and sturdy evergreen plant and can grow in adverse conditions with very little maintenance. It is a common decorative indoor plant which can be up to 50m in height with bushy 8 to 20 cm heart shaped leaves. Considered as a very suitable climbing plant on trellis and wires, it can also be used as a green façade. A photo of Devil's ivy is shown in Figure 2.

Figure 2: Image of Devil's ivy to be used as green façade (Source: https://commons.wikimedia.org/wiki/File:Money_plant_(Epipremnum_aureum).jpg)

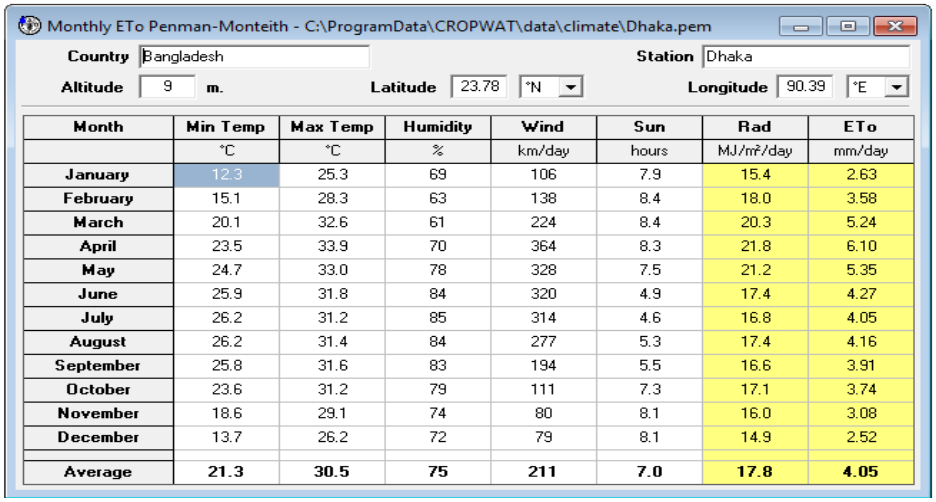
5.0 ENERGY SAVINGS BY GREEN FACADE

Using the Penmen-Monteith method (as discussed in Section 4.1), the evapotranspiration of Devil's ivy was calculated by using the CropWat software. The climatic data required for running the CropWat model for Dhaka city (monthly maximum and minimum temperatures, relative humidity, wind speed and sunshine hours) and the output of the model as monthly evapotranspiration rate (ET_0 in mm/day) are given in Figure 3. The climatic data have been collected from the Bangladesh Meteorological Department (BMD, 2017).

It can be seen from the table that the maximum and the minimum evapotranspiration for Dhaka city occur in the months of April (6.1 mm/day) and December (2.5 mm/day) and average annual value is 4.0 mm/day (ET_0 values in the last column of the table).

Considering the average annual evapotranspiration rate of 4.0 mm/day for Dhaka city, the average energy saving by Devil's ivy as green façade (in 1 m^2) can be calculated as (using equation 2):

E = 0.004(m/day) x Area (1 m^2) x 2257 (in kJ/m^3) = 9028 kJ/m^2 day = 104.5 W/ m^2



Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\Dhaka.pem

Country: Bangladesh — Station: Dhaka

Altitude: 9 m. — Latitude: 23.78 °N — Longitude: 90.39 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	12.3	25.3	69	106	7.9	15.4	2.63
February	15.1	28.3	63	138	8.4	18.0	3.58
March	20.1	32.6	61	224	8.4	20.3	5.24
April	23.5	33.9	70	364	8.3	21.8	6.10
May	24.7	33.0	78	328	7.5	21.2	5.35
June	25.9	31.8	84	320	4.9	17.4	4.27
July	26.2	31.2	85	314	4.6	16.8	4.05
August	26.2	31.4	84	277	5.3	17.4	4.16
September	25.8	31.6	83	194	5.5	16.6	3.91
October	23.6	31.2	79	111	7.3	17.1	3.74
November	18.6	29.1	74	80	8.1	16.0	3.08
December	13.7	26.2	72	79	8.1	14.9	2.52
Average	21.3	30.5	75	211	7.0	17.8	4.05

Figure 3: Screen shot of calculated average monthly and annual evapotranspiration for Devil's ivy in Dhaka city by CropWat model.

The average ET_0 during the summer months of March – June is 5.24 mm/day and the average energy saving during the summer months can be calculated as:

E = 104.5 x 5.24 / 4 = 136.9 W / m^2 (for the summer months).

The details of the calculations are given in Saleh (2016).

5.1 Assessment of the Impact of Green Façade on Energy Savings in a Building

A schematic diagram of a typical building in a typical canopy of Shiddeshwari Ward with south/front, east and west facades are shown in Figures 4(a) and 4 (b).

The energy saving due to green façade was estimated from the decrease in energy requirement of a building with and without a green façade as:

$$Q_E = Q_T / Q_C \qquad (3)$$

where: Q_E is the energy savings in %, Q_T is the energy savings due to green facade and Q_C is energy consumption of a building without green façade (all expressed in W/m^2 day).

For the energy based assessment using equation 3, it is necessary to know the value of Q_C, which is energy consumption of a building without green façade (W/m^2 day). There has been a very recent assessment of such consumption in Dhaka city by Haider and Ahmed (2016). Their study showed that for the residential apartment buildings, the average energy consumption varied between 57.5 to 136.4 W/m^2 day. The study also showed that the higher consumption is in areas where the ratio of open space to built-up area is low (1.6 compared to 3.3).

For the typical building of Shiddeshwari Ward canopy as shown in Figure 4, the total floor area is 19.81x 24.39 = 483.2 m^2(65' x 80' = 5200 ft^2). From personal communication with the local developers it was clear that out of the total floor area, about 25% to 30% of the area is taken up by the common spaces (elevator, stairs, landings etc.). Hence, the actual apartment floor area is about 362.4 m^2 (assuming 75% of floor

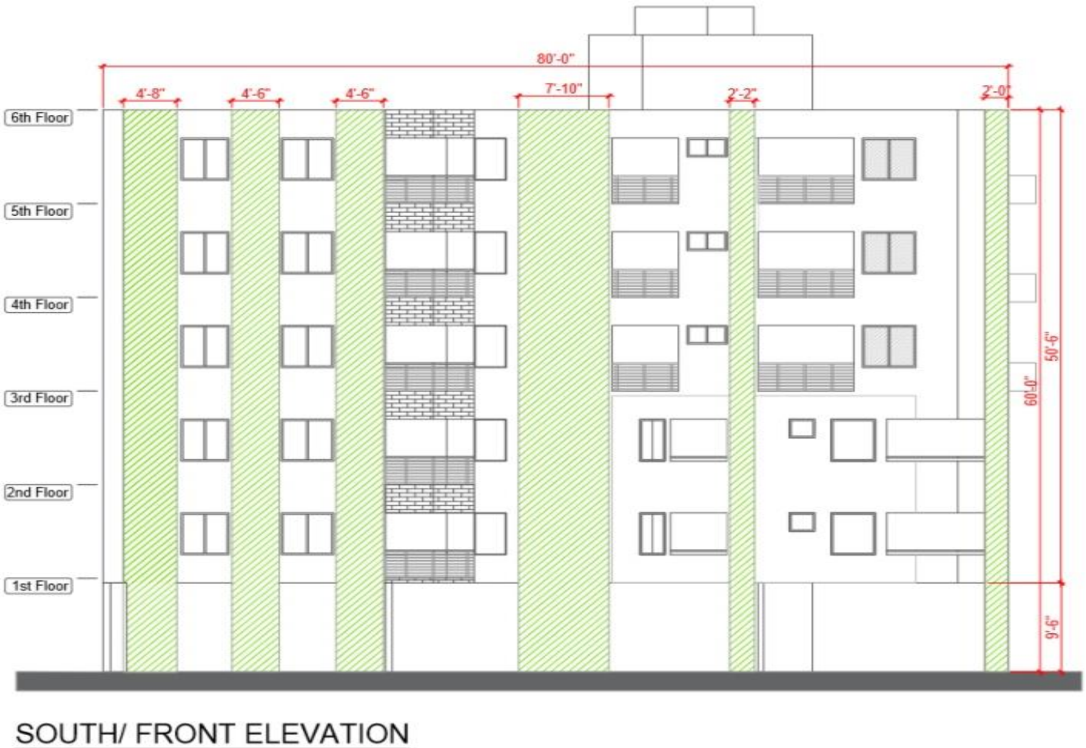


Figure 4 (a): Sketch of a typical building with green façade in a typical canopy of Shiddeshwari Ward (Southern/Front elevation).

Figure 4 (b): Sketch of a typical building with green façades in a typical canopy of Shiddeshwari Ward (East and West elevations).

area). Since the building has five floors, the total floor area is 1812 m^2. As the energy consumption varied between 57.5 to 136.4 W/m^2 day, the total energy consumption of the building for a month would vary between 104.2 KW-h to 247.2 KW-h. Since Shiddeshwari Ward is in a highly built-up area, the energy consumption for a month would be on the higher side and may be considered as 200 KW-h.

Now, if green façades are introduced in three facades of the building (east, west and south) as shown in Figure 4, except for the north, the total green area can be calculated as 457.3 m^2, which is about 38% of the total area of the three facades. The total area of the three facades is about 1200 m^2. No green area is provided in the north façade as it is on the backside of the building and normally has the service and utility lines/pipes. This facade also faces the backside of the building of the opposite canopy.

Thus, the energy saving from the green façade of 457.3 m^2 would be:

457.3 x 136.9 = 62.5 KW-h during the summer months.

The energy saving from about 38% of green facade is (as shown in Figure 3 from the three facades of the building):

E = 62.5 / 200 = 31.3% of the total energy demand (Equation 3).

As there is no estimate of total energy requirement for cooling, ventilation and air conditioning, it was not possible to estimate the effect of green facades on the energy consumption for these usages. But, in a study on decrease of cooling loads by green walls in nine cities across the world, Alexandri and Jones (2008) showed that for two cities of the region (Mumbai and Hong Kong), the decrease is 35% and 66%, respectively.

6.0 CONCLUSIONS

Although a number of studies on green walls in the developed countries have positively asserted their role in energy conservation, there is a general lack of such studies in the developing countries. This study, conducted in Bangladesh, is an attempt in that direction, but it is in no way comprehensive and holistic, and can only be considered as indicative. In this study the possible impacts of green walls on energy savings during the summer was analyzed by using Penman-Monteith method based on 'CropWat' model. Although the performance of the model could not be validated because of lack of field data, the 'CropWat' model has an advantage that being developed by FAO, it is tested and also recommended worldwide for the estimation of evapotranspiration. Because of the worldwide acceptability of the 'CropWat' model, the output of the model may be considered as realistic. The energy based assessments based on 'CropWat' model show that the energy savings from cooling by green façade during the summer months would be about 31% of the total energy consumption.

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PROMOTING SUSTAINABLE CITIES:
SUGGESTIVE APPROACH FOR EVOLVING ENERGY EFFICIENT DESIGN OF URBAN SETTLEMENTS

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Abstract**:** Considering limited availability, spiralling market prices and ever-rising demand for conventional sources of energy, issues related to energy consumption, energy conservation and promoting non-conventional and alternate sources of energy are assuming local and global concerns. However, these concerns have largely remained focused in the area of industry, lighting and vehicles. Not much research has gone in the context of buildings, cities and towns. With rapid industrialization, urbanization, globalization and concentration of large population and activities, urban settlements are fast emerging as major consumers of energy. Accordingly, paper objectively and critically, looks at the prevailing pattern of energy consumption in urban centres for meeting the basic human needs of living, working, care of body & spirit and circulation. In search of appropriate solutions to make cities and towns energy efficient, paper looks at various options including redefining planning; making cities compact; promoting mixed land use; rationalizing mobility and designing green buildings besides using Information Technology (IT) in the urban context.

Keywords: *Compact city, Mixed land use planning, Density, Green buildings,*

1. INTRODUCTION

Year 2007 marked a watershed in the human history, when for the first-time half of the world's population was recorded to be living in cities. With urban populations expected to increase by 1.5 billion over the next 20 years and number of megacities to double, UN predicted that by 2015 "million cities" will number 358 and "mega-cities" with ten million or more will be 27. Scale and pace of urbanisation has opened up unforeseen possibilities, large concentrations of people and goods providing increased opportunities for creativity and higher levels of productivity besides creating cultural and political opportunities associated with urban life. Rapid urbanisation propelled by rural-urban migration, has led to urban settlements growing bigger in size and volume. Bigger the city grows, larger becomes the distance between place of working, place of living and place of recreation essential for human operations. These elongated distances increase travel needs and travel demand. In the process, transportation network comes under enormous pressure requiring more and more vehicles to keep the city moving. With transportation requiring vital fossil fuel to run the vehicles, cities have emerged large consumers of energy. Cities, being the main arena of human activity, have emerged as the greatest consumers of natural resources and energy. Consumption pattern of cities have also undergone radical change due to construction and operation of large number of buildings beside running industry and services which form the very basis of urban fabric. Very little attention has been paid to understand and analyse the energy implications of urban dynamics. Issue related to energy required to keep a city moving has never been addressed and focused while planning, designing and managing the urban centres. With globalization, liberalization and opening up of economies, income levels of urbanites have gone up and energy consumption patterns of the cities have been greatly distorted. Globally urban centres account for 70% of total energy consumption with buildings and transportation cornering the majority share. With limited resources of non-renewable fossil fuel available, the increased consumption has led to considerable energy crisis, hitting the national economies to a great extent. In addition, it has also led to creating large number of environmental problems besides promoting global warming and increased carbon footprints. Greater demand for fossil fuel by fast developing economies has also led to considerable increase in the price of the oil, fuelling inflationary forces in the process. In order to overcome emerging crisis, it becomes important that consumption patterns of cities are, critically and objectively, reviewed and rationalised to make cities energy efficient. Considering the prevailing pattern of energy consumption, there appears to be ample opportunities for achieving economy in energy by evolving appropriate patterns of urban development and urban mobility as significant as those achievable through the design of buildings.

2. ENERGY CONSUMPTION PATTERNS

Energy consumption patterns have been found to be at variance globally depending upon pattern of development, climate, living standards, car ownership and mobility prevailing in a country. In U.S.A, 25% energy is used in transport, 19% by the residences whereas 15% is consumed by commercial use and rest 41% by the Industry. Of the energy used in buildings, heating space accounts for 18% followed by water heating and air-conditioning. Similar consumption pattern has been observed in UK, with the difference that energy consumed by transport is bit lower because of its compact, small size and lower car-man ratio. However, higher proportion of energy budget goes for space heating. Energy consumption in India has been observed to revolve around industry, transport and households, as detailed below in Table1.

Table 1: Sector Wise Energy Consumption In India *

S.No	Sector	Energy Consumption (86-87)	(2004-05)	% age Change
1.	Industry	57.7	51.1	-6.6 %
2.	Transport	19.4	22.7	+3.3 %
3.	Household	12.7	19.8	+7.1 %
4.	Agriculture	8.7	4.8	-3.9 %
5.	Services	1.5	1.6	+0.1 %

*Source: CMIE, 2005

In India, transport and household together accounted for 1/3rd of total energy consumed in 1986-87 which went up to 42.5% during 1986-2004 period. Transport sector has emerged as the second largest consumer of energy after Industry, which account for more than half of total consumption. Looking at the energy consumption pattern, there exists considerable scope of affecting economy, if our patterns of urban development and transportation requirements are rationalized, buildings made more sustainable and industry more energy responsive.

3. REDEFINING PLANNING

Cities are known to be large consumers of energy and resources besides generators of waste. Accordingly, creating energy efficient cities would require new order of urban planning to be put in place, considering the contours and complexity of urban settlements. New order of planning would involve making planning energy and people centric, transparent, community oriented and flexible. Its focus shall be to minimize prevailing urban dualities and contradictions and to promote development based on equity, inclusiveness and providing equitable opportunities to all. Master Plans, which have been used by planners as the panacea to overcome all the urban ills, will have to be redrawn /redefined with appropriate innovations/changes made in the intent, contents and scope of such plans. New order of Master Plans will not be merely land-use plans, defining/freezing the city's future once for all for next two decades, indicating the use of every parcel of land in the city. They will take a 'whole city' approach to planning and will focus on the energy, urban form, shape and typology of the city. Since cities are dynamic entities, ever changing, ever shaping, ever evolving and ever devolving, they will require plans which provide inbuilt flexibility to cater to urban dynamism. The master plans would accordingly be dynamic in nature, growing and evolving with the growth of towns. New breed of Master Plans would be based on state of art technologies and a distinct vision, evolved after detailed study, analysis and understanding of the city fabric and its growth potential, duly supported by detailed planning and development guidelines. The vision shall be achieved through well-defined missions for different facets of city involving planning and development. Each development project shall be evaluated in the context of defined vision and guidelines, by a multi-disciplinary team of experts by involving stakeholders before accepting. The city planning shall not be dictated exclusively by planners but will involve larger set of experts representing different shades of city planning, growth and management to rationalize decision making. Architects, urban designers, energy and landscape experts, service providers, environmentalists, transport experts, conservationists, art and culture historians and sociologists etc. will have major role in planning the future cities. New order of planning will be geared to make the city compact to reduce travel and minimise service network to bring economy and operational efficiency in the city. In this context, the focus of the city shall be people and energy. Planning shall also promote better relationship between living and work by adopting the mechanism of transit oriented development and mixed land use planning rather than pure land use planning. In this pattern, the focus shall be to provide housing, offices, work areas, commercial and institutions along the mass transport network, within walking distance. Green spaces on the defined norms shall form integral part of urban living and working in order to promote highest order of environment and ecology. Such cities will be planned on the basis of inclusiveness, self-reliance and self-sustainability, having minimum impact on local and global environment and ecology. Considering the major implications of urban areas, being largest consumers of energy and resources, generators of waste and emitters of greenhouse gasses, largely due to transportation and built environment, the new regime of planning will focus on minimising travel and create buildings which are least consumers of energy and resources. Smart planning will focus on creating cities which are highly energy efficient made possible by adopting shape and size of the city which involve minimum travel and services In addition, to *looking inward*, new regime of urban planning will also be *looking outward* so as to link the city with its surrounding areas/ rural settlements. No city exists in spatial isolation. Every city has its periphery/area of influence to support it. This zone of influence varies with the size, location, primacy, accessibility, population, nature of specialisation, administrative status, amenities, services etc. The existing pattern of urban planning ignores the critical role and importance of periphery in sustaining/rationalizing the city growth and development. In fact majority of prevailing urban ills have their genesis in ignoring the planning, growth and development of surrounding urban/rural settlements. Accordingly, new regime of urban planning will involve an approach which would involve inward and outward looking at the cities. Most efficient cities in the world have adopted *Regional perspective* and not just looking at cities growth. The Regional approach/model has helped them in minimizing local competition and conflicts, over/under investment in infrastructure and overcoming confusion over role and responsibilities of various agencies and making city smart. In the process, it has promoted higher order of co-operation and growth, of not only of the city but of the region. Looking outward can also help in achieving the objectives of integration and decentralized planning. Accordingly, city planning has to gel with regional planning in order to make cities more productive and energy efficient.

4. MAKING CITIES COMPACT

As already stated, globally cities have been found to be large consumers of energy and resources besides generators of waste. Most of the energy consumed by cities goes into travelling and buildings. If we can rationalize our travel and design energy efficient buildings, we have fair chances of making our cities more energy efficient and sustainable. Accordingly, for making cities sustainable, green and energy efficient, it would be critical that energy as an issue is built-in as an integral part of the urban planning and designing process and all plans evolved for growth and development of the cities are based on considerations, which minimize the need for energy.

Planners normally do not study the energy implication while planning cities. However, studies indicate that there exists relationship between urban form and sustainability, the suggestion being that the shape and density of cities can have considerable implications for their future operations. Certain urban form and shapes invariably involve longer road network, longer travel and consequently higher needs of mechanized modes of travel, leading to higher consumption of energy. On the contrary, there exist forms and patterns which make city more compact, limiting need of mobility, reducing energy consumption and making cities more energy efficient. Grid iron pattern, unless super-imposed by diagonal roads, has been found to be highly energy inefficient due to invariably longer distances involved in reaching different parts of the city besides being ill suited for putting in place an efficient mass transportation system. Circular shapes with radial roads, offer much better option for evolving energy efficient settlements because of the inherent property of a circle, resulting in smaller distance besides offering best options for rapid inter-connectivity between various parts of the city. Chandigarh, finest example of city planning in India, is suffering from traffic blues because of grid iron pattern adopted for planning the city without having diagonal roads (Figure1). Linear cities are also known to offer good option for evolving energy efficient human settlements. Size of the city has also considerable impact on the energy consumption. Cities with 3-5 lakh population are known to be most compact and ideal in terms of travel and sustainability.

Compact cities are also known to be promoters of energy efficiency due to minimized travel and reduced services. For making a city compact, it has to be planned, designed and developed as a vertical and inward looking city. No horizontal and outward looking city can be compact. Horizontally spread cities are known to be cost intensive, energy and land inefficient because of larger spread of services and road network. Horizontal spread of city leads to larger travel demand and greater trip length, making city large consumer of resources and energy, generating greenhouse gasses, creating more pollution, adversely impacting the health and quality of life of the residents.

Horizontal cities invariably lead to numerous operational and management problems besides making the city environmentally unsustainable. For promoting sustainability we have to evolve strategies and option which minimizes urban sprawl and outward expansion of the city and promote compact pattern of urban development. Creating compact city would essentially involve promoting high density development for providing large built up area using minimum land. It would involve using the principle of mixed land use to minimize distances between living and working besides ensure easy access to basic infrastructure, services and day- to-day amenities essential for human living. It is for this reason, compact city is called, 'City of short distances'.

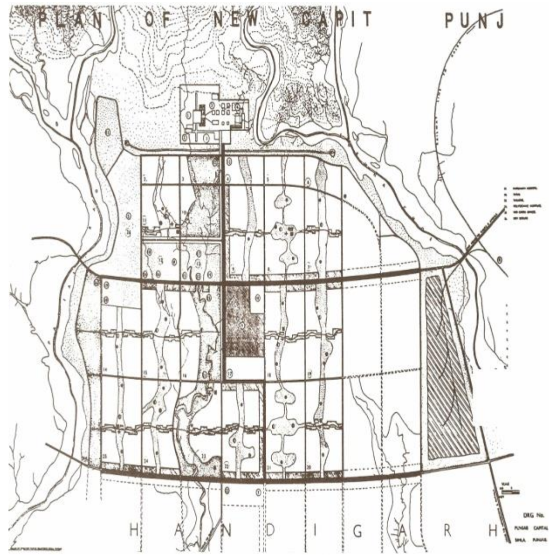

Figure 1 *Le Corbusier's Master Plan for Chandigarh (Source: Chandigarh Administration)*

Designing compact city to achieve a more sustainable urban form has been focused by numerous planners and nations globally. Approach adopted for designing compact cities in western world usually involve a mix of urban regeneration, revitalisation of town centers, limiting urban areas, promoting higher densities, adopting mixed-use development and promoting public transport. The approach has not only led to creating roadblock for urban sprawl and melting of cities but has also promoted less car dependency, reduced energy consumption, better public transport services, increased accessibility, optimum use of available infrastructure/previously developed land, revitalizing of existing urban areas and better quality of life. Compact cities are also known to lessen the adverse impact on environment due to reduced travel. They are also credited with promoting urban economy by promoting productivity, minimising the cost of service network and increasing operational efficiency of infrastructure. Compact cities are generally characterised by two basic elements i.e. compactness and accessibility measured in terms of density, proximity, public transport systems and accessibility to local services and jobs.

In order to make cities compact, concept of 'Low Rise High Density' or 'High Rise High Density' settlements also needs to be given a thought. Bigger plots, haphazard and ribbon developments in and around the cities are making cities highly energy in-efficient because of greater length of roads, services and trip lengths. For limiting size of city and making it more energy efficient, it would be important to have a re-look and rationalise existing density patterns, population distribution, size of plots, quantum of open spaces including their placing, norms for covered area, FAR and zoning. In fact energy as an issue has to be built in all the mechanisms controlling, regulating and impacting city, its growth development, management and its day to day operation.

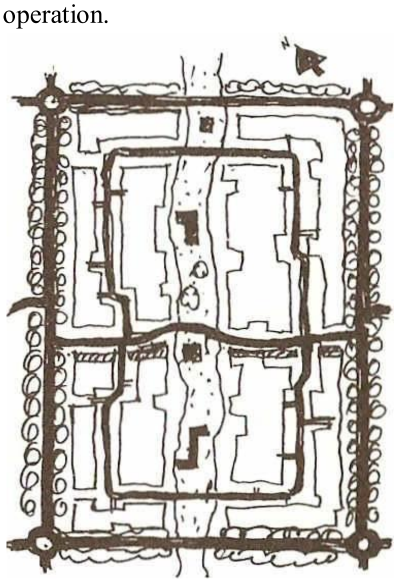

Figure 2 *Typical Layout of a Residential Sector in Chandigarh (Source: Urban Planning Department, Chandigarh Administration)*

For promoting energy efficiency, city needs to be segmented into smaller self-sufficient and self-contained units, on the pattern of Sectors created as neighborhood units in Chandigarh, to reduce travel needs and to cut down the energy consumption (Figure 2). Accordingly, promoting decentralization and mixed land uses besides making cities compact should be the watchwords in the planning of human settlements if energy consumption levels are to be lowered and patterns of energy consumption are to be rationalized.

5. TRANSPORTATION & PEDESTRIANISATION

Ever since the onset of the Industrial revolution in the 18^{th} Century, urban settlements have witnessed enormous increase in demand for transportation. Traffic and travel have emerged as the worst gifts of urbanisation. Stage has now reached where the total economy, efficiency and functioning of a city is largely governed by the efficiency of its transportation system. Cities, as explained above, are known to consume major proportion of global energy and generate greenhouse gas emissions, with majority of contribution coming from transportation and buildings. With traditional fuels, transportation sector consumes large proportion of energy. Challenges posed by transport sector accordingly remain daunting and formidable in creating energy efficient cities. The root cause of urban traffic maladies lies in our approach to traffic and transportation, which focuses on planning for vehicles and promoting mobility. This needs to be changed '**from planning for vehicle to planning for people'** and **"promoting accessibility rather than mobility"** for making cities energy efficient and more sustainable. To make city least consumer of energy, best option would be to minimise travel, reduce travel demand, reduced trip length and promote sustainable urban transport in order to make cities cleaner, greener and smarter. Compact cities offer great opportunity for promoting planning for people and promoting accessibility because of smaller size of city and reduced distances between living and work places, to use alternate modes of travel including walking and cycling. Promoting sustainable urban transport should form integral and essential part of any strategy to promote energy efficiency in cities where highest priority for travel would be to promote pedestrianisation followed by cycling and public transport with least priority going to personal transport. People need to be encouraged to walk down to the place of work, recreation etc. by creating a well-planned network of walkways and cycle network. Over a distance of 3-5 Kms people should be encouraged to use cycles. Example of China can be followed in large cities by creating exclusive Express Cycle- ways where only cyclists are allowed with safety and speed even during the peak hours of the day. These express ways have helped in diverting large number of people from motorized to non-motorized means of transport making the congested areas very clean and city highly energy efficient in the process. No energy efficient city should be without a bicycle plan. The bicycle is the most economical and most energy efficient form of human transportation ever invented. Cycling accounts for 20% of passenger trips in Basel, 25% in Tokyo; 50% in Groningen, Netherlands and up to 77% in Chinese cities of Tianjin and Shenyang.

6. BUILDINGS

Considering the fact that buildings globally use over 50% of world's total energy, consume 30% of raw materials, 25% of timber harvested, and 16% of fresh water withdrawal and are responsible for 35% of the world's CO2 emission, 40% of municipal solid waste, 50% of ozone depleting CFC besides making 30% of residents sick, criticality of buildings and their role in minimizing energy consumption and promoting sustainability of human habitat assumes importance. Buildings as they are designed, constructed and used have enormous energy implications. With number of people and institutions rushing towards urban centres, energy requirements of cities due to buildings are going to rise sharply in future. As per projections made by the Mckenzie Global Report on India Awakening', India will need to construct 700-900 million square metre of built up space on annual basis to meet the demand of 590 million people in the year 2030, those who will opt for making urban centres as their preferred residence. Experience has shown that buildings can be designed to meet the occupant's needs for thermal comfort at reduced level of energy consumption by adopting an integrated approach to building design, using simple techniques of building construction; evolving efficient structural design; adopting principles of solar passive techniques; using energy efficient equipment; making operational control and operation strategies for lighting, heating, ventilation, solar energy; using local materials and replacing energy intensive materials with low energy components etc. Orientation can be effectively leveraged to evolve energy efficient building design by making use of solar radiation and the wind, to meet the energy demand of buildings. However, requirements of building design would vary from region to region, state to state and within regions and states. Accordingly, buildings with regard to sun and wind will have to be oriented differently in different regions. In order to ensure that buildings make best use of solar and wind energy, it would be essential that majority of buildings should have the site advantage. Accordingly, in this context town planners have important role to ensure that while planning, maximum number of plots should have best size and orientation making it easier for Architects to evolve an energy efficient building design. Professional bodies, academic institutions, builders, developers and promoters etc. should take up the agenda of creating awareness, evolving well defined manuals and norms for energy consumption for the professionals to be followed while designing green buildings and their construction. Energy implications of building design must be quantified before approval of building plans in order to enable Architects to modulate/amend their design to bring it within the prescribed norms of energy consumption for making buildings energy efficient.

7. USE OF INFORMATION TECHNOLOGY

Information Technology, providing larger access to information and technology, has revolutionized the entire concept of human living and thinking. Accordingly, rapid strides made in information technology are going to have far reaching implications for effective governance, future growth and development of the cities. IT has enormous potential in planning and designing of compact cities and buildings, promoting operational efficiency of service delivery, monitoring the energy implication of various urban activities and reducing the energy demand of cities. With IT, city patterns are likely to undergo qualitative and quantitative changes to reshape relationship between place of work and place of living. Many institutions would become obsolete with space requirements undergoing substantial change. With IT taking the lead, most of the day to day functions can be performed at or near home with need for travel drastically cut down. Most of offices are likely to become paperless and individuals may work at home. Children may not go to school with best of education being accessed through computers. Extensive use of video-conferencing will cut down the need to travel to larger cities for attending conferences, seminars, and workshops etc. Houses will function as offices and schools.

In addition, IT can be effectively leveraged to promote accessibility while reducing mobility, leading to reduced traffic on the roads, making cities cleaner, liveable and energy efficient in the process. Information technology holds enormous promise but its use in designing built environment, urban planning, development and management has to be geared up. It is important that IT companies/experts should support planners and architects in improving urban planning tools, planning practices and planning techniques. Designing green buildings and creating compact/energy efficient settlements would be largely contingent upon how planning and architecture professions meet the challenges of future urban development by evolving new order, approaches and strategies with the support of IT and IT enabled services.

8. GREENING CITY

Trees have enormous capacity of modulating day time temperature, controlling humidity, reducing heat emissions, managing water resources and rationalising energy demand of buildings and cities. Trees are also known to transpire moistures, provide shade, minimise heat island impact, filter air and improve quality of air/environment. A tree lined street has the capacity to filter pollutants, reduce noise level and lowering of temperature. Greening cities through extensive landscaping and massive plantation can be effectively leveraged for lowering the overall temperature, minimising impact of heat islands, regulating humidity, improving indoor air quality and to bring the climate within the comfort zone leading to considerable reduction in energy expenditure. Shading of building through vegetation, using trees and shrubs as barriers to direct solar radiation can help in reduction in energy demand of cities. Compact city offers enormous environmental advantages due to fewer roads and more landscaped public spaces. Parks, gardens, trees and other landscaped areas provide vegetation that shades and cools streets and buildings in summer, absorbs rain, reduce discharge of urban rainfall and prevent city from flooding. Accordingly, mechanism of greening needs to be used extensively to make cities more energy efficient by massive and strategic plantation involving creating city forests, green roofs, green walls and creating vertical gardens etc.

9. CONCLUSION

The way cities use land, consume energy, eat up resources, generate waste, impact quality of life and environment, they are fast emerging as ecological disasters. Uncontrolled and haphazard growth devours land, water and energy from the surrounding landscape. The emerging contemporary patterns of settlements have created cities which have high level of consumptions of energy due to auto dependence; high energy demand for buildings; water pollution from excessive toxic run off; air pollution and other environmental effects which considerably increase health risks. Invasion of automobiles has made cities highly polluted, energy inefficient, congested and largely frustrating. In addition to global macro ecological problems caused by high level of energy consumption by cities, current settlement patterns have created host of local ecological problems. Urban sustainability is not just about environmental concerns; it is also about economic viability, liveability and social equity. Urban heat islands drive up energy use for cooling besides trapping pollutants in the city. Majority of urban problems has its genesis in the design of cities, settlement patterns and urban spatial fabric.

Human habitat needs restructuring on priority so that we live within the limits imposed by our life sustaining eco-systems and follow the basic principles which promote the quality of life and reduce their energy footprints. To minimize the energy consumption levels and the ecological disasters caused by today's **grey cities**, we have to change our perception, approach, and strategy to plan, design and manage our cities. We have to learn to think ecologically to create **green and energy efficient cities** which are more humane, effective, efficient, productive, sustainable and liveable besides least consumers of energy. Objectives should be to create zero energy, zero car, zero carbon and zero waste cities.

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ASSESSING THE WASTE MANAGEMENT SYSTEM AND 3R MODEL POLICY IN KHULNA CITY

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Abstract: *Waste management is considered as one of the most serious environment problems in the third world cities. Generally solid waste is the outcome of various domestic and industrial activities caused by human being. Solid waste management is an obligatory function of urban local bodies in Bangladesh. But unfortunately, inefficient management and disposal of solid waste are an obvious cause of degradation of the environment. To save the environment and its components, waste management more effectively is a must. 3R model that is reduce, reuse and recycle; is an innovative approach to minimize the waste generation. The aim of this study to find out the existing waste management systems and how 3R policy are implemented in Khulna city. The data will collect from different local bodies related to waste management in Khulna city such as Khulna City Corporation and different NGOs related to waste management and environment through face to face conversation. After analyzing the gathered data few recommendations will provide that will help to mitigate the waste management problem in the Khulna city area.*

Keywords*: 3R model, Reduction, Reuse, Recycle, Solid Waste*

1. INTRODUCTION

Waste management is one of the most serious problems now a day confronting by the third world countries. Rapid population growth, urbanization, industrialization, improved lifestyle etc. are considered as influential factors of brisk waste generation (Zahur, 2007). Inefficient management with lack of appropriate technology is the prime reason of degradation of the environment in most cities of the world (Ahsan et al., 2009). Khulna is the third largest metropolitan, and 2nd port city in Bangladesh covering an area of 47 square kilometres comprising 31 wards. Due to the establishment of large and small-scale industries and development of shrimp farming Khulna city is facing the moderate pressure of migration from the nearby areas. The stats are saying that 50% of the total population in Khulna are migrants, mostly employment purposes (Ahsan et al., 2012) and number is still increasing. Because of increasing population, the city generates a massive quantity of waste every day from different sources. In Khulna City, KCC is responsible for collection, transportation, and treatment of waste. But due to its constraints and limitation KCC is unable to manage the whole task of waste management. In order to supplement the activities related to waste management a number of non-governmental Organizations (NGOs), have come forward (Murtaza, 2002). The aim of this research is given below:

- To find out the existing waste management system.
- To analysis the condition 3R model policy.
- To identify the existing problem of waste management.

2. METHODOLOGY

2.1. Literature Review

Solid waste refers to non-liquid material that is no longer valuable to the owner as including rubbish, garbage, trash, or refuse. Solid wastes are generated by human activities the unavoidable outcomes of domestic and industrial production; and, exerting physical, social, economic and political effects on all sectors of society (Peprah et al., 2015).There are various factors which affect waste generation rates, such as socioeconomic development, degree of industrialization, and climate. Generally, the greater the economic prosperity and the higher percentage of urban population, the greater the amount of solid waste produced (1999).

Table 01: Sources and Types of Solid Wastes

Sources	Typical Waste Generator	Type of Solid Wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, woods, glass, ashes and other household wastes.
Industrial	Light and heavy, manufacturing, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes.
Commercial	Stores, hotels, restaurants, markets, office building etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, other wastes.
Construction and Demolition	New construction sites, road repairs, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal Services	Street cleaning, landscaping, parks, beaches, other recreational areas, waste and water treatment plants.	Street sweepings, landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge
Process	Heavy and light manufacturing, refineries, chemical and power plants, mineral extractions and processing.	Industrial process wastes, scrap materials, off-specification products, slag, tailings
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides)

Source: The World Bank, 1999

Craven et al. (1994) reported that construction activity is approximate to generate 20-30% of all wastes deposited in Australian landfills. Ferguson et al. (1995) found that more than 50% of the waste deposited in a typical landfill in the UK comes from construction waste.

A pilot project was launched in Khulna city in 1997 with a phasing out date of 2000. The project was financed by the Swiss Agency for development and Co-operation (SDC). The main objective of that project was to find out the present solid waste generation and disposal pattern within households, the primary and the secondary disposal points and the waste disposal timing. Their findings were solid waste increased steadily over last five years because of higher consumption and greater packing goods. Household approximately generates 2 kg waste per day. Waste dumped indiscriminately due to lack of roadside bins or bins in poor conditions. Participates suggested that more effective cleaning of these drains by the KCC would not be enough to solve this problem and the community education to prevent dumping should be increased.

3Rs' model is considered as a state-of-the-art philosophy of waste management. 3Rs means Reduction, Reuse and Recycle. The aim of this model is achieving sustainable solid waste management (Peprah et. al, 2015). Many countries use 3Rs model for their solid waste management, such as in Europe landfill receives 66% of waste, incinerated (18%), composted (6%) and recycled (10%); in Eastern Europe, landfill takes 90% and recycled (10%) (EU, 2001). In the USA, recycling, for instance, takes care of cans, bottles, shipping cardboard, unsold food and scrap (Goldman & Ogishi, 2001).

2.2. Study Area

Khulna is the third largest city in Bangladesh with a population of 1.5 million and located on the banks of the Rupsha and Bhairab rivers. Most of the manufacturing industries are located along the rivers in which the industrial waste are dumped. Not only that municipal solid wastes are also dumped into those rivers because of improper management, which poses threat to environment, biodiversity and health. According to the KCC Ordinance 1984, The KCC is responsible for collection, transportation and treatment of solid waste but they failed because of lack of resources and other constrains.

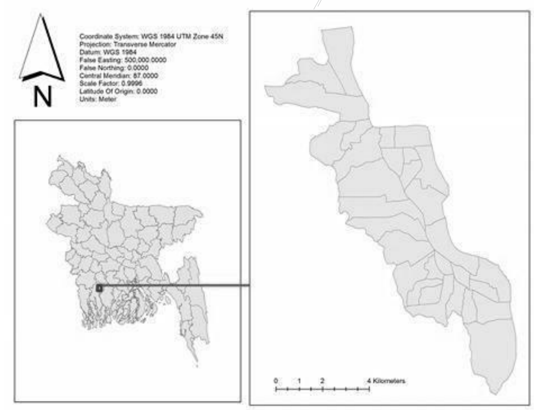

Figure 1: Study Area Map

2.3. Data Collection

Primary and secondary data collection included interviews with employees of Khulna City Corporation (KCC), household members, community people, ward commissioner, local people and waste management workers.

3. DISCUSSIONS

3.1. Governing Bodies

As waste management considered as one of the serious environmental problems, different Government and Non-government organizations are introduced to protect human and nature from environmental hazards. In Khulna, Khulna City Corporation is the only formal organization responsible for waste management in an area of 47 sq. km. Among the 8 functional departments, Conservancy department has the sole right to manage the waste of Khulna City. They perform the following activities:

- Collection, management, maintenance and monitoring of solid waste.
- Street sweeping.
- Cleaning public latrine and urinal.
- Drain sludge.

Apart from Khulna City Corporation, few NGOs are playing some prominent role in waste management. Prodipan and PRISM (Project in Agriculture, Rural Industries, Science, and Medicine) Bangladesh are the two national NGOs initiated waste management in Khulna city. But at present they are not directly involved in field level. They generally monitor the work and sometimes suggest the partner NGOs who are directly related to waste management. NGOs are also involved in waste management in Khulna city are: RUSTIC, Prodipan, PRISM Bangladesh World Vision, Muktir Alo, Samaj Progoti Sangsta (SPS), Bangladesh Resource Improvement Centre (BRIC), Rupayan, and An Organization for Socio Economic Development (AOSED), Nabarun Shangsad, Proshanti and Centre for Human Development (CHD). They generally do the following activities:

- House to house waste collection.
- Transportation of waste from house to secondary disposal point.
- Construction of secondary collection points.
- Building awareness of the city dwellers.

But unfortunately their works are limited to few wards of the city. The NGOs and their active working areas are tabled below:

Table 02: Involvement of NGO in Waste Management

Name of NGOs	Worked Area (Ward)	Name of NGOs	Worked Area
AOSED	25 and 26	Prodipan	6, 12, 17, 24, 27, 28
BRIC	3,4,5,6,7 and 8	Proshanti	30
CHD	16	Rupayan	20
Muktir Alo	23	RUSTIC	18
Nabarun Shangsad	24 and 27	SPS	9, 14 and 15
PRISM Bangladesh	every ward (part)	World Vision	18

Source: Conservancy Department, Khulna City Corporation.

3.2. Collection System

The prime sources of wastes are generated from households, retail markets, hotels, restaurants, slaughter house, hospitals, industries, etc. The type and sources of waste in Khulna city are given below:

Table 03: Sources and Types of Waste in Khulna City

Type	Unit	Quantity
Domestic	Kg/day/household	1.0 – 0.5
Retail Sale Market	Kg/day	50 – 200
Hotels and Restaurants	Kg/day	50 - 150

Source: Environmental Risk Management Action Plan for Khulna City, 2000

Waste collection in KCC areas is done by the NGOs. Door to door collection system is conducted for waste collection and dispose of the nearby secondary disposal site. Where the NGOs involvement is inactive, it is the responsibility for the local household or respective bodies to dispose their wastes to the nearby dustbins or nearby disposal sites.

Figure 2:Door to Door Waste Collection

KCC has motorized and non-motorized vehicles for the collection and transportation of waste materials. Motorized vehicles carry waste from the secondary disposal site to the ultimate disposal site where non-motorized vehicles are used to collect waste from community dustbins to secondary disposal sites. This collection and disposal generally occur daily from 8 am to 5 pm. To manage the waste KCC have the following manpower and other infrastructure facilities:

Table 04: Waste Management Facilities in Khulna City

Manpower	Supervisory	30
	Sweepers	100
	Labours	300
	Truck Drivers	40
Infrastructure	Dustbin	1000
	Secondary Disposal Sites	60
	Waste Container	50
Vehicle Facilities	Motorized Vehicles	40
	Non-motorized Vehicles	220

Source: Conservancy Department, KCC

3.3. Collection Point and Disposal Site

There are over thousands dustbin in all over the city corporation area where waste from households, retails markets are dumped here. Besides more than 60 secondary disposal sites are available where the waste from hotel, restaurants, slaughter house and community bins are accumulated there. Meanwhile recently few container bins are set in some important places such as parks, schools, universities and besides busy road sides.

