ICGrA 2018
INTERNATIONAL CONFERENCE ON GREEN ARCHITECTURE

# Proceedings

## 2nd International Conference on Green Architecture (ICGrA 2018)

**Green Architecture in Achieving Sustainable Developments Goals**

**12-14 July 2018, Dhaka, Bangladesh**


ORGANIZED BY

BUET

rACe Green Architecture Cell
DEPARTMENT OF ARCHITECTURE
B U E T

IN COLLABORATION WITH

SREDA
Sustainable and Renewable Energy Development Authority

Department of Architecture, BUET

ARCAAB

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**Proceedings**
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# *EDITORIAL*

As an adverse effect of rapid industrialization and unplanned growth of built environment, overall sustainability of this planet has been threatened. On the other hand, imbalanced economic growth has put a considerable part of the world population on hunger. On 25 September 2015, under the initiatives of the United Nations, countries have adopted 17 Sustainable Development Goals (SDGs) and 169 targets to 'end poverty, protect the planet and ensure prosperity for all'. Each goal has specific targets to achieve by 2030. This has been accepted as a universal agenda. Bangladesh, as a part of this initiative, has also taken drives to utilize its all opportunities to implement this global development framework, reflecting priorities of the SDGs in the national policies and action plans.

Globally and locally, it has been a quest to find how concepts and practices of green architecture can assist accomplishing the SDGs, through developing an environment-friendly, energy efficient and socially responsive built environment and its management system. To bring off such ideas to reality, collaborative efforts among academy, industry and other stakeholders are inevitable.

The Green Architecture Cell (GrACe), Department of Architecture, Bangladesh University of Engineering & Technology (BUET) is working in line with activities towards achieving the desired sustainability goals, as an endeavor to make this world green and liveable. With this objective, GrACe has organized the 2nd International Conference on Green Architecture (ICGrA 2018), on 12 - 14 July 2018 at International Convention City Bashundhara (ICCB), Dhaka. The conference has been organized in collaboration with the Sustainable & Renewable Energy Development Authority (SREDA), Ministry of Power, Energy and Mineral Resources, Government of the Peoples Republic of Bangladesh, Environment & Energy Division, Department of Architecture, BUET and Architecture Alumni Association of BUET (ArcAAB).

The conference ICGrA 2018, has been set on its main theme as the 'Green Architecture in Achieving Sustainable Development Goals'. It has chosen 4 sub-themes out of the total 17 SDGs, namely, Affordable Clean Energy; Industry, Innovation and Infrastructure; Sustainable Cities and Communities; Responsible Consumption and Productions. However, any allied topic has also been invited for scholarly dissemination on a broader platform.

A good number of enthusiast authors came up with their papers and posters, based on their research and reviews. The papers and posters cover the desired 4 SDGs and also related fields. Those works have gone through double-blind peer reviews and revisions to their presentable final version. Encouragingly, a majority of contributing authors are young, in terms of their affiliation and research experience. We have envisaged a prospective future in their works and took this opportunity to encourage their research potentials through this conference.

We would like to convey our thanks to all authors, reviewers, session chairs, collaborators, volunteers and others, who have relentlessly supported us in intellectual, enthusiastic and advisory capacities. We wish, this type of scholarly exercise will promote motivation, awareness and strategies in developing an effective implementation framework for a sustainable development agenda for the people and the planet.

***Prof. Dr. S. M. Najmul Imam***
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# A COMPARATIVE STUDY ON THERMAL PERFORMANCE OF SANTAL MUD HOUSES AND BRICK HOUSES IN DINAJPUR

**Dipa Saha**[1]

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***Abstract:*** *In Bangladesh, mud house is one of the traditional housing types. Mud is broadly used in areas of less rainfall dry climate, lateritic soil (rich in minerals, typically red in color) and where the lands are normally above the flood level. It is cheap, durable and fireproof building material and available all over the country. Thick mud walls act as thermal mass and heat insulator in both summer and winter season. In the western side of the country above 50% of houses are made of mud. Santal and other tribes living in this area are particularly renowned for their unique mud houses. This vernacular house form not only reflects their cultural identity but also emerged to address the harsh climatic condition of the area. This traditional type of housing is locally called Kutcha ghor. Nowadays in rural and suburban areas, economically stable Santal and other communities try to build semi pacca (more permanent brick wall) houses instead of mud house. But are this brick wall house provide more comfortable interior environment than the traditional mud houses? The aim of the study is to investigate the thermal performance of both