Figure 3: Secondary Disposal Site

From the secondary sites wastes are transported to the ultimate disposal point which is known as Rajbandha, only ultimate disposal site located 10 km far from the main city. Here, open dumping practices for ultimate disposal, as there is no controlled or engineered landfill in Bangladesh.

Figure 4: Ultimate Disposal Site

3.4 Utilization of Waste

Few NGOs are involved in further utilization of waste through composting plant situated around Khulna city. Among them PRISM Bangladesh operates four plants. PRISM Bangladesh involved in composting process from June 2001. The commercial name of compost product is Green Gold which is sold at 6 tk. per kilogram. Prodipan and RUSTIC, each operates a plant. Prodipan started composting of waste since 2001. The compost plant of Prodipan is located at Rajbandha in Khulna city. Similarly RUSTIC introduced composting since 2001 but it was small scale pilot project. The initial production capacity was 245 kg in a period of 45 days. But due to the strong complain of nearby people, city authority ordered to stop the plant. Then the new compost plant of RUSTIC is constructed on its own land in Rajbandha (Ahsan et.al, 2012).

3.4. 3R Model Policy

3R refers to reduce, reuse and recycle the existing waste. In Khulna city 3R policy is not formally introduced, but maintained informal manners. In 3R model the first 'R' is the reduction of waste materials and dump the least amount of waste to the landfill site. In Khulna waste minimization is carried out by collecting waste from door to door with a charge of 60 Tk. Per month (Field Survey, 2016). But unfortunately as there is no control landfill in Bangladesh, all the waste is openly dumped to the ultimate disposal sites.

The second 'R' involves the used one as substitute of other purposes considering the vast treasure not trash. Currently, the authority does not practice reusing of waste officially. The people who are related to farming are seen to collect the waste from the dumping site and use it on the farm to improve soil fertility. Most often children and women are sent to collect bottles from the disposal site and sell it to the open market with a cost of 5 or 6 tk. per bottle. In later, those are used as drinking water and others beverage bottle.

The third 'R', recycling of waste into new products. Although the recycling part of waste management has been ignored by the local authorities, many individual waste collectors and dealers have been performing recycling activity as a source of income for a long time in Bangladesh. Recyclable waste is collected by the private sector including paper, glass, plastic and are transported to industries located in Dhaka for recycling.

3.5. Waste Management Problem

Management of waste is not an easy task because production of waste is an inevitable factor in our daily life though it can be minimized. Lack of man power and resources are one of the main constraints of waste management. Beside, a suitable system by which people can easily dispose of waste in a certain place is absent. For instance, people prefer throwing their waste into any open place without storing in their house and give it back to the waste collectors. Lack of dustbin and non-user-friendly design of dustbin are another reasons for pollution. Again shortage of landfill is also creating problem for waste management. Frequency of waste collection is not maintaining and ideal waste transportation routes are not identified properly. Furthermore, lack of awareness, motivation etc. also hampers the waste management system.

4. RECOMMENDATIONS

Although KCC (Khulna City Corporation) has taken many initiatives already, the results/outcome are yet to come. Wastes are dumping in many open places beside residential areas, which leads to serious environmental pollution causing odour, mosquito breeding, traffic jam, aesthetic view etc. here are some recommendations if follows accordingly, the problem can be dissolved.

- Design some user-friendly eye catching dustbins so that people can easily dispose their wastes.
- Make properly sealed dustbin with considerable size.
- Shift waste collection time to night, that'll not harm the traffic system.
- Provide waste disposal container at a very cheap rate so that people can store their waste in home instead of throwing outside. The container has to be well designed. The con be of two types like one for bio degradable and the other for non-biodegradable.
- Provide some penalties for the polluters by developing a mobile app with free internet so that people can inform from anywhere to concern authority.
- A planned waste disposal route so that the waste can be dispelled within shortest possible time.

Apart from above ideas, a well-planned waste management system is needed to face this problem. Further research on human behaviour pattern as well as encouraging people for reusing materials is necessary. Technology for recycling of waste materials is also important to reduce the amount of waste and cost.

5. CONCLUSION

Production of waste in our daily life is unavoidable but with proper initiatives, it can be reduced. Otherwise, after a certain period of time, the whole world would turn out to be a pile of waste. For management of waste, 3R (reduce, reuse and recycle) is a very important concept. For reducing the waste, people need to be more cautious about consumption of goods and materials. Besides, the people and the concerned authority should focus more on reusing waste materials in productive work. Moreover, the government should invest more on recycling process so that they can earn from the waste materials as well as help reducing the amount of wastage. The authority should encourage people for reusing and recycling waste materials by providing reward scheme.

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SIGNIFICANCE OF A SMALL RIVER AND SMART CITY MISSION: PROSPECTS AND CHALLENGES OF INCLUSIVE AND GREEN REGIONAL DEVELOPMENT

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Abstract: *Rivers are of enormous value geologically, environmentally, historically, culturally and economically. The geography of mankind's first home and rise of the civilization are defined by a river and healthy rivers play a vital role as natural infrastructure in urban and regional ecosystem. Over the past two decades, the Indian cities and their surrounding regions have experienced radical changes in its built and natural landscape. The urban development demands, over utilization of water and large quantity of waste have deteriorated and damaged the river environment. Big rivers could barely survive this adverse situation, however many small rivers lost their natural immaculate condition. However, insufficient consideration to the larger ecological processes, inadequate policies, and ineffective implementation of programmes and skewed participation of stakeholders further deteriorate the urban and regional environment. In recent times "smart city" concept in India has gained popularity among urban development policymakers and emerged as a model to improve existing urban environment. The concept was also seen capable of dealing with such natural resources and an array of hazards associated with it. The emerging challenges consist of making proper smart policies and creating effective policy implementation plan for future planning of the region where nature (river) and culture (stakeholders) are interrelated. In above context the paper discusses linkages between value of a small river (river Vishwamitri, Vadodara) and urban planning issues in alignment with the main aspects of a smart city (Vadodara, Gujarat, India) development.*

Keywords*: Culture, Nature, Small River, Smart city mission, Stakeholders' perspective, Urban and Regional development.*

1. INTRODUCTION

Water is an important basis of human life and rivers are a key source of water. Rivers are not only strong ecological system but also important part of human physical and spiritual environment because they reflect diverse values and issues. The British Geographer (surname, 2014) elaborate that a river simply cannot only be defined as a process by which river balances its "load" and "transport" it to the ocean but rivers constantly interact with physical environment, human factors and climate. The sound health of river is equally essential for healthy and economically wealthy society, as in the past society has always benefitted due to presence of a river (Postel and Richter, 2003).

Rivers have played a vital role in forming people's socio-cultural, religious and spiritual beliefs in India (Kumar et al., 2005). Rivers are significant and valuable for the society but their condition has been deteriorating. The industrialization, rapid urbanization and constant human nature interaction are some of the reasons for declining condition of rivers. Water bodies have been encroached and river beds have been converted to residential and commercial land uses. As a result, many urban and peripheral villages facing disasters such as frequent floods, overflowing drains and contamination of drinking water.

In India, many initiatives were taken by government and non-government agencies in the past to address the issues with regard to condition of rivers. The conventional system of physical planning also offers responses such as green belt, check dam, diversion channels and tree plantation but in spite of all efforts, the rivers and adjacent built and natural environment have been deteriorating.

Hence to create more liveable and smart regions, it is essential to pay close attention to the dynamics of development, role of key stakeholders and management of water bodies. In the above context the paper focuses on participatory component of smart city concept. It is vital to understand how people value and interact with natural resource such as a small river. It can give first clue to the revitalization process of dying small rivers and deteriorating quality of life of urban and periurban regions. This paper is based on researcher's PhD minor research study, in which a critical examination from stakeholder's perspective was conducted for river Vishwamitri, a small river which flows through Vadodara (Gujarat, India).

2. SMART CITY CONCEPT:URBAN AND REGIONAL PLANNING

The concept of smart cities has gained in popularity among policymakers over the last two decades and emerged as a model to alleviate existing urban and regional predicaments and to meet the growing demand for more liveable built environment and sustainable regional development. Smart city initiatives have flourished in both the developed and the developing world in last two decades. In recent years it has taken on a new aspect of using information and communication technology (ICTs) to construct and assimilate vital infrastructures and services in rapidly expanding urban areas. The smart city's new structure for urban policy emphasizes the positive impact of investment in new technologies and urban information technology and digital networks in enhancing city's economic development and securing more equitable results for the local inhabitants (Smedley, 2013). In many discussions, the smart city is conceptualized as a representation of a sustainable and better liveable urban region, whereas a majority of forums present model images of smart city which include smart mobility and transportation, smart environment, smart economy, smart people, smart energy and smart living (Figure 1). However, some experts draw attention to the lack of clarity and difficulty to put in action for policy implementation purposes with regard to smart city concept. In this context, very little research found which explores vital and conceptual questions such as what really makes cities smart? Whether stakeholders play any role in making city smart? Why conditions of natural resources are deteriorating in-spite of smart efforts? Therefore it seems the concept of smart city has been made without concrete conceptualization. The label of smart city is used in ways that are neither always consistent nor a single definition, define it holistically. Many urban, economic and geographers planners have claimed that improvement in digital or physical network has inadequate effects on economic and social condition of the urban and rural region. According to them, smart city strategies should be aiming to make stakeholders socially stronger along with enhanced connectivity.

Building upon the above arguments, the remaining part of the paper discusses the efforts to bring stakeholders' perspective (through a method of photo preference survey conducted in the river region) in the process of policymaking and physical planning which has emerged as an important tool for policy makers.

2.1 Small river issues: Policies, programmes for smart city development

In recent years the rapid urbanization has been phenomenal in South Asian countries including India which resulted in dynamic change of land use, land cover, landform and condition of natural resources. The change has been creating social and environmental problems (Gadgil and Guha, 1995). The hydrological and hydro geological setting of each region has deteriorated due to growing urbanization processes (National Environment Policy, 2006; Water, and mega cities, 2014). Shiva (2002) has witnessed the conversion of her land from water abundant country to water stressed country. The river health is depleting to meet ever increasing competing demands of urbanization. However, the urban areas are under land crisis and acquiring of river watersheds land, wetland, lakes and city parks is a very common practice of urbanites. Indian rivers and their tributaries are highly polluted due to discharge of untreated sewage disposal and industrial effluents drained directly into the rivers (The Encyclopaedia of Earth, 2009).

However it is found that the government of India had not paid enough attention towards making effective policy, legal instrument or programme for river protection. The National River Conservation Program and action plans in India have failed to show success in securing or rejuvenation of a river, though recently, union environment minister made a public statement about including biodiversity assessment in the impact assessment. The abysmal water management practices, river watershed encroachment, pollution, dams and diversions are reasons for permanent damage to many river systems in India (Thakkar, 2012).

National water policies formulated for giving direction to the utilization of water resources of the country, however at national level, big river basins get sole attention but tributaries do not find any place (Water Resources Information System of India, 2014). Mishra (2006) has worked closely with various river systems in Bihar and found huge gap between people's understanding, aspiration and the interpretation by authorities in terms of making policies and programme implementation of river related policies and programme. Such attitude and a huge mismatch have been the reason for rising conflicts in the social and natural environment.

2.2 Stakeholders' participation in shaping a smart city with a small river

Increased pressure on natural resources in the periphery of rapidly urbanizing settlements has been negatively affecting human society and living environment (Nagar, 2006). A change in the landscape reflects changes in the society. The deterioration and crunch of natural resources are creating "ecological crisis" which generate conflicts and affecting social fabric. India has not given sufficient thought to the larger environment processes in the development of river related policies (Gadgil and Guha, 1995).

It is recognized that India's middleclass, a sizable percentage of population has a very important impact on the environment. The major changes in policies, social relations; urban governance are possible by analyzing Indian middle classes' perspective and their behaviour (Mawdsley, 2004).

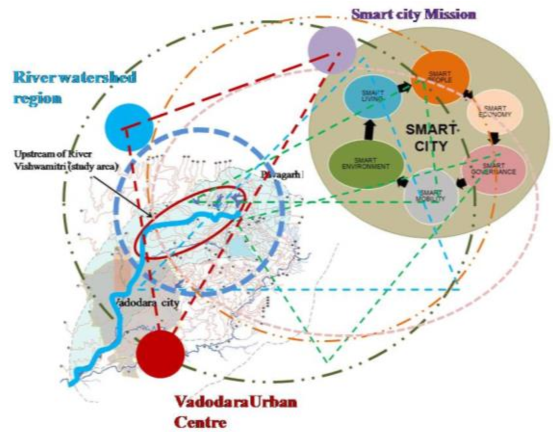

Figure 1: Conceptual plan for stakeholders' participation to integrate a small river issues in smart city mission.

Source: Base map adopted from a map from Gujarat Ecological Society (GES) and conceptual map drawn by author

Therefore, public participation recognized as an important tool for policy decision makers to understand people. People's consciousness about their own environment is an important force that shapes their behaviour and actions.

The situation demands to develop necessary methods for natural resource management. Devising policies concerning management of natural resource is a complicated issue. It involves various stakeholders, with different needs, resources and perceptions. The research conducted all over the world in the field of environmental psychology, shows a pattern of strong relationship of individual's value system and pro-environmental behaviour (Schultz and Zelezny, 2003). Stakeholders' participation reduces hostility and allows certain degree of satisfaction in shaping our environment (Zube, 1980).

Stakeholders' participation can be improved by new technologies but will not automatically branch out from it. Therefore, in the context of smart city initiatives, once smart infrastructures are in place, smart strategies such as stakeholders' participation can help to improve people's and local development authorities' ability to take hold of the potential advantages of new ICTs technological and networking opportunities. This involves taking a holistic vision of the urban landscape and involving the entire network of stakeholders in the design and implementation of smart urban policies in the urban and regional ecosystem.

3. INCLUSIVE AND SMART DEVELOPMENT STRATEGY FOR A REGION WHICH COMPRISES A SMALL RIVER

The question of understanding people's perspective and perceptions seems to be missing in case of urban planning processes in various settings, especially for the often-neglected small rivers in India.

In the existing physical planning system in India, stakeholders' participation is skewed. Their opinion is taken into consideration only after policies drafted. This participation is limited and takes place in a piecemeal manner, which later on has negative impact on river and living environment. Therefore, in the era of smart city movement, this paper discuses the photo preference survey method which involves stakeholders' view with regard to a small river and facilitates to integrate smart development approaches for a small river. Understanding the subjective realities (value and meaning of the river) of people's participation in the physical planning processes in the context of river Vishwamitri through the photo preference survey was an important element of author's minor PhD research.

3.1 Value and meaning of a small river

Rivers are significant because they reflect diverse values and issues. The term 'values' is often associated with rivers and placed on other natural resources also. The elements of the landscape are ecologically woven into a complex interactive whole, consisting of overlapping niches. The whole and parts are integrated with context and context changes in dynamic equilibrium, with human kind. Rokeach (1972) who has given theoretical perspective; considered values to be a type of belief linked to an individual's value system and determines a personal behaviour.

The use of value as a verb implies that some higher-level evaluations have taken place and stakeholders are expressing a deeper meaning associated with that entity (river). The values are considered as attitudes, motivations, substance, measurable quantities, substantive areas of behaviour, customs or traditions, and relationships such as between individuals, groups, objects, and events (Kluckhohn, 1951).

Two motivational dimensions determine the value system. These two dimensions can be understood in terms of two fundamental human problems (conflicts), one is *openness to change* and the second dimension is labelled as *self-enhancement–self-transcendence* (Schwartz, 1992).

Attitudes about people–environment relationships lead to different cultural perceptions of resources. The values individuals held for natural resources are also defined as 'to refer to general goals and preferences (Seligman et al., 1994; pp. 107).

In any culture, the underlying land use ethics structures people's attitudes and perceptions. In order to understand stakeholders' perspectives about a small river, it is necessary to know their perceptions about the natural resource and also important to understand why these perceptions have emerged. Importantly, the values that are constructed by individuals are dependent on the context from which they emerge (Seligman et al., 1994, pp. 108) and will influence the decisions made regarding a specific situation.

3.2 River Vishwamitri: A small river

River Vishwamitri is a small seasonal river and a tributary of river Dhadhar. River Vishwamitri flows through Vadodara city and peripheral region which is located in Gujarat state in India. Vadodara is known for rich urban development efforts during pre-independence period and rapid and advanced industrial growth in post- independence period.

The river Vishwamitri is considered religiously significant as the author of the Gayatri Mantra, Sage Vishwamitra's name is associated with it (Sharma and Rupera, 2013). The river related literature clearly shows the cultural, social importance of river Vishwamitri. The literature discusses the rich flora and fauna; landform, landscape and land cover of the entire river Vishwamitri watershed region and explains the pristine condition of a small river (Thaker, 1997). The literature indicates that religious norms and practices were integrated and were used as tools for public participation that helped to maintain the fine balance between people and river environment.

The river Vishwamitri is a unique example, which is religiously very significant and still acts as a common property of natural resource for surrounding rural but rapidly industrializing area. At present Vadodara city and river Vishwamitri both have been facing multiple interlinked issues and challenges such as pollution, flood, encroachment, mis- use and abuse of surrounding region of the river. Above literature, directs the research focus towards exploring the stakeholders' point of view on values and meanings of a religiously significant river Vishwamitri that is in degraded condition now.

3.3 Photo Preference Survey: a smart strategy to involve stakeholders in river related decision making process

In author's PhD minor research, Photo Preference Survey (PPS) is the second major data collection method which is employed to find four major groups of stakeholders' preferences for upstream of river Vishwamitri on four themes. In PhD minor research, four main groups of stakeholders were identified as key target population. The stakeholders (GEs, FVs, RAs, IPs) are individuals who are directly or indirectly associated with the river Vishwamitri. These groups are as follows.

Group one (GEs): Government Employees
Group two (FVs): Farmers and Villagers
Group three (RAs): Researchers and Activists
Group four (IPs): Industries Personnel

In this paper, out of four key themes, the first theme "river value and meaning" is discussed in detail to explain the stakeholders' perception about a small river.

The photo preference survey (PPS) uses photographed scenes and asks participants to indicate their preference (Figure 2). It is one of the most significant methods used in the field of landscape assessment. This is used as fundamental instrument to measure stakeholders' preference and perception of upstream of river Vishwamitri landscape scenes. This method is adapted and refined by of Rachel Kaplan and Stephen Kaplan, Professors of psychology at University of Michigan. According to Kaplan

Systematic approaches to the management of the visual resource tend to based on categorizations, and on assumption of what is valued or preferred. While direct questioning regarding environmental perception is unlikely to be fruitful, it has been shown that the use of preference reactions to photographic material is a highly effective procedure for deriving salient perceptual categories. (Kaplan, 1985, pp.161)

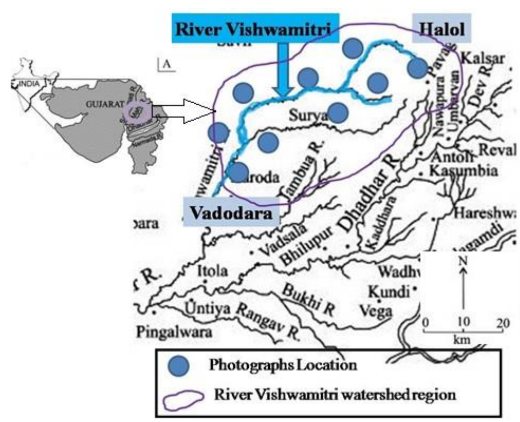

Figure 2: Photographs scene's location in up-stream of river Vishwamitri.

Source: Adopted from Raj (2007): "Late Pleistocene fluvial sedimentary facies, the Dhadar River basin, Western India." Science Direct, 159.1(2007): 93-101.Print

The photo preference survey consists of participants' preference rating (1-5 one for least preferred and five for most preferred) on selected images (photographs) from a number of scenes mainly taken during pre monsoon and post monsoon period in the river Vishwamitri up stream watershed region. These scenes depict main issues raised in four themes in the objectives. Here, the photo preference survey ascertains and quantifies public perceptions of the visual quality of river Vishwamitri watershed region (Figure 2).

The photographs included variety of settings. Those settings were not completely natural or fully manmade. They were showing transition in river watershed environment. These thirty-five photographs selected for preference rating using the Likert (5-point) scale (1 being least preferred and 5 being most preferred) by total 73 stakeholders representing four different groups of stakeholders. To understand the overall preference for thirty-five photographs, least preferred and highest preferred photographs observed.

As with any data analysis process, the descriptive statistics and Category Identifying Methodologies (CIMs) aim at efficient and meaningful data reduction, organization and interpretation. Computing descriptive statistics, such as the mean rating of each scene for all group of participants and then for each group (e.g. GEs, FVs, RAs, and IPs) is done using computer based statistical programmes (i.e., SPSS). This reduced the quantity of data and generated diverse and useful information (Babbie, 2001). It also helped explain certain patterns of preference related to specific scenes in the photographs.

The degree and magnitude of similarities and differences in the preference ratings among and between four groups of stakeholders are helpful in revealing the underlying issues and experiences and providing a useful, empirical way to understand the reasons for conflicts and compromises and collaborations among and between these groups. Another way to gain further insights into the patterns of stakeholders' preference and perception is by using factor analysis based CIMs (Kaplan, 1985; Kaplan and Kaplan, 1989).

Subsequently factor analysis was carried out using the photograph preference ratings in which main components were extracted and three new themes were coined.

4. RESULT AND DISCUSSION

Photo preference survey (PPS) results indicate that the scenes represented pristine and scenic conditions of river, were valued most (high mean preference) by all groups of stakeholders, however Government Employees (GEs), and Researchers and Activists (RVs) showed higher preference than Farmers and Villagers (FVs) and Industries Personnel (IPs). The research results reveal that the value of a preferred river landscape is determined by not only the presence of natural elements but also by the meanings, which are perceived by the stakeholders in these elements(refer figure 3).

The research demonstrates that the social-cultural and ecological values are the most common values attributed to river Vishwamitri, which form an association among all groups of stakeholders. The research findings suggest that the river Vishwamitri upper watershed region appreciated in the larger context of natural resources situated in the surrounding region and human development is not negatively affecting their natural condition(refer figure 6). These results suggest that overall; the stakeholders most prefer river in their natural clean form (refer figure 4). Among the three least preferred scenes, all three photographs show pollution and waste collected near river bank due to human made elements of development. These results suggest that on the whole, the participants do not prefer river region which is polluted and has heaps of waste dumping around it (refer figure 5).

The analysis suggests that though all stakeholders prefer natural resources with balanced human related development but Government Employees' (GEs) preference for balanced development over other values and issues is highest among all four categories of stakeholders(refer figure 3). The stakeholders were inclined towards balanced management of land resource, availability of river water for agriculture, systematic building and infrastructure construction

The PPS comments suggest that the river Vishwamitri upper watershed region appreciated in the larger context of human development in harmony with the nature (refer figure 6). The words commonly used to describe the reasons of low preferences are polluted, misuse, overuse and negative human intervention which degrade environment.

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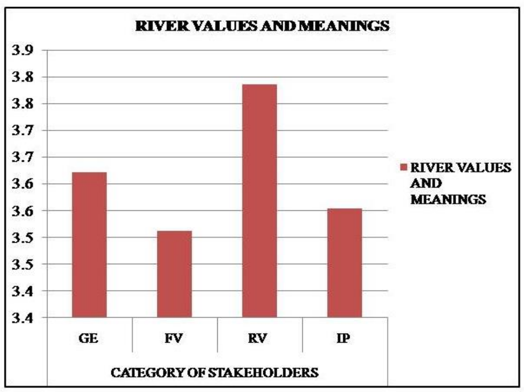

Figure 3: Comparative photo preference for theme 'river value and meaning' for all four groups of stakeholders.
Source: Vasudeva, 2015

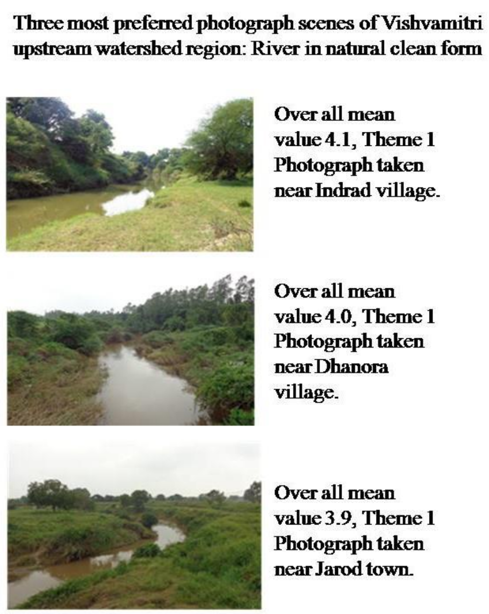

Figure 4: Most preferred photographs scenes in up-stream of river Vishwamitri.
Source: Vasudeva, 2015

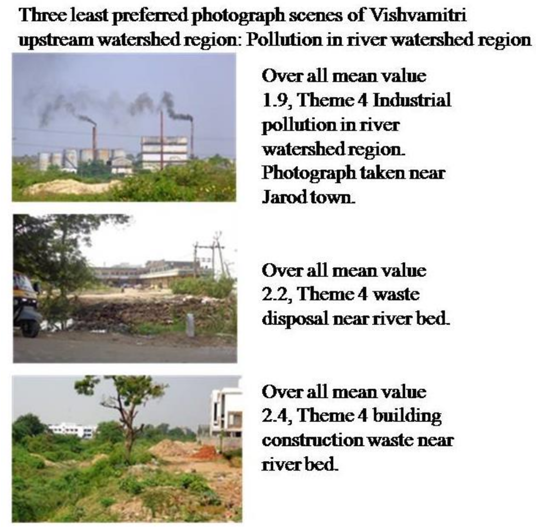

Figure 5: Least preferred photographs scenes in up-stream of river Vishwamitri.
Source: Vasudeva, 2015

. The degradation of the environment was found associated with overuse of resources, inappropriate land use planning and bad management of human related development. This perspective is critical to keep in mind for future resource planning and management actions.

The factor analysis was carried out using the photograph preference ratings. Ten components were sought and three components (photographs included from component one, two and three with high Eigen value and coefficient value more than 0.55) extracted with meaningful thematic consistency. Three categories emerged following the above process.

Category 1 - Development with resource conservation [theme represented: 1,2,3; overall mean:3.44 total number of photographs where coefficient value >= 0.55 are ten(10)](refer figure 6)

Category 2 - Resource degradation theme represented: 2, 3,4; overall mean:2.4 total number of photographs where coefficient value >= 0.55 are six(6)]

Category 3 - Pure natural landscape theme represented:1 overall mean:3.65 total number of photographs where coefficient value >= 0.55 are two(2)]

Theme 3 (1, 3.1)
Industrial development near River Vishwamitri watershed region

Theme 3(2, 3.10)
Educational campuses near River Vishwamitri watershed region

Theme 3(3, 3.4)
Farmhouse development near River Vishwamitri watershed region

Theme 3(4, 3.9)
Farms and temple near River Vishwamitri watershed region

Theme 5 (5, 5.4)
Arial view of Pilol village and River Vishwamitri

Theme 2 (6, 2.6)
View of Pratapura Reservoir near Halol and River Vishwamitri

Figure 6: Six photographs from perceptual category one (development with resources)
Source: Vasudeva, 2015

5. CONCLUSION

This paper is based on author's PhD minor research in which stakeholders' perspectives is explored about up-stream of River Vishvamitri, a small river which flows through Vadodara. The paper discusses the stakeholders' perspectives on present values and meanings of the river which can facilitate to shape inclusive smart city and regional development policies and programmes. The research demonstrates that stakeholders' values attributed to small river Vishwamitri are diverse. Each individual stakeholder views the resource from a number of perspectives.

It can be concluded that majority of stakeholders lack the knowledge of the natural pattern and processes of the river. Rapid building development activities in the ravines of river Vishwamitri and ignorance of natural patterns of the river further causes the damage to both (the people and the river environment). Therefore, an awareness programme, which informs and disseminates the knowledge with regard to river processes, is a prerequisite in smart city mission.

This research reveals that there are values, which are common to the key stakeholders that should be incorporated into any physical planning and policy direction that is undertaken for the river. However district level top decision makers commonly have neutral perception with regards to river and related issues which impede the development of holistic vision for the river.

For marginal farmers the river is an important natural resource and their perspectives can solve many conflict areas and improve the outcome of river related policies and programmes (check dam, plantation on river bank, green belt zone).

This research is an effort to strengthen smart city initiatives by making more comprehensive policies, which are emerging worldwide, and draw on the use of communication technologies to facilitate stakeholders' participation in decision making. It helps to make possible cooperation between actors, and support the local urban development and management authorities and local economy (Hodgkinson, 2011).

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INVESTIGATING THE ARCHETYPE OF VERNACULAR ARCHITECTURE OF 'MARMA' ETHNIC GROUP, RANGAMATI, CHITTAGONG.

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Abstract: *Vernacular architecture of any settlement is characterized by architecture and construction methods developed by local masons and builders. Vernacular architecture develops with respect to culture, religion, traditional methods, local materials and geomorphology and evolves through a process of trial and error, adapting eco-cultural changes over time. The vernacular architecture of 'Marma' ethnic group of Rangamati district in Chittagong Hill Tract has been enriched by experiencing changes in their socio-cultural context. The objective of this paper is to study the architectural features of the archetypes of vernacular 'Marma' architecture. The architectural features were found and compiled through interviewing the local ethnic people and direct observation based on authors' perception. The empirical findings from the discussed features provided a new understanding of vernacular approach of Marma settlements. The paper focuses on learning and appreciating the principles of vernacular architecture of Marma ethnic group.*

Keywords*: Change in Archetype, Traditional Ethnic Architecture, Vernacular Architecture.*

1. INTRODUCTION

Vernacular architecture is the most sophisticated phenomenon in relation to the environmental context. Traditional vernacular architecture is influenced by a great range of different aspects of human behaviour and its eco-cultural environment, leading to different varieties of building forms for almost every different context. Many times one can find the solution to optimize the use of resources and to achieve the human comfort by critically evaluating the vernacular architecture of that place (Kingston, 2009). Inhabitants often use and employ various adaptive features in their houses to keep the indoor conditions within comfortable zone in accordance to their contextual needs (Krishnan, A. et. al., 2001). The best way to understand the archetype of any context is by conducting field survey and explanatory analysis on its features, through observation and interviewing the locals. The following study is on the archetype of Marma vernacular architecture. During the physical on-site investigation of the archetype, an individual automatically starts gaining knowledge about the procedure of shaping their built environment and evolution of the archetype. (Kingston, 2009; Koenigsberger, O.H. et. al., 1973). The following study was conducted to gain knowledge and wisdom from the local masons and builders, often the inhabitants themselves, about the Marma archetype in accordance with their way of living, built environment, indoor-outdoor spaces and to analyze the traditional contextual impact on their archetype, as a response to the local vernacular architecture.

2. METHODOLOGY

The paper is based on literature study, field survey and semi-structured interview of the Marma people of Naikyongchora, Rajostholi upazila under Rangamati district. Before starting the field survey a thorough literature study was made which helped to conduct the field survey. The whole field survey was conducted in several steps. A reconnaissance survey was conducted to understand the environmental and geographical context of the settlement. A set of questions for interview was taken and the interviewing of 43 local Marmas of three Marma paras (clusters) was conducted for the next two days. The questionnaire survey contained open ended questions regarding following parameters:

i. Form and zoning of a house/unit
ii. Structural features & materials
iii. Cluster pattern & details(circulation, service etc)
iv. Settlement structure & placement
v. Policy on household & settlement expansion
vi. Relation of an archetype of Marma house with their culture & lifestyle

The empirical findings from the discussions and study will help to understand Marma vernacular architecture and assist one for study further.

3. ORIGIN OF ‘MARMA’ ETHNIC GROUP

‘Marma’ in the literal sense is the word for Burmese. The Marmas live in the three hill districts of Rangamati, Bandaraban and Khagrachori. Presently the number of Marmas in Bangladesh is about 350,000. They are Arakanese descendants and speak in Arakanese dialect. The material culture of the Marma society includes many basic tools and weapons of primitive societies (Khan, 2012).

The nuclear family is predominant in the Marma community though extended family is also seen. The husband is the head of the household. Kinship ties are strong in the Marma society. Both sons and daughters inherit parental properties. The 'auroth' (most favourite) child gets the ownership of the house and has to take care of the parents. In recent times, however, inheritance of landed property follows a rule according to which the property is distributed in the ratio of 2:1 between sons and daughters (Khan, 2012).

Agriculture is the main occupation of Marmas. Jhum cultivation is their primary agricultural pursuit. Small-scale homestead gardening is also common among them. Other important economic activities of Marmas include basketry, brewing and wage labor. Weaving is a very common activity of Marma women.

The traditional political administrative system in the Marma community is three-tiered. Village level administration is headed by a karbari. The mouza level is headed by a headman and the circle level is headed by the circle chief (Raja) (Khan, Sadat Ullah et. al., 2012).

4. DESCRIPTION OF THE ‘MARMA’ SETTLEMENT

The aim of this study was to find out the salient architectural features of the Marma settlements in Chittagong, Bangladesh. For that a traditional settlement in the hilly region of Rangmati district was selected. The settlement was situated in Naikyongchora, Rajostholi upazila under Rangamati district having 22°20’30.46’’N latitude and 92°11’45.11”E longitude. It has tropical monsoon climate (Google Map, 2016). In figure 1 the selected site is shown.

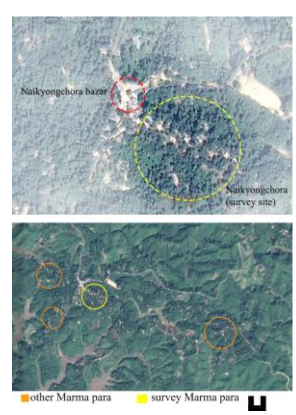

Figure 1: Naikyongchora survey site

4.1. Cluster

In the cluster pattern the building forms are aligned on both sides of an access road in linear arrangement which they call *para.* This access road of 6-8 feet is mainly used for their internal accessibility. There are 10-15 houses in one cluster *(para)* and the distance among these houses varies from 8-20 feet. Each hill has one cluster; the distance among these clusters is 300-500 metres. Generally a village consists of 4-6 clusters. These clusters are generally established alongside a source of water, for example, creeks, canals and wells. In figure 2 the linear arrangement of the cluster with detail is shown.

The pattern of the cluster depends mainly on its geographical context and road layout of the site. The hilly terrain of the site determines the shape and planning of the settlements. For the curvy access road in the hilly terrain the houses have become rectangular and very few are of square shape.

Figure 2: The cluster pattern

4.2. Orientation of the road and built form

The access road in the cluster has a north-south orientation and the houses alongside this road are arranged in east-west orientation. The entrance of these houses cannot be seen from the main road.

The intimate relationship among the dwellers and for gathering purposes the houses are aligned in such orientation. Also their belief in Sun God is another reason for such orientation as the sun rises in the east.

4.3. Boundary

There is no boundary around the houses and cluster. But the open balcony space in the macha is surrounded by bamboo fence which is 2.5'-3' high. Sometimes they use bamboo fence on the backside of their house. In figure 4 the boundary around the macha is shown.

Figure 4: The bamboo fence around the open balcony.

For intimate spaces among the houses, gathering purposes are the main focal point of not having any boundary among their houses. Even one of the distinct factors of the Marma society is their very liberal attitude towards the male female relationships. Free mixing of all sexes is not restricted as both the males and females share their works together in the houses and in the outdoor activities. These reasons bring them all to a common place and so there is no boundary among their houses.

The balcony space in the macha requires fence for the security from animals and vicious insects.

4.4. Policy and future expansion

The Marmas can use the full space of their private land after leaving 6-8 feet space for the access road while building their houses. For future expansion, if the family enlarges they keep their old house and build a completely new house.

Generally when the Marma family expands the newlywed couples build their own houses near their father's in the same compound. This is mainly for the privacy of the new couple and space concerns. Also they usually don't break their old houses without any severe reason.

5. SALIENT FEATURES OF THE ARCHETYPE OF 'MARMA' VERNACULAR ARCHITECTURE

The socio-cultural interaction involvement has a great impact on the constitution of the history of Marma vernacular architecture. The indigenous materials of the hilly areas and the environmental and ecological factors play a major role in forming their vernacular architecture. Their living pattern, houses and surroundings have been carried down to centuries and little affected by the changing modern world.

5.1. Building form (Massing)

The shapes of the building forms are rectangular and very few are square. The dimensions vary from 16’x12’ to 22’x14’. There are a few separation walls for privacy and to distinguish the spaces for various functions.

The geography of the hilly settlement with its terrain determines its shape. For the selected site most of the houses are either rectangular shape or square with few partition walls. For their close relationship and gathering spaces the houses have more open space than large rooms.

5.2. Structural features

5.2.1. Elevated platform (Macha) & Post

The elevated platform that is known as ‘Macha’ is stationed 3-6 feet high from the ground level. The wooden posts are used as the pillar system which they address as ‘Khongshe’. They use around 18 posts and infix them to -3 feet level under the ground. Bamboo posts are also used for the support. Bamboo thongs are used to tie the structural elements. In figure 5 and 6 the bamboo joints with wooden and bamboo posts and the structural system of the elevated platform (macha) are shown respectively.

In the hilly areas the cold wind, hill slopes, rain create various kinds of environmental problems with wet surfaces. The small windows and doors with elevated platforms are the climatic demands for protecting oneself from these natural calamities. The elevated macha is very advantageous for the locals in the monsoon climate. Raising the house to a specific height at which the cooling upper breezes can penetrate, away from the rain water mud and providing excellent under floor ventilation in the monsoon weather. The tall posts of the macha keep the inhabitants free from diseases and local animals and vicious insects.

Figure 5: The bamboo joints with wooden post and bamboo post

Figure 6: The structure of the macha

5.2.2. Roof (Shakre)

The roofing system of the houses is double pitched roof and Marmas call the roofing system ‘shakre’. Tin or chan with bamboo post is used as the roofing material. Generally wooden beam is used in the roofing structure. The space in the beams inside the house is used for keeping daily utilities. The roof structure and the space using in the beam are shown in figure 7. The height of the top post is 12-16 feet and the other height is 7-8 feet. In figure 8 the section of the roofing system is shown with other structural elements like wooden posts, bamboo posts, wooden beam, ladder etc.

Figure 7: Use of beams in the roofing system (left) Space using in the beam (right)

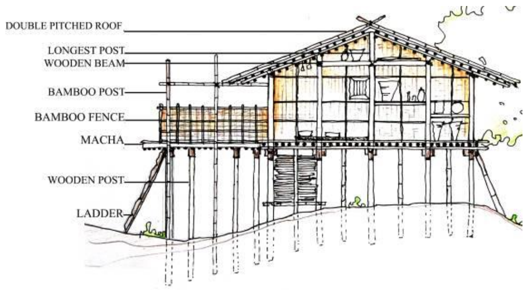

Figure 8: Section of the roofing system with other structural elements.

The double pitched roofing system is climatically useful to the Marmas as it seeps away the rain water in the heavy monsoon weather. Also the strong wooden beams and chan are their traditional material. The use of tin is the urban influence in the roofing system, an outcome of newly laid road links to the city area.

5.2.3. Floor (Choipang)

The Marmas address their floor as 'choipang' and it is generally made of wooden planks. Local tree planks are used such as, gorjon, gamari etc. They have flooring made from bamboo fence and it is here that the family lives, sits, rests, receives visitors and accommodates guests. In the figure 9 the wooden floor and bamboo fence floor is shown.

The floor of the house is constructed in the most innovative way. The final floor rests on two to three layers of support, counting for a very durable rigid floor that can take tremendous support. For the load of the wooden posts, roofing, walls and the climatic reasons like, the hill slopes the house floors are constructed very strongly so that it can bear a huge amount of load.

Figure 9: The wooden floor (left) and the bamboo fence floor (right)

5.2.4. Wall (Theraing)

The wall which the Marmas call 'theraing' is made of bamboo fences. There is no use of clay plate on the walls. In figure 10 the bamboo fence wall is shown.

The most common material for the Marmas is the bamboo fences. It is easy for them to collect and construct the bamboo fences than the mud walls. Also the tradition of using this material has a significant role. So generally they use bamboo fences as the wall material. Presently for the urban influences some Marmas are using brick walls but their number is very few.

5.2.5. Fenestration (size, material, position)

The windows are called 'Latang' and the size of a window is 1'6"x1'6". They use Tin with wooden panels in the windows. The windows are generally positioned on the north south walls and on the entrance wall.

The doors are called 'Thengkoboi' and the size of a door is 5'6"x 2'6". The material for door construction is generally wood like gargan, gamar, shilkoroi etc.

Figure 10: The wooden panelled door, the wall and the small windows

In figure 10 the wooden door, wall and the small windows are shown.

The main reason for the windows and doors being so small is climatic one. The cold wind and monsoon weather apparently make the house windowless as a natural response to the environmental demand. The hill slopes with heavy rain and wind are the primary reasons for the doors and windows being so small. The north south position of the window is for the ventilation purpose. Another reason of the windows and doors being so small is for protection from forest animals.

5.2.6. Structural Material:

All of the houses in the Marma community in the study are made of bamboo, wooden posts, chana and corrugated sheet (tin). The trunks of certain timber species, from which the bark is stripped, serve as the main posts and major crossbeams of a Marma house. The two most common species used in construction are Gamar (*Gmelina arbora*), Gorjon (*dipterocarpus turbinatus*) and Silkoroi (*Albizia procera)*.

Durability and resistance to bio-deterioration of the species are the main reasons the tribal people use these timbers. For example Gamar shows no degradation after long periods of use and dimensionally stable. What is interesting is that although the tribes use these materials based on their transmitted traditional knowledge but are unlikely to be aware of the scientific reason.

5.3. Zoning and functions of the building form

5.3.1. Zoning

The zoning, functions and section of the building form spaces are shown in the figure 13. The houses are typically in east-west orientation. The house entry is either on the east side or west side. There is a ladder in the entrance in every house. The ladder is known as 'Shegrang'. In the entrance they have an open space or balcony type space which they call 'Tamang'. The functions are divided into several rooms such as, balcony (tamang), bedroom or multipurpose room (uingdong), kitchen (thamakhauing), store (tongthach), toilet (khijirung) and cattle shed (chichang). In figure 12 a typical elevation is shown with the indigenous material utilization in the built form.

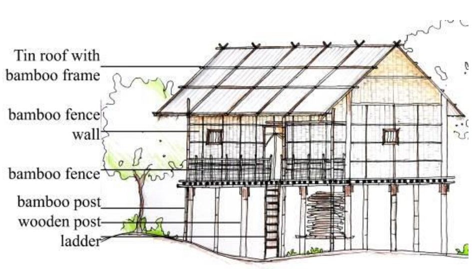

Figure 12: Typical front elevation of the archetype

In the selected site for the north south orientated road the houses are aligned in east west direction. Generally they always try to build their house with an entry from the east because the sun being one of their Gods, every morning they want to start their journey in the earth with having a look of their God when they wake up and open their eyes. For that reason the houses are basically east facing.

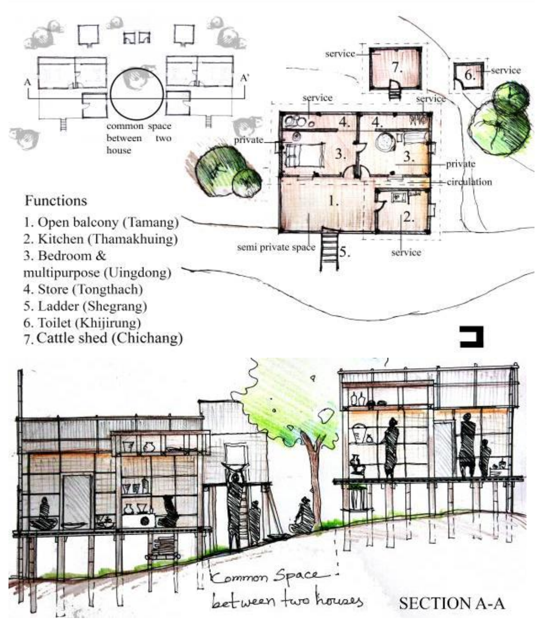

Figure 13: The Plan, zoning and common space section of the archetype

They use the ladder for climbing the macha and the position of the ladder is generally on the entrance in east or west direction.

The open space or balcony space is used for gathering purposes and working purposes. For the intimate relationships among the Marmas these balcony or open spaces are very spacious and important to them.

The other functions are divided in other separate rooms as per necessity. The rooms are not very large as they use most of the house spaces in the balcony or open space. The orientation of the bedroom is north-south facing for ventilation purposes.

5.3.2. Services (kitchen & toilet)

Kitchen is situated within the house. It is a totally separate room on the elevated platform (macha). The minimum kitchen dimension is 5'x6'. The Marmas use mud oven in their kitchen firewood as fuel. The roof and wall of the kitchen are separated.

Toilet is generally situated 15 to 25 feet away on the backside of the house. Each family has one sanitary toilet. Their main sources of water are the preserved well, tube-well and the creeks.

The kitchen room is made separated for privacy concerns and for ventilation reasons. As a result the roof and wall of the kitchen are totally separated.

For the liberal nature of the settlement a minimum privacy is given. But the latrine site is always screened off by ample thick foliages and shrubs. They don't feel the need for any enclosed bathing area as the male members bathe and wash in the stream or river and the female members take bathe in the downstream.

5.3.3. Working zone

The open balcony is used for crop drying and family gathering space. Net weaving, knitting are one of their main professions. Weaving process requires very little space and the instruments are also light and small, mostly of wood and bamboo. Husking pedal once was used in the backyard of the house but presently it is not seen.

The space under the macha is used for storing firewood, instruments for jhum cultivation like chopper, spade etc.

They keep their domestic animals like cow, goat, chicken, pig, ducks and pigeons in the backyard in a separate room (chichang).

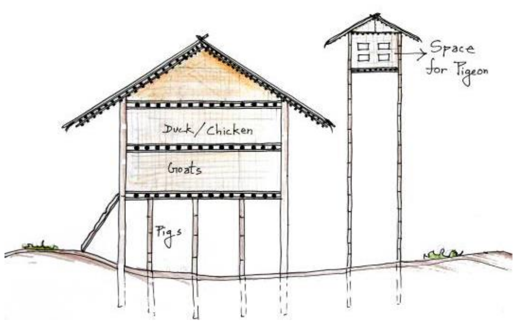

Figure 14: section of domestic animals shed

In the animal shed, the chickens and ducks are kept on the upper level and the goats are kept under them as the goats need to be put in a dry place. For pigs they use the space under the macha for it stays in the mud and for pigeons they make another small elevated room alongside the chichang. In figure 14 the section of the animal shed is shown.

5.3.4. Religious space & decoration

The main religion of Marma is Buddhism. The prayer space is usually situated in an elevated altar in the room.

For decoration purpose local materials are used. Various flowers, horn of animals etc. are seen on the wall.

5.4. Technological influence

In recent times, the use of solar panel is seen among the Marmas as power source. Advancement in technology has affected the Marma community as use of various gadgets, like lights, fans, cell phones etc. are now common among them.

5.5. Economic influence on the settlements

Most of the locals of the villages are from poor background and have a few belongings and ornaments. Their occupation also has a very limited economic return. Majority of the Marmas do field works, knitting and weaving.

The most surprising finding is that the cost of construction of a house is practically zero. The bamboo, chan and wooden poles are easily cut from the hills and the whole family helps in building which is complete within four to five days. Major repairing and re-roofing are needed after two to three years.

6. DISCUSSION

The field survey was conducted in different parts of Naikyongchora, Rajostholi upazila under Rangamati district. The cluster's road is linear in some places and curvy in some places in accordance with the geographical context of hilly areas. But all the houses are in linear arrangement alongside the roads. The application of new structural techniques, modern materials in housing which are more sustainable is an example of their adaptation to the modern world and urbanization. But there are also many local families in the hilly areas who still maintain their old traditional housing pattern. In figure 15 the construction process with the featured architectural elements are shown.

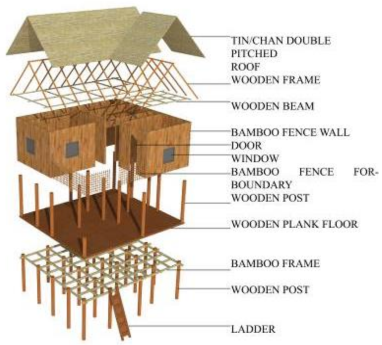

Figure 15: Construction process with the featured architectural elements of the Marma dwelling

The field survey and observations suggest maintaining the old traditional techniques in their housing pattern as it is more effective, simple and sustainable for a hilly region. Uses of tin instead of chan on the roof, wooden door instead of bamboo fencing are some examples of their housing development. But the basic of structure pattern hasn't changed that much over time; the wooden and bamboo posts as pillar, wooden beams and double pitched roofing system, the elevated platform (macha), bamboo fence in the walls are still the basic requirements in their housing system. All these made of their indigenous materials which keep their houses simple yet sustainable. So, it can be said that this vernacular architecture pattern is adopting modernization but not changing the basic structural tradition.

7. CONCLUSION

From the above study it can be seen that the archetype of Marma ethnic group has developed some structural techniques and the use of local indigenous materials to adapt themselves to the geographical and environmental conditions of the terrain. The Marma people are carrying out their way of living for generations which affect the surrounding environment at a minimal level. Socio-cultural conditions of the Marmas has a great impact on their housing pattern like, the use of open balcony, working together on the macha, having a common space in the cluster etc. The dimensions of Marma with various physical and spatial qualities of its related time involves with complementation of various cultural roots. The archetype of Marma vernacular architecture should be widely studied for their vernacular features which show the way of living green and should be analysed before designing any kind of settlement in the hilly region. This study on Marma vernacular architecture can be evaluated as guidance in designing built form in Chittagong hill tracts. The field and literature study with direct observation on the traditional Marma vernacular architecture of this paper can be further utilized in evaluating the changes of Marma vernacular architecture over time.

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EVALUATION & VALIDATION OF INDOOR AIR TEMPERATURE FOR DIFFERENT LEVELS OF A MULTI-STORIED OFFICE BUILDING IN THE TROPICS

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Abstract: *From the case study and previous findings, it has been identified that in the urban area, there is a growing trend of constructing multi-storied office buildings with noticeable amount of glass facades. These buildings with their glass facades act as heat box, which afterward affects the thermal comfort of the occupants of those buildings. Therefore, vertical distribution of air temperature becomes an important aspect of indoor environment, which must be taken care by architects and engineers for designing multi-storied office building in an urban area. The main objective of this research is to analyse the vertical indoor air temperature distribution of a multi-storied office building, situated in an urban area of Chittagong city, Bangladesh. In the first step of this study, the air temperature of a multi-storied office building has been monitored in different heights for three days by using the infrared temperature monitoring sensor and data logger. Mathematical analysis has been conducted in the second step for the evaluation of existing monitored data. From the field monitoring, it has been identified that the air temperature has been increased from ground floor to upper floor with a range of 3.8-4.2°C (average). The maximum air temperature deviation has been found for the uppermost floor level where the direct solar radiation reflected on the roof. This study will contribute to a better understanding of indoor air temperature of a multi-storied office building in tropics.*

Keywords: *Air temperature, Office building, Thermal comfort, Tropical climate.*

1. INTRODUCTION

As a consequence of rapid urbanization, the demands for multi-storied office buildings are growing day by day. There is a growing trend of constructing these buildings with large proportion of glass for higher transparency, better view, and creating distinctive images [1-3]. The energy efficiency and the thermal performance of these glass facade buildings are often questioned. High glazed office buildings having risk of higher energy use for heating and cooling with poor thermal comfort [2-5]. A poor thermal environment has negative consequences on productivity in tropical buildings [2] [3]. Building height also has a significant effect on surface temperature which later influences thermal comfort of the occupants [6-8]. Hence, the objective of this research is to compare the vertical indoor air temperature (T_i) ºC distribution of a multi-storied office building in different levels. The result of this research can aid better understanding of indoor air temperature of a multi-storied office building. This research is based on thermal issues like indoor-outdoor air temperature (T_i-T_o) ºC, indoor air velocity (V_s) ms^{-1} and relative humidity (RH) %.

2. CLIMATE CONSIDERATION

This research is conducted in Chittagong, Bangladesh within tropical region. The weather of Chittagong is characterized by tropical monsoon climate.

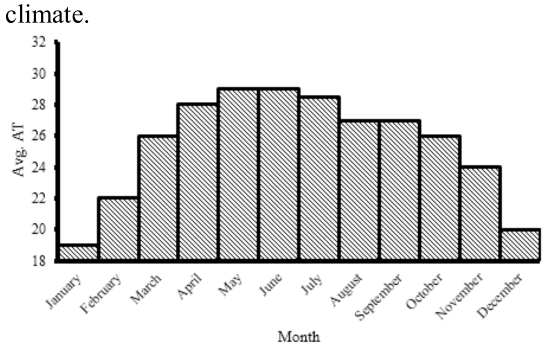


Figure 1: Average AT in Chittagong, Bangladesh

The dry and cool season is from November to March, pre monsoon season is from April to May which is very hot. The sunny and monsoon season is from June to October, which is warm, cloudy and wet. Fig.1 shows average min and max temperature in Chittagong and the hottest months are March, April and May respectively. Fig.2 and 3 show the average wind speed and relative humidity of Chittagong [7-9].

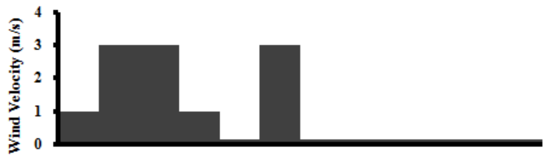


Figure 2: Average wind speed (ms^{-1}) in Chittagong, Bangladesh

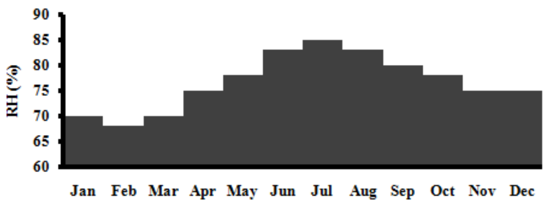


Figure 3: RH (%) of Chittagong, Bangladesh

3. RESEARCH METHODOLOGY

In the first step of this study, the air temperature of a multi-storied office building has been monitored in different heights for three days by using the infrared temperature monitoring sensor and data loggers. Parametric evaluations have been conducted in the second step for the prediction and validation of existing monitored data. In the first step of the study, T_i (°C), V_s (ms^{-1}), RH (%) was measured in three different height of a multi-storied office building by using Lutron LM. 8102 environment meter. Fig.4 shows the multi-meter which has a speed range of 0.4 to 30 m/s (Anemometer) and RH is 10-95% with Temperature sensor.

Figure 4: Lutron LM 8102

The field survey was conducted in a multi-storied office building with a floor area of 670m^2 and located in Muradpur, Chittagong, Bangladesh. The survey data were collected for three different days in between 13-20 February 2017. Daily T_i, V_s, RH was recorded at three different points of a floor at one hour interval manually from 11.00 to 16.00 corresponding to the office hours. Level 2, level 5 and level 9 were selected for the experiments with almost identical plan layout where desk work was the main function. Three points, two near exterior wall two ends (2' from wall) and one at the middle of the building were selected for data collection. Fig.5 shows the interior spaces of the selected points where the windows allow external wind flow through the spaces. Although some of the rooms were equipped with Air Conditioner (AC) and ceiling fan, all mechanical ventilation systems were switched off during the monitoring to allow the effect of natural wind flow. The data collection was done manually with the device being 3' from floor level in a handheld position. Due to limitation of measurement devices and the circumstances of the office, 20 minutes time lags in data collection among three levels have been considered.

Figure 5: interior spaces of three selected points

The structure of the research work is shown in figure 6.

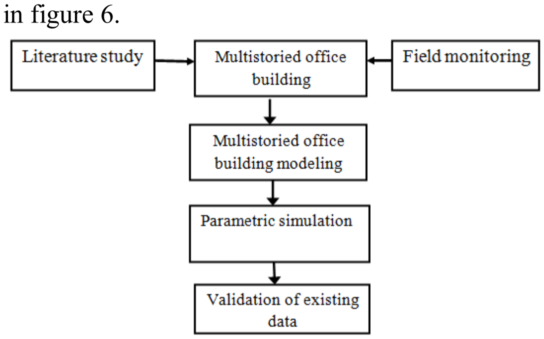


Figure 6: Structure of the research work

Finally, for more accuracy, parametric studies have been conducted with the building simulation engine EnergyPlus (E^+) for the summer design days (Chittagong, Bangladesh) to differentiate of indoor air temperature.

4. BUILDING SELECTION CRITERIA DESCRIPTION

Board of Intermediate and Secondary Education, Chittagong was selected for this study for several reasons. The reasons being, the building is North-South oriented with typical type of sliding recessed glass windows, the rectangular plan with no more than three segmentations which represents the common attributes of multi-storied office building in terms of stories and shape and there is no other notable high rise or midrise structure in the immediate context of this building, as result, air and day light can easily penetrate into the building's indoor, which is the most important considerable part of this study. Here, Fig.7 shows the site location of the building which is located at Muradpur, Chittagong.

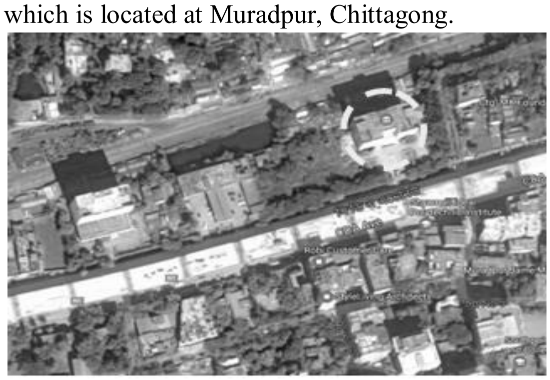


Figure 7: Site location of the building

It is the administrative building of Chittagong Education Board with ten levels and a floor area of 670m^2. Fig.8 and 9 illustrate the typical floor plan and elevation of the surveyed building.

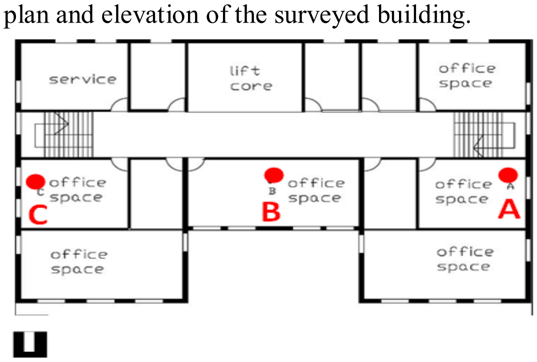


Figure 8: Floor plan of the office building with the measurement points (A, B, C) during the survey

Figure 9: South and North side of the building

Fig.10 shows the 85m long corridor around which the functions are grouped with stair at two ends. The services as lift core and toilets are placed at the north side. Ground floor and first floor contains archive, storages, and bank. Regular office work is held at level 2 to level 7 and level 9 with an even plan layout for all these levels.

Figure 10: Central corridor of the building

Fig.11 (a) indicates level 8 with an open plan layout which holds different meetings and seminars. During the survey (Fig. 12) there were 100 to 120 no's people working in the office each day. The office hour was 9.00 to 17.00 from Sunday to Thursday (Fig. 11b).

Figure 11(a): Interior of level 8 of the building

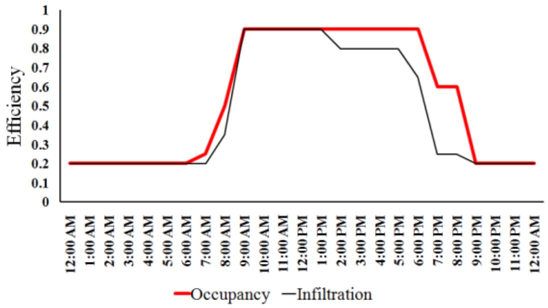


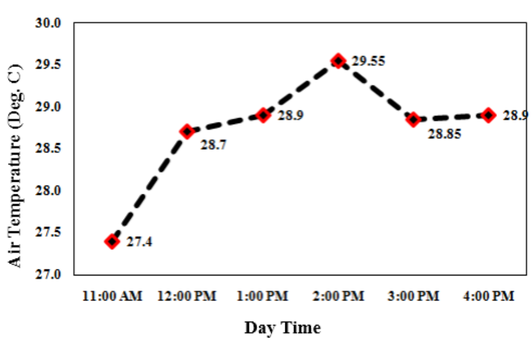
Figure 11(b): Scheduling of working day

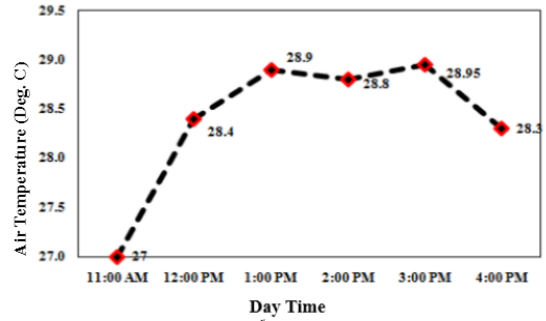
Figure 12: Field Monitoring

5. DATA MONITORING & ANALYSIS

From the monitoring and data analysis, it has appeared that T_i reaches its peak between 1.00PM to 3.00PM and falls gradually from that time keeping pace with T_o. Fig.13 shows the T_i data for point A at different level. Fig. 13 presents the air temperature of the selected building. At point A (Fig. 8) which faces east, the maximum value was recorded at 2.00PM about 29.55ºC whilst the minimum was at 11.00AM 27.4ºC in Level-2. In Level-5, the maximum value was recorded at 3.00PM about 28.95ºC and the minimum was at 11.00AM about 27ºC. For Level-9, the maximum value was recorded at 1.00PM about 29.5ºC and the minimum value is at 11.00AM& 4.00PM about 27.6ºC.

[Here, X Axis = Air Temperature; Y Axis = Day Time]





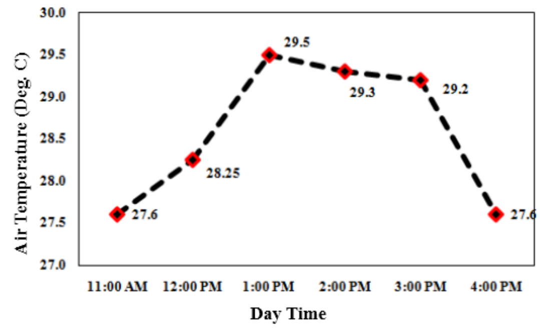
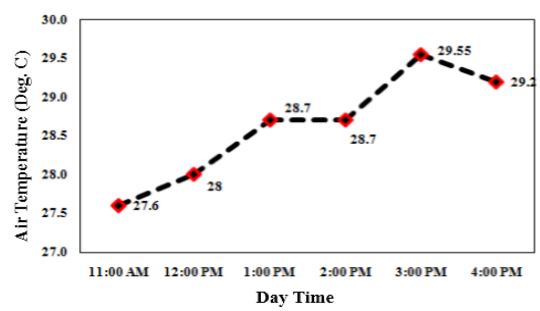
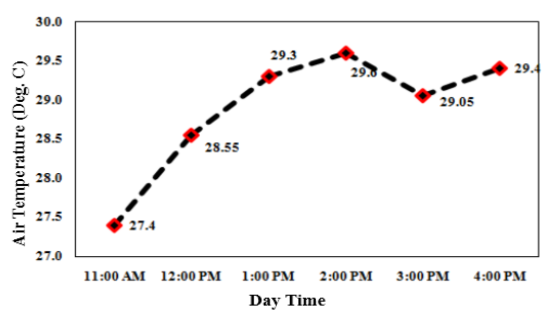


Figure 13: Indoor air temperature distribution of point A (level 2, 5, and 9 respectively)

From Fig. 14, it has been illustrated that at point B (north), the maximum value was recorded at 3.00PM about 29.55ºC and the minimum was at 11.00AM about 27.6ºC in Level-2. In Level 5, the maximum value was recorded at 4.00PM about 29.4ºC and the minimum value was at 11.00AM around 27.4ºC and in Level-9, the maximum value was recorded at 1.00PM about 29.3ºC and minimum temperature was at 11.00AM about 27ºC.





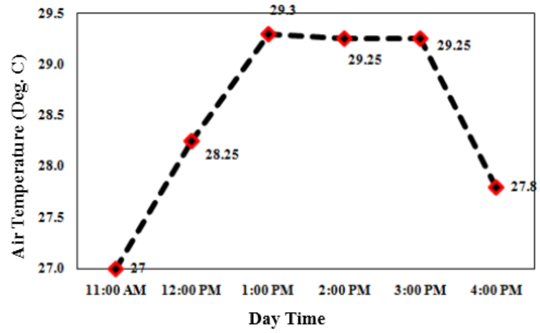


Figure 14: Indoor air temperature distribution of point B (level 2, 5, and 9 respectively)

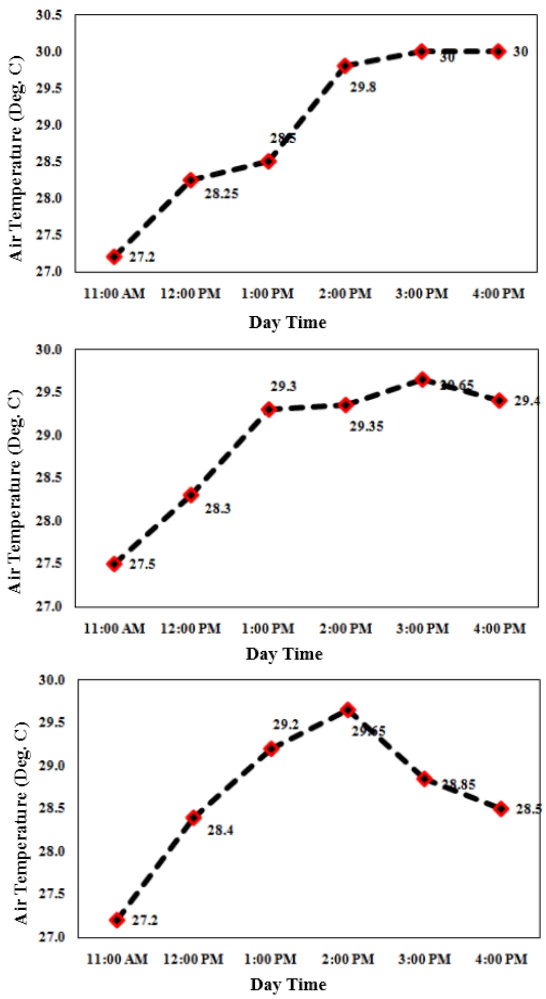
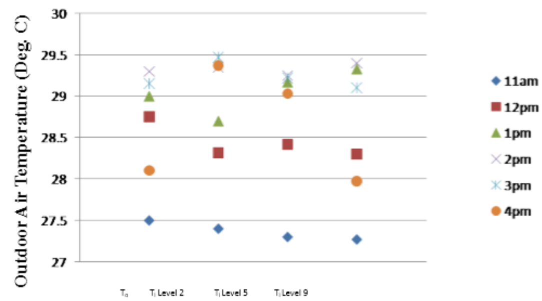


Figure 15: Indoor air temperature distribution of point C (level 2, 5, and 9 respectively)

At point C (Fig. 15) which faces west, the maximum value was recorded at around 3.00PM-400PM about 30ºC whilst the minimum was during 11.00AM about 27.2ºC in Level-2. In Level-5, the maximum value was recorded at 3.00PM about 30.65ºC and minimum was at 11.00AM about 27.5ºC and for Level-9, the maximum value was observed at 2.00PM about 29.65ºC and minimum value was recorded at 11.00AM about 27.2ºC.



[Here, X Axis = Indoor Air Temperature; T_i; Y Axis = Outdoor Air Temperature; T_o and Level 2, Level 5, Level 9)]

Figure 16(a): Outdoor and indoor air temperature (T_o-T_i) comparison

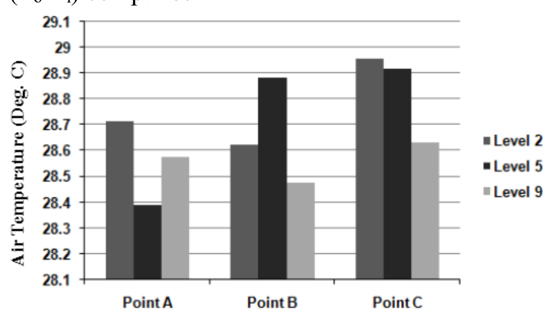


Figure 16(b): Average air temperature (TºC) comparison between different levels

Fig.16 (a) indicates the comparison between average outdoor temperature (T_o) record during survey (13-20 February 2017) and indoor air temperature (T_i) at different building floor levels. The comparison of T_i between different levels at different points (A, B, C) has been shown in Fig.16 (b).

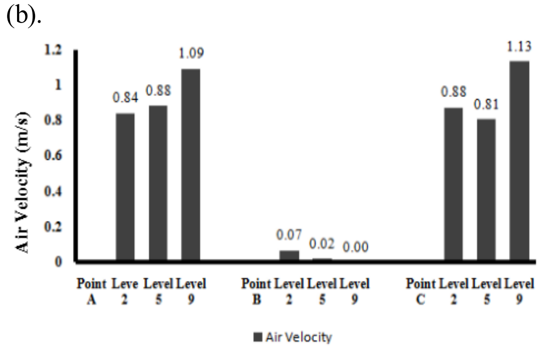


Figure 17: Comparison of Air Velocity (V_s) of different point

Fig.17 shows the comparison of air velocity of different points, at point A, B and C; level 9 V_s was higher than other two levels. At point B, V_s was significantly lower because of its position.

Here, Fig. 18 represents the comparison between T_i and RH data for point A at different levels of a day. From the survey data, it appeared that the RH (%) value falls gradually from 11.00AM to 1.00PM with the increase of T_i. Lowest RH was recorded between 1.00PM to 3.00PM when the T_i reaches to its peak. From 3.00PM RH value gradually increases. From the comparison, it was observed that, RH value changed gradually which was inversely proportional to T_i for level 2 and 6. On the other hand, the variation and fluctuation of RH value was very small at 11.00AM to 1.00PM for level 9.

[Here, X Axis = AT ºC and RH; Y Axis = Day Time]

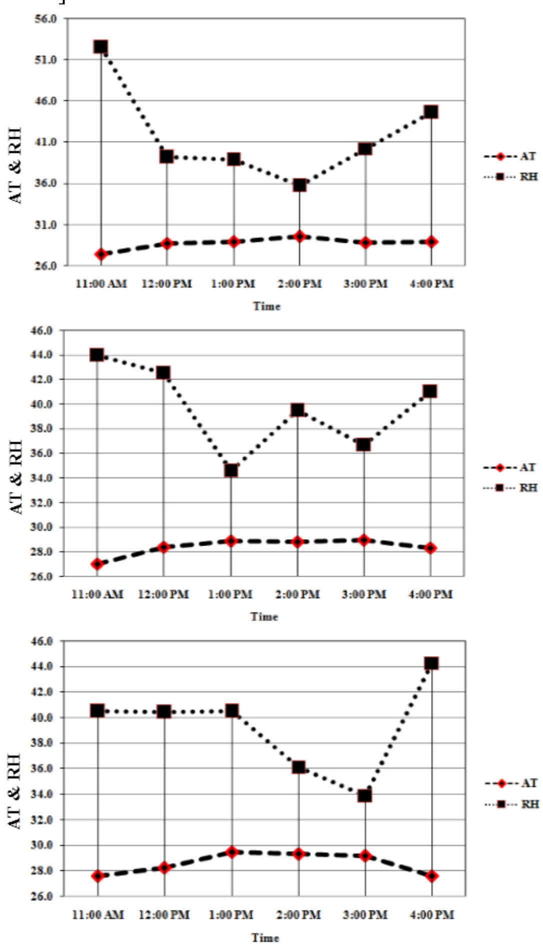


Figure 18: Comparison of T_i and RH for point A

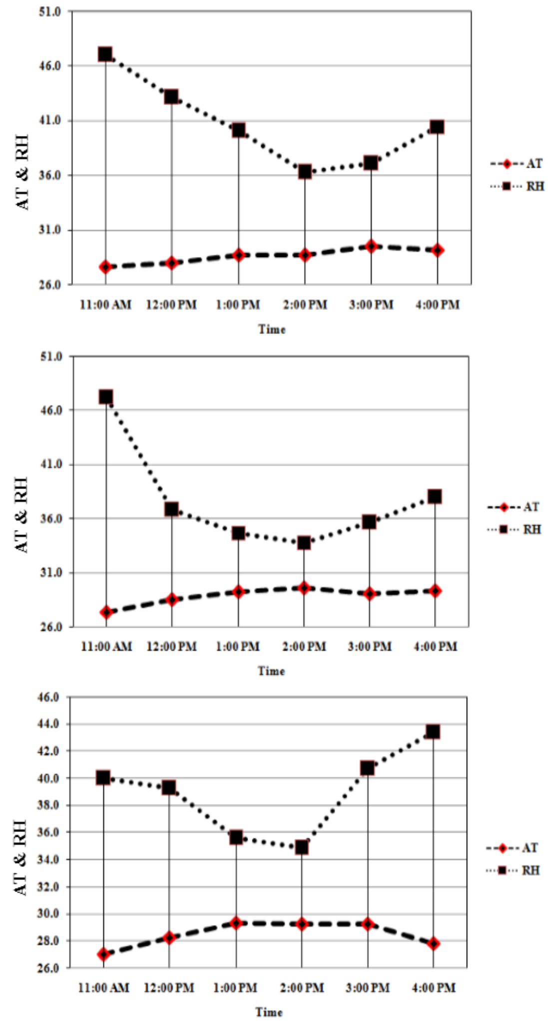


Figure 19: Comparison of T_i and RH for point B

Here, Fig. 19 represents the comparison between T_i and RH data for point B at different levels of a day. Lowest RH value was recorded at 2.00PM in different level. For level 2 and 9, the variation of RH values was gradual which was inversely proportional to T_i. For level 6, the variation of RH value was very low between 12.00PM to 3.00PM and highest average RH value (40.6%) was recorded at level 2 which gradually decreased for upper levels. From the data analysis, it was identified that the RH values decrease gradually from 11.00AM to 12.00PM with the increase of T_i. Less variation of RH values was initiated between 2.00AM to 3.00PM.

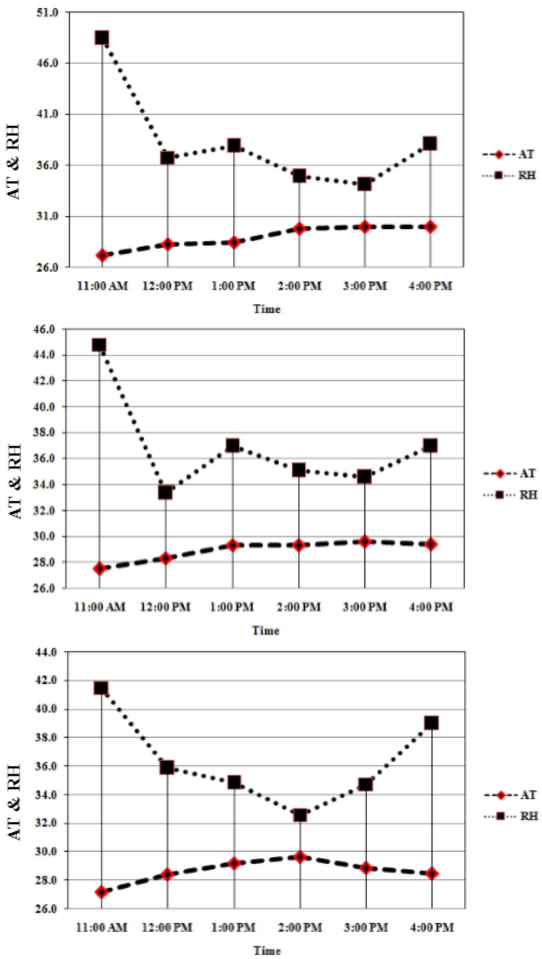


Figure 20: Comparison of T_i and RH for point C

Only for level 9 the variation of RH values was gradual than the other 2 levels. Highest average RH value (38.3%) was found at level 2 which decreased gradually for upper levels. The results show a significant relationship between RH and T_i.

6. ANNUAL SIMULATION & PREDICTION

The Fig. 21-22 shows the relationship between mean air temperature value and comfort level with percentage for the whole year that obtained from the overall energyplus (E^+) simulation. This monthly relationship represents from statistical analysis where AT and comfort band are the main variables. The simulation was performed for year long duration where each study gives 168×365 hourly outputs. In this study temperature gradients and three building zones used. The figure represents significant outcomes. In this study, it has been observed that April-August indicates the hottest month according to the comfort criteria and indoor temperature rises about 45ºC almost 24% of the whole year.

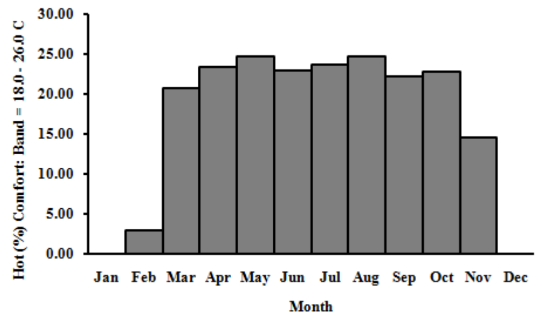


Figure 21: Annual comfort simulation

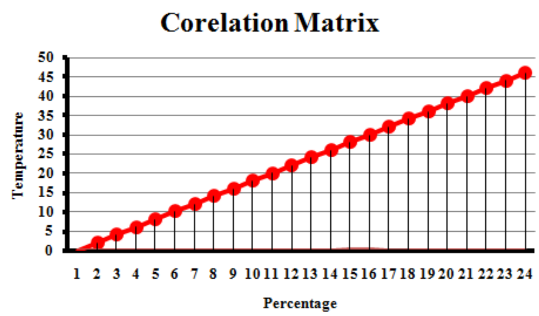


Figure 22: Co relational matrix for indoor thermal comfort

For a mean temperature value less than 35ºC then standard deviation will be around 2.0 whereas a temperature with a value more than 35ºC reflects higher standard deviation ranges from 3.0 to 4.0.

7. DATA VALIDATION

For more accuracy a comparison was conducted between E^+ generated weather data for Chittagong city and Actual Meteorological Year (AMY) generated from Met Office, Bangladesh [8-11]. From the comparison, it should be noted that at the time of the field measurements, T_o accuracy was an avg. 0.18ºC higher than E^+ generated weather data. On the other hand, the maximum difference of T_o was found about 1.95ºC and RH (%) varied about 4-5%. The changing pattern of outdoor AT observed approximately same in all conditions. Maximum Standard Deviation (SD) was observed for AT (ºC) not more than 1.18 (0.6 Avg.) and 5.28 (3.10 Avg.) % for RH. From this analysis, it was noted that the uncertainty and average errors that have been occurring in the result of the parametric studies not more than 0.10±0.85°C (AT) ºC and 0.75±3.10 % (RH) in an acceptable range.

8. SCOPE & LIMITATION

The research work presented in this study concentrates on performance evaluation of indoor thermal comfort of a typical multi storied office building in Chittagong city. Mainly AT and RH have been considered for the research study only. Some degree of uncertainty has been presented in the data collections during field investigations due to leakage of air flow between the roof and the envelope. However given the limited time and scope of study, this research has been concentrated on the thermal issues only. The performance of workers and productivity regarding HVAC system, heating, cooling, ventilation, lighting issues, acoustics, insulation, safety and security are beyond the scope of this research [12-16].

9. CONCLUDING REMARK

This study was based on field experiments and observations regarding indoor thermal evaluation and comparison. It may be noted here that the paper is based on just one building measurements so it is very difficult to draw conclusions and require more monitoring and evaluations. Hence, from these experimental data, several findings relevant to indoor thermal range for office activity were identified for different building levels. Based on the analysis of the result from the investigation described above, the followings major observations can be drawn:

a. Indoor temperature fluctuation at upper zone is relatively higher than lower zone of an office building during peak working hours.
b. Value of T_i, RH and V_s for various indoor spaces has significant deviation and indoor heat fluctuation for different zones.
c. Air temperature is increased from ground floor to upper floor with a range of 3.8-4.2°C (average).
d. The maximum air temperature deviation is found for the uppermost floor level where the direct solar radiation reflected on the roof.
e. If there, higher mean temperatures exists (inside circle) fluctuation is more than the lower mean temperature values.

Finally, this study will contribute to a better understanding for the architects of indoor air temperature fluctuation scenario of a multi-storied office building in tropics and for more accuracy, further detail research regarding this issue should be considered necessary.

ACKNOWLEDGEMENTS

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COMPARATIVE STUDY OF THERMAL INSULATION COATINGS TO MODERATE THERMAL PERFORMANCE OF BUILDING

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Abstract: *The continuous growth and careless development of the urban environment has a major impact on the urban microclimate. Application of high reflective coating has found effective in reducing surface temperature especially during daytime. This paper presents the results of a comparative study aiming to investigate the effect of reflective coatings on lowering surface temperatures of the urban environment, and thus test their suitability for lowering indoor temperatures and energy consumption. Six reflective coatings, selected from the international market and an uncoated concrete block was compared. A high stability controlled air temperature and relative humidity (RH) environment chamber was used to carry out the experiment in two steps: steadying the state for 6 hours, where temperature and RH remained constant; and periodic experiments for 48 hours (two cycles of 24 hour), where the chamber was set to simulate the weather conditions corresponding to the summer days of hot humid climate. The study shows that lighter thermal insulation coatings have higher albedo and lower heat flux which can reduce the surface temperature up to 6.9°C than the uncoated one. From this understanding Predicted Mean Vote (PMV) level for a small room was simulated numerically with the realistic climatic condition of Dhaka, Bangladesh to analyze the effect of insulation coatings on thermal comfort of the occupants. This study can support in choosing more appropriate coatings for building envelopes and contribute to moderate the thermal performance and energy efficiency of the building.*

Keywords: *Thermal insulation coatings, Surface temperature, Thermal performance, Thermal comfort.*

1. INTRODUCTION

The temperature of cities are continuing to increase because of the heat island phenomenon and the undeniable climatic change. Summer urban heat islands with daytime average air temperature difference between urban and rural areas can be 5–15 °C [1]. The observed high ambient temperatures intensify the energy problem of cities, deteriorates comfort conditions, put in danger the vulnerable population and amplify the pollution problems. To counterbalance the phenomenon, important mitigation technologies have been developed and proposed [2]. Among the causes that contribute to the heat island effect, surface properties, i.e. roughness coefficient and solar reflectivity play a very important role [3]. Applying the high reflective coating could be one method to reduce heat storage by improving reflectivity of the material. This method has found effective in reducing surface temperature specially during daytime [4, 5].

In this paper, the basic performance of surface temperature of six reflective paints ware investigated by chamber experiments. Temperature rise of the surface was measured and compared to that of an uncoated concrete in reference with the experimented data. The spectral reflectance and albedo of the samples were measured to further investigate the relationship with the temperature difference and albedo of the samples. Then the Predicted Mean Vote (PMV) analysis have been performed for a small room in order to identify the cooling potential and the possible improvements of indoor thermal comfort caused by application of insulation coatings under the realistic climatic condition of Dhaka, Bangladesh.

Table 1: Specification of selected samples

No.	Sample Description	Color	Origin	Albedo
S1	Uncoated Concrete		Japan	0.19
S2	Infrared reflecting coating	Dark Brown	Asahipen, Japan	0.18
S3	Infrared reflecting Waterproof coating	Light Green	Asahipen, Japan	0.28
S4	Infrared reflecting coating	Sky Blue	Asahipen, Japan	0.24
S5	Infrared reflecting coating	White	Asahipen, Japan	0.73
S6	Dirt Resistant Coating	White	Asahipen, Japan	0.69
S7	Synthetic Resin Spray Coating	Silver	Aspen, Japan	0.58

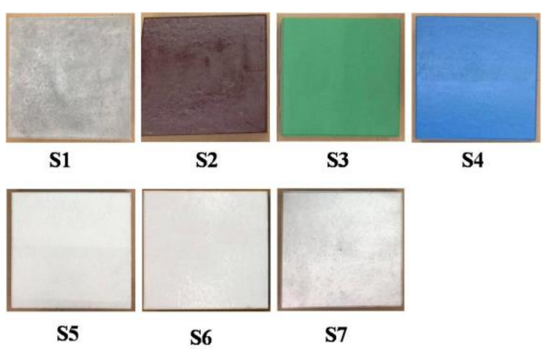

Figure 1: Tested samples

2. STEADY STATE EXPERIMENT

2.1. Description of the selected coatings

Six reflective external surfaces coatings were applied on 30cm x 30cm x 5.5cm concrete blocks and experimented. An uncoated concrete block was also studied as reference. The specifications and albedo measured by pyranometer of selected samples are presented in *Table 1*. The pictures are shown in *Figure 1*.

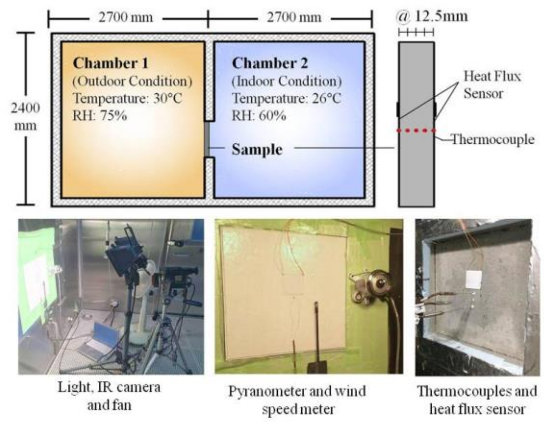

Figure 2: Experimental arrangements

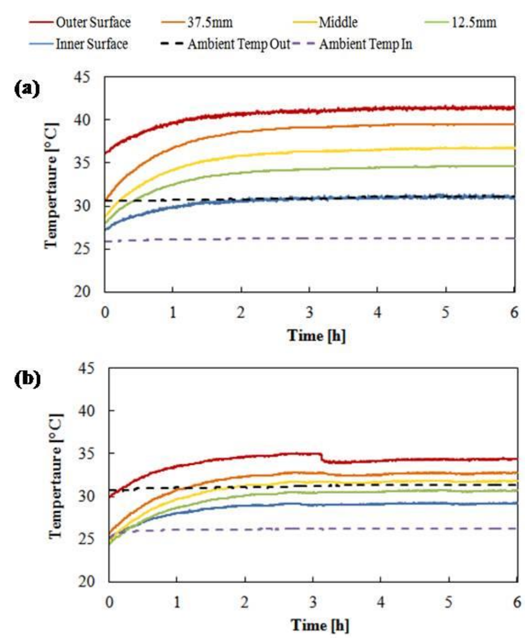

Figure 3(a)-(b): Thermal performane of S1 and S5

2.2. Experimental site and Methods

A high stability controlled air temperature and relative humidity (RH) environment chamber (W2700 x H2400mm x D2400mm) was used to carry out the experiment. Chamber 1 was set as outdoor climate condition with 30°C temperature and 75% RH. Chamber 2 was set as indoor climate with 26°C temperature and 60% of RH. The thermal performance of the samples was measured in the chamber for six hours to achieve the steady state. The basic experimental setup is shown in *Figure 2*. Equipments used in the experiment are listed in *Table 2*. Instantaneous values were measured and saved on a data logger every 10 seconds. Comparative temperature measurement of the outdoor surface was also made with an infrared camera with 10 minute interval. During the experimental period, wind velocity was controlled between 0.6 to 0.7 m/s by one fan in outdoor chamber. Two halogen lamps (Promate, 500W) were placed 1.5m away and approximately at 45° angle with a radiation of around 750 W/m².

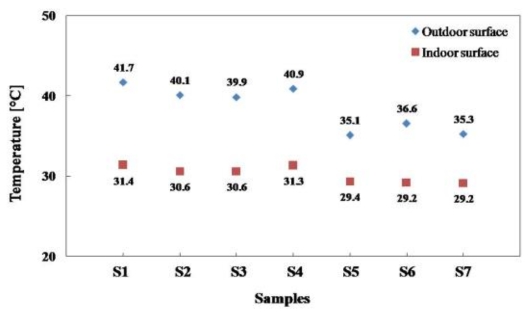

Figure 4: Thermal performance comparison from steady state experiment

3. PERIODIC EXPERIMENT

Temperature changes under actual weather conditions involve several factors, for example, variation of temperature and relative humidity from day to night time, and solar radiation. Therefore, periodic experiment was introduced to include these important factors of climatic boundary conditions.

3.1. Materials and methods

The materials measured in the steady state experiment were again used to investigate their performance in the periodic experiment. In one cycle (24 h) of the experiment, the environment of the chamber was set to simulate the weather conditions corresponding to one day. Two cycles, a total of 48 h, were carried out for each material.

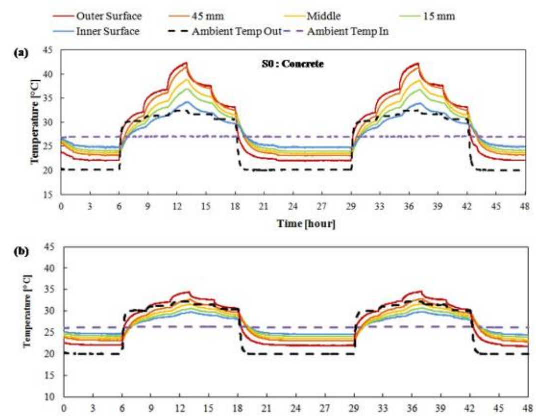

Figure 5(a)-(b): Thermal performane of S1and S5 from periodic experiment.

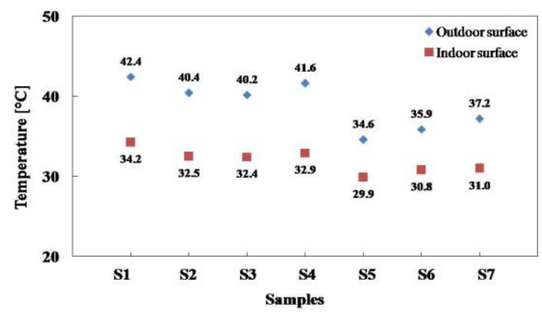

Figure 6: Thermal performance comparison from periodic experiment

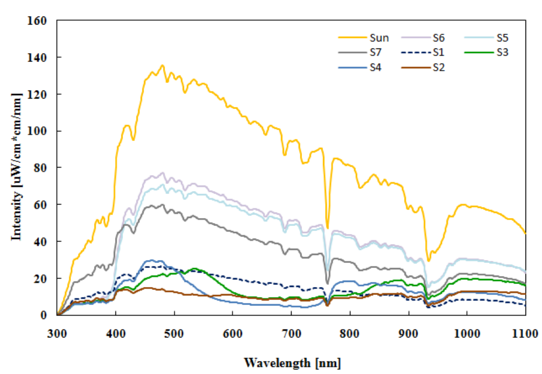

Figure 7: Natural solar spectral reflectance

The environmental conditions of the left chamber were changed in three stages: (i) at the first 6 h, air temperature and RH were kept constant at 20°C and 85% respectively and the lamps were turned off. (ii) From the 6th to 18th hour air temperatures and RH was maintained to 35°C and 75%. During these hours, three lamps were turned on sequentially at 2.5 hour interval to simulate solar radiation at approximately 650 W/m². (iii) At the last stage, all the lamps were turned off and air temperature and relative humidity were changed to 20°C and 85% respectively. Right chamber was kept in a constant condition of 26°C temperature and 60% RH throughout the whole cycle. Wind velocity in outdoor chambers was maintained constantly at 6- 6.5 m/s at every cycle.

4. RESULTS AND DISCUSSION

Figure 3(a)- 3(b) show temperatures measured from 5 different depth of S1 and S5. It shows the temperatures reach steady state approximately within four hours and remain stable onwards. The comparison of outdoor and indoor temperatures is given in *Figure 4*. The white coloured coatings in general have the ability to reduce the surface temperature of the concrete block. The minimum value for outdoor surface was found for white infrared reflecting coating (S5), which can reduce the temperature up to 6.6°C than the uncoated concrete. The minimum inner surface temperature value was found 29.1°C for dirt resistant white coating (S6) and synthetic resin silver spray (S7) which can reduce the temperature up to 2.2°C than the inner surface of uncoated concrete.

Figure 9(a)-9(b) show temperatures measured at different depth of uncoated and white paint applied concrete block. The estimated outdoor and indoor temperature for each coating sample is given in *Figure 11***.** It shows that the white coloured coatings in general have the ability to reduce the surface temperature. The minimum value for outdoor surface was found for white uneven thermal barrier coating (S5), which can reduce the temperature up to 7.8°C than the uncoated concrete. The minimum inner surface temperature value was also found for S5 which can reduce 4.3°C than the uncoated concrete.

For better understanding of solar reflection capability solar spectrum analysis was done. As shown in *Figure 6*, the white coatings have higher reflectance that can reflect a major part of the light and also appear to stay cooler. It shows higher albedo paints can reduce more surface temperature.

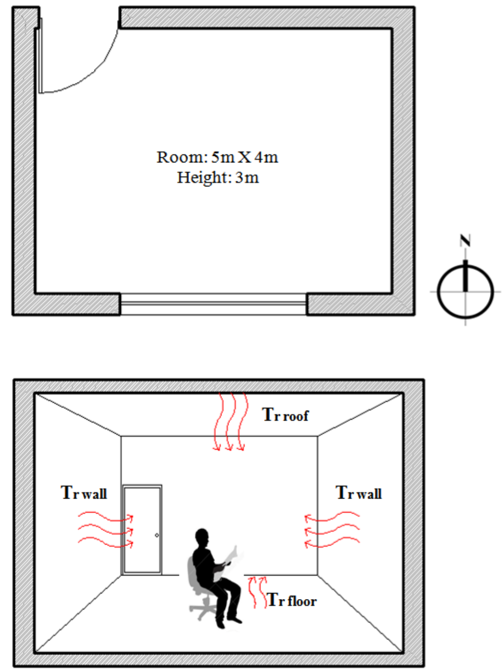

Figure 8: Thermal comfort analysis for simple room condition

5. PREDICTION OF THERMAL COMFORT MODERATION LEVEL

To understand the moderation of thermal comfort for Dhaka's climate condition and analyse the effect of the coating the PMV for a 5m x 4m x 3m room with one door on the north side and one window at south were calculated. The occupant was assumed as sitting at the centre of the floor and doing some lightweight activities. Malchaire Analysis were used for calculating the PMV. Figures 5-26 show the view of the interior space.

Place: Dhaka
Month: April
Artificial light: No (as the calculation was done for daytime only)
Occupants: One person (lightweight work)
Window: (1.5m x 3m) on south wall, single glazed

Door: (1m x 2.17m) on north wall
Average outside temperature at 9 AM (T^o): 33ºC
Albedo of concrete wall surfaces (a): 0.54
Outside heat transfer coefficient h_c: 6.4 W/m2 -K

Average solar radiation on south wall (9am) Is: 314.161 W/m^2
Average solar radiation on east wall (9am) Ie: 314.161 W/m^2
Average solar radiation on north wall (9am) In: 135.478W/m^2
Average solar radiation on west wall (9am) Iw: 135.478W/m^2
Average solar radiation on roof (9am) Ir: 500W/m^2
Average solar radiation on window (9am): 314.161 W/m^2 (no shading)

The temperature of outdoor surface were fond from following equation.

$$T = To + (1\text{-}a) \times I/h_c)$$

Here,

T = Outdoor surface temperature (°C)

T_o= Outdoor air temperature (°C)

a = Albedo (-)

I = Solar intensity (W/m²)

From this temperatures indoor surface temperature was derived from following equation

$$Ti = (hc^* \; To + \frac{\lambda \; X \; Ts}{dx}) \; / \; (hc + \frac{\lambda}{dx})$$

Here,

Ti = Indoor surface temperature (°C)

λ= Thermal conductivity (W/m.K)

dx = Thickness of the wall (m)

South Tsi = 38.65ºC
east Tei = 38.65 ºC,
North Tni= 33.59 ºC,
West Twi =33.95 ºC,
Door Tdi = 6.25 ºC
Glazing Tgi = 39.85 ºC and
Roof Tri = 43.54 ºC

Indoor radiant temperature was calculated from following equation:

$$Tr = \frac{\sum T_1 \times A_1 \ldots\ldots\ldots\ldots T_n \times A_n}{\sum A}$$

In a similar way indoor radiant temperature is calculated for 6:00 AM, 12:00 PM, 3:00 PM and 6:00 PM for both uncoated concrete and white coating and input into Malchaire Analysis for achieving PMV of the occupant with 150 cm height and 53 Kilogram weight sitting at the centre of the floor. The parameters of PMV are summarized in Table 2.

Table 2: The parameters and calculated results of PMV

Time (hour)	Ta	Tr (S1)	Tr (S5)	Va	RH	M	lcl	PMV (S1)	PMV (S5)
6	33	29.4	28.1	0.2	39.9	230	0.6	2.24	2.09
9	35.4	35.1	31.6	0.2	34.8	230	0.6	3.07	2.65
12	33.3	35.7	33	0.2	44.0	230	0.6	3.08	2.75
15	28.2	29.9	29.2	0.2	58.2	230	0.6	2.08	2.00
18	26.6	25.9	26.5	0.2	68.6	230	0.6	1.54	1.6

Here,

Ta = Air temperature (°C)

Tr = Radiant temperature (°C)

Va = Air velocity indoor (m/s)

RH = Relative humidity (%)

M = Metabolic rate (W)

lcl = Clothing insulation (clo)

The PMV achieved from Malchaire analysis is shown in Figure 9.

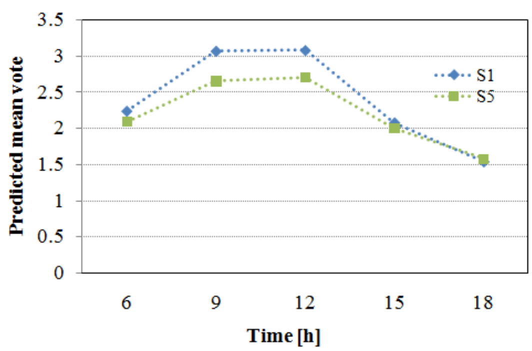

Figure 9: Comparison of PMV for uncoated concrete and White reflective coating.

The result shows that using of white coating (S5) can improve the thermal comfort situation from very hot to hot condition which can lead to a better performance of building and occupants, and finally lead to the reduction of energy consumption for cooling demand. The above example illustrates the calculation of PMV for a single zone naturally ventilated building. The method can also be extended to multi-zone or multi-storied buildings.

6. CONCLUSION

Six types of reflective coatings were studied and it was found that the use of an appropriate reflective coating can significantly reduce surface and indoor temperatures. The differences in the thermal behaviour that were observed from steady state and periodic experiment among coatings are due mainly to the differences in their spectral reflectance which mainly affects their performance during the day. In general, the higher the reflectance of a sample, the cooler it stays. A ‘‘cool’’ white coating can reduce a white concrete tiles surface temperature under hot summer conditions by 7.8°C. The use of reflective coatings can contribute to the reduction of surface temperatures, improve building comfort and reduce cooling energy use.

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AN ANALYSIS OF SOUND POLLUTION IN URBAN NODES WITH EXPERIMENTAL SURVEY OF BUS TERMINALS IN CHITTAGONG CITY, BANGLADESH

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Abstract: *Sound pollution refers to the excessive noise that interferes with normal activities, potentially leading to a lower quality of life. On major streets, noise pollution is caused by hydraulic horns of vehicles, microphones and cassette players and according to the literature data, maximum sound pollution is created in major traffic urban nodes. Chittagong is a major coastal seaport city and financial centre in south-eastern Bangladesh. Due to the rapid development of this city, vehicular movement is increasing and generally it is observed that bus terminals in major urban nodes creating massive sound pollution. How much noise is created and how it hampers its community in a bus terminal along with its adjacent urban context can be determined from this study. This study is based on the survey of several major bus terminals in Chittagong city with experimental survey. Creating mass awareness to the community about sound pollution is the main objective of this study. For the measurement of different noise levels, a Noise Dose Meter (TES-1355) has been used and Geographical Information System (GIS) has been engaged to determine kernel density of noise through interpolation process. This study can be helpful in further comparative analysis, rational distribution of sound pollution and can also be a guideline for urban planners and architects. Furthermore, this study will determine the proper distance for habitable land use to be settled in resilience mode from urban traffic node.*

Keywords*: Sound pollution, Noise level, Urban community awareness, Urban node.*

1. INTRODUCTION

Urban life consists of so many issues where sound pollution is one of them. Unwanted sound which is referred as noise is the bad outcome of rapid urban growth (González, 2014). It decreases the quality of life in an urban area. Besides, with the increasing density of an urban area, to accommodate the increasing number of people, the number of traffic is also increasing. The worst situation occurs in the Traffic Urban Node (TUN) such as bus terminals of a city (Louiza, 2016). The level of noise pollution of this TUN is alarming for city life. Like other developing city, Chittagong is facing this problem.

Not only the increasing number of transportation but also the use of hydraulic horn in public transport is also responsible for this (Sultan, 2012). Though the government has banned import of the hydraulic horn, use of hydraulic horn are rapidly increasing day by day (Tuhin, 2008)

The aim of the paper is to find out the present situation of sound pollution in Chittagong city especially in bus terminal of this city. A large set of data was recorded in order to take account the variation of noise pollution during the working day. The noise measure parameters have been recorded by using Noise Dose Meter (TES-1355- this model has limitations; cannot measure noise levels below 70 dBA and frequencies above 10 kHz) and GIS (Geographical Information System) has been used for finding the statistical variation with distance.

2. RESEARCH METHODOLOGY

At first literature data have been collected about the noise level, urban life, survey process as well as the survey area. After understanding the survey process, two bus terminals have been selected as they are strong noise polluting areas in Chittagong (As these two points are Urban Traffic Hubs as well as the connecting traffic nodes for this reason we choose our study area Oxygen and Bahaddarhat bus terminals.). During survey, data for the analysis were collected. It was primarily assumed about the noise range of individual are during the data collection process. Then the collected data has been analysed and put through Spatial Assessment by using GIS. In this way, actual noise level was found out of those areas and different noise level also analyzed according to distance of the bus terminal which is source of noise for different land use of adjacent area.

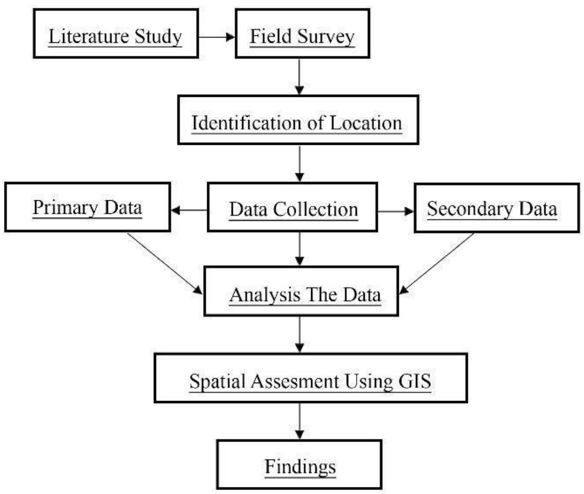

Figure 1: Structure of the research work

3. LITERATURE SURVEY

3.1. Urban area

An urban area is the region surrounding a city. Urban areas are developing, meaning there is a density of human structures such as houses, commercial buildings, roads, bridges, and railways as well as bus terminals. (Rutledge, 2011) 'Urban Area' is defined in varies way which differ from country to country and time to time. An urban area can be defined by one or more of the following:

i) Administrative criteria or political boundaries can distinguish the Urban area.

ii) the number of threshold population size, an urban area depends on its population size which differ country to country (Typically -2000 to 50000),

iii) It also is defined as population density; major profession of the population such as significant majority of the population is not primarily engaged in agriculture.

Urban area can be identified with characteristics like paved streets (modern transportation system), electric lighting, sewerage and drainage etc.

3.2. Transportation

Urbanization has been one of the dominant contemporary processes as a growing share of the global population lives in cities. Considering this trend, urban transportation issues are of foremost importance to support the passengers and freight mobility requirements of large urban agglomerations. Transportation in urban areas is highly complex because of the modes involved, the multitude of origins and destinations, and the amount and variety of traffic. (Jean-Paul Rodrigue, 2013)

Developing countries in particular, cities have to face transport-related challenges such as pollution, overcrowding, accidents, public transport decline, environmental degradation, energy depletion, visual intrusion, and lack of accessibility for the urban poor (Pojani, 2015). Public transportation system is one of the major transportation systems in urban context. Because of excessive development in the remote urban area many problems have been created in this field. So, maximum problems related to transportation are mainly originating from the urban traffic nodes especially in bus transit points, known as Bus terminals. Noise pollution is one of the problems of the bus terminal area.

3.3. Standard data of permissible noise

The way that noise can permanently damage one's hearing is from a single brief exposure to a high noise level, such as blowing hydraulic horn near one's ear. But hearing damage can also occur gradually at much lower levels of noise if there is enough exposure over time.

It is stated that sound levels above 85 dBA are harmful. BNBC gives a permissible limit of noise exposure over lime which is given in Table 1.

Table 1: Permissible Exposure Limits for Steady – State Noise by BNBC

Sound Level dBA	Time Permitted (hour – minute)
85	16-00
86	13-56
87	12-08
88	10-34
89	9-11
90	8-00
91	6-58
92	6-04
93	5-17
94	4-36
95	4-00
96	3-29
97	3-02
98	2-50
99	2-15
100	2-00
101	1-44
102	1-31
103	1-19
104	1-09
105	1-00
106	0-52
107	0-46
108	0-40
109	0-34
110	0-30

Source: (BNBC, 2006)

3.4. Survey area- Chittagong City

Chittagong is the second largest metropolis in Bangladesh. Situated in the Bay of Bengal, Chittagong has historically been an important centre of commerce due to its geo-strategic location and is regarded as the commercial capital of the country.

The Chittagong Statistical Metropolitan Area (SMA) covers an area of 1,152 square kilometres and consists of six metropolitan thanas. 68 wards and 236 mohallas (localities) with a population of 3.38 million. Chittagong City Corporation covers an area of 155 square kilometres with a population of 4,009,423 in 2011, which had grown on average by 3.6% per annum between 1991 and 2001. The population growth is much higher compared with national growth of about 1.6 percent. Cities are being inundated with people looking for a job and a decent income. The Chittagong City is not an exception to it. Like many developing country cities, it is experiencing a rapid growth of population mainly because of rural-urban migration. (BBS, 1981, 1991, 2001)

In this city, Bahaddarhat and Oxygen Bus terminal are two major traffic urban nodes which are mainly used for northern and southern part of Chittagong district and other districts of the country. This experiment is basically based on these two terminals as urban nodes. Bahaddarhat Terminal is the transit point for buses in Chittagong-Kaptai- Rangamati-Bandarban- Lohagara-Chakaria-Cox's Bazar route. On the other hand, Oxygen Terminal is the transit point for buses in Chittagong-Hathazari-Fatikchari-Manikchari-Rangamati- Khagrachari route.

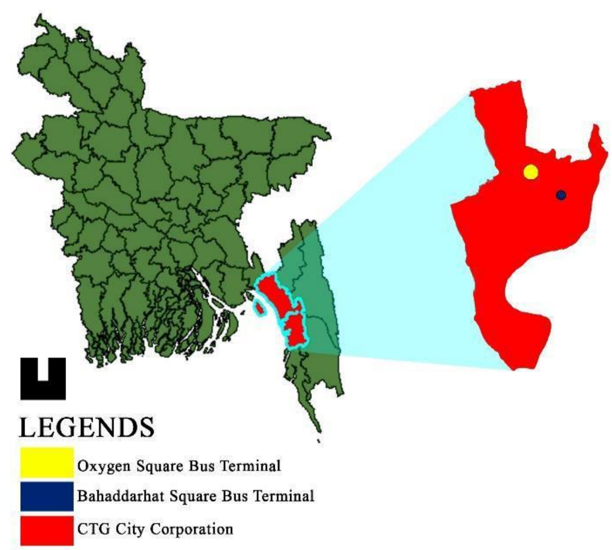

Figure 2: Location Map

The remote areas of this city are developed especially urbanized day by day. For this reason, the land use pattern of major traffic urban nodes are also changing now and then.

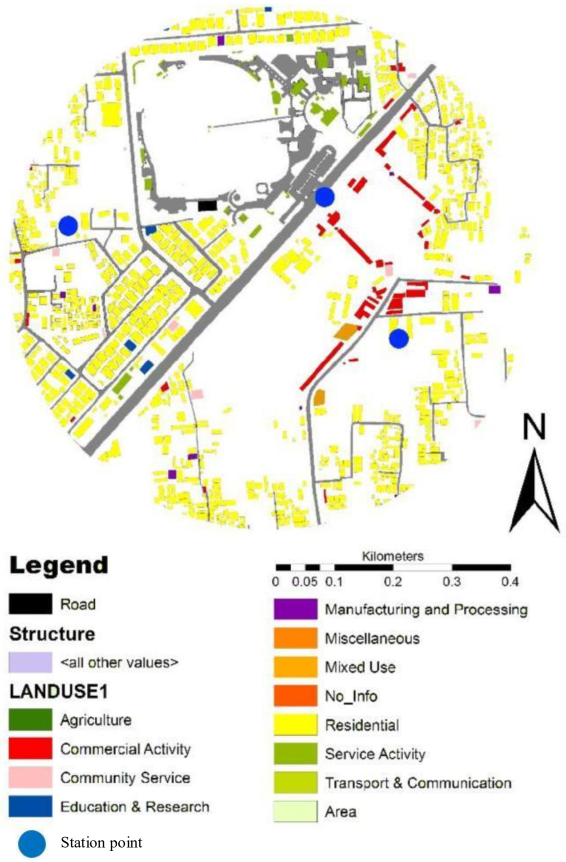

Figure 3: Land use map of Bahaddarhat bus terminal and its surrounding areas

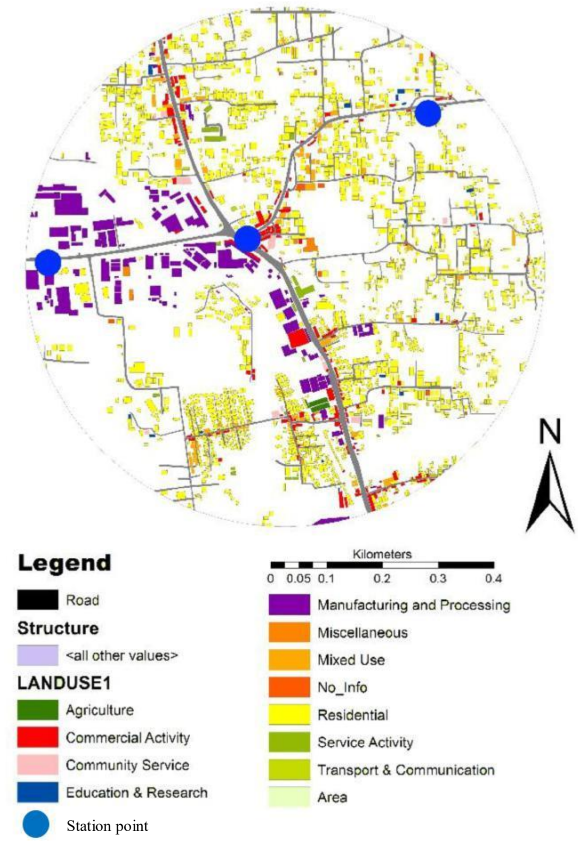

Figure 4: Land use map of Oxygen Square bus terminal and its surrounding areas.

In Bahaddarhat Bus terminal (Study area - 01) land use of the surround areas are mainly residential. There are also some schools, park, commercial buildings and market in this zone.

On the other hand, Oxygen Square bus terminal (Study area - 02) is surrounded by industrial and residential areas. Commercial development along the road has also become a major issue.

4. DATA COLLECTION

In this study, an effort is made to find out the noise level of Bahaddarhat bus terminal and Oxygen square bus terminal in Chittagong along with its adjacent area. Three points have been selected in each terminal for the measurement of noise level using noise dose meter (TES-1355). The data has been collected in morning (7:00 AM to 9:00 AM) and evening (5:00 AM to 7:00 AM) peak hours. (The main objective of our study is to find the maximum noise pollution level, but in off peak hours, volume of the vehicles is less, so is sound pollution. That's why we ignored the off-peak hour data.). In each point, each ten minutes' readings had been taken for 2 hours. From every ten minutes, the highest noise level was put into the data collection chart. Data has been collected at same point during morning and evening time.

Table 2: Field monitoring data at Bahaddarhat bus terminal during morning peak hour (7:00 AM – 9:00 AM)

Sl. No	Time	Point A (dBA)	Point B (dBA)	Point C (dBA)
01	7:00 AM-7:10 AM	86.3	85.4	82
02	7:10 AM-7:20 AM	87.9	88.4	80.5
03	7:20 AM-7:30 AM	90.4	85.3	85.1
04	7:30 AM-7:40 AM	98.5	89.1	89.5
05	7:40 AM-7:50 AM	93.3	88.2	90.5
06	7:50 AM-8:00 AM	89.5	86.9	89.7
07	8:00 AM-8:10 AM	95.2	93.4	90.3
08	8:10 AM-8:20 AM	83.5	88.7	89.5
09	8:20 AM-8:30 AM	80.3	86.9	87.3
10	8:30 AM-8:40 AM	86.5	84.3	83.5
11	8:40 AM-8:50 AM	90.6	88.2	90
12	8:50 AM-9:00 AM	85.2	91.2	94

Source: Field survey(February,2017)

Table 3: Field monitoring data at Bahaddarhat bus terminal during evening peak hour (5:00 PM-7:00 PM)

Sl. No	Time	Point A (dBA)	Point B (dBA)	Point C (dBA)
01	5:00 PM-5:10 PM	85.9	83	82.6
02	5:10 PM-5:20 PM	83.3	89	92
03	5:20 PM-5:30 PM	86.4	90.6	86.5
04	5:30 PM-5:40 PM	93.9	85.2	86
05	5:40 PM-5:50 PM	89.5	91.9	88.2
06	5:50 PM-6:00 PM	90.3	85.5	93.2
07	6:00 PM-6:10 PM	92	86.7	115.4
08	6:10 PM-6:20 PM	86.6	93	87.4
09	6:20 PM-6:30 PM	84.3	87.6	90.4
10	6:30 PM-6:40 PM	111.2	89.7	83.4
11	6:40 PM-6:50 PM	96.3	86.6	86.6
12	6:50 PM-7:00 PM	93.4	83.4	93.6

Source: Field survey(February,2017)

Table 4: Field monitoring data at Oxygen bus terminal during morning peak hour (7:00 AM - 9:00 AM)

SL. NO	TIME	POINT A (dBA)	POITNT B (dBA)	POINT C (dBA)
01	7:00 AM-7:10 AM	82.1	70.3	78.7
02	7:10 AM-7:20 AM	85.1	76.2	85.2
03	7:20 AM-7:30 AM	79.1	82.4	88.1
04	7:30 AM-7:40 AM	87.1	88.5	84.2
05	7:40 AM-7:50 AM	93.2	96.4	87.5
06	7:50 AM-8:00 AM	87.6	77.1	90.5
07	8:00 AM-8:10 AM	88.9	80	87.9
08	8:10 AM-8:20 AM	96.3	81.4	88.3
09	8:20 AM-8:30 AM	90.6	82.8	87.7
10	8:30 AM-8:40 AM	87.2	86.7	89.8
11	8:40 AM-8:50 AM	89.1	92.7	85.2
12	8:50 AM-9:00 AM	90.7	87.4	88.3

Source: Field survey(February,2017)

Table 5: Field monitoring data at Oxygen bus terminal during evening peak hour (5:00 PM-7:00 PM)

SL. NO	TIME	POINT A (dBA)	POITNT B (dBA)	POINT C (dBA)
01	5:00 PM-5:10 PM	87.7	87.3	89.3
02	5:10 PM-5:20 PM	88.3	91.2	86.7
03	5:20 PM-5:30 PM	90.8	88.7	90.2
04	5:30 PM-5:40 PM	97.8	87.3	89.5
05	5:40 PM-5:50 PM	98.5	96.6	93.5
06	5:50 PM-6:00 PM	83.9	91.3	87.6
07	6:00 PM-6:10 PM	89.3	87.4	86.4
08	6:10 PM-6:20 PM	90.7	103.4	93.6
09	6:20 PM-6:30 PM	85.3	93.9	99.2
10	6:30 PM-6:40 PM	96.6	87.4	87.2
11	6:40 PM-6:50 PM	91.3	95.3	89.7
12	6:50 PM-7:00 PM	86.9	85.6	96.3

Source: Field survey(February,2017)

5. DATA ANALYSIS

5.1. Field data analysis

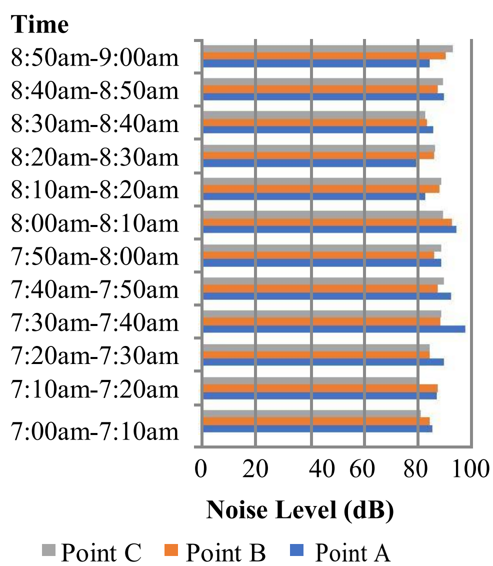

Figure 5: Field monitoring data at Bahaddarhat bus terminal during morning peak hour (7:00 AM – 9:00 AM)

At Bahaddarhat bus terminal during morning peak hour (7:00 AM-9:00 AM) max. value of noise is 98.5 dBA and min. value is 80.3 dBA avg. value is 88.1 dBA.

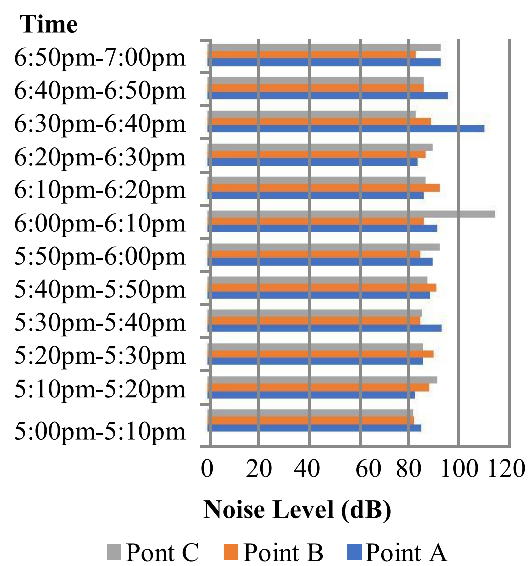

Figure 6: Field monitoring data at Bahaddarhat bus terminal during evening peak hour (5:00 PM-7:00 PM)

At Bahaddarhat bus terminal during evening peak hour (5:00 PM-7:00 PM) max. value of noise is 115.4 dBA and min. value is 82.6 dBA avg. value is 89.73 dBA.

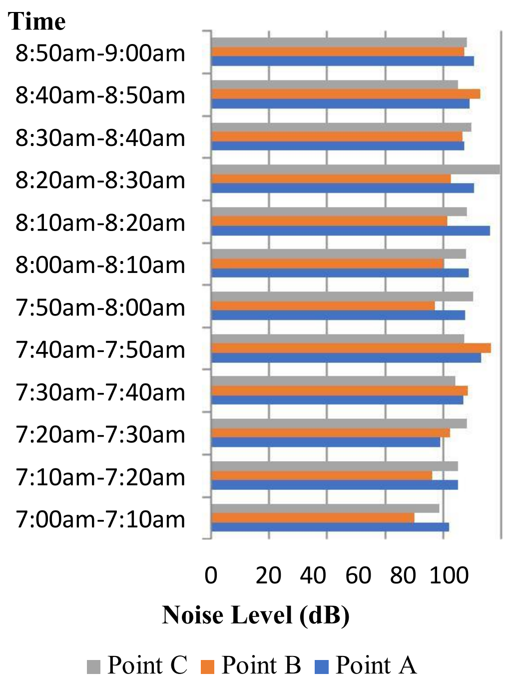

Figure 7: Field monitoring data at Oxygen square bus terminal during morning peak hour (7:00 AM – 9:00 AM)

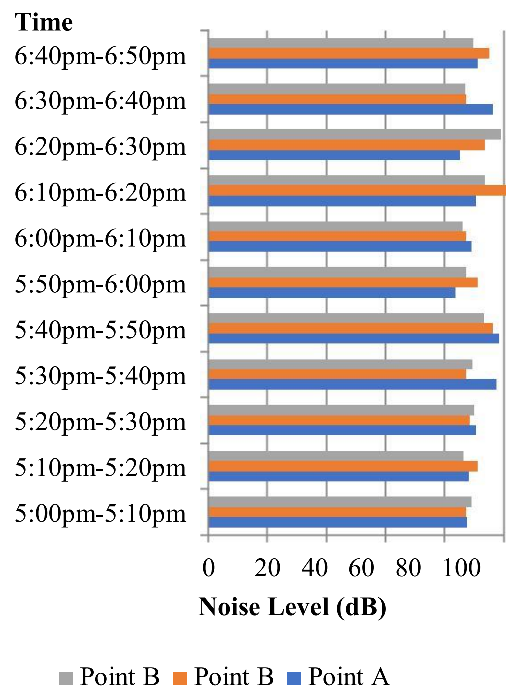

Figure 8: Field monitoring data at Oxygen square bus terminal during evening peak hour (5:00 PM-7:00 PM)

At Oxygen square bus terminal during morning peak hour (7:00 AM - 9:00 AM) max. value of noise is 99.6 dBA and min. value is 70.3 dBA avg. value is 86.46 dBA.

At Oxygen square bus terminal during evening peak hour (5:00 PM-7:00 PM) max. value of noise is 103.4 dBA and min. value is 83.9 dBA avg. value is 90.8 dBA.

5.2. GIS Simulation analysis

GIS Simulation has been derived through the Interpolation (Inverse distance weightage through barrier – z value as the structure height, which calculated the deflection and reflectance of sound) method. At first, shape file of the study area had been created.

Then, through geo referencing, points had been plotted. After measuring the sound spatial areas through the interpolation process, three concentric zones had been created. The centre of each zone is originating sound. As the band goes to red to blue the level of sound decreases (GIS Simulation has been derived through the Interpolation (Inverse distance weightage through barrier – z value as the structure height, which calculated the deflection and reflectance of sound) Absorption is negligible.). Except the blue colour, all other colour denotes noise polluted areas.

In study area 01 (Bahaddarhat bus terminal) there consist of sophisticated functions like community park, residential areas, educational institutions etc. which falls within noise pollution area and their functions are greatly hampered by this issue. During morning peak hour, the intensity of the sound is not that much acute due to less vehicular activities. But during evening peak hour intensity of the sound is much more due to increased vehicular activities.

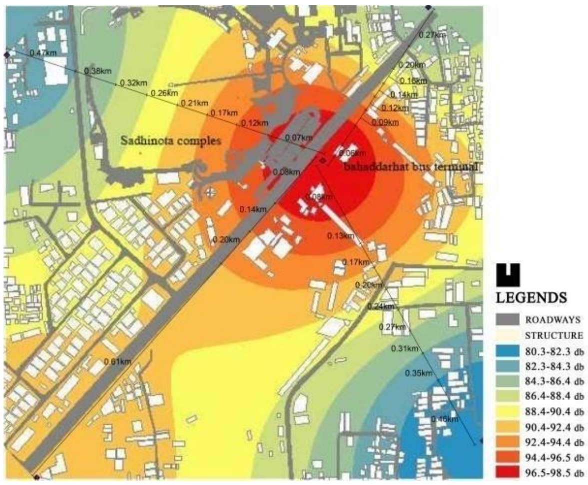

Figure 9: GIS simulation at Bahaddarhat bus terminal bus terminal during morning peak hour (7:00 AM – 9:00 AM)

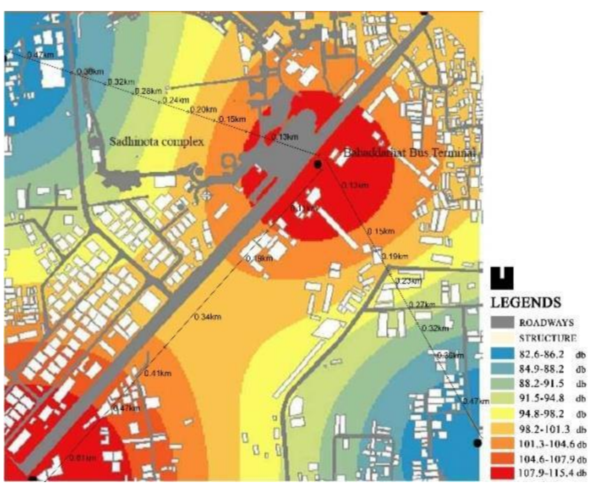

Figure 10: GIS simulation at Bahaddarhat bus terminal bus terminal during evening peak hour (5:00 PM-7:00 PM)

On the other side, study area 2 (Oxygen Square bus terminal) contains commercial areas along the road as well as industrial and residential areas. It is observed that more industrial area is situated in this study area so noise pollution hampers less than study area 01. During morning peak hour, traffic flows from north direction towards south direction. That's why major noise pollution occurs in the southern side of study area. During evening peak hour, traffic flows from south towards north direction. Due to that reason, major noise pollution occurs in the northern side of the study area.

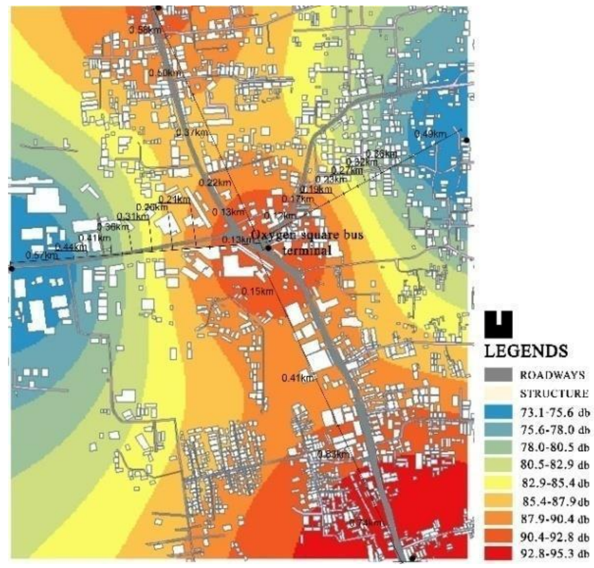

Figure 11: GIS simulation at Oxygen Square bus terminal during morning peak hour (7:00 AM – 9:00 AM)

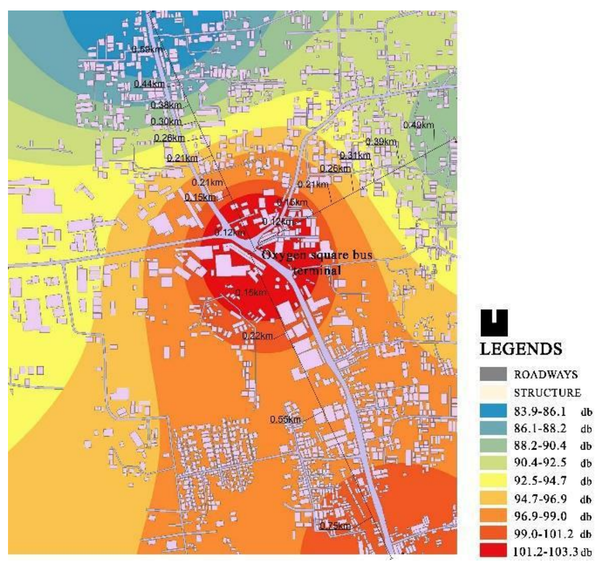

Figure 12: GIS simulation at Oxygen Square bus terminal during evening peak hour (5:00 PM-7:00 PM)

6. FINDINGS AND CONCLUSION

As the noise level, does not fluctuate much so it is assumed that its continuous. The avg. value of noise levels is 88.25 dBA. From **Table 1,** it is considered that if that noise level continuous for two hours then severe health issues will rise. There are some educational institutions, residential areas as well as commercial areas which will not be totally functional within the avg. noise polluted perimeter of 0.2 km. So the land use policy of that area should be revised or necessary step would be taken to reduce the sound pollution of the terminal.

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ANALYSIS OF NOISE POLLUTION IMPACTING EDUCATIONAL INSTITUTES NEAR BUSY TRAFFIC NODES IN CHITTAGONG CITY

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Abstract: *Education is the key prerequisite for any sustainable development. As better educational environment allows every student to acquire knowledge, talents, attitudes and values necessary to shape a sustainable prospect. The necessity of better educational environment for teaching-learning needs a suitable location and surrounding environment. Unfortunately, nearly all the educational institutes are located adjacent to the busy places such as main streets, public areas, nodal points, where several levels of noise pollution are occurred by the horn of vehicles and various sound systems. From previously established researches, it is found that students exposed to elevated noise level are suffering from decreased attention, social adaptability and increased opposite behaviour relation to other people and especially disturbs teaching-learning process, reduces the capacity of work efficiency and causes health hazard gradually. Ideally, the sound level should be about 35 dBA (BNBC 2006) in an educational institution, particularly in classrooms. As a number of traffic volume is increasing day by day, the problem of traffic noise is also becoming unbearable. This study was carried out at three educational institutions of Chittagong city situated at similar busy urban nodes. To evaluate the deviation from standard noise levels, measurements were taken at schools from 9.00 AM to 12.00 PM using a Noise Dose Meter (TES-1355) in several points and different interval of time and different distance from roadside. This paper has also conducted a comparative analysis by questionnaire survey among students and teachers to establish in-depth qualitative analysis. The study found that the intensity of noise level was higher in horizontal and diagonal directions than vertical distance from the noise sources. Literatures were reviewed for reliability and as a guideline of land use planning to illustrate how to reduce noise level by resilience parameter for the existing urban context.*

Keywords*: Busy Traffic Street, Educational Institute, Noise Dose Meter, Noise Pollution, Urban Street Node.*

1. INTRODUCTION

Noise is unwanted sound and it has undesirable physiological or psychological effect on people (Guidelines for community noise by WHO, 1999). It is generally accepted that the learning and performance of school children are depreciated by noise and the older children in this age group are more affected than the younger children (Guidelines for community noise by WHO, 1999), (Institute for Environment and Health, 1997). Previous established research found that students suffer from several complexities like decreased attention, social adaptability and increased opposite behaviour relation to the other people because of exposition to elevated noise level (Ismail *et al.*, 2015) and it also disturbs teaching-learning process, reduces capacity of work efficiency and causes health hazard gradually (Shield *et al.*, 2002), (Shield & Dockrell, 2002), (Alam *et al.*, 2006), which can be observed in many urbanized city. Being victimized by the rising degree of air and water pollution, the inhabitants of Chittagong city are also being exposed to high level of noise pollution (The Daily Star, 2013). Due to fast urbanization in the city of Chittagong, educational institutes are forced to be located adjacent to the busy places in urban areas, such as main streets, public areas and nodal points. The noise from road vehicles is mainly generated from the engine, from frictional contact between the vehicle and the ground and from the horn of vehicles (Pall & Bhattacharya, 2015). However, those noise pollution adversely affects educational environment (Hodgson *et al.*, 1999), (Debnath *et al.*, 2012), (Maxwell & Evans, 2000) .In this study, the primary aim was to find and modulate existing information about noise status and assessment of impacts on teaching learning process during the school hours.

2. CLASSROOM NOISE LEVELS AND IMPACT

The external noise level in school yards should not exceed LAeq 55 dB (Ismail *et al.*, 2015), (The American National Standards Institute, 2002), (Krishna *et al.*, 2007), (Moodley, 1989). Shield and Dockrell (2002) found that the ambient noise level in an occupied primary school classroom was closely related to the pupil activity. The measured activity levels ranged from 56 dBA (silent activity) to 77 dBA LAeq when the pupils were engaged in noisier activities involving group work and movement around the classroom. BNBC (Acoustic, Sound Insulation and Noise Control, 2006) guides an occupied classroom noise levels should not be greater than LAeq 35 dB (Shield & Dockrell, 2003). Additionally, ASHA suggests that the speech-to-noise ratio (SNR) at the child's ears should be at least +15 dB. Several recent studies have investigated the effects of noise on student's reading, numeracy and overall academic performance (Shield *et al.*, 2002). Hetu *et al.* (1990) found a significant drop in student's performance, particularly in learning to read, when the background noise level interfered with speech.

3. STUDY AREA

To measure noise level at educational institute, this study surveyed three different Girls High School in two different areas placed adjacent to node point of busy road in the city of Chittagong, where two schools (School-X and School-Y) are situated in the same boundary (Fig. 1, Fig. 2& Fig.4).Observation nodal point as (N_A) Amtola Bus Stand, (N_B) KC-Dey Road and Nandankanon Road intersection, and (N_C) Jubili Road and Nandonkanon Road intersection. Besides, another one (School-Z) is in a different location (Fig. 3& Fig. 5), where nodal point as (N_D) Kaptai Raster Matha, Chittagong-Kaptai Road, where N is marked as node point.

Fig.1. KrishnoKumari City Corporation Girls' High School, Newmarket, Chittagong.

Fig.2.AparnaCharan City Corporation Girls' High School and College, Newmarket, Chittagong.

Fig.3. City Corporation Girls' School and College,Kaptai Raster Matha, Chittagong.

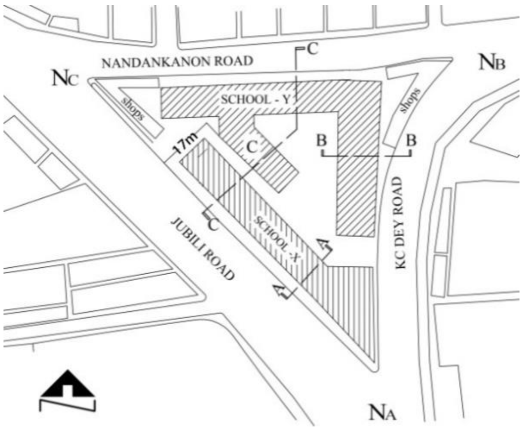

Fig. 4.Study Area 1 (School X & Y), located at the intersection of three roads: Jubili Road, Nandankanon Road and KC-Dey Road.

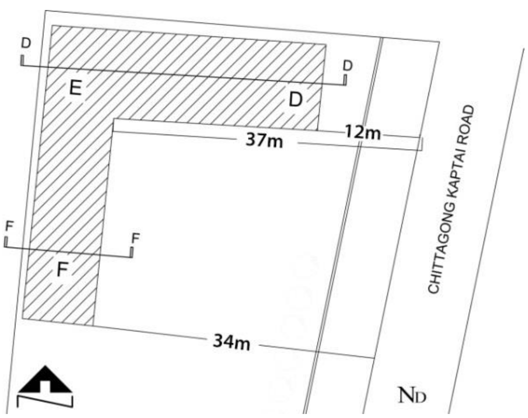

Fig. 5. Study Area 2 (School Z), adjacent to Chittagong Kaptai Road.

4. MATERIALS AND METHODOLOGY

4.1. Survey Process and Technique

For measuring noise level, in this study was conducted mixed method approach for data collection and analysis. The questionnaire survey was done to find out in-depth information on the classroom's teaching-learning environment for qualitative data. For quantitative data, Noise Dose Meter (TES-1355) was used to measure the noise level. Classified recording of hourly volume and composition of the traffic were made. Vehicles in each site were categorized into three node point for Study Area 01 and one node point for Study Area 02. The study was also concerned surrounding vehicular pattern for instance, light vehicles (two-wheelers, auto rickshaw), medium vehicles (car, van, jeep & mini bus).Table1 shows categories of vehicles.

Table 1: Description of Vehicle Categories Prevalent in the Study Area

Vehicle category	Description
2-wheelers	Motorcycles/Scooters/Mopeds on two wheels without side cars;
Light motor vehicles	Motor vehicles on three or more wheels and not in the other vehicle categories, namely, Cars, Vans, Jeeps;
Medium weighted vehicles	Buses including Mini and unarticulated vehicles equipped with one rear axle with four tires;

Source: Field Survey, 2017

4.2. Data Collection and Analysis

As a part of quantitative survey, the noise levels were recorded at twelve points in two schools which are at distances depending on location of the building from the road. Observations are taken during the school hour from 9am-4pm. In every interval it has been considered the average of 5 frequent readings at an interval of 15s. A total of one hundred teachers and students from these two selected schools randomly were questioned by using questionnaire forms. The questions were about different problems they have been facing during the teaching-learning process in the schools, for instance, (1) teaching-learning process, (2) difficulties for discussion and (3) health condition. Recording of data was made by tally markings for each hour to sample the diurnal deviation of existing traffic condition. All measurements were carried out during peak hours (9am-12pm) of working days and under sunny climatic conditions.

4.3. Limitations

This study did not consider fourth floor of School-Z, to maintain comparability among all school structures. Moreover, when noise was being measured, it was not possible to consider accurate traffic volume in every interval due to different locations and various vehicular movement, parking facilities of vehicles. Besides, the density of public access also varies where one site was situated at the city centre and another located at periphery of the city growth point with high traffic flow for long route.

5. RESULTS AND DISCUSSIONS

Table 2, Table 3 and Table 4 show the situations and the noise levels of the different school areas. Table 2 shows the data of noise level and Fig. 6 depicts Section AA for floor levels with respective points A1, A2 and A3 in School–X. The highest average noise level is observed in 1st floor as 75.6dBA and the lowest at ground floor. Noise level of 72.8dBA at 2nd floor is comparatively lower than the 1st floor noise level.

Table 2: Measured maximum, minimum and average readings in the Study Area 01 (School-X).

Study area 01	Observations Sound pressure level in dBA		
	Min.	Max.	Avg.
A1	63.7	84.1	72.8
A2	69.5	87.1	75.6
A3	64.6	88.9	74.3

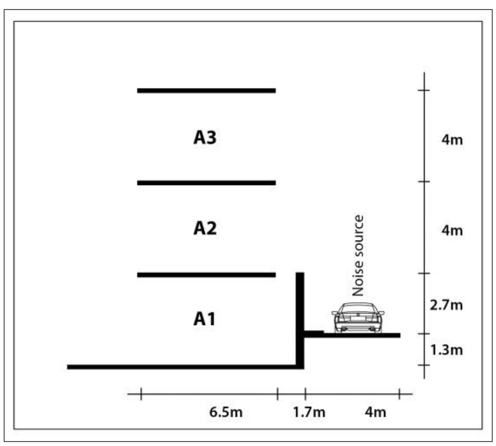

Fig. 6. Section AA

Table 3 tabulates the data of noise levels and Fig. 7 shows Section BB for different floor levels with respective points B1, B2 and B3. As the school is situated adjacent to the road, highest average noise level is observed in 1st floor as about 74.1dBA and then in started decreasing. Relatively lower noise level is found in ground floor level as 72.3dBA. Noise levels at Block B of School–Y follows similar pattern of School-X. The study found that the cause of lower noise levels at ground floors of both blocks were due to the surrounding 2.5 m to 3.0 m high walls and s small shops, which are acting as 'noise barrier'.

Table 3: Measured maximum, minimum and average readings in the Study Area 01 (School-Y).

Study area 01	Observations Sound pressure level in dBA		
	Min.	**Max.**	**Avg.**
B1	65.3	84.5	72.3
B2	67.5	85.2	74.1
B3	68.3	86	73.2
C	61.4	74.7	65.2

The block C (Fig. 8) of School-Y, which is situated at the central position of the school and surrounded by other school blocks, is least affected and shows the lowest average noise level of 65.2dBA.

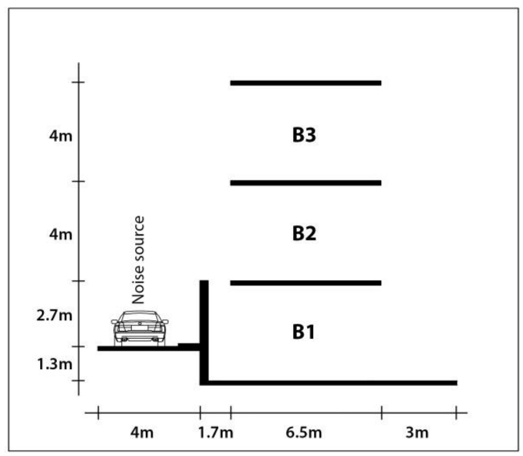

Fig. 7. Section BB

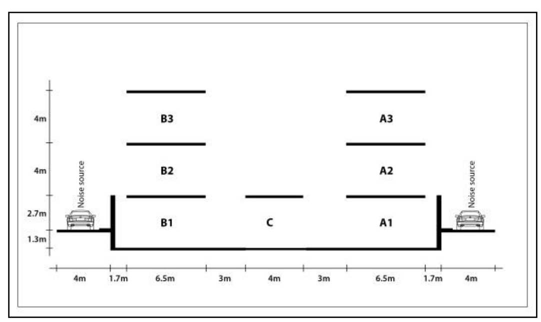

Fig. 8. Section CC

The study site 02 (School-Z) is another girls high school in a separate location, which is an L shaped four-storied building. From Fig. 5, Fig. 9 and Table 4, we may find noise level pattern similar to those of school-X, while both schools are located adjacent to roads. In School-Z, 1st floor average noise level (76 dBA) is higher than those of ground floor (72.9 dBA) and 2nd floor (75.2 dBA). On the other hand, point E (Fig. 9) and F (Fig. 10) are located at far distances from noise sources and show different results of average noise levels compared to those in preceding discussions.

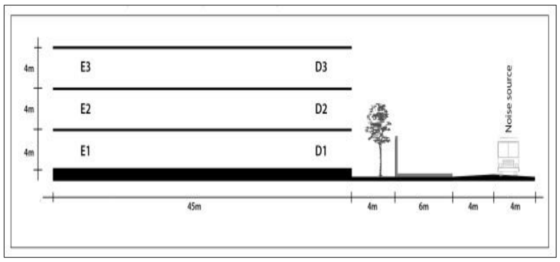

Fig.9. Section D-D

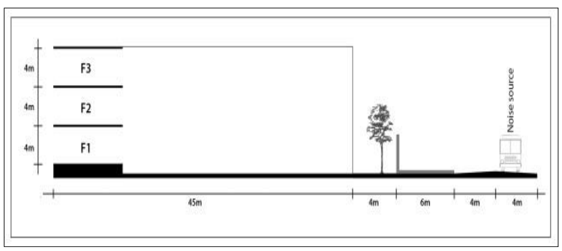

Fig. 10. Section F-F

In Table 4, it is remarkable that noise levels gradually increase from ground floor to upper floors. At Site-2, the minimum noise affected point is E.

Table 4: Measured Maximum,Minimum and Average readings in the Study Area 02 (School-Z).

Study area 02	Observations (sound pressure level in dBA		
	Min.	Max.	Avg.
D1	64.3	80	72.9
D2	64.9	81.2	76
D3	64.5	81.7	75.2
E1	62.2	75.8	68.0
E2	63.1	76.6	69.85
E3	63.5	77.7	70.5
F1	65	81	72.1
F2	66.8	82.9	74
F3	65.2	83.7	74.97

Fig. 11 shows a comparative analysis among noise levels in different floors of three different schools respectively. It is apparent that these three schools experience less noise level at the ground floor whereas School-X and School-Y are recessed from the road level and also surrounded by high boundary walls, trees and roadside shops .In these blocks noise is at highest level at the first floor but that gradually reduces with the increasing vertical height from road side.

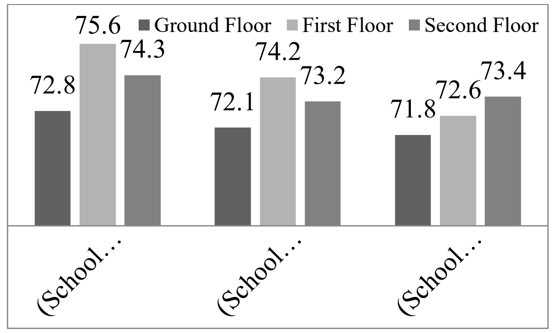

Fig. 11. Comparison of noise level in different floors of threedifferent schools respectively.

In case of C.D.A. Girls High School, the building blocks are placed at a distance from the road and also the school is surrounded by boundary walls. These reduce the noise level at ground floor and gradually it increases the in upper floors. The low-height boundary wall as well as the low dense trees, which are used as a buffer, cannot minimize the noise level. Minimum noise level is observed at the building block C of School Y, which is surrounded by other school buildings on all sides. Among those three schools, maximum sound level is observed in School-X, which is sited at a close proximity with Amtola Bus Stand (N_A) and the distance between road and school building is less than 3 m. As a result, the school is experiencing a high degree of noise pollution. In all cases, the calculated average noise level is above the permissible limit. During day time, the permissible level of noise is 50dBA for 'Quiet Zone', which includes schools (Pall & Bhattacharya, 2015).

After analysing the questionnaires survey, it is found that 60% of respondents agree with noise pollution affected in teaching-learning process in classrooms, 25% stated health problem and 15%

pointed out the difficulties of discussion in classrooms. The results on these questions are summarized and are shown in Fig. 12, based on the percentage of effect created by road side noise sources.

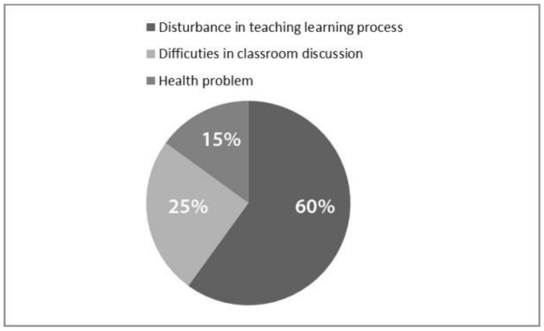

Fig.12. Adverse Effect in percentange of Roadside Noise Sources.

6. CONCLUSION AND FUTURE WORK

From the study, it is observed that noise can only be reduced either by any obstacle such as a 'noise barrier' or by increasing the distance from noise source. Schools in this study are surrounded by boundary walls, roadside shops and trees, which perform as obstacles against noise. Besides, the effect of noise is comparatively lower at upper floors as intensity of noise is reduced inverse squarely with the increase of distance from noise sources (Alam *et al.*, 2006). Chittagong city is rapidly becoming urbanized and over populated area, where educational institutions are being constructed rapidly in an unplanned way, without considering its suitable location and educational environment. Considering current development in Chittagong city, this study recommends that if educational institutes are built beside the busy roads, a wide buffer zone should be considered. The buffer space may have functional noise barriers by placing multi-storeyed commercial buildings, high boundary walls or trees with dense foliage. These may reasonably reduce noise in school premises and as well as in classrooms.

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POINT TO PONDER ON THE PAVEMENTS OF DHAKA: A STUDY OF EXPERIENCE ON THE FOOTPATHS OF MIRPUR ROAD AND APPROPRIATE DESIGN RESPONSE

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Abstract: *In a vibrant and densely populated South-Asian city, pedestrian trips always dominate in the numeric data set of trip generation. All the trips invariably start and end up as pedestrian. In a study on Dhaka pedestrians, the traffic is found to be about 60% of all traffic. But, no planning or design takes care of the pedestrian traffic. Such pedestrian trips take place mostly through undesired areas with foul experiences – ranging from unwanted confrontations with auditory, olfactory and visual situations, to basic ergonomic and psychological discomforts, referred here as experiential discomforts. Such discomforts can be studied, relating them to the physical attributes of the pavements and their surroundings. This correlation is expected to show ways for appropriate response to mitigate the undesirable experience. Mirpur Road is a major arterial thoroughfare in Dhaka where the pedestrian traffic is at odds with other modes and the experience is not satisfactory.As such, most representative section of Mirpur Road is taken as a subject for a qualitative study, with a focus on improvements on experiential comforts. This would help in developing a guidelines/checklist of do's and don'ts for a sustainable pedestrian friendly pavement in terms of physical attributes, thus ensuring sustainable response towards prevailing negative experiences of Dhaka strollers.*

Keywords*: Experiential Discomfort,Pedestrian, Traffic, Space, Sustainable response.*

1. INTRODUCTION

Through the advancement of technology, people have evolved countless mechanized options and assistances to travel. But, the pedestrian travel still plays the most pivotal role (Wilkie, 2015) in travel, as each and every journey starts and ends up with a walk. According to Transport Plan 2015 (STP-15), about 40% of the traffic is composed of pedestrian where as another study carried out by the author in Motijeel area shows pedestrian traffic to be 60% (Mowla & Khaleda, 1999). Unfortunately, none of the planning of Dhaka so far took this factor, a point to ponder in their planning. This paper is aimed at finding out the different types of discomforts that are experienced by a common pedestrian, inside a fast growing and densely populated urban context, with ill-organized pedestrian ways/spaces and surroundings. Besides, such or similar urban setting are never found based on any planning guidelines or regulations relevant to experiential discomforts of the pedestrians. Pedestrian ways are the most important interface between all urban activity systems. A vibrant urban space or street makes a city vibrant (Mowla, 2017). A good pedestrian way reduces dependency on automobile and also enhances the environment by promoting human scale; creating retailing activity and improving air quality. A successful pedestrian way must have adequately safe and secure environment; adequate space and activity support (entertainment, food services, and good views) and amenities (benches, planters, lighting, bins etc (Mowla, 2000 & 2017).

Dhaka, the capital of Bangladesh, is a densely populated city, having vastly diversified spatial characters, generated over more than four hundred years of its urban history as the capital. Pedestrian spaces of Dhaka show similar layers of diversification. Rapid urbanization in recent periods left Dhaka with little scope to organize the development in a planned manner (Mowla, 2012). Some non-planned locations of this city possess no defined pedestrian paths; other planned areas have defined spaces for pedestrians, but with little or no specific amenities for the pedestrians, in terms of comfort or interaction. Yet we know, ensuring pedestrian friendly environment in the street will contribute to increasing pedestrian users and trips, as well as increased accessibility and mobility (Soni & Soni, 2016). Under such circumstances, Dhaka provides us with the opportunity to examine pedestrian discomforts in depth, and suggest ways for policy and physical interventions towards a sustainable and responsive development approach in pedestrian spatial morphology.

2. METHODOLOGY

This is a generalized study taking in to consideration a typical segment of an arterial road, with an expectation that the findings would be replicable in similar contexts in Bangladesh or of an eastern city. Fundamentally it is an environment-behaviour study (EBS) with experiential observations. Focusing on the regimental urban setting of pedestrian Dhaka, the solitary (Fiona Wilkie,2015) walk of a person is thoroughly investigated. In this process, three perspectives were taken into consideration. *First*, previous studies are thoroughly reviewed to gather positive pedestrian space oriented data, visions and arguments. *Second*, specific spatial types are grouped together based on the physical features of pedestrian street spaces and their relation to the adjacent areas or functions, through field survey and *third*, identification of undesired physical and psychological human experiences with respect to the physical features of pedestrian spaces.

After the identification of necessary physical attributes of pedestrian spaces and the relative experiential discomforts, collective experiences of pedestrians are taken into consideration. The collective and solitary needs of the pedestrian traffic, both are taken to be addressed from the study autopsy report and authors' field experience.

Finally, the necessary features of generic pedestrian spaces in the context of Dhaka is also established through literature review, to help determine an ideal framework and guideline for further works.

3. DETERMINATION OF STUDY AREA

Mirpur road is one of the major transportation corridors of Dhaka. It starts from the New Market/ Nilkhet node in the southern and stretches to the starting of Dhaka-Aricha highway in the Dar-us-Salam/Technical node in the north, near Housing and Building Research Institute (HBRI), having a length of about seven kilometres.

To determine the study area, broad spatial characteristics of Mirpur road were analysed. It is evident from the empirical observations that the stretch starting from New Market/Nilkhet node and ending in the Crescent lake road node includes most variations of spatial characters (Fig 01). Specific characters are found in several locations in the study area, which are identified through a field survey. The analysis on this typical segment is expected to deliver satisfactory results that would be compatible for other arterial roads of Dhaka.

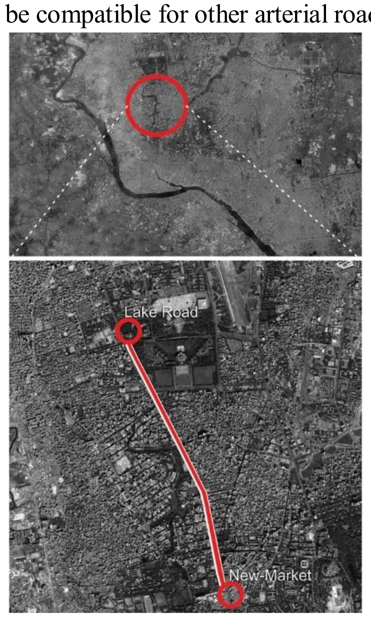

Fig 01: Study Area in Dhaka

4. ANALYSIS AND DISCUSSIONS

4.1. Literature Review

Experiential comfort of the pedestrian traffic relates to their expectation and perception of spatial features and amenities of the pedestrian space. This idea of perception can be seen as the process of attaining and interacting with sensory information (Pratiwi, Zhao, & Mi, 2015) obtained from specific spatial features. Spatial features of an urban pedestrian place are often not addressed in the planning process, however, when seldom addressed; it sees only the economic efficiency of its adjacent spaces. The common experiential needs of pedestrian users are often neglected in such process (Wang, Siu, & Wong, 2016). The facilities and inadequacies of the physical environment of the streets are more effectively experienced by the pedestrians rather than by other road users (Rankavat & Tiwari, 2016). Pedestrian places act as platforms for social accumulation of multiple activities and transactions, as ‘connective tissues’ that integrates and interrelates different lives and dimensions together (Crawford, 1999), providing vibrancy to an urban area (Mowla, 2017).

In the eastern cities the roads are social as well as connecting space for different activities (Mowla, 2017), the traditional concept of addressing roads and streets as vehicular arteries and incorporating the pedestrian path along them as a secondary function, leads to encroachments when the roads are to be widened or when the adjacent function overflows. The concept is gradually changing worldwide towards having the primary focus on the pedestrian space, and to address the roads and streets more as ‘shared spaces’ in between vehicular and pedestrian traffic (Image 1). Besides, opposing the modernist view of the road design process as a traffic engineering problem, newer concepts argue that streetscape design should not follow ‘standard’ frameworks in every case. Rather, it should be specific and context - sensitive. (Kaparias, Bell, Biagioli, Bellezza, & Mount, 2015).

A responsive streetscape would depend on a) having positive visual open space element and that may be achieved by screening and landscape treatment of undesirable visual elements; Right of way parking and median planting; and enhancing the natural environment as viewed from the road and pedestrian path. b) Giving orientation to driver / pedestrian and to make the environment legible, which can be attained by landscaping to enhance environmental districts along the road; Streetscaping i.e. lighting, furnishing, signs and symbols; developing a system of vistas, visual references to adjacent land uses and landmarks (Mowla, 1994& 2017).

Image 1: Pedestrians using vehicular path

4.2. Spatial Characteristics Within Study Area

Spatial characteristics of pedestrian spaces along the study stretch of Mirpur road are identified through physical survey on strategic points. Physical feature parameters are:

1. Width and height of the pedestrian space,
2. Presence of road frontage in between pedestrian space and adjacent function or land,
3. Presence of street furniture,
4. Surface material and maintenance condition,
5. Encroachment on pedestrian space,
6. Grade changes along the thoroughfare etc.

Image 2: Presence and absence of frontage

4.2.1 Width and Height of Pedestrian Space

Pedestrian path width varies from a minimum of 1600 mm and up to 5300 mm. 9 of the 14 survey points show a consistent width of 3000 mm, whereas the rest shows a variety in measurement. In 8 survey points, height was consistently within a range around 300 mm. In extreme cases, highest height level of pedestrian path was found to be 750 mm.

Width of the pedestrian path is crucial in denoting pedestrian thoroughfare and static or interactive spaces. The effective width of the pedestrian thoroughfare is less than the respective physical measurement of the path. The 'shy distances' from each extreme edges of the path, as well as from encroaching objects, may be deducted in order to determine the effective thoroughfare width. The shy distance is considered as 450 mm. In extreme cases, it provides the clear pedestrian thoroughfare space of only 700 mm width. From field observations it is evident that most pedestrians (76%) often leave the defined path in such cases and use the vehicular path instead.

4.2.2 Presence of Road Frontage

Road frontage is considered as the interactive space in between built structures and pedestrian path. Non-interactive boundaries (particularly solid ones) between the pedestrian space and adjacent land use have not been considered as road frontage (Fig & Image 2).

Presence of active frontage is found to be commercial in nature in all cases. In some cases, these commercial functions include individual shops that provide with individual active frontages. Such individual frontages allow the pedestrians direct access to the indoors from the pedestrian path. In other cases, market structures tend to provide with partially active frontages that allow controlled access towards a shared indoor space from the path to some extent, and controlled visual connections with the individual shops for the rest.

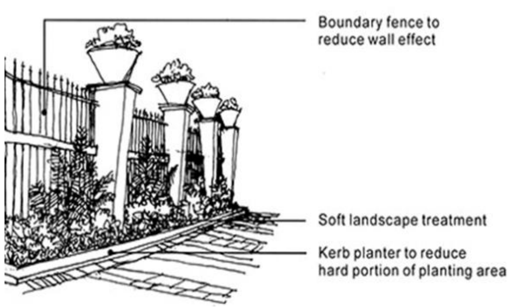

Fig 2: See through or perforated boundaries help integrate the place with the foot path.

Absence of road frontage shows three basic characters. The first one shows solid boundary walls of individual plots, situated just on the edge of the pedestrian path. Such negative walls tend to increase the shy distance in between the edge and the pedestrian. The second character shows a degree of perforation in the boundary wall or fence. Such a character allows passive visual interaction for the pedestrian with the adjacent property (Fig 2: provides passive interaction). The third character has a small number of examples – which shows solid boundary walls at a distance of 1200 mm to 1800 mm from the path edge and a low height or man height fence at the edge. In all cases, the buffer in between the solid wall and the perforated fence, have small green patches. Solid high walls are most repulsive. Given the option, most people (82%) opt to walk by interactive (passive or active) frontage.

4.2.3Presence of Street Furniture

Street furniture for pedestrian path can be of many types, having several functions served by them. Although in the study area, only two types of street furniture were identified. The first one is the street light. Previously used sodium-vapour lamps are now being replaced with LED lamps by the City Corporation. These lamps are placed high above the ground and focused towards the road space only. No lighting is dedicated to the pedestrians. In the adjacent area of Russell Square of Mirpur Road, there are dedicated pedestrian lightings but no such initiative is found in the main thoroughfare.

Image 3: Poorly positioned public seating

The other type of street furniture is shaded public seating in the bus stoppages. Existing seating are hardly being used by the public, mostly because of their ill maintenance and ill illuminated. In some cases, these are used by the hawkers and street vendors. The positioning of these seating is also not well thought out i.e. placed arbitrarily alone without any supportive functions that could make them vibrant and active (Image 3).

4.2.4Surface Material and maintenance Condition

Pedestrian path surface is well constructed in most of the area, which does not have any irregularities, such as frequent change in frontage, level ups and downs, parking provisions etc. Cases of ill-maintenance are found in some points. One such case includes the remains of removed advertisement billboards or broken tiles. Since 2010, illegal billboards have been removed gradually from pedestrian paths. Due to the absence of maintenance, there remain the cut-out billboard columns or broken tiles on the pedestrian path, causing hindrance and accidents. Pedestrians (64%) are observed to be avoiding such locations.

Another issue is of annoyance in the surface condition is the presence of dust. Heavy amount of dust covers the pedestrian path and the air becomes dusty as well, because of the high speed vehicular traffic adjacent to the path. The pedestrian areas have no buffer zone to minimize the dust effect. Areas having frequent vehicular movement remain at high risk of suspended dust pollution (Meza-Figueroa, Gonzalez-Grijalva,Río-Salas & Coimbra, 2016). In dry seasons, this risk is higher, as the moisture tends to settle the dust in the wet season. Roadside dust tends to have more toxic metal pollutants and is generally a major source of toxic metal substances in the human body (Chutke, Ambulkar, & Garg, 1994). People have no option but to walk through in Dhaka roads.

4.2.5Encroachment on Pedestrian Space

Pedestrian spaces in the study area are found to be encroached upon by several objects. Sometimes motor cycles ply on footpaths. Most encroachment occurs by informal shops and hawkers. In some cases, these shops acquire a form of informal tenure at specific points, and encroaches the pedestrian path with wooden furniture and temporary shed. In other cases, floating hawkers tend to display their items directly on the path. In both cases, footpath width decreases, and some examples show that virtually no dedicated pedestrian thoroughfare exists, instead it has been merged with the shy distance from the remaining edges (Image 4).

(Image 4: Encroachment by parking and illegal built form)

4.2.6 Grade Changes along the Thoroughfare

Abrupt change in height/level along the pedestrian path causes discomfort in walking. Level change occurs when individual plots grind down the pedestrian path in order to create vehicular entries on the same height level of the vehicular road. Most of the Mirpur road adjacent plots have direct entries into their plot disrupting the footpath's pedestrian traffic.

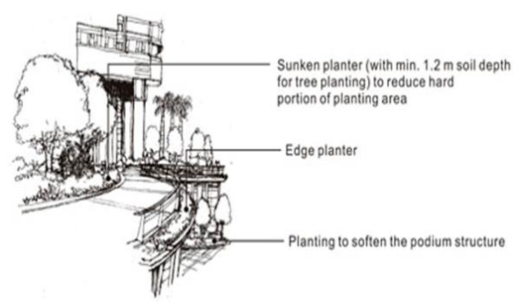

Fig 3: Planting demarcating open space and footpath and at different grades

BNBC (Bangladesh National Building Code) allows such practice, and no remedial guidelines (like Fig 2 & 3) are there to tackle the situation. As per regulation anybody can cut down the footpath for vehicular access with the authority's approval.

4.3. Experiential Characters within Study Area

The pedestrian space alongside Mirpur road has an experiential dimension that is often neglected, becoming subject to a methodical study. The experiences of a pedestrian can be critical from a number of aspects. These include the physical, auditory, olfactory and visual experiences.

4.3.1Auditory Experience

Undesirable level of noise is a common feature for the Mirpur road throughout the day. Main reasons for the noise pollution are high speed vehicles and excessive use of horns; noise generated by street adjacent shops and market places etc. Observations suggest that spaces having blind non-interactive walls and high pitch horns cause more auditory disturbing experience. Open spaces having water bodies and vegetation tend to reduce noise pollution (Ariza-Villaverde, Jiménez-Hornero, & De Ravé, 2014). In the study area, such spaces are found in at least two locations ie. Kalabagan play field to Russel Square and the Sangsad Bhaban area. Potential spaces are also situated at BCSIR area, Teacher's Training Institute, and Kalabagan Govt. Colony area; all of which shares solid walls with the pedestrian space, despite having extensive vegetation or green field immediately after the wall. Remarkably, all these spaces are government owned. A combined initiative can incorporate these spaces with the pedestrian path without encroaching upon them in order to improve the pedestrian space quality and especially auditory, olfactory and visual experiences performance.

4.3.2 Olfactory Experience

Dust is one of the major sources of olfactory discomfort in the study area. Pedestrian space should be connected through a vegetation buffer with the vehicular path in order to decrease the level of dust (Fig 4&5).

Another source of discomfort is odour, originating from vehicular traffic, open waste bins and open littering. Use of old and ill-maintained mechanized vehicles increase exhaust smoke pollution, and yet passive mitigation measures, such as vegetation or green buffer, is not being used in the street. Open waste bins usually kept directly on the vehicular path beside the pedestrian space spreads unbearable odour. Waste collectors appointed by the City Corporation apparently removes the waste on a regular basis, yet the odour effect prevails. It is because the waste collection process itself is not precise, and general practice of dumping wastes around the waste bins worsens the situation. Observations show recent installations of small waste bins along the pedestrian path by the City Corporation have negligible impact on open littering practices (Fig 6).

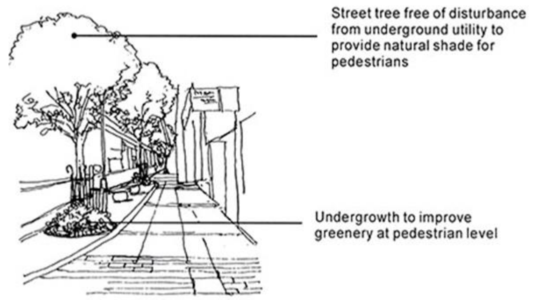

Fig 4: Plantation within pedestrian space; minimize dust, noise, heat.

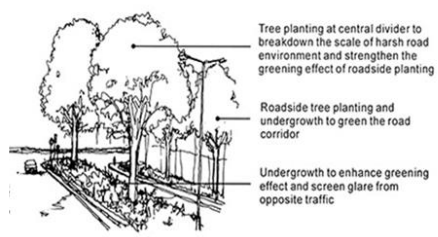

Fig 5: Plantation buffer in between vehicles and pedestrian (Mowla, 2000)

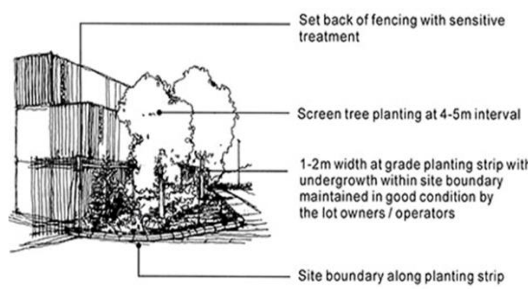

Fig 6: Pedestrian Walkway/Footpath; Unsightly / Garbage areas hidden behind plantation (Mowla, 2000)

5. DISCUSSIONS ON DESIGN RESPONSES

In order to improve the space quality and betterment of pedestrian experience, responsive design schemes should be incorporated within the development plan of the study area. Figures 2-6 in the foregoing discussion provides guidelines of necessary design interventions in different situations. Besides those, following more responses may be adopted as interventions

Image 5: Adjacent water front and small land patches along the road may be planted with colourful plants.

Image 6: Nooks and Corners along the road and open spaces may be lined by pedestrian ways with plantation and seating arrangements for the pedestrians.

Roadside plantation and high quality hard landscape should be provided to improve the quality of the street environment. Tree planting, shrub beds, landscaped areas should be incorporated to soften the hard edges and to reduce heat build-up of street environment. In order to ensure the provision of shaded pedestrian routes, where necessary, species may need to be physically robust and resistant to traffic fumes.

Sky walk and Lobby can be another intervention in the existing congested areas to relocate the hawkers and footpath encroachers to an upper level freeing the ground space (Fig 7). Besides, foot over bridges if connected to the adjacent public buildings also reduces the load on the ground.

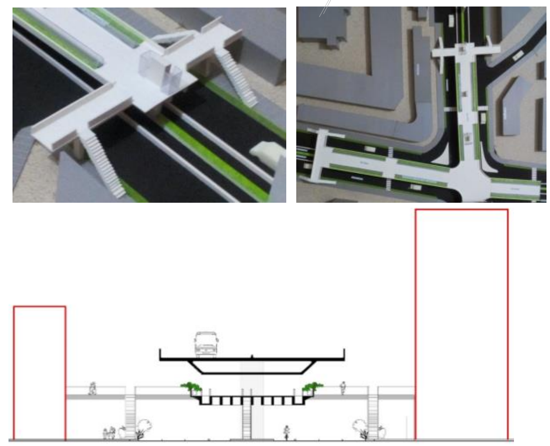

Fig 7:Footoverbridges may be integrated with adjacent public buildings /shopping centres.

6. RECOMMENDATION

Analysis, Observations and discussions lead to the following recommendations.

- Effective pedestrian thoroughfare width should be maintained as a priority.
- Street frontage can be maximized in two phases. In the government owned properties and structures, a common guideline would be followed to incorporate smaller and more active commercial street frontages. In privately owned properties, specific incentives may be declared under building by-laws, such as bonus FAR, TDR (Transfer of Development Rights), reduced taxes, other commercial fees, property taxes etc.
- Use of situation and case specific street furniture, such as pedestrian level lighting provision, inviting seating, shaded seating devices, covered waste bins, ATM/Phone outlets etc.
- Encroachments on pedestrian space must be removed completely, and regulatory monitoring system with adjacent property owners should be incorporated in order to discourage them in future.
- Abrupt level changes should be modified (and grade change planting) to a minimum number so as to allow pedestrian an uninterrupted walking experience.
- Important nodes may be provided with sky-walk / plazas connected to adjacent open spaces on either sides of the road i.e. in

Russel Square, Kalabagan, Science Laboratory and New Market nodes.

- Open spaces having vegetation and water bodies should be incorporated with the pedestrian spaces at grade or above the grade in observed locations. Besides, incentives may be offered for the private property owners to encourage such initiative for maintenance as per guidelines.
- Adjacent property owners should be made responsible for the maintenance of space between the property and the road as per given guide lines.
- Unless absolutely essential no property adjacent to the road should be allowed to build solid walls higher than 2500mm. Road side boundaries should be see through.
- Waste collection system should be upgraded so that the waste collection ensures complete removal of wastes. Collection points should be hidden in nooks and corners, preferably with vegetation.
- Public awareness regarding waste disposal and littering should be enhanced by out-reach programs and incentives for beneficiary groups and road adjacent property owners, which might also include the users of major thoroughfare and general citizens.

7. CONCLUSION

Pedestrian spaces along a major thoroughfare such as Mirpur road require separate incentives / responsibility package to the adjacent property in order to encourage effective use and maintenance. Provision of pedestrian amenities, safety security and engagement of property owners in the development and maintenance is the major recommendation of this study. This study initiated a process to find out the needs and priorities of the large pedestrian people of a major arterial road - Mirpur road, which is believed to be applicable to all such situations. However, further such studies can be carried out throughout Dhaka to determine location and place sensitive interventions for all pedestrians.

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AN ANALYSIS OF THE OPPORTUNITIES AND PROSPECTS OF NEGLIGIBLE SPACE UNDER FLYOVER

A CASE STUDY ON BAHADDARHAT FLYOVER, CHITTAGONG

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Abstract: *Transportation system in developing country is a big challenging sector in recent years. Rapid urbanization and booming population per capita are creating an additional stress on urban transportation and traffic system, for instance, the number of public and private vehicles are increasing without widening the roads. Besides, the volume of traffic or modal split produces demands for space greater than the available road capacity which has created traffic congestion and affected the living life of urban residents. Instead of long term plans, the respective authorities are taking initiatives to build flyovers by narrowing the main roads reducing the effective width of carriageways as an immediate outcome and these mega structures turn into a big burden for the further urban design and planning of the city whereas many countries of the world are dismantling their flyovers. In parallel, these constructed flyovers are creating leftover spaces under it with negligence of its effective uses and also accelerating more traffic congestion. However, this type of unused spaces are functioning as a visual barrier with both sides of the roads, spoiling the city environment, street aesthetics and civic demands. The main objective of this study was how to find the effective use of such spaces under flyover and how it becomes more environment-friendly in city level. The study was focused on the existing conditions and issues under the 'Bahaddarhat-flyover' at Chittagong city having a degraded scenario. The prime concern of this analysis is based on empirical survey and the perception of surrounding localities of that area. Throughout this study approach, some problems were recognized and explored its opportunities and prospects into urban planning framework by feasibility analysis method to enhance urban environment and streetscapes.*

Keywords: *Environment-Friendly Design; Flyovers; Space Utilization; Street Aesthetics; Urban Environment.*

1. INTRODUCTION

In present times flyovers are built to reduce the traffic congestion and split the traffic flow but are not a long term solution. However the underneath spaces of a flyover are unused and creating visual barriers (Islam & Kabir, 2015). These spaces are negative spaces which need to be considered as a problem and require a solution. By making these underneath spaces more effective and environmental friendly, urban and street aesthetics can be developed.

Bahaddarhat is a very important node in Chittagong which creates a huge traffic congestion. For splitting the traffic flow, a flyover was built above Bahaddarhat node which in spite of solving the problem, has created more traffic congestion on the underneath narrow roads and also created leftover unused spaces underneath. In this study the objective is to find effective use of these spaces and make these spaces more interactive to the civic life. Thus it will have a positive impact on the surroundings and make the unused spaces effective. For this clear conscious use identification of specific portion of the underneath spaces and adopting policy measures accordingly is an essential task.

2. LITERATURE REVIEW

In our country Planners and designers design and construct projects with futuristic and modern thoughts and most of the time the contextual needs of our country remain absent. In addition structures, surrounding environment and street aesthetic get absorbed by technology. Moreover, the lacking of foresightedness in planning and design creates urban voids. However, the places underneath the flyovers are one of the examples of this unintended planning. In most cases, the fly under voids has no use. They are kind of dead space with neglected landscaping. Therefore, lack of spaces in the city has made these voids a desirable resource for poor urban homeless people. Their spontaneous use of fly under spaces is damaging the potentials of these voids. To discuss the mentioned cases, this study paper has envisioned some design opportunities that may boost the fly over's role as a public space through the facility of some social and recreational activities for the marginal people in Chittagong city. (Islam & Kabir, 2015)

Space under flyover reflects the people's desire for space simultaneously to explore the possibility of greater use of various forms of open space (Shi & Duarte, 2016). In fact participation by the community is the driving factor behind a successful habitation of the leftover spaces. It is the existing community that understands the shortcomings in their everyday life in order to function fittingly.

Technically flyover is a single bridge which structured constructed upon long pier (Shi & Duarte, 2016) and purpose of flyover is to eliminate traffic congestion as much as possible. It's an underneath space that is longitudinal. The volume of space, height variation depends on construction user's requirement. Depending on the heights different activities happen. Pavement, paved road, earth and natural landscape are covering the ground. (Zaman, Samadi, & Azhari, 2013)

Though the negative impact produced by elevated side-by-side highways to a community can be worse than the one produced by the elevated stacked highway. Shadowing, noise, disconnection of neighborhoods are negative effects of this structure, and views are disrupted to those of the elevated stacked highway. However, the negative effects produced by elevated highways can be reduced through careful design and more important the incorporation of the spaces below into their surrounding urban environment. (Shi & Duarte, 2016)

Unused spaces under the flyover have no specific definition it can be called leftover space or urban void. This place has the opportunity to reform and design. (Shi & Duarte, 2016)

3. METHODOLOGY

Existing information is collected by the process of observation, reconnaissance survey, focus group interview, SWOT analysis. In the survey process direct observation help to understand the present situation of the area, people activity and participations, problems and data recorded in the form of photographs, sketches and writing records were documented and received. The secondary data on bahaddarhat flyovers adjacent areas and related aspects were collected from various published sources. The reconnaissance survey was performed by walking through the adjacent area. Interviews of local and ongoing people were asked various questions, and conversation was made to analyze problems they face and those people were selected for their specific knowledge, experience and opinions regarding the flyover. For further find outs, opportunities and possible recommendation, the SWOT analysis was conducted.

Policies and ideas have been given by analyzing situation through stages. By going through steps their priority has been enlisted. Some policies and opportunities envisioned to enhance the flyover under role as a public space through the accommodation of some social and recreational activities.

All the collected data regarding transport, traffic analysis and land used related information were analyzed by Google Earth ,GIS map, MS Word, MS Excel, Adobe Photoshop, PDF Converter etc.

4. STUDY AREA AND EXISTING SITUATION

Chittagong is known as the major coastal seaport city and financial center in southeastern Bangladesh. The population of this city is more than 2.5 million and the metropolitan area has a population of 4,009,423 at the 2011 Census, which makes it the second largest city in the country and this rapid growth of population is becoming burden on urban transportation and traffic system. As a result the number of public and private vehicles is increasing day by day. However, to handle this vulnerable situation, CDA (Chittagong Development Authority) is building flyovers which are reducing the effective width of carriageways. (Wikipedia, 2017)

Bahaddarhat intersection connects Chittagong with the south eastern parts of the country. It is a very congested road junction. A various mix of vehicles such as bus, minibus, trailer, truck, rickshaw, microbus, car, motor bike, and various forms create traffic at intersection point. Also a large number of pedestrians are also circulating through-out the intersection (Rahman & Ahmad, 2015). In addition the surrounded area of intersection generally consists of both residential and commercial establishments lining both sides of the connecting roads.

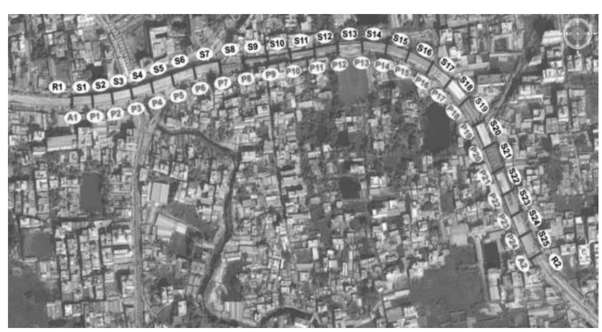

Fig. 01: Satellite view of piers location of Bahaddarhat flyover (Rahman & Ahmad, 2015)

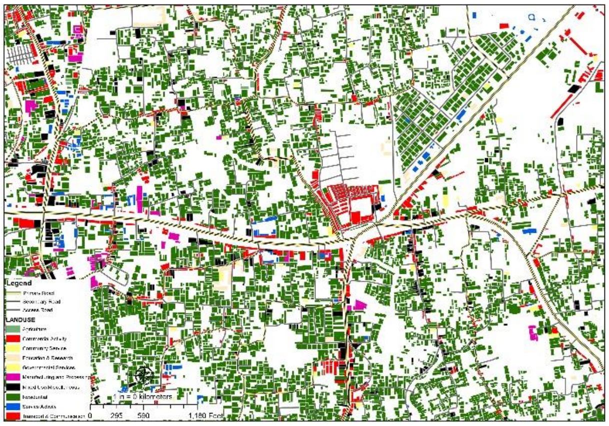

Fig. 02: present land use condition around Bahaddarhat flyover
Source: Authors

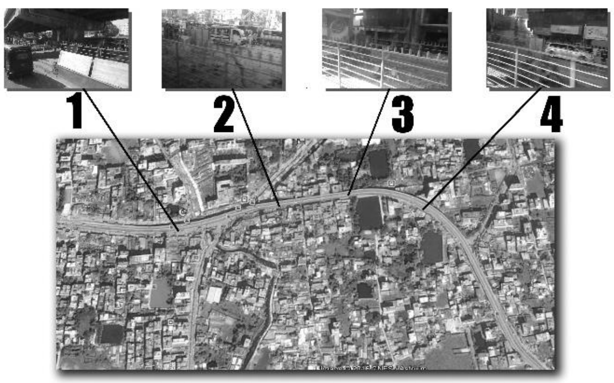

Fig. 03: Bahaddarhat flyover present condition
Source: Google earth and Field survey

Fig. 04: Blow up of Bahaddarhat flyover present condition (location 1)

Fig. 05: Blow up of Bahaddarhat flyover present condition (location 2)

Fig. 06: Blow up of Bahaddarhat flyover present condition (location 3)

Fig. 07: Blow up of Bahaddarhat flyover present condition (location 4)

The Bahaddarhat flyover which is 3.7 km long has been commissioned in October 2013 in Chittagong City. Figure 01 shows the satellite view of piers location of Bahaddarhat flyover. As we know Bahaddarhat has been a very important and crowded zone, a large number of people and vehicle circulate in this zone every day. In part of the fly under section of this flyover has unplanned usages, lacking of spaces in the city has made these spaces a desirable resource for poor urban homeless people. Their spontaneous use of fly under spaces is damaging the potentials of these voids. Moreover, absence of landscaping, proper lighting system transform the voids as crime zones specially at night. Instead of planning long term plans, the authorities are confining the spaces by steel railings. (Rahman & Ahmad, 2015). Figure 02 has shown the current land use scenario around study area which is main civic dominating spaces and functions. In figure 03 we can see the different points of study area and figure 04,05,06,07 show the current condition of these points.

5. RESULT AND PROPOSAL

SWOT analysis helps to understand the strength, weakness, opportunities, threat of the unused spaces of Bahaddarhat flyover. It also clarifies issues more closely. Field observation at different times provides a better understanding of possible strategies of leftover spaces. It also added a visual glance of people relationship with environment. The findings show that most of the structures are used for residential purposes as we can see in Table 01. To improve habitants' civic life some activities such as resting zone, exhibiting the history through a path, street children opportunities and recreational activity services for all section of people can be served by using the voids. Figure 08 shows the land use near 100m area of Bahaddarhat flyover, that layout of land use can be visible also in figure 01.

Table 1: Structure number of landuse pattern.

Land use	Number of structures
Residential	719
Commercial Activity	217
Community Service	24
Manufacturing & Processing	11
Transport & Communication	8
Education & Research	24
Mixed Use	110
Miscellaneous	32
Service Activity	71
Others	6

Source: Field survey

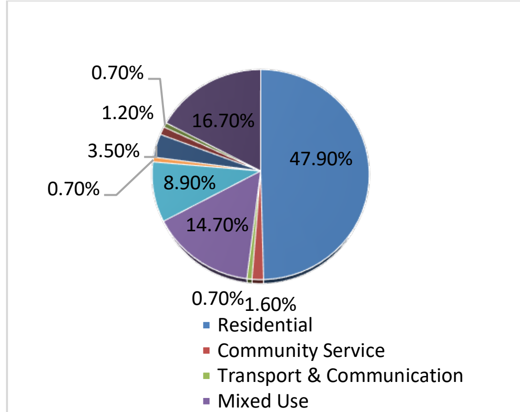

Fig. 08: Land use near 100m of flyover
Source: Field survey

300ft distance from the node should be used as green space and simple sitting zones which can be used for resting and waiting for vehicles. Newspaper reading walls can also be proposed where people will read the daily news. Underneath spaces of flyover can also be used as bicycle parking (figure 09, 10). In night time and in holidays when the traffic flow is less, night schools can be set up for educating street children (figure 11, 12). This will make the space more active at night and crime rate will decrease.

For executing these proposals the most important factor would be accessing these spaces. Specific zebra crossings should be used to cross the road and access these underneath spaces from the side of the main roads.

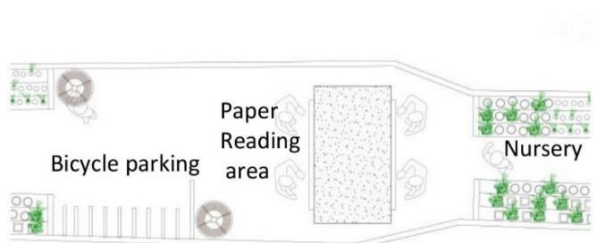

Fig. 09: Plan of proposed newspaper reading space, bicycle parking and nursery.
Source: Author

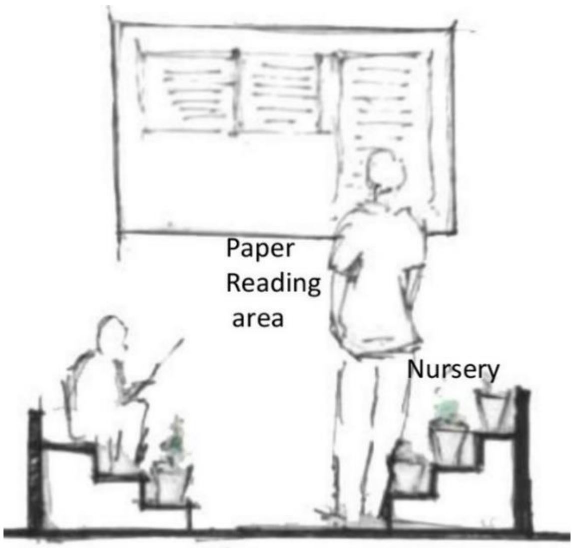

Fig. 10: Section of proposed newspaper reading space.
Source: Author

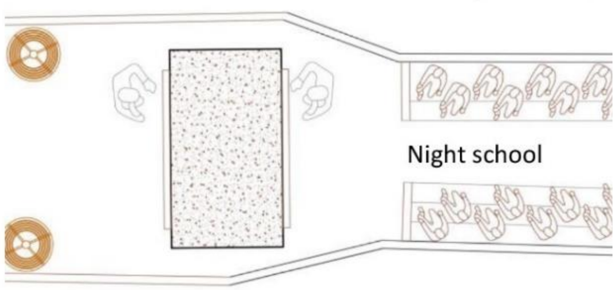

Fig. 11: Plan of proposed night school.
Source: Author

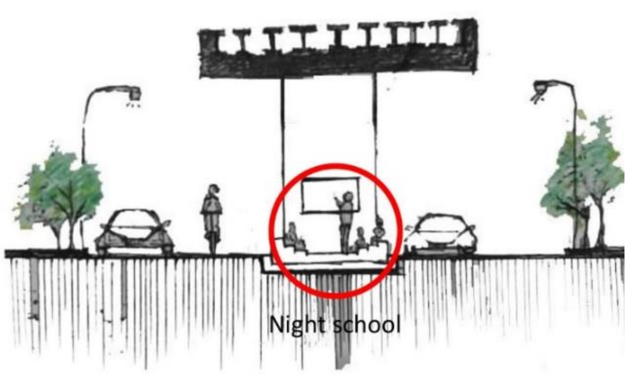

Fig. 12: Section of proposed night school.

6. CONCLUSION

The population of urban cities regularly suffers from lack of proper urban facilities. As urbanization requires more and more infrastructure for housing, business and transport networks as a result it causes to lose its desirable urban spaces. However, the construction of new flyovers actually does not consider the mass people during their design and planning. On the other hand the leftover spaces underneath the flyovers have potentials to accommodate urban facilities which somehow overcome the need of desirable urban spaces. This study shows how to bring these neglected voids into the public territory with design proposals and create a better spatial environment for the local neighborhood and surroundings.

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RETHINKING RESIDENTIAL DEVELOPMENT PROCESS
A STUDY ON RESIDENTIAL AREA IN DHAKA CITY

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Abstract: *A city should be a place where inhabitants have a common life for a noble end. The fast-growing megacity Dhaka always goes through transformation, change and readjustment, which are the main reasons behind Dhaka's organic development. With ever increasing population, residential area has been naturally developed without any thoughtful planning. Within this methodology, some parts of the city have been planned deliberately as residential area in where lands are divided into plots; Infrastructure and utility facilities are also developed following building rules. But it has shortage of amenity facilities and sustainable living environment. This type of planned residential area is a major reason behind fast disappearing old structure of social communities, greenery and common shared life. The paper focuses on urban planning of Dhaka city, which should be considered as an art of shaping and guiding the physical growth of urban area, creating environments and buildings to meet the various needs such as social, cultural, economic, recreational etc. The study was based on the field survey conducted in 2015 in Dhaka. Books, published reports, bulletin, journals and newspapers were the sources of secondary data. The aim of the paper is to rethink the planned residential area beyond plot dividing system and an attempt to show an already developed residential area in a new way. It is found that, group housing provides higher quality of urbanity and better community facilities, more green and open space, drawing connection with the built and un-built, sustainable living environment and shared life style, although after achieving greater density. It is expected that this study paper will be useful to provide a guideline for further development of residential area to make a green city.*

Keywords: *Group housing, Planned residential areas, Sustainable environment.*

1. INTRODUCTION

1.1 Background and Objective of the study

Dhaka is the capital of Bangladesh, it has grown mostly without planning interventions; substantially organic in nature. Today, the Dhaka Metropolitan Area is the 11th largest city in the world, with a population of 14.54 million and is predicted to be the 6th largest by the year 2020 if the current growth trend continues. Dhaka alone contains 37% of total national urban population; population growing by an estimated 3.96% per year, one of the highest rates amongst Asian cities (RAJUK, 2015). The Greater Dhaka Area has a population of over 18 million as of 2016, while the city itself has a population estimated at about 8.5 million (Dhaka population, 2017). It is one of the most densely populated areas in the world, with a density of 23,234 people per square kilometre within a total area of 300 square kilometres (RAJUK, 2015 and Dhaka population, 2017).

With ever increasing population, residential area has been naturally developed without any thoughtful planning. According to the reports of DAP-2006 and RAJUK-2013, in those seven years, Dhaka's residential area increased from 28.16% to 37.36%. Another report of RAJUK showing that current average residential density is 799p/ha, which will increase up to 1068p/ha by the year of 2035, and according to the UN estimates, Dhaka will be home to 25.94 million people by the year 2035 (RAJUK, 2015) (Table-1). But the housing condition of Dhaka is truly miserable. There is over 1.9 million dwelling unit, among them 40% are formal and 60% are informal. This city contains more than 1 core people of which only 15% have their own house, 18% people live in colonies, 13% live in slums and 34% live in rented houses and the left 20% is floating (Mowla & Afrin, 2008). In Dhaka presently number of dwelling units added per year is about 25,000, which is far less than the required number. According to BBS (Bangladesh Bureau of Statistics) data, the backlog of dwelling units in 2015 will be 0.76 million (RAJUK, 2015) (Table-2).

In this scenario, some parts of the city have been planned deliberately as residential area in where lands are laid out on a grid iron pattern and consist of rectangular plots; Infrastructure and utility facilities are also developed following building rules. In beginning periods of plotting system, predominant house form was individual private homes with a front lawn and a back garden. That was a picture of perfect residential area. But as Dhaka started expanding rapidly, those residential areas had to accommodate the pressures of substantial urbanization. Not only that, due to the weakness in planning rules and zoning policy, non-residential functions invaded into the planned residential area to meet the demand of the growing population. As a result, the planned residential areas have changed into a mixed land use pattern and transformed into an unplanned state in relation to their physical layout. This type of planned residential area is a major reason behind fast disappearing old structure of social communities, greenery and common shared life. And shortage of open space, amenity facilities creates unsustainable living environment.

The objective of this paper is to discuss that why plotting system is not appropriate for current situation of residential development and which type of development we have to choose for us. It's an attempt to explore alternative imaginative models of residential development which will develop as one single housing complex, intention should be to achieve greater density, better environment for living, including generous open spaces, play field, gathering areas, amenity facilities with small commercial facilities and shared life style. There will be more light, air and green for each unit. Loan and Tax relief incentives may be offered for initiating such projects. For new areas under planning housing should be enforced by requirement.

1.2. Research Methodology

The study began with the conceptualization of identifying the necessity of well-planned residential area for an orderly urban development of Dhaka. Because the problem is not urban growth itself, problem is how to manage that growth in ways that both minimize costs and maximize benefits to individuals and to the larger public. The characteristic of the residential areas in the city has undergone dynamic changes mainly due to commercialization. Thus, urban lifestyle and house form experiences a series of alteration and adjustment in its planning, organization and hierarchy of space, and façade treatment, that correspond to the changing habits and activities as opposed to traditional behavior. By considering the present situation of residential area in the city of Dhaka, the approach was to search the factors for which plotting system is no more effective for present situation. The study was based on the field survey conducted in 2015 in Dhaka. To conduct the study, a total of 403 multi-storied buildings are considered in the study area. The field survey covers the statistics of present building stocks, height and land use pattern, existing plot and unit size, household income, expenditure, housing cost and affordability, findings and possibilities. Published reports, bulletin, journals and newspapers were the sources of secondary data relevant to present situation of residential areas. A combination of quantitative and qualitative data analysis was used to grasp a better understanding of the real picture that exists in existing residential areas and the study area.

2. PRESENT SITUATION AND PROBLEMS OF PLANNED RESIDENTIAL AREA

Dhaka city grew from a rural settlement to become a mega city without much planning effort. Grid iron pattern roads with rectangular plots are known as planned parts of Dhaka, which started in the city for the first time in Wari and Gandaria in 1885. In 1905, Ramna was also planned as government residential district. The planning authority first planned residential areas in Dhanmondi in 1948. Comprehensively planned residential areas of Gulshan, Banani, etc. are the successors of this type, which were developed by the city authority DIT (Dhaka Improvement Trust) (presently RAJUK). National Housing Authority developed some of the residential areas or estates according to their plan, which includes Mohammadpur and Mirpur for lower and lower-middle income groups. Another major planned residential project was the Uttara Model town (1360 hectare), which was planned by DIT. Baridhara was developed in 1972 as high-class residential area acquiring 150-hectare land (Khan and Nilufar, 2008). All these planned residential areas follow a rigid grid iron pattern with some semi-circular arcs. Almost 90% structures in RAJUK area are being used for residential purpose. RAJUK is the leading public sector land development agency in Dhaka city supplying about 75% of the city's serviced housing plot by the public sector. It has developed some 13 townships /housing estate/site & services projects. The private land development companies are also engaged in developing various land-based housing projects, through which they supply serviced plots. They are actually now playing the lead role in the supply of serviced housing land (RAJUK, 2015).

It has been revealed on morphological study that there is very little change in the physical layout, the block and street pattern exhibits minor changes, but the total numbers of plots have gradually increased. The land use study represents the changes in land use pattern and building height. Due to the change in building height, total environment of the residential area transformed into an unsustainable situation. Most of the plots are surrounded from three sides of it, so the open air and light are not sufficient in here, only 3feet/6feet gap remains between the buildings, which are also covered by pavement. Because of these types of residential developments, temperature rises far more. The researchers found that 30% area of the capital city was hot in 1989. The hot area expanded up to 65% by 2014. These are densely populated commercial and residential areas where 80% of the city dwellers live (Haq, 2011).

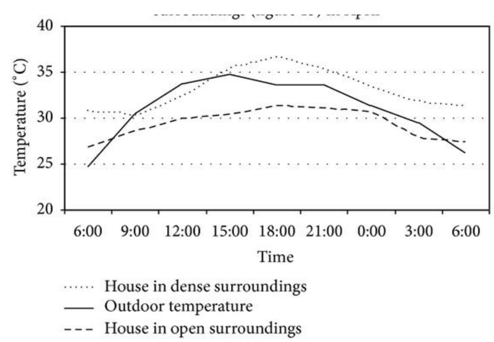


Fig 01: Comparison of indoor temperatures between in a house in dense surroundings and open surroundings.

For the lack of soaking land, the flow underground water level is decreasing, thus, occurring water and soil pollution. Lack of interaction spaces, play fields, open spaces, amenity facilities are creating gaps among urban dwellers and disappearing old structure of social communities as well as making unhygienic environment. So, it can be declared that the strategy of producing housing through plots is neither economically productive nor socially effective. The intention should be to achieve greater density, better environment for living, better community facilities and shared life style (Ashraf, 2012).

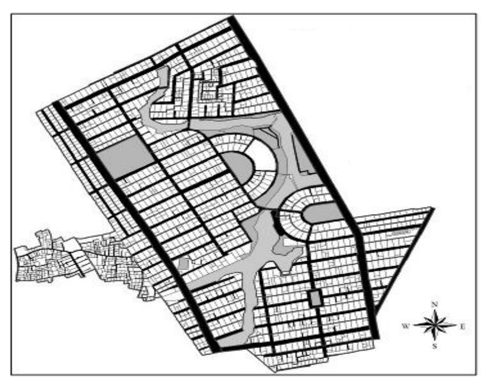


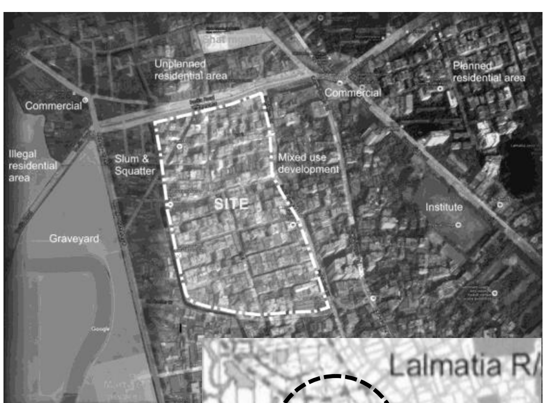
Fig 02: Dhanmondi residential area a example for plotting system

3. THE STUDY AREA

Ward no 33 of north DCC has been selected as the site for case study. This ward is located in the western part of Dhaka city (Fig-03). In Detailed Area Plan, this area is demarcated as

Detailed Planning Zone (DPZ) 9, Zone-05, Group-C. The site starts from 120' wide Mohammodpur to Baribadh link road. Once there was a water body on the west side that remains as a polluted box culvert. Secondary road, known as Sadek khan road, is situated on the east side and the site ends at a dead-end secondary road. Land use of this area is mainly residential. Two developer companies "Katasur housing society and Kaderabad Housing Ltd" developed ploting based housing for middle income group. Haphazard development is prominent in this area. Land price is also increasing at a high rate. It's an already over build up site which has fewer amenity facilities for people and doesn't have any kind of open space.

The Site area is 48.6 acres and Built-up area is 42.25 acres. Residential, commercial and mixed plots exist on 39.25 acres, 1.23 acres and 2.9 acres respectively. Vacant plots are 2.9 acres, Mosques are on 0.33 acres of land, and roads and utilities have occupied 7.25 acres. A box culvert remains in western side of the site with 2 acres of land and other 3.2 acres bare land is created by building gaps. But there is no open space or play field on the site. Neither there has any kind of proper amenity facility nor has proper infrastructure system. Existing population of the site is approximately 15600 and existing households are 2796. So, there approximately lives 321p/acre already.



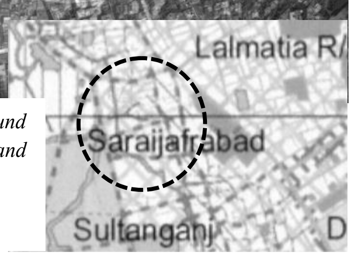


Fig. 03: Existing Ground Analysis of Site and Surrounding.

3.1 Existing Land Use:

In the existing study area, 55% of plots are used for residential purpose; among them total 316 are Residential buildings. 4% of plot is used as mixed use building area. On the other hand, there is 3% commercial land and a *KACHA* bazar situated in the centre of the site. 15% of the site is covered by roads, but roads are narrow and without pavements. There are differently sized plots in the site, maximum of them are 5 and 6 katha. Many buildings of the site have deviated the BNBC rules. But FAR (Floor area ratio) analysis for study area's plot is showing that if all the buildings are built according to FAR then the situation will be worse than existing. So it is high time to think about building FAR. Building FAR rules are beneficial for large size plot, for small size plot it makes the situation worse.

Fig 04: Existing land use map with building height

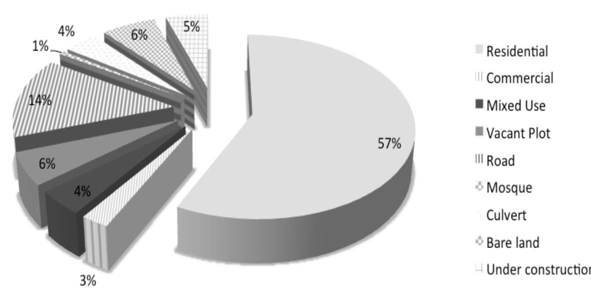


Fig 05: Ratio of Existing Land Use

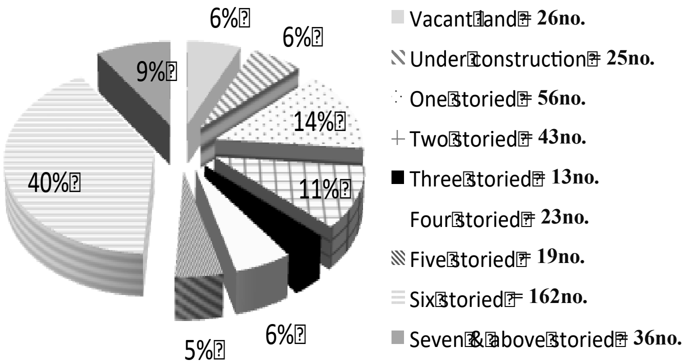
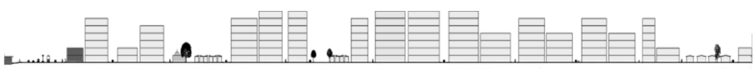


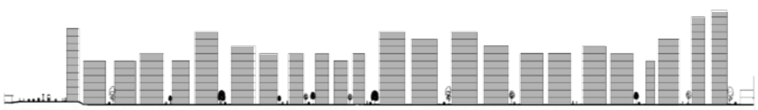
Fig 06: Ratio of Existing Volume study

[Existing FAR = 75,31,922.25 sft, (approx.)

Existing population = 15600 no. (approx.)]



Section of Existing Volume study



Section of Volume study According to FAR

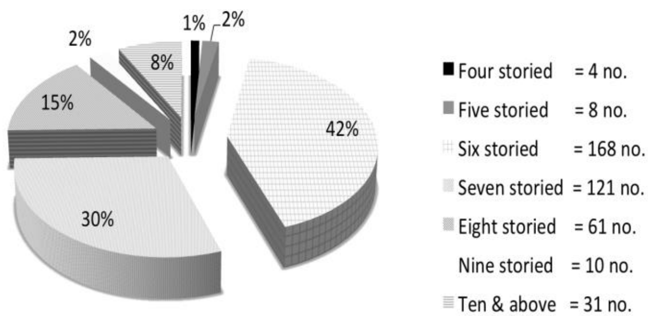


Fig 07: Ratio of Volume study according to FAR

Future total FAR could be = 68,75,535 sft – 79,36,801.85sft

In future total population will be = 25305 person (approx.)

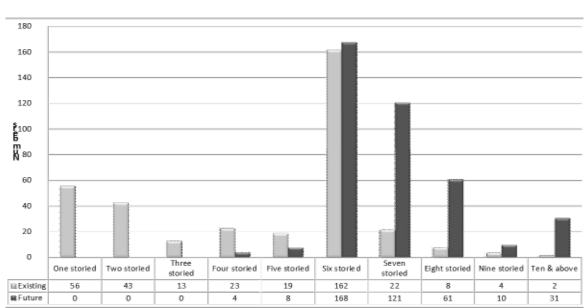


Fig 08: Comparison between existing and according to building FAR building height

3.2. Proposal for study area:

Fig 09: Propose Master plan for study area

LEGEND

MOSQUE
HIGH SCHOOL
PRIMARYSCHOOL
COMMUNITY CENTER
RETAIL SHOPS
ADULT PLAY FIELD

Design of a group housing has finally been proposed for the study area with sustainable living environment, generous open space and gathering space, all kind of amenity facilities for community living after achieving greater density. In this design, there is a total number of seventeen highrise residential (15storied) buildings, which are used to allocate 3300 households. Each building has its own inter connected micro level interaction point or sky terrace for different age group people. Every residential block has its own central play field, a common play field of the total housing is also designed for adults.There are two primary schools, one High school, two mosques, two community halls and two community office also designed for providing proper amenity facilities. Different leveled open spaces are used to achieve sustainable environment. It is expected that this proposal will full-fill the expectations to provide a guideline for further development of residential area to make a green city.

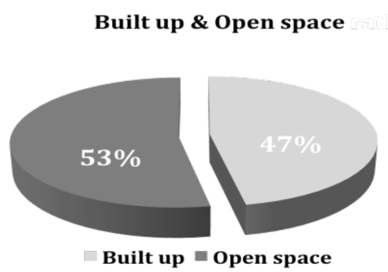


Fig 10: Ratio of Proposed Open space and built up area

POLICY FOR PROPOSAL BASED ON:

Environmental Issue:

1. Proper living environment.
2. Natural light and ventilation.
3. Including generous open spaces. Play field and gardens.
4. Add amenity facilities.
5. The crisis of pollution will be solved.
6. Individual spaces for different age group.
7. Create wetlands beside water channel.
8. Encourage lake side activity

Design Issue

1. Start land sharing, stop plotting.
2. Develop as one single housing complex.
3. Develop neighborhood concept.
4. Turn a building to a home.
5. Achieve greater density.
6. Same sqft will be given as the existing.

Social Issue

1. Formed community with shared life style.
2. Respecting the culture and context.
3. Safety and security will be established.

Economical Issue

1. Economic partnership and incentives may go towards creating housing.
2. Loan and tax relief incentives may be offered for initiating such projects in exiting built conditions.
3. Income group will be changed.
4. Per sqft price of dwelling unit will increase.
5. Owner can be asking for big rental price.
6. It is economical more productive then plotting.

Table-3: *Existing Flat size and Numbers from Physical survey of 2015*

EXISTING FLAT SIZE (sft)	NUMBER	Total (sft)
600	492	295200
750	600	450000
900	1272	1144800
1100	1020	1122000
1200	160	192000
1300	516	670800
1400	231	323400
1500	300	450000
1600	302	483200
1700	160	252000
TOTAL	5053	48,03,400

Table-4: *Proposed Flat size and Numbers*

PROPOSED FLAT SIZE (sft)	NUMBER	Total (sft)
1000	1800	1800000
1400	750	1050000
1800	750	1350000
TOTAL	3300	42,00,000

According to Physical survey 62% dwellers of the study area are land owners and 38% dwellers are flat owners. Same or greater sqft will be provided to flat owners. But their income group will be changed because of increasing land value or per sqft value. Physical survey also showed that 54% dwellers of the study area are living by rental basis; they rent their flat from land owners. So, when the whole environment of the study area will be changed by the proposed design, then the rent of the flats will be increased, therefore owners can ask for greater rental price for even smaller flat. Design will try to provide same or greater sqft to land owners. Some land owners will get commercial space from central retail shops as an exchange with residential flat.

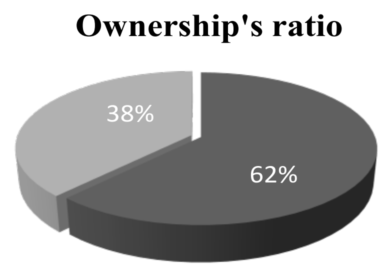
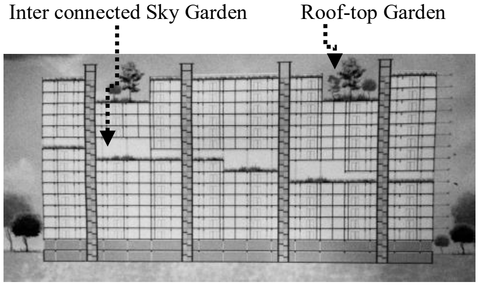
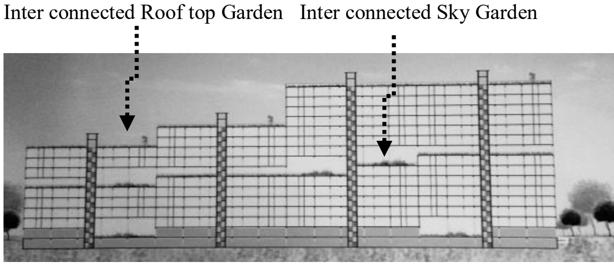


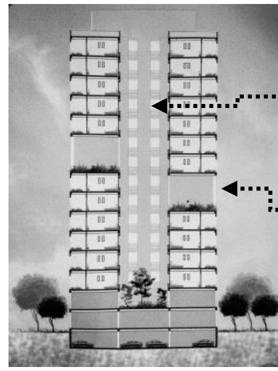
Fig11: Ratio of Land owners and Flat owners



Section of a road side building (1000sqft)

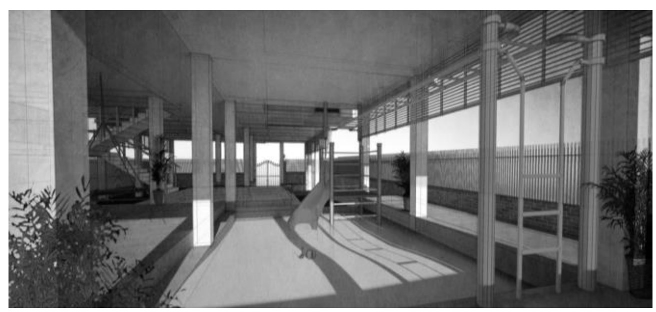


Section of a lack side building (1800sqft)



Section of building

Central Play Field between two buildings



Inter connected Micro level Interaction space

4. CONCLUSION

This study tries to identify impacts on the study area for haphazard development and recommends some policy guidelines from planning perspective to manage the unplanned development process of the study area and finally propose a design of group housing for the study area with sustainable living environment, generous open space and gathering space, all kind of amenity facilities for community living after achieving greater density. A strong central governmental body should be established to monitor such projects. Developers and private companies in Bangladesh should take initiatives to establish group housing. It is also expected that with all those limitations of our country we will dare to think in a new way to develop the present situation and turn our city into a green city.

ACKNOWLEDGEMENTS

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APPENDICES

Table-1: *Population Growth Scenario from Base Year 2000 to 2035 (figures in millions).*

Year	Pop from NI	In-migrant & its NI (Cumulative)	Total Pop.	Total Increase	Cumulative Increase	Share of NI %	Growth Rate %
2000	10.28		10.28				
2005	10.92	1.42	12.34	2.06	2.06	30.78	3.72
2010	11.53	3.20	14.73	2.38	4.44	25.72	3.60
2015	12.13	5.19	17.32	2.59	7.04	23.09	3.30
2020	12.74	7.09	19.83	2.51	9.54	24.14	2.74
2025	13.33	8.88	22.21	2.38	11.92	24.86	2.30
2030	13.85	10.37	24.22	2.01	13.93	26.09	1.75
2035	14.30	11.64	25.94	1.72	15.66	26.24	1.38

Source: Total population up to 2010 from UN estimates. Notes: NI= Natural Increase; NI rates for both base population and migrants assumed as same, interpolated from UN national NI rates projection

Table-2: *Housing Need Estimation for RAJUK area upto 2035 (in millions)*

Region	Population/ Demand	Year					
		2010	2015	2020	2025	2030	2035
Central Region	Population	8.61	9.76	10.83	11.76	12.46	13.05
	Household	1.88	2.11	2.36	2.63	2.87	3.07
	Demand	0.41	0.46	0.51	0.45	0.63	0.67
Northern Region	Population	1.58	2.09	2.60	3.11	3.55	3.91
	Household	0.39	0.5	0.66	0.84	1.05	1.28
	Demand	0.07	0.09	0.11	0.14	0.18	0.22
Eastern Region	Population	0.60	0.66	0.73	0.83	0.95	1.08
	Household	0.14	0.15	0.17	0.19	0.21	0.23
	Demand	0.03	0.02	0.03	0.03	0.03	0.04
Southern Region	Population	1.91	2.22	2.50	2.76	2.97	3.15
	Household	0.45	0.52	0.6	0.68	0.76	0.82
	Demand	0.07	0.09	0.1	0.11	0.13	0.15
South-Western region	Population	0.77	0.87	0.95	1.06	1.18	1.31
	Household	0.17	0.19	0.22	0.25	0.28	0.31
	Demand	0.03	0.03	0.04	0.04	0.05	0.05
Western Region	Population	1.25	1.73	2.21	2.69	3.11	3.44
	Household	0.33	0.42	0.54	0.65	0.74	0.81
	Demand	0.07	0.07	0.09	0.11	0.12	0.13
Total	Population	14.73	17.32	19.82	22.21	24.22	25.94
	Household	3.36	3.89	4.55	5.24	5.91	6.52
	Demand	0.68	0.76	0.88	0.88	1.14	1.26

Source; Population Census 2011 & Compiled by Consultant, RDP
*Household size in 2011 was 4.51 where as it is expected to be lowered to 4.01 in 2035 through government effective population planning and motivational measures.

A STUDY ON LOCAL VULNERABILITY AND SUSTAINABLE DEVELOPMENT STRATEGY FOR A RIVERINE FISHING COMMUNITY

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Abstract: *Bangladesh is already evidencing the adverse impact of climate change by facing some extreme natural hazards. Over the years, disasters like cyclone, storm surge, sea-level rise, river-bank erosion and so on have frequently caused large scale damage to millions of lives and property. Among them, riverine communities face direct consequences at various levels for their geological location and socio-economic condition. This study explores the different aspects of vulnerability indexes due to climate change in a selected riverine fishermen community on the bank of Karnaphuli, Chittagong. It has been seen that disaster vulnerability makes the inhabitants of such community the worst victim of climate change. The aim of this paper is to identify a sustainable development strategy for the existing community from an in-depth empirical research and survey on vulnerability to climate change. Both quantitative and qualitative methods are employed to generate primary data. Field visits and reconnaissance surveys have been conducted in the beginning. 50 households have also been surveyed through a predefined questionnaire. Data generated from the field survey identifies the vulnerability context in social, economic and environmental issues. These findings show that some residents of the communities are resilient, while others are passive and are more vulnerable to natural hazards. In addition, this paper will propose some community-based adaptations to pursue disaster resilience by reducing local vulnerability.*

Keywords*: Riverine community, Local vulnerability, Sustainable development strategy, Community-based adaptation*

1. INTRODUCTION

Bangladesh is currently ranked as one of the world's most disaster-prone countries, with 97.1 per cent of its total area and 97.7 per cent of the total population at risk of multiple hazards (World Bank, 2005) [1]. Climate change is expected to increase the frequency and intensity of current hazards and the probability of extreme events, and also to spur the emergence of new hazards (e.g. sea-level rise and new vulnerabilities with differential spatial and socioeconomic impacts [1-2]. This is expected to further degrade the resilience of poor, vulnerable communities of Bangladesh. Climate change is set to become an increasingly important strategic economic and political concern as it starts to eat into Bangladesh's high economic growth rates and affect the lives and livelihoods of millions of people [3].

The definition of vulnerability to climate change is controversial for the same reason why the concept of vulnerability in general is difficult to define [4]. For example, Watson et al (1996) define vulnerability to climate change as the extent to which climate change may damage or harm a system, which depends not only on the system's sensitivity but also its ability to adapt to new climatic conditions [4-5]. Cutter (1996) points out that vulnerability to climate change can be decomposed into three distinct components; risk of exposure to hazards, capability for social response, and attribute of places such as geographical location [6]. He defines vulnerability to climate change as "the likelihood that an individual or group will be exposed to and adversely affected by a hazard."

IPCC (2014, 2007) defines vulnerability as a function of exposure, sensitivity, and adaptive capacity [7]. These three components are the key factors in determining a system's vulnerability to climate change and provide useful information for assessing and reducing climatic threats. In order to propose a sustainable development strategy for a community that faces direct consequences of natural hazards, understanding of local vulnerability context is the prior concern.

2. PROBLEM STATEMENT

Among all of the vulnerable communities, riverine communities are considered as the most vulnerable to the effects of climate change for their geological location and socio-economic condition [8]. They have survived various natural hazards but their homes and livelihoods are affected for many months of each year. The communities seem to have been largely ignored, marginalized and excluded from the planning process and emergency responses [9]. This study aimed to identify the contexts within which people of the fishing community on the bank of Karnaphuli are vulnerable to various natural hazards and consequent local responses to living with such disasters in the area.

3. STUDY AREA

The selected site South Koibortopara is located in the north-east corner of the Chittagong City at Chandgaon Thana (Fig. 1). It is just beside of Kalurghat Bridge on the bank of Karnaphuli River. This area is under City Corporation (ward no. 52). In Detail Plan Area (DAP) of Chittagong the site is situated on DPZ-4 (Bakalia -Chandgaon). South Koibotro Para is one of the eight oldest fishing communities of Chittagong. This old (more than 150 years) fishing community now exist with 10.03 acre area with a population of about 157 households. Due to the location of the village near the coastal belt the habitants have to face major threats of disaster at a regular interval. Natural hazards like cyclone, storm surge, tidal flow, riverbank erosion, and earthquake were witnessed by the inhabitants of the village over the past years (Fig. 2).

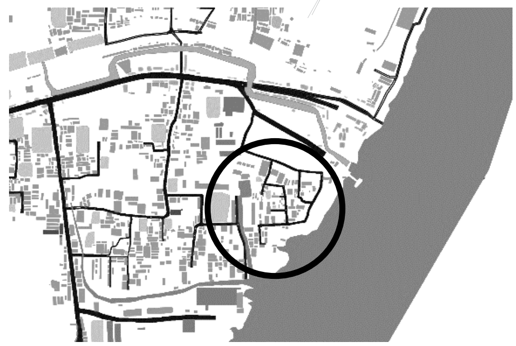

Figure 1: Area map of the village.

The situation is being worsened because of climate change in the recent times. For example, the village has already lost its about 10% land by the riverbank erosion.

Figure 2: Images of study area.

Every year the remaining land is overflowed by the tidal water even for a several months. The vulnerability context of the village can be better understood by the living condition of these people. The impact of such hazards also causes a long term effect on their socio-economic condition. Constantly fighting with both natural & man made calamities and extreme poverty these extraordinary riverine fishermen fall a victim of local vulnerability [10].

4. RESEARCH METHODOLOGY

This study focused on the local vulnerability context of the surveyed fishermen village due to climate change over the period of time. For this purpose, both secondary (literature review and desk research) and primary data have been gathered to identify the characteristics of the residing riverine fishing community in the area in terms of its disaster vulnerability and coping strategies.

Primary data have been collected using a semi-structured questionnaire (see Appendix) survey and complemented by personal interviews and secondary through literature review process.

50 households from the selected fishing community have been surveyed. Questionnaires were administered purposively among household heads aged more than 45 years who had multiple severe disaster experiences, female respondents and people with every occupation in the fishing community.

Field observation was also done as a means to verify the existing land use and geographical features. Photo documentation and field-notes have aided this step of data collection. The collected data were then analysed using mixed method approach.

Basically, the data were analysed using frequency tables and percentages. Qualitative data were analysed by associating responses and interpretations with respondents point of view in terms of local vulnerability and coping strategies with natural hazards.

Full structure of this research has been illustrated in Fig. 3.

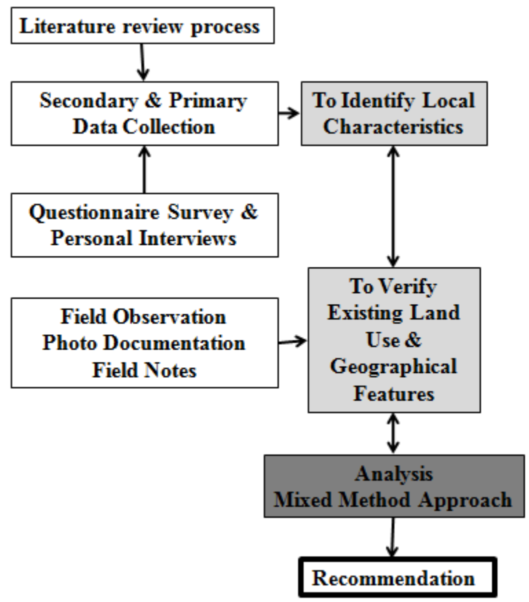

Figure 3: Research structure

5. DISASTER SCENARIO FROM SURVEY

Vulnerability context of the fishing community due to the disaster in all the sectors of their lives depicts as a major threat in recent times. In the following paragraphs local vulnerability context of the surveyed community will be presented.

Table 1: Type of disasters that affect most

S/N	Causes	Frequency	Percent
1	Cyclone & storm surge	40	80%
2	Overflow of tidal water	48	96%
3	Riverbank erosion	45	70%
4	Earthquake	12	24%

Source: Field survey 2015.

Table 1 above shows the types of natural hazards which cause severe effects on the area and from the analysis, 96% of the households indicated the over flow of tidal water as a major natural hazard in the area; 80% indicated Cyclone and storm surge, while 48% indicated Riverbank erosion and about 24% mentioned earthquake.

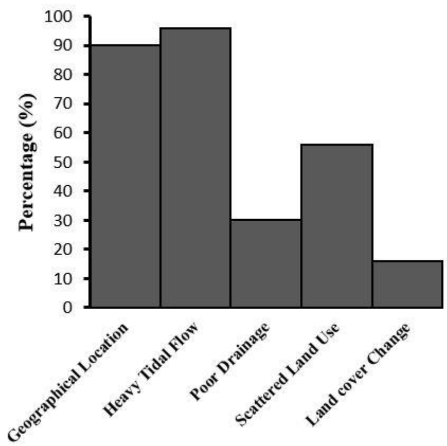

Figure 4: Perceived causes of vulnerability due to disasters

Figure 4 above shows the perceived cause of disasters in the area and from the analysis, 90% of the households indicated their geographical location as a major cause of disasters in the area; 96% indicated heavy amount of tidal water, while 56% indicated poor land use planning and 30% &16% went for poor drainage and land use change.

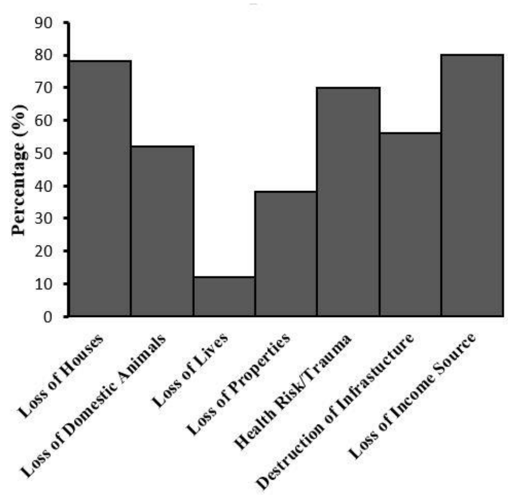

Figure 5: Impact of Previous disasters

Figure 5 above analyses the impact of previous flood in the area. From the figure, 78% lost their houses; 52 % suffered loss of domestic animals; 70% of them indicated that they suffered stress, emotional trauma as well as some health challenges. About 38% lost their valuable properties and there were about 12 recorded deaths due to past flood disasters. Community infrastructures and income sources were severely affected.

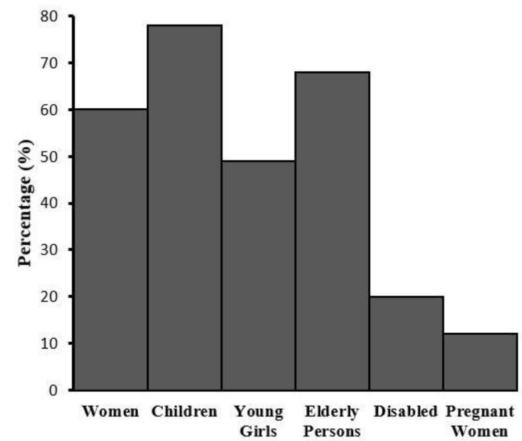

Figure 6: People who suffers the most

From Fig. 6, it has been illustrated that mostly children and women suffer the most [11]. Because of precaution, pregnant women and disable persons are kept safe after the warning of disasters from Government and other institutions. About 64-70% of elderly people face difficulties during such events.

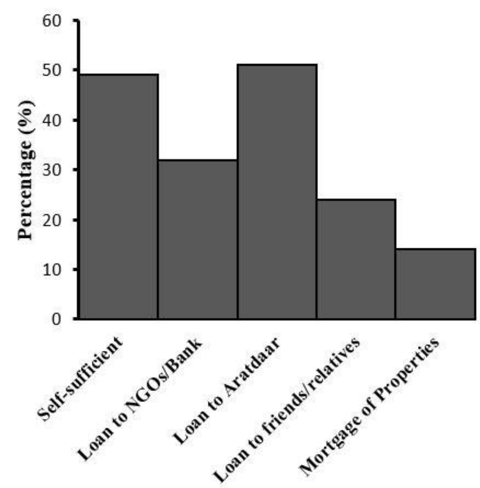

Figure 7: Socio-economic condition after disaster

Local vulnerability in socio-economic condition is the most important factor for the fishing community.

From Fig. 7, it was identified that, 32% take loan from bank, 51 % from Araatdar; 24% of them from friends/relatives. About 49% fisherman family can mitigate the losses by disasters wherever 14% of them have to mortgage their properties.

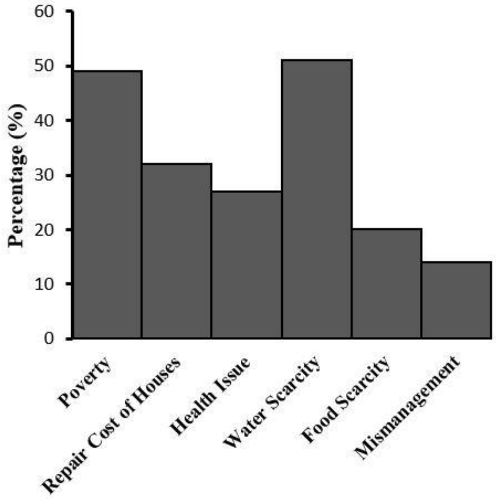

Figure 8: Sectors where fishermen suffer after disaster

From the above analysis in Fig. 8, vulnerability context in various sectors of the fishing community is shown. About 32% of the family needed to repair their house structures after the disasters, 51 % suffer from water and food scarcity. About 49% fisherman family had to face the poverty and 14% of them fall a victim of mismanagement in the community.

Table 2: Level of resilience of households to disasters

S/N	Causes	Frequency	Percent
1	Prepared	28	56%
2	Not prepared	16	32%
3	Undecided	6	12%

Table 2 above shows the level of preparedness of the residents to future flood hazards and from the table, 56% of the people indicated that they are ready to face any type of hazards, 32% are not prepared, while about 12% are undecided.

On the willingness of the people to relocate from the flood prone areas, table 3 shows that despite the impact of the past disaster on the people, over 68% of them are unwilling to relocate their residence, with only about 22% showing willingness to change their residence.

Table 3: Willingness of the households to relocate from the area

S/N	Causes	Frequency	Percent
1	Willing to relocate	11	22%
2	Not willing to relocate	34	68%
3	Undecided	05	10%

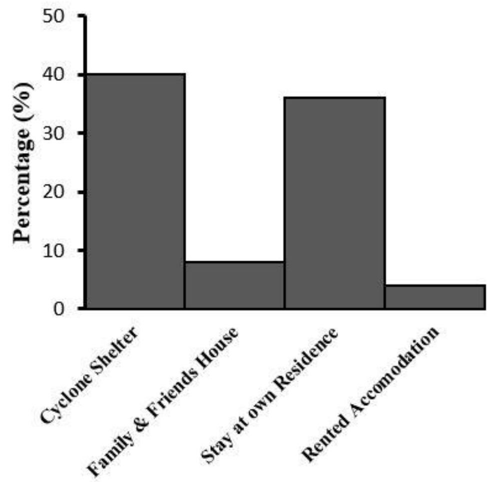

Figure 9: Evacuation during Disasters

Figure 9 above shows that about 8% of the people relocated to their friends and families in safer areas; about 4% moved to rented accommodation even, while about 40% were moved to nearby cyclone shelter in public school building. But significant number of families (i.e. 36%) stay at own houses during such times.

6. INTERVENTIONS

After any natural hazard, the affected people usually require and receive various forms of instant help such as boiled or dry food, clothes, clean water, emergency medicine, and oral saline. This relief comes from different government and nongovernment organizations, local social organizations, local elite, relatives, and volunteer organizations. Figure 10 describes the intervention by government and non-governmental agencies during and after the flood disaster. About 48% affirmed that government and other agencies arrange community discussion with residents and 56% told that they provided relief materials to hazard victims. Similarly, about 96% of them affirmed that even before the floods, government agencies gave early warnings of floods, even though many never took them seriously. About 49% noted that government provided capital support to victims in instalment basis and provided counselling, enlightenment and reorientation to the victims.

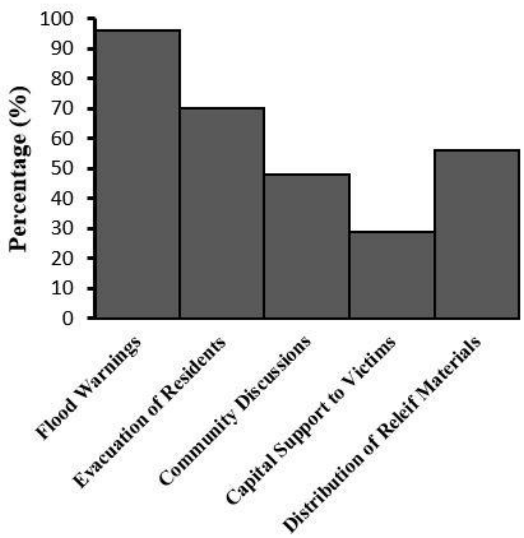

Figure 10: Government and NGOs' interventions during & after disaster

7. DEVELOPMENT STRATEGIES

Disaster mitigation is defined as any action taken to permanently eliminate or reduce the long-term risk to life and property from natural and technological hazard [12]. It was found through survey that local people have taken some adaptive measures to cope with the losses by disasters. But these coping strategies need to be modified for a sustainable living. Here are some development strategies for the fishing community derived through a qualitative research method. Survey respondents were requested to answer some questions asked by the Authors in their own words. To get a deeper insight into the phenomenon under this study, observation and field monitoring have also been accomplished by the author. It should be noted that future Government initiatives for the respective area have been considered in formulating the development strategies for the surveyed area.

a. Structural measures such as embankment or coastal forestation on the riverbank can be accomplished to resist the overflow from the river.
b. Channelization through the existing canal inside the village should be regained.
c. Landuse zoning of the village should be done according to the local climatic condition.
d. Disaster adaptive houses with strong structural measures and low maintenance cost
e. Providing scope for extra income sources like household vegetation, handicrafts by women etc. to overcome the financial crisis after the disasters.
f. Raising awareness to response to the warning of the disaster given by govt. Or other organization and taking precautions to survive the aftermath of disasters.

The instinctive survival strategies during and after any natural hazard have existed for generations in the surveyed fishing community. But vulnerability due to climate change is worsening the condition more violently that it has become very difficult to cope with the losses of the disasters in recent times [13]. On the basis of the research reported here, the in-depth analysis of local vulnerability context of the community will lead the government to take proper protective measures for them. These strategies will help to reduce the sufferings of the fishing community of the village caused by the disasters.

8. CONCLUSION

Vulnerability and reactions to natural disasters may differ from country to country, area to area, and person to person. They also depend on the physical and socioeconomic conditions of a particular area [14].

So any kind of sustainable development strategy for a riverine fishing community should be based on the present vulnerability context of the area [15]. As it is nearly impossible to stop the natural hazards to occur, so the strategies to cope with the disasters should be implemented for the betterment of the community with a long-term effect. For this purpose, active participation of all age groups in coping the devastation by these natural hazards is mandatory.

Community engagements in the initiatives taken by government for the particular area must be ensured. Otherwise the fisherfolk community can not ever be able to come out of the vicious cycle of the underdevelopment caused by such natural events.

LIMITATIONS OF THE RESEACH

Although this research work has reached its aims, there were some unavoidable limitations. First, this research was conducted on limited respondents. The study may have involved more participants with different parameters (i.e age group, monthly and annual income and expenditure, religion etc.). Time was a big constraint so more time could not be devoted to individual respondent of every household. Selected members of a particular household were asked to answer the questionnairies. Second, the questionnairies should have included more specific terms to cover all the aspects of vulnerability due to climate change in the surveyed area. Last but not the least, the sustainable development strategies mentioned in the research paper were mostly based upon the opinion of the survey respondents and authors‘ considerations to reduce the adverse impact of climate change. Experts opinion on this subject may improvise the strategies with more accuracy.

ACKNOWLEDGEMENTS

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APPENDIX

QUESTIONNAIRE FOR THE INHABITANTS

1. What have you observed as natural hazards of the region?

2. What kind of disaster is the most harmful?

3. Why do the disasters make damages to the area frequently?

4. What was the damage scenario here?

5. How do you suffer due to the occurance of disasters?

6. Who has to face severe difficulties during and after the disaster?

7.What is your financial condition after the disaster/s?

8.Are you prepared to reduce the losses by disaster?

9. Do you want to relocate from the village?

10. How did locals save themselves during this disaster? How did they save their assets?

11. What are the programs taken by the government and other NGOs in the locality?

EFFECTIVE WIDTH OF LIGHTSHELF FOR DAYLIGHTING CLASSROOMS CONSIDERING DIFFERENT SEASONS AND SKY CONDITIONS OF DHAKA

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Abstract: *In a classroom the students near the windows may get sufficient daylight for their learning activities but individuals far from the windows often do not get proper daylight. Increasing the size of windows can create glare problem. Light shelf can be an effective solution in this condition as light shelf is supposed to reflect daylight to the inner part of a room. Studies show, in a tropical location, such as Bangladesh, the introduction of light shelf at any height produces an overall reduction of illumination on the work plane throughout the interior space; however, light shelf can be an effective element to enhance the quality of daylight in tropical buildings, if designed and located properly. The objective of this research is to study the impact of the width of light shelf on indoor day lighting quality considering different seasons and sky conditions in context of Dhaka, at the same time analysis the performance of folded light shelf for better results. Field survey was done on small scale prototype designed classroom by Local Government Engineering Department (LGED), GoB where the indoor condition (e.g. classroom size, sill height, lintel level and window size) is fixed; but the outdoor surrounding context (e.g. orientation, setback and road width) is different. As in Dhaka the sky condition differs in three seasons it has been tried to get the effective width of light shelf through computer simulation study in three different times of a year. The computer analysis compared the fixed and folded light self to find out the most effective light shelf type which will ensure effective illuminance level in classrooms throughout the year.*

Keywords*: Classroom, Computer simulation study, Daylighting, Elementary students, Illuminance, Light shelf.*

1. INTRODUCTION

In Bangladesh very few studies have been done on the impact of daylight and student performance. As a result the consideration of natural lighting quality in classroom is in less concern during designing an educational building. The environment of a classroom has great impact on students. The lack of good environment of classroom can result physiological and psychological impacts on the children. Individual student in a classroom often does not get equal daylight on their desk. The students near to the windows get much light than the ones sit far from the windows. On the other hand, those who sit just beside the window sometime get excess daylight, which creates glare problem. As a result they shut down the window and use artificial light. Eventually the electricity bill raises unnecessarily, which gives a negative impact on the national energy consumption. Over and above the situation changes with the changing of the seasons as the sky condition differs and the lighting quality is different in individual seasons of Bangladesh.

A large number of students are enrolling in the primary education level and it is the highest group of population. According to Bangladesh Education Statistics Report 2015 by Bangladesh Bureau of Educational Information and Statistics (BANBEIS) the total number of primary school is 80,397 and the enrolling student number is 16,225,658; which is a large number and the problem demands attention. This children group starts their first learning in a primary level school.

The situation is more or less same in most of the schools in Bangladesh.

Light shelves are horizontal projections placed below a window lintel to reflect sunlight further into the interior. It is typically placed above eye level to reflect daylight to the deeper part of a room. The light shelf uses interior ceiling as a reflector instead of a typical shaded interior ceiling (A.G.S., 2000). In addition, the light shelf shade the lower portion of any window and reduces the amount of light near the window, where, generally has much higher illumination experienced than the deeper parts of spaces and help projecting the light towards the back. Thus it results a balanced luminous environment with less contrast and glare. A light shelf also divides a window into a view area below and a clerestory area above. Literature shows, light shelves and overhangs are not effective for redistributing light under overcast sky conditions and may decrease the amount of daylight reaching the interior space (Eagan et al., 2002).The objective of this study is to study the performance of folded light shelf to ensure fare distribution of illumination to student desks in a classroom for the whole year, in the context of Dhaka, considering glare reduction.

This paper consists of three major parts. The importance of daylight, light shelf, classroom and standards are described in the first part. The second part elaborates the steps of research methodology. Finally, the third part presents the findings of simulation results with conclusion. It is expected that, the examples of daylight simulation presented in this paper will help designers to comprehend the significance of effective light shelf design for daylighting classrooms.

2. LITERATURE REVIEW

2.1. Vision and light

The most obvious effect of light on humans is in enabling vision and performance of visual tasks. According to Boyce et al. (2003), the nature of the task—as well as the amount, spectrum, and distribution of the light—determines the level of performance that is achieved. Performance on visual tasks gets better as light levels increase.

A study by Santamaria and Bennett (1981) shows that, if the amount and distribution of light are controlled, most everyday visual tasks (such as reading and writing) can be performed under daylight conditions as similar to under artificial light sources (such as fluorescent light); however, daylight is superior for tasks involving fine colour discrimination when it is provided at a high level without glare or any reduction in task visibility caused by ceiling reflections or shadows (Boyce et al., 2003).

2.2. Classroom and learning environment

School systems or learning environments, in general are one of the most critical environments with some correlative actions (Higgins et al., 2005). Special attention is a prior need for providing such conditions to improve the situation, as learning has a special place and role in human life. Now with the developed technology the facilities for upgrading educational places are improved as well. Among all environmental elements, lighting has a very powerful impact on people’s life and health (One workplace, 1999).

Students’ performance is negatively affected if there is no well controlled windows and lighting in a classroom (Johnson, 2011). Designing a learning place is the most critical and important situations but most of the time this importance are ignored. Many people spend the majority of their time in the work or learning places. Therefore, good environmental designing in schools and universities is a kind of stimuli for students and even teachers to have better performance. To upgrade the lighting condition in buildings in tropical area light shelf acts effectively if designed properly (Joarder at el., 2009).

2.3. Standards in classrooms

According to BNBC (2006) Illuminance level in Class and Lecture Rooms are Desks 300 lux, Black boards 250 lux and Art rooms 400 lux. Whereas the International Standard ISO 8995-1 – CIE S 008/E measured the level in Reading area: 500 lux and in Art rooms: 750 lux. The European norm EN 12464-1 provides more specific guidelines for illuminations at schools buildings that are shown in Table 1.

Table 1:Overview of tasks in a classroom together with the requirements for the illuminance.

Task	The Teacher	The Student	Standard Illuminance	
			In class	In general
1	Writing on Blackboard	Reading on Blackbored	500 lux vertical	200 lux
2	Talking to students	Paying attending to the teacher	300 lux	300 lux
3	Showing a presentation (powerpoint, slides, etc)	Looking at the screen	300/10 lux	10 lux
4	Paying attention to working students	Writing, Reading, drawing etc.	300 lux	300 lux
5	Coaching computer activities	Looking to the computer screen and the paper	50 lux	300 lux above the computer
6	Preparing lessions	Not present	300 lux	50 lux

2.4. Sky conditions of Dhaka city

The climate of Dhaka is tropical and has mainly three distinct seasons :–

hot dry (March-May);

hot humid (June-November); and

cool dry season (December-February) (Ahmed, 1994)

The sky can be clear or overcast in different parts of the various seasons. During summer (Hot Dry) the sky remains both clear (sunny with sun) and overcast. However, during the warm-humid (March-November) period, which includes the monsoons, the sky remains considerably overcast most of the time. It is only during the winter (December-February) that the sky mostly remains clear. (U S D E, 2008)

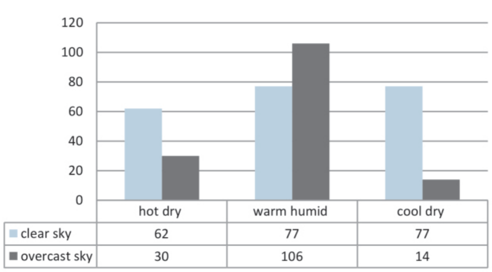

Figure 1: Different sky condition of Bangladesh with respect to cloud covers the sky round the year (Joarder, 2007).

Analyzing this data and further literature review Dhaka has composite climates where both overcast, intermediate and as well as clear conditions are observed during the course of each year. So, a fixed width light shelf might not be suitable to use in all different conditions around the year. Effective width of a light shelf for clear sky condition and overcast condition in school buildings is expected to be different.

3. METHODOLOGY

3.1. Selection of Site and a Typical School Building for simulation

As Bangladesh is a developing country the urbanization is growing very rapidly here. Dhaka, as the capital, is overloaded with population. Consequently the climate and physical characteristics are different from the other parts of the country.

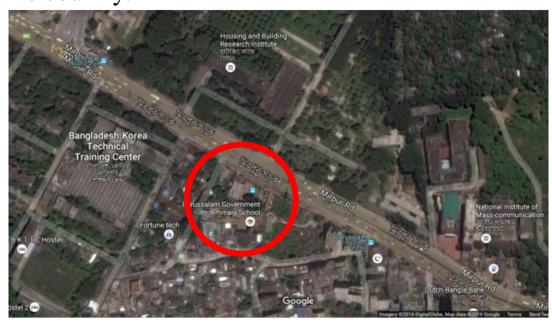

Figure 2: Google map of the site and the surroundig

Some basic factors are considered for selecting the site and building, e.g.: the site should be within the urban area and the case building should be a typical design school building;–

The building should be built in accordance with the Building Construction Regulations of the City Authority; and class rooms must have the provision for significant daylight inclusion and distribution.

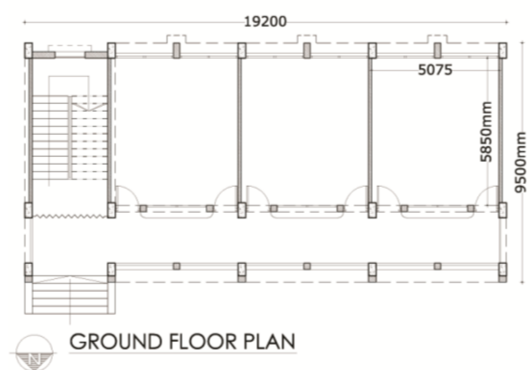

Figure 3: Plan of the case school building

Local Government Engineering Department (LGED) is working on Primary Education Development Project (PEDP) since 2003. There are several projects for example; reconstruction, renovation and new school building construction, that are completed and under construction. For these projects Design Section of LGED developed a prototype school building which is being constructed in the new or old site in Dhaka and other parts of Bangladesh (EMR, LGED; April 2016). Considering the mentioned criteria Darrussalam Government Primary School at Mirpur, an LGEDPEDP was selected as case school building. The site is near to the Mirpur Road and approached with a branch road which is connected to the Mirpur Road (Figure 2). It is a two-storey building with three classrooms on each floor (Figure 3). There is an open ground on the east side of the building. Another old building was on the east side within the school complex (Figure 4).

Figure 4: View from the open ground to the new building and the old building

3.2. Simulation Study

Through simulation study the quantity and the quality of daylight penetration can be measured. In simulation study the influence of one variable can be measured keeping the other aspects constant and it minimises the complexity. Again the study can be examined for any period of the year by assigning simulation parameters (e.g. location, date, time, and sky condition)

The study has done with two PC version simulations on different width of light shelves to find the sensible one which will perform better all over the year (Joarder et al., 2009). The first program is a comprehensive building analysis software Ecotect v5.50 which is a highly visual, architectural and analysis tool (Crawley et al., 2005) with lighting, thermal, energy, shading and acoustics performance analysis functions (Osaji et al., 2009). The second program is more focused and accurate daylighting simulation tool, Desktop Radiance 1.02 (Baker, et al., 2002; Ward, 1994).

3.3. Simulation Parameters

The quantitative and qualitative assessments for the design strategies were based on the following parameters

Location: Dhaka, Bangladesh. (90.2° E, 24.0° N)
Time: 1 April, 12.00 pm
Calculation Settings: Full Daylight Analysis
Precision: High
Local Terrain: Urban
Window (Dirt on Glass): average
Sky Illumination Model: CIE Overcast

3.4. Study Space

For simulation study one classroom was chosen at the first floor in the middle of the building (Figure 3). All indoor and outdoor parameters were considered as constant as found during the physical survey. While modelling the interior, the room was created as vacant without any furniture as these may impact on the result. The other values of the space are as following :-

Room area: 30 sq m
Clear height of classroom: 2850mm
Work plane height: 750mm

The following parameters of existing internal finish materials (as found in the field survey, Figure 5) were used in the model for simulation:

Ceiling: white painted plaster (reflectance: 07).
Internal wall: light yellow painted plastered wall (reflectance: 07).
Floor: neat cement finish (reflectance: 06)
Glazing: single pane of glass width aluminium frame (reflectance: 0.9, U value: 6 W/m^{2}K).

Figure 5: The study room of the school building

3.5. Performance Evaluation Process

The classroom was divided into grids with the reference to the furniture layout (Figure 6). Then 36 intersecting points were selected for generation of daylight levels at 750 mm above floor level (standard height of the desk in a classroom). Intersection points of the grids were coded by number-letter system (Figure 6).

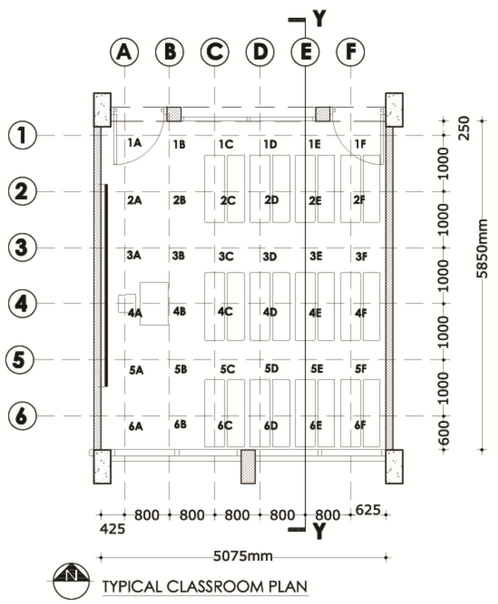

Figure 6: Plan showing the grid with node references

At first, to find predicted daylight levels the simulation was done for 36grid points by ECOTECT. Then the illumination values were compared for different situations. An axis YY' was drawn on the plan for analysis of the drop of illumination from the window to the opposite wall (Figure 6). Then, the models were exported to RADIANCE Synthetic Imaging software to generate realistic prediction of lighting levels.

The findings of the computer simulation were evaluated based on the following criteria.

a) Average daylight level on the work-plane height.

b) Fluctuation of daylight levels from the window towards deeper parts of the classroom.

c) Comparison of RADIANCE generated rendered images of the study classroom for luminance level on specific surface.

d) Comparison of illumination on two points on the floor (near and far from the window), for three different dates (1st January, 1st April and 1st July) of three different sky conditions the analysis was done (Figure 10).

3.6. Simulation of Light shelves

Custom light shelves (metal deck, reflectance:0.88, U value:7.14 W/m^{2}K), provided in ECOTECT, was used for simulation. According to Dhaka Metropolitan Building construction Rule 2008, a maximum overhang of 500mm is allowed over mandatory open spaces. Five alternative models were created with a fixed projection (500mm) at outdoor and five different widths (without light shelve, 300mm, 450mm, 600mm and 750mm) of indoor projections of light shelf (Figure 7).

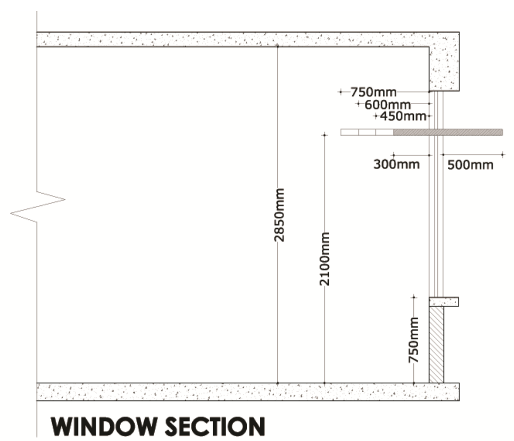

Figure 7: Section showing different light shelve widths examined in the study

4. RESULT.

Table 2 is a summarization of simulation results at 36 node points for daylight levels on five different cases. It shows that the maximum illumination level decreases and the minimum illumination level increases with the use of light shelves of any widths. Again the average illumination value is lowest with a regular height window with no light shelf. After using the light shelf the illumination value became higher than the previous one.

Table 2: Daylight distribution on node points with no light shelve and light shelves of different widths

Light shelves width (mm)	Analysing nodes	Minimum illumination value (lux)	Maximum illumination value (lux)	Average illumination value (lux)	Number of points width values higher than 300 lux
None	36	102	378	161	6
300	36	126	312	168	1
450	36	125	310	166	1
600	36	125	309	164	1
700	36	124	306	163	1

Figure 8 shows the comparison of average illumination value of the five alternative widths of the studied light shelves. The highest value of illumination level found is 168 lux for the 300mm width.

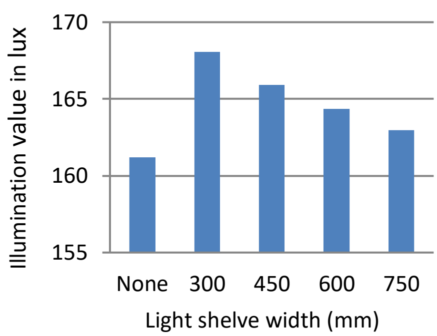

Figure 8: Average illumination levels vs. light shelf widths

Figure 9 shows the drop of illumination value with the distance from the window to the opposite wall. From the Figure it is found that the 300mm width light shelf performs better than the others.

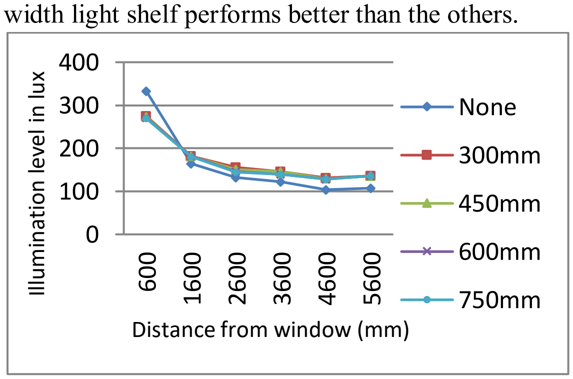

Figure 9: Drop of light along YY' axis with light shelf of five different widths

Figure 11 shows the qualitative distribution of illumination level by Radiance rendered image on three different dates for five alternatives light shelves. The images show that on the 1st January 650mm wide light shelf creates better condition. On the other hand the quality is better for 300mm on 1st April and 450mm for 1st July.

Again comparison of illumination at two points (one near to window another far from the window) 650mm is quite better for 1st January as the difference between two illumination level is lowest than the others. On 1st April it is almost same for both 300mm and 450mm. In addition 450mm wide light shelve performs better on 1st July for overcast sky.

In summary, the findings demonstrate that the illumination was better at 600mm for 1st Jan., 450mm for 1st July and 300mm for 1st April, so the average 450mm width could be an effective width of light shelf in residential building of Dhaka which can perform better to enhance daylighting quality in the interior space throughout the year. For better performance an effective light shelf can be designed with different folding portion which can be converted into different width 300mm, 450mm and 600mm in different seasons with different sky conditions (Figure 10).

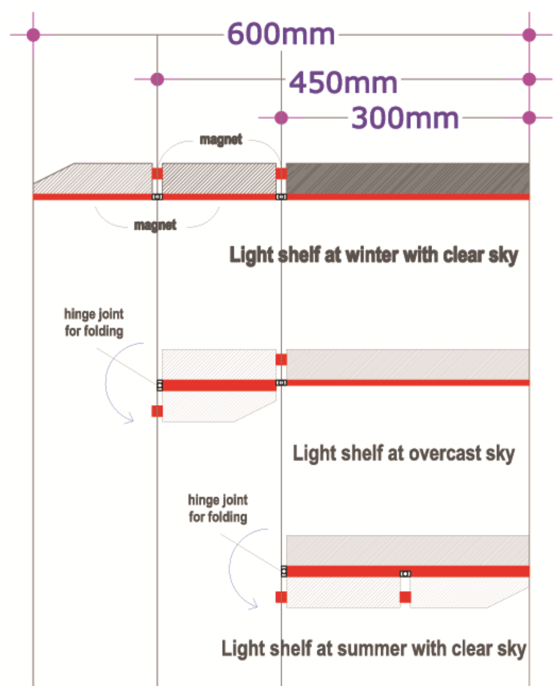

Figure 10: Proposed effective light shelf which can be

converted into different width under different sky and sun angle

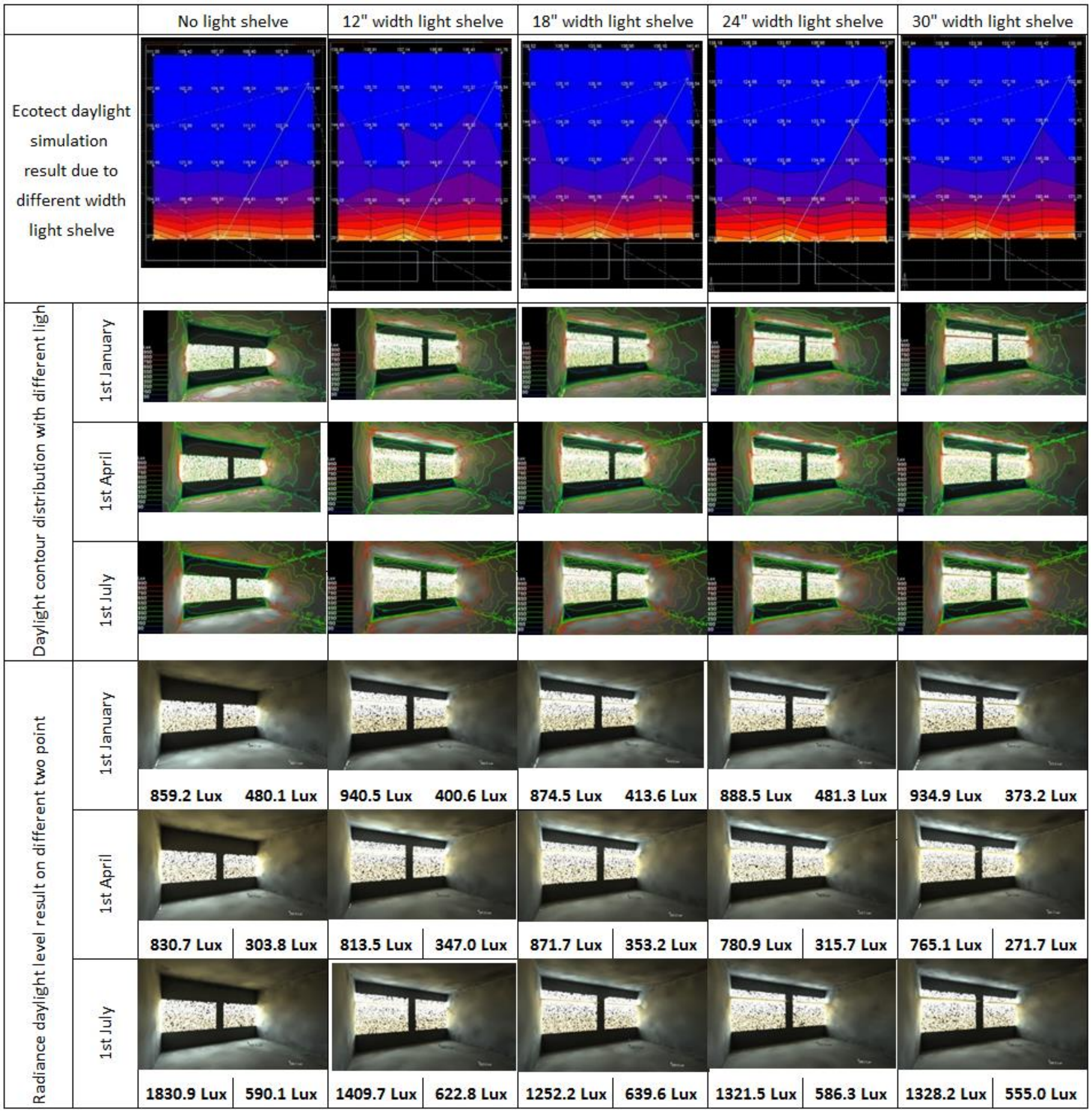

Figure11: Daylight simulation result on different dates

5. CONCLUSION

The study illustrates that by using a light shelf in a window of a classroom, the illumination might be lowered but possibility of glare will be decreased and the overall distribution of light will be better, which also supports the previous studies. Here the study tried to found the effective width of light shelf that will perform better all over the year. Light shelf with a fixed depth give a better quality of daylight rather than the no light shelf option; however, a single width light shelf hardly satisfied the different types of sky condition whch performs best for daylighting

for different times of the year. As the sky on Dhaka acts differently in different seasons the perfect width is difficult to be measured. Therefore, this study proposed folded light shelf which can be converted into different widths under different sky conditions. Only three options for light shelf widths have been tried for three dates. The different widths of light shelf are 300mm, 450mm and 600mm in different seasons with different sky conditions. Further analysis could be done to identify the widths more precisely for other dates. An automatic folding/compressed light shelf could be the best option. It is expected that the outcome and methodology presented in this paper will help architects to understand the importance of light shelf width and its proper installation in school buildings to achieve effective daylighting in classrooms.

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PERFORMANCE ANALYSIS OF A FLAT PLATE SOLAR WATER HEATER FABRICATED WITH LOCALLY AVAILABLE MATERIAL IN BANGLADESH

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Abstract: *Solar energy is an alternative to the available conventional energy sources. Coal, diesel, gas and wood are usually used to generate heat and produce steam for various purposes. But the solar thermal water heating system is the technology to harness the plenty amount of free available solar thermal energy. Designing the system depends on availability of solar energy, temperature of the water, geographical position and on the positioning of the system. The objective of this study was to evaluate the performance of flat plate solar water heater. It is expected that with the same collector space better thermal efficiency and water temperature can be obtained. A test setup was made by using locally available materials and experiments were conducted to study these aspects under ambient conditions. For small water heating systems, natural circulation is used for fluid flow for which we developed such a model. By studying the parameters and taking instantaneous data, the setup proved to have an instantaneous efficiency of 44.65% and the average inlet and outlet temperature was recorded as 31.2°C and 48.5°C during the experiments. The linearity between the efficiency and temperature difference was also checked for the purpose. Given the limitations, it was an attempt to create a model for the rural areas in developing countries such as Bangladesh, for harnessing solar energy with the use of locally available materials as a cost-efficient way of utilizing green energy.*

Keywords*: Bangladesh, Flat Plate Collector, Green Energy, Performance, Solar Energy.*

1. INTRODUCTION

Sunlight as a potential source of renewable energy is mainly used in thermal and photovoltaic systems but it also has the real scope of being used in hot water system for various domestic purposes. The solar radiation incident on the “Flat plate Collector” is transformed into the heat energy, which is used to heat water to a temperature less than 100°C. It makes direct use of sunlight available in abundance most part of Bangladesh for most of the time. This system saves the costly consumption of electrical energy and provides uninterrupted hot water flow any day, any time without worrying about power cuts and electrical shocks. Proper design of solar water heating system is important to assure maximum benefit to the user, especially for a large system. Designing a solar hot water system involves appropriate sizing of different components based on predicted solar insolation and hot water demand. In general, different nations of the world depend on fossil fuels for their energy needs. However, the obligation to reduce CO_2 and other gaseous emissions, to be in conformity with the Kyoto agreement is the reason behind which countries turn to non-polluting renewable energy sources [1]. An important issue in solar thermal system for domestic applications is the optimal sizing of the system i.e., appropriate sizing of the collectors, storage and heat exchanger [2]. Greatest amount of solar energy is available in two broad bands encircling the earth between 15° and 35° latitude north and south. The next best position is the equatorial belt between 15˚N and 15 °S latitude. Most of the developing countries, being situated in these regions, are in a favorable position in respect of solar energy. Bangladesh is situated between 20.34° and 26.38° latitude north and as such has a good solar energy potential. Average daily solar irradiation at flat surface is around 4.0 to 6.5 kWh/m^2 in Bangladesh [3].

2. LITERATURE REVIEW

The solar water heater is a heat exchanger which converts the heat from solar radiation to fluid flowing through channels. The type and construction may vary but the working principle remains same. For a flat plate, solar water heat is absorbed by a flat plate. Based on the pumping power requirement, there are active and passive systems. In this test, this is a passive system where circulation occurs by the buoyancy force and vertical head without the need of extra pumping power. The performance of a solar water heater can be described by efficiency of the system which indicates an energy balance of incident solar energy into useful energy gain. So, it is expressed as the ratio of useful gain to the incident solar energy over some specified time. The relation is,

$$\eta_c = \frac{Q_u}{A_c \ I_o} \quad (1)$$

$$Q_u = mC_p(T_o - T_i) \quad (2)$$

The irradiation map shows good solar potential for Bangladesh prepared by Renewable Energy Research Centre (RERC), Dhaka and Bangladesh and National Renewable Energy Laboratory (NREL), USA [3]. Average annual solar radiation on a 24° inclined surface is estimated as 5kWh/m^2/day [4] which is also used for our calculation. For determining the proper materials and sizes, the values are compared with table data. The aperture area, riser no and diameter and fin width can be derived from corresponding charts and tables. The absorber plate types are also provided and corrugated plate is chosen for better heat transfer through wider area of contact [8]. The elevation angle was determined by the following process:

$$\alpha = 90° - L + \delta \quad (3)$$

$$\delta = 23.45° \sin\left[\frac{360}{365}(284 + d)\right] \quad (4)$$

$$\alpha + \beta = 90° \quad (5)$$

From the above equations, β values can be determined by substituting latitude value and checking the corresponding sign of β, the direction can be determined [6].

3. DESIGN DESCRIPTION

The structure of experimental setup consists of the following components:

The Collector Housing: The exterior box, which integrates the other components that make up the collector. The box was made of M.S. sheets

The collector: It receives the sun's rays and heats the water, is composed of four parts. These parts include as followings:

- *Absorber Plate:* 18 gauges M.S. sheet as absorber plate was used with black coating [11, 12].
- *Tubes or Channels:* Seamless M.S. pipe of inner diameter of 0.01905m is used as riser pipes and inner diameter of 0.0381m is used as header pipes to circulate water. For this purpose, six risers were used.
- *Thermal Insulation:* Polystyrene (Thermocol) was used.
- *Glazing:* One transparent cover, which is made of low iron glass was used.

Storage Tank: A plastic water tank of 100L was used for supply and storing hot water in the closed loop.

Inclining Setup: The stand was constructed of mild steel angle bar.

The storage capacity was considered as 80 Liter for a family of 2 persons as the average daily demand for water per person varies from 40L/day-50L/day in Bangladesh. The aperture area was determined in a stepwise process including the estimation the heating load to be carried out. In this case an aperture area of 1.24m^2 was derived mathematically.

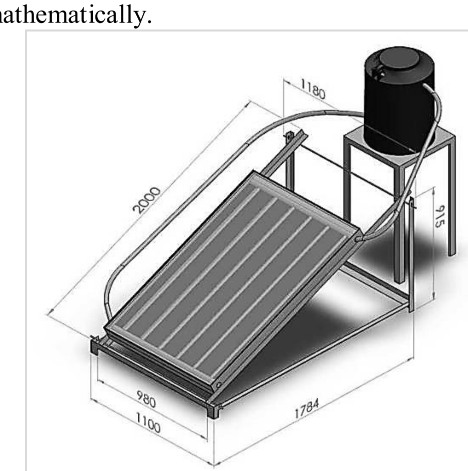

Figure 1: Isometric View of Experimental Setup.

The sizing of absorber plate was done accordingly keeping 1.32m length and 0.94m width. The piping diameters were chosen differently as mentioned before and holes were made in headers to fit in the risers and welded them together. The appropriate distance between risers was calculated considering several factors such as fin efficiency and overall heat transfer co-efficient [2]. The grooves were made in absorber plate accordingly. Single glazing of 2.5mm thickness was used for the covering [4] and Styrofoam of 0.127m thickness was used for insulation. The casing or box was made of Mild Steel sheets, folded and joined together with nuts and bolts for the ease of assembly. Finally, all components were assembled to prepare solar collector and mounted on a stand made of Mild Steel angles which were first resized for proper inclination and balanced load bearing.

4. TESTING PROCEDURE

The whole setup was installed on the roof of EME building at BUET, Dhaka, Bangladesh (23.7^0N Latitude). The collector was inclined at an angle of approx. 24^0 on the stand facing south which was determined as average inclination angle for 365 days with respect to the latitude of Dhaka [5].

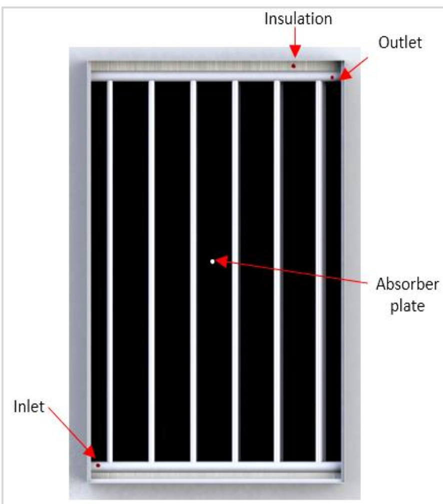

Figure 2: Different position of thermocouples.

For performance analysis, the temperature of inlet, outlet, insulation, absorber and tank using K-type thermocouples at five positions of interest was measured. Series of data was tabulated from 9am to 5pm with 30 min interval for 11 days. During data collection flow rate was checked by traditional bucket method. Change in temperature with time was observed and efficiency was calculated for the temperature difference between outlet and inlet. As the absorber transfers heat to the water flowing in risers and headers, the temperature of outlet rises for useful energy gain. The remaining part of the heat is dissipated through sides and back.

5. RESULTS

The solar energy is a variable source of energy because of several factors affecting the intensity of incident radiation. The Sun's position and the clouds are mainly responsible for variable nature of the solar radiation. As a quick insight of the observed data and predicted graphical representation, shows the instantaneous efficiency is high at mid-day. The inlet and outlet temperature line shows a pattern of ongoing difference between them at different hours of the day. The observed value of average inlet temperature was 31.2 ^{0}C, the maximum possible outlet temperature was 48.5 ^{0}C, the maximum temperature rise of water was 15.4ºC and the maximum average efficiency that can be accounted for this solar water heater is recorded as 36.81% and maximum instantaneous efficiency as 44.65% which is close to our estimated efficiency during designing of the collector.

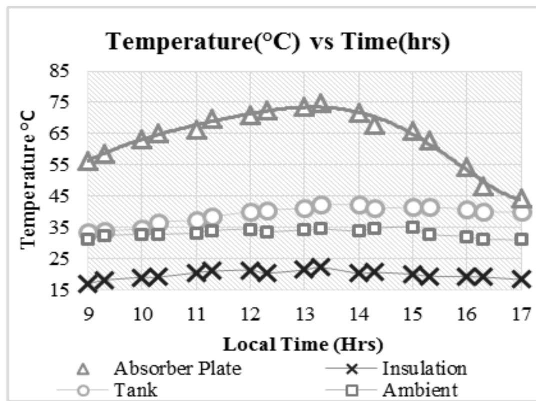

Figure 3: Plate, tank, insulation and ambient temperature change over the day time.

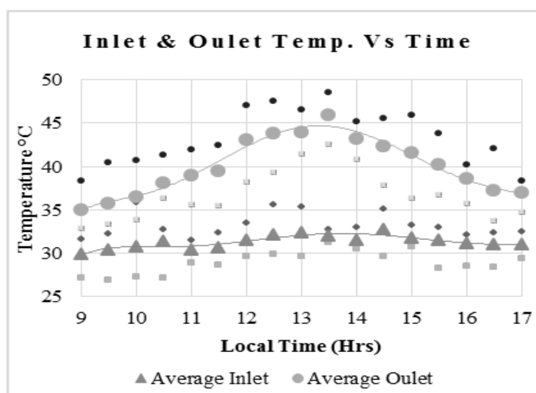

Figure 4: Average inlet and outlet temperature change over day time.

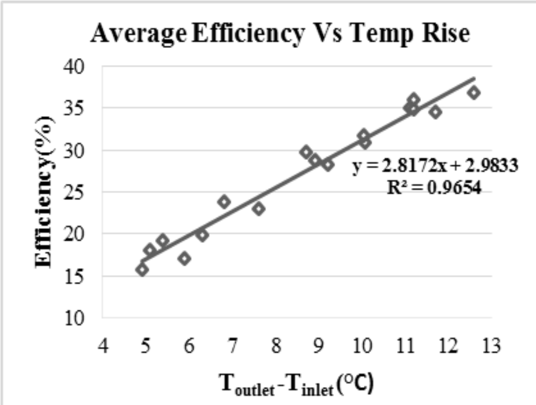

Figure 5: Linear relation of efficiency and temperature rise in inlet and outlet.

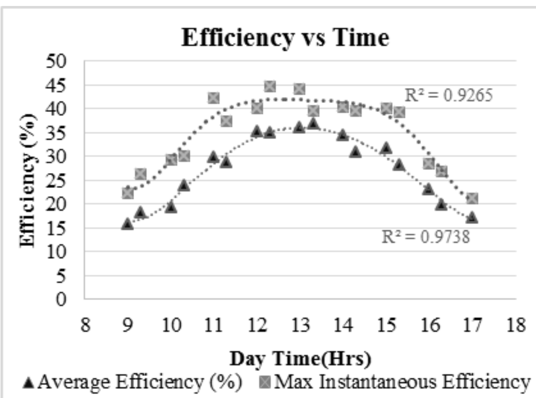

Figure 6: Average and instantaneous efficiency over day time.

The curves of temperature differences vs. daytime shows an upward trend up to a time of the day as the temperature difference is increased and then a downward trend afterwards. The efficiency vs. temperature difference (inlet and outlet) graph shows a straight line with positive slope. The temperature range for both inlet and outlet are also determined for easy understanding of the variations in temperature at different conditions which is observed in a series of accumulated data. The consolidated data is represented as summary of tests performed.

6. CONCLUSION

In Bangladesh, the heating process of water is almost traditional. Flat plate solar collector can be a new cost-effective technology of heating process to have warm storage of water. Currently, a large fraction of water heating energy is generated from natural gas or from electric joule heating. But natural energy resources are running out where natural gas is one of the main fuels for power plants in our country. Thus, flat plate collector presents a significant opportunity to reduce natural gas and electric heating consumption for domestic water heating. The actual potential of flat plate collector depends largely on economic and market barriers to the deployment of current and future flat plate collector systems. The main target of this work was to utilize this green energy and retain the hot water temperature of the storage tank reducing the heat loss from the tank. The results from the experiments show a brighter perspective of the utilization of green energy and future use of an easily made low cost solar water heater for rural poor people.

LIMITATIONS & FUTURE WORK

Since the box holds absorber plate, riser and header pipes, there is always possibility of heat loss to the surroundings. To keep the thermal loss the sides and back, Thermocol has been used. Although machining process affects the dimensions the housing was enough to hold a rigid structure for installation of other components. The set up was a bit heavy for the materials used for riser and header pipes. The working fluid was water as it is easily available but a filter and pH monitoring process are needed to maintain better water quality. Copper has better heat conductivity and can improve the actual heat gain by efficient heat transfer. But in this experimentation, mild steel tube is used for riser and header pipes instead of copper taking the cost in consideration. At first double layer of glass was tried but after installation the bottom glass cover broke due to uneven thermal expansion. So, with tempered glass this problem can be solved in future. The thermocouple used for experiments has minimum error regarding the instantaneous data being collected. As the performance of a solar water heater is dependent upon the weather conditions, some variations are also observed in the measured temperatures for the absorber plate, inlet and outlet of pipes.

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WASTE TO WEALTH: RICE HUSK

REDUCING THE USE OF FOSSIL FUEL AND CARBON FOOTPRINT

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Abstract: *India is the second largest rice producing nation in the world. However major attention is given to the final Rice quality whereas waste generated during this process is cornered. Rice husk is a co-product generated in the rice milling procedure. This husk contains around 22% of the total rice crop weight. This rice husk is disposed off by open-air burning or dumping which causes momentous local pollution. Burning consumes a large amount of fossil fuel, affecting the fertility of the soil concurrently. The Indian government is promoting the use of biomass for energy purposes to substitute the fossil fuel utilization and to reduce the environmental impact caused by them. To find a solution for the Rice husk disposal, it becomes essential to ensure that the process used is harming the environment least way. The site area selected for the study is Gorad village, (approximately 6 acres) located in a rural area consisting of 6 tribal padas. The research aims to use the rice husk to generate electricity in a most environmental friendly way to satisfy the electrical demands of Gorad village. To achieve this, the research is divided into three main stages- Properties, contents and potential uses of rice husk; Data collection; and Data analysis using Life Cycle Analysis approach. Assorted methods such as literature review, questionnaires and interviews with the villagers contribute in the final design output. Results from the above stages are analysed in the context of necessary policy demands, the local government guidelines, the production process of generating electricity from rice husk, the infrastructure availability and distribution practicality of the electricity.*

Keywords*: Biomass, Electricity, Environment, Fossil fuel, Off- Grid electrification, Rice crop, Rice husk.*

1. INTRODUCTION

When we hear the word innovation, we often think of new technologies which provide comfort in our day to day lives. But it really means that to provide a solution, ideas or technologies and making them accessible to millions of people who are lagging behind the world. One area where this is desperately needed is access to electricity. In the age of the Modern technology, iPads and Tablets, it is easy to forget that almost a quarter of the world's population still lack electricity. This is not just an inconvenience; it takes a severe impact on economic life, education and health. It's estimated that in India one million people die prematurely each year as a result of pulmonary diseases resulted by the indoor burning of fuels for cooking and light.

In today’s developing world, after the sun sets, everything goes dark. In India, about 44% of the population lack electricity. However, no country has more citizens living without power than India, where the vast majority of them villagers, have no electricity. The place that remains most in darkness is mostly rural areas, which has more than 80 million people, 85% of whom live in households with no grid connection.

Because rural area has nowhere near the capacity to meet its current required power demands, even those few with connections receive electricity occasionally, often at odd hours, when it is of little or no use. Hence there is a need to take initiative to solve this issue at least up to certain extent so that each and every person living in the country should get a chance to live "Quality life."

2. Rice husk: a Renewable Energy Source…

Rice is the major crop of the Wada district, Maharashtra state, which is cultivated on 70% of the total area under cultivation. The Wada district ranks second in rice production in the State.

Rice husk-based power generation shows many potential benefits, some of which are listed below:

- Distributed generation
- Base load power
- Suited for rural areas
- Ability to have small, kW scale power production
- Rural economic upliftment.
- Efficient utilization of renewable biological sources
- Low Cost Resource

Distributed generation – Since biomass is available in almost all places, and especially in rural areas, gasification based power production can be done on small scale for power generation.

Suited for rural areas – Biomass based power is well suited to remote villages with no access to electricity grid. Biomass gasification based power production can be done at small scales unlike other sources of power that require much larger scales. Such type of ideas is suitable for small villages that have only a few households.

Rural economic upliftment - Possibility of enhancing the prosperity of rural areas especially if dedicated energy crops become common for biomass based power production.

This has the double benefits of a more reliable biomass supply chain simultaneously providing the much needed employment for the rural masses.

2.1.1 Importance of rice husk

In Rice crop almost 22% of the paddy weight is husk. Although there are some advantages for rice husk, it is still often considered a waste product and therefore mostly either burned in the open or dumped on wasteland. Husk has a high calorific value and therefore can be used as a renewable fuel.

2.1.2 Characteristics of rice husk

Rice husk is difficult to ignite and it does not burn easily with open flame unless air is blown through the husk.

Rice husk is highly resistant to moisture penetration as well as fungal decomposition. Husk, therefore, makes a good option as an insulating material.

Rice husk has a high silica (SiO_2) content which denotes that it decomposes slowly when brought back to the field. It also makes it a poor fodder.

Handling of rice husk is difficult because it is bulky and dusty. The angle of repose is about 40-45° which states that its flow ability, is very poor.

Rice husk has a low bulk density of only 70-110 kg/m³, 145 kg/m³ when vibrated or 180kg/m³ in form of brackets or pellets.

When the ash content burned is 17-26%, a lot higher than fuels (wood 0.2-2%, coal 12.2%). This means when used for energy generation large amounts of ash need to be handled.

Rice husk has a very high average calorific value of 3410 kcal/kg and hence it is a good, renewable energy source.

Because of the high silica contents rice husk is very abrasive and wears conveying elements very quickly.

2.2.1 Chemical composition of Rice Husk *(Table 1)*

Proximate analysis *(Table 1.1)*

Property	Rice husk
Volatile matter	64.7
Fixed carbon	15.7

Ash	19.6

Ultimate analysis *(Table 1.2)*

Property	Rice husk
Carbon	38.7
Hydrogen	5
Oxygen	36
Nitrogen	0.5
Sulphur	0.1

Chemical composition *(Table 1.3)*

Chemical composition	% d.b.
SO_2	86 - 97.3
K_2O	0.58 - 2.5
Na_2O	0.0 - 1.75
CO	0.2 - 1.5
SO_3	0.1 - 1.13
Cl	trace - 0.42

2.2.2 ***Physical properties*** *(Table 2)*

Bulk density, kg/m^3

Property	Rice husk
Loose	73-112
Vibrated	122-145
Bricketed or pelleted	180
Ground	230-400

(Source: Houston, 1972)

Porosity: Porosity is the volume occupied by air in relation to the volume of the husk. The volume of air occupying the husk pores and the interstices in a rice husk bed is 85 % while a single husk has a porosity of 54 %, with the majority of the pores being closed (Kaupp, 1987). This porosity denotes the low bulk density of the husk.

Thermal conductivity: Rice husk has a thermal conductivity of around 0.036 W/m °C, which is comparable to most insulation materials has a potential to be used as a building material.

3. Process, Results and Discussion

After burning the husk in the plant, CO2 emits which is generated from biomass combustion and hence, being part of the global carbon cycle, does not contribute to global warming. This is a distinct advantage of biomass-based energy production. SO2 emission of the project is also less than emissions from coal and oil power plants.

This result was expected since the rice husk contains only about 0.4% sulphur. Though the amount of SO2 is little high, but is still less than the overall emissions generated from conventional electricity production methods.

Similarly, NOX emissions from the project are also lesser than coal and oil power plants, but higher than gas power plant. It must be noted here that the rice husk power plant performs better than conventional electricity production even though there are NOX and SOX removal equipment installed in the latter.

Both these emissions contribute to acidification and in addition, NOX also contributes to photochemical ozone formation and nutrient enrichment. Thus, the electricity production from rice husk is better than the conventional electricity production on these counts.

CO, formed during combustion when it is incomplete, is slightly higher than the conventional electricity production, mainly for improving the combustion in the rice husk power plant.

Total Suspended Particulates (TSP) from rice husk energy is quite large when we compare it to conventional electricity production. Dust emission from rice husk power plant is also higher than coal and gas power plants, but slightly less than oil power plants.

Rice husk combustion generates significant amount of particulate matter. Since the rice husk power plant uses multi-cyclone and electrostatic precipitator for dust removal, the measurements are checked twice to confirm the result.

4. Conclusion

In India, a large portion of the electricity production is from fossil fuels causing concern for energy security as well as environmental emissions of CO2, SO2 and NOX and many more dangerous gases. Biomass has been proposed as one of the alternative (renewable) source of energy which can, up to certain extent, offset the use of fossil fuels. This is especially suitable for India since it is an agricultural country.

This study considers the environmental assessment of power generation from rice husk, a waste product in rice fields. The study was carried out in Gorad Village which is having a capacity of producing 500 quintals of rice husk as a feedstock. About 520 quintals of rice husk is received as raw material to produce around 30 Megawatt of energy, which is sufficient to supply energy to 250 households for 10-12 hours per day. This electricity can be supplied to domestic and commercial consumers for fixed 10-12 hours a day.

The study reveals that the emissions of Sulphur Di- Oxide (SO2) and Nitrous Oxides (NOX) are lesser in case of coal and oil-fired power generation, but slightly more than the natural gas. The emission of Carbon Di- Oxide (CO2) from combustion of rice husk is considered negligible since they do not contribute to global warming. CO are slightly higher than conventional power production but in the same order of magnitude. This denotes the need for improving combustion efficiency of the biomass power plant.

Emissions from the biomass power plant are lower than oil-fired power plants, but higher than the other types. Overall, the study indicates that rice husk has a high potential for use as a feedstock for electricity production. It performs much better than the fossil fuels (especially coal, wood and oil) from the point of view of environmental emissions.

The process of converting rice husk into electricity can be used in many other villages and rural areas where there is ample provision of Rice Husk. This is a very good alternative energy source to produce electricity where the electricity is unreliable and not available when needed.

5. Acknowledgments

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EVALUATING THE IMPACT OF HIGHRISE BUILDINGS ON ADJACENT URBAN WIND ENVIRONMENT:
A CASE STUDY ON GULSHAN AREA

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Abstract: *The urban wind environment is one of the most important factors determining the quality of life of urban habitants. Actually, the airflow within urban canopy layer is a driving force of wind induced ventilation of room air of urban buildings, thus, urban wind condition affects the efficiency of passive control of room air quality. In the present context of rapid urbanization, lack of space and high price of land have given rise to construction of tall buildings in Dhaka city. But due to unplanned urbanization, these high-rise buildings are causing significant impact on the natural and built environment and affecting the environmental quality of urban spaces. These impacts can be severe when the high rise is located within or near a residential block. This paper presents the results of an investigation how high rise buildings impact the adjacent urban wind environment through wind simulation techniques. The results are analysed and possible guidelines for improving the present condition are discussed in order to enhance urban microclimate.*

Keywords*: High-rise 1, Urban wind environment 2, Wind simulation 3.*

1. INTRODUCTION

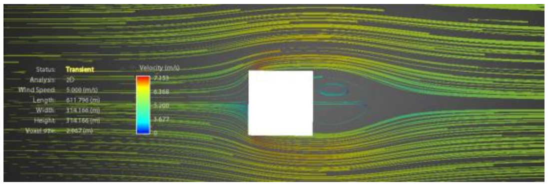
Heat stress in summer is a growing environmental concern for the city; thus it is important to assess the effects of building height on outdoor microclimate in the city [1]. The main environmental settings which affect the thermal consciousness of heat are the air and the radiant temperatures, and the air velocity over the body. The effect of air velocity on the thermal sensation depends on the environmental temperatures. At temperatures below 33℃, increasing air velocity reduces the heat sensation due to higher convective heat loss from the body and lowering of the skin temperature [2].

For this reason, it is important that natural air flow is maintained on the streets and open space adjacent to residential units. But in urban areas, main air flow from prevailing winds are strongly modified, depending on constructions' morphology and urban microclimate effects [3]. Wind field modifications have become particularly significant because of the increasing number of high-rise buildings.

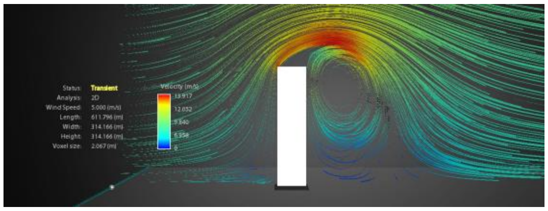
2. IMPACT OF HIGH-RISE ON ADJACENT WIND FLOW

Prediction of the wind speed in the built environment is difficult. One of the reasons is "surface roughness". The many obstacles and different heights of buildings give the built environment a high roughness coefficient [4], compared to open, rural locations. Due to the high roughness in the built environment, the wind speed close to the ground becomes a local parameter (dependent on local conditions near the ground).

Neighbouring structures may either increase or decrease the flow induced forces on building, depending mainly on geometry and arrangement of these structures, their orientation with respect to the direction of the flow and terrain conditions [5]. Therefore, this effect, commonly known as Interference must properly be assessed by designers and planners.



(Plan view)



(Elevation view)

Figure 1: Wind flow field around a building

If a low building is located in the wind shadow of a tall building, the increase in height of an obstructing block will increase the air flow through the low building in a direction opposite to that of the wind. The lower wing of a large vortex would pass through the building.

3. THE STUDY CONTEXT

Urban areas and inhabitants of cities tend to increase. Nowadays, about half of the world total population live in urban settlements. Cities are always developed and transformed through the interaction between different social, political, economical, and technological forces. Dhaka is also not an exception. Dhaka represents a composite urban form developed through ages. In its evolution, the city of Dhaka has been experiencing a process of rapid change in its land use structure, which influenced the development of residential areas. The research site is selected at Gulshan, a mixed residential cum commercial zone in Dhaka, Bangladesh, a location in the tropical monsoon climate zone.

Gulshan is an affluent neighborhood of Dhaka, the capital of Bangladesh. Gulshan was founded as a planned model town in 1961 with its own Pourashabha (municipal corporation), while the neighboring Banani Model Town was founded in 1964. Gulshan Thana was established in 1972. Gulshan Pourashabha was abolished in 1982. In 1984, Gulshan, along with Mirpur municipality, was absorbed into Dhaka.

The state sponsored planned extensions for the upper classes were contrasted with the unsanctioned, spontaneous, tawdry development in the organic areas of Dhaka. Planned residential areas Dhanmondi, Gulshan, Banani, are important example of this type. Their street layout follows a rigid gridiron pattern with some semicircular arcs [6]. All these three areas were developed in the early fifties in the method of site and service scheme to provide residential accommodation for high and higher middle-income group of population in Dhaka city. The area was originally built with the purpose of being solely residential, however, over the years many commercial buildings have been set up. The population explosion of Dhaka leads to rapid expansion of the city in order to provide accommodation to the growing number of urban dwellers. This expansion took place both horizontally and vertically. Vertical expansion includes the demolishing of the low-rise structures in the existing residential neighbourhoods and converting them into high-rise structures, whereas the development of peripheral areas in the north and southeast of the city for new residential areas covers the horizontal expansion [7]. The independent houses of early 1970s that stood far from each other in Gulshan area have vanished because of the commercial boom; to the point of old residents' claiming it is not a residential area anymore. [8]

2001 2004

2008 2012

Figure 2: Morphological change of Gulshan area. (Source: https://maps.google.com)

The planned areas under study have gone through major changes in terms of land use pattern in recent years. Although the plots of Banani Residential Area were primarily allocated for residential buildings with a maximum height limitation of 6 stories, now most of the single houses are turning into high rise residential cum commercial apartments. As a result, the increasing numbers of high rise commercial buildings are making the area as a high class slum which in turn is arising the problems such as dampness, shadow, disruption of air flow, turbulence of air flow, chillness etc. [9]

From satellite images, it is clearly seen that in last two decades, Gulshan area has seen some major shifts in land use pattern. Scarcity of land coupled with high price, gave rise to high-rise building construction. But the area was not designed for high-rise buildings initially. Therefore these new tall buildings are creating adverse effects for the residential neighbourhoods located in close proximity. Due to the close spacing of the high-rise commercial building blocks, a significant number of buildings falls into the wind shadow zone of the adjacent blocks which results in the inadequate supply of airflow for the adjoining residential apartments which is not a healthy condition for occupants of these apartments.

Figure 3: Selected study area of Gulshan (2016). (Source: https://maps.google.com)

To find out the impact on wind environment through simulation, a 450m X 450m area was selected near Gulshan 1 circle marked by the shaded box. The selected zone has a major node point (Gulshan 1 circle) at the intersection point of primary roads. Majority of the high rise buildings are located in the south and eastern side and the impact zone (residential blocks) is located on the north-western side of the selected zone.

4. RESEARCH METHODOLOGY

The research was done in two phase. In the first phase, simulation was done for different heights and different wind directions to find out the overall impact of high-rise buildings on the adjacent wind environment. For this purpose, three dimensional models were made from physical survey and GIS data. To set up the simulation, climatic data were collected for wind speed and prevailing wind direction.

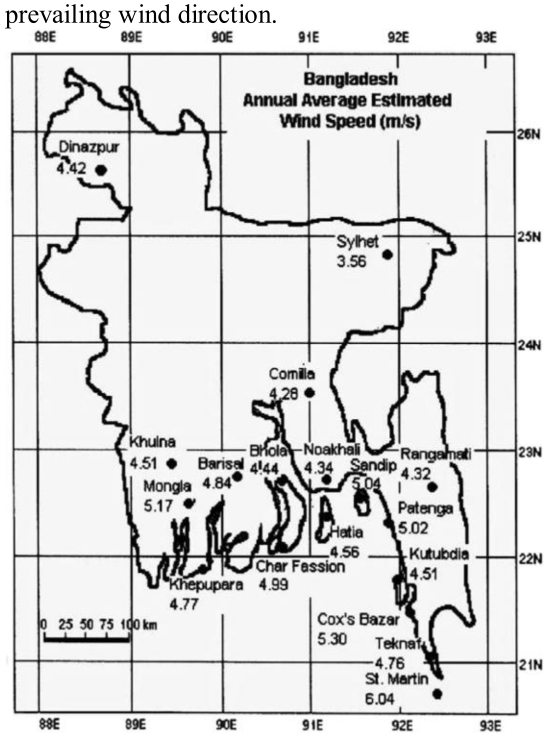


Figure 4: Wind map of Bangladesh at 50 m height using NASA SSE data set.

Approximately, from March to September wind blows continuously at an average speed of 3 m/s to 6 m/s over Bangladesh from south-south-east direction [10]. So for simulation, a wind speed was kept constant at 3m/s to see the impact on residential blocks located on the north- western side of the selected zone. Simulation was done for wind coming from south and south-east direction which is the prevailing wind direction for Dhaka city during summer and monsoon season to recreate realistic situation.

In the second phase, field survey was conducted to compare the data gained from simulation with actual scenario.

5. ANALYSIS OF SIMULATED DATA

External wind flow analysis was done in Autodesk Flow Design. The simulation had its limitations as wind speeds and directions are never fixed in real life, buildings are also part of a broader landscape with other buildings and topography that are difficult or impossible to fully account for in a traditional CFD or physical wind tunnel test.

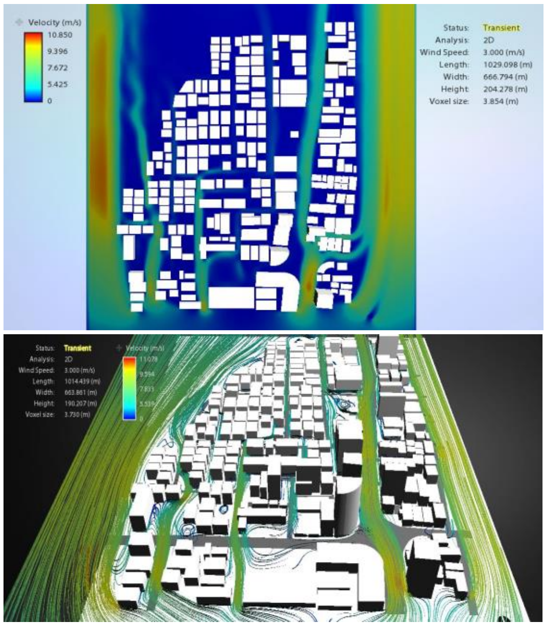


Figure 5: Wind flow pattern at 3m from ground level from south direction.

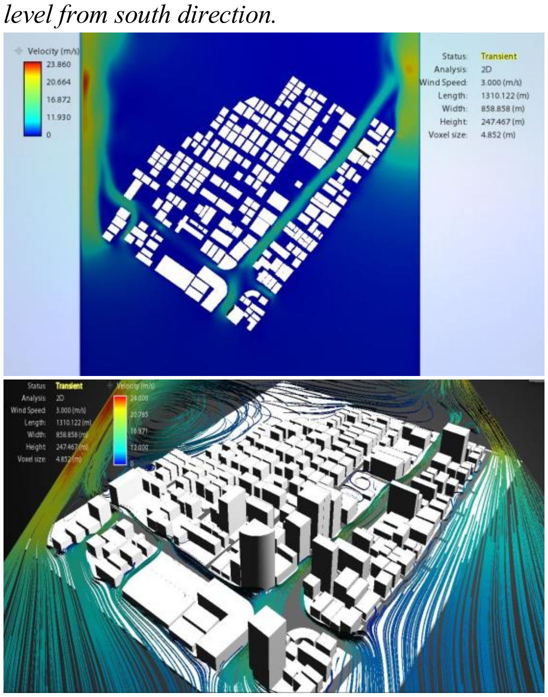


Figure 6: Wind flow pattern at 3m from ground level from south-east direction.

Case 01: From 3m level, it can be seen that though the wind speed in primary and secondary roads were within satisfactory zone, but in the residential blocks the wind speed was negligible as the residential zone falls into the wind shadow zone created by the high-rise buildings. Wind penetration was greater for wind coming from south direction than south-east direction.

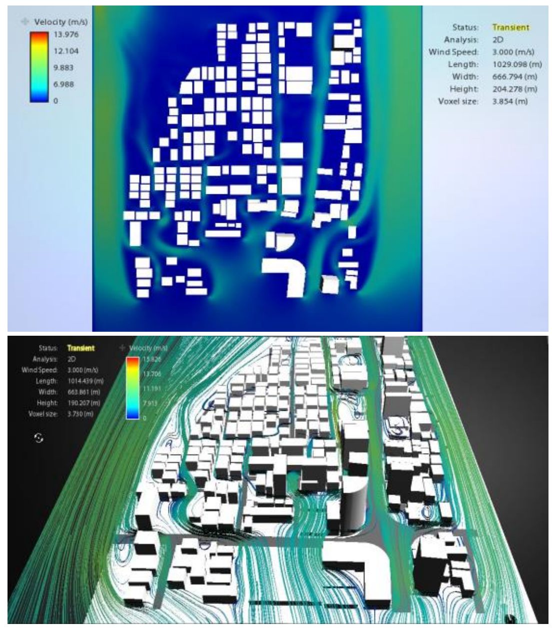


Figure 7: Wind flow pattern at 12m from ground level from south direction.

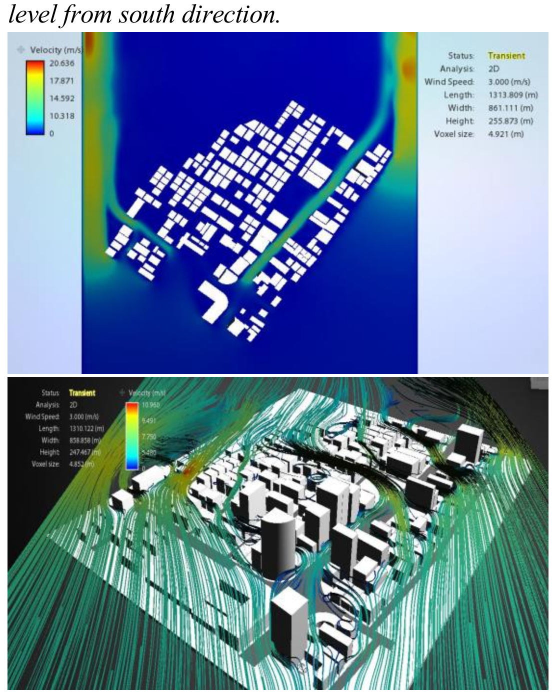


Figure 8: Wind flow pattern at 12m from ground level from south-east direction.

Case 02: From 12m level, the wind speed in primary and secondary roads were greater than 3m level. In the residential blocks the wind speed was noticeable for south direction wind but negligible for winds coming from south-east direction. The wind flow has increased with the increased height and high turbulence can be seen near the edge of some high-rise.

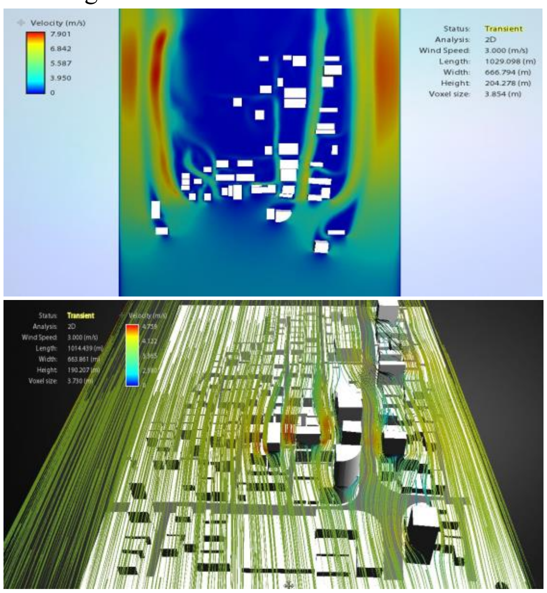


Figure 9: Wind flow pattern at 24m from ground level from south direction.

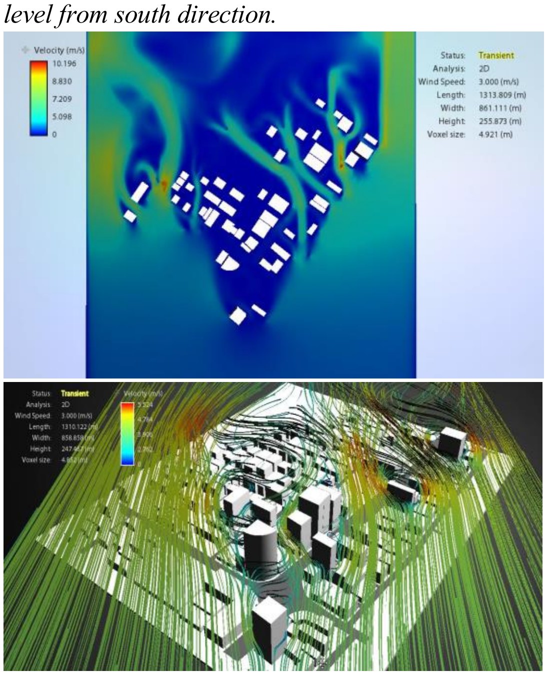


Figure 10: Wind flow pattern at 24m from ground level from south-east direction.

Case 03: Due to less interference from build structures, increased wind speed can be observed at 24m level. From simulations it can be seen that the high-rise buildings are generating large wind shadow zones behind them for wind coming from south and south east direction. Funnel effect can be observed in few areas which in generating high wind speed. Results show a better wind flow above the streets for wind coming from south direction compared to wind from south east direction.

6. FIELD SURVEY DATA

Wind speed in Bangladesh is high during the month of April, May and June[10]. So field survey was conducted during this time. Data were collected from artery roads and also from internal roads in residential zones. Wind speed was measured using anemometer from 6 feet above road level. Readings were taken only when there was no traffic movement so that vehicular movements do not impact the measurements.

Figure 11: Data collection points at ground level

Station point	Minimum Wind Speed	Maximum Wind Speed	Wind Direction
01	0.2 m/s	1.0 m/s	S
02	1.2 m/s	2.6 m/s	S
03	1.3 m/s	2.4 m/s	S/S-E
04	0.0 m/s	0.1 m/s	S
05	0.3 m/s	1.1 m/s	S/S-E
06	0.2 m/s	0.8 m/s	S
07	0.0 m/s	0.1 m/s	S
08	0.2 m/s	2.2 m/s	S/S-W

Table 1: Maximum and minimum wind speed from data collection points

As seen from the data (Table 1), the on field data shows similarity with the results found from simulation. From station point 01, the wind speed is quite satisfactory as the roads are wide enough to allow air flow. At station point 02 and 03, the wind speed increased due to the wind turbulence created by adjacent high rise building. At point 04, there was almost no airflow as there were high rise buildings on every side in close proximity. At point 05 and 06, moderate amount of air flow is present. The wind direction is from south to south east as the wind channels in from the artery road on east. At point 07, again almost no wind flow is detected due to lack of open space and prevailing wind directions blocked by high rise buildings. But at point 08, wind speed increases due to presence of large open space (Gulshan Lake). The wind direction is from south- south west which is different from other station points.

7. CONCLUSION

From the results, it is clearly seen that high-rise buildings have profound influence on the micro climatic wind environment. Due to long wind shadow cast by the buildings, the relatively low rise residential zone lack proper wind flow. As a result, human comfort is hindered on street level and inside the living zones as well. As the field survey was done for only a limited amount of time, further field study should be conducted to get more conclusive results. The findings can be helpful for the planners and architects while developing new urban areas so that the existing problems are not repeated in the future.

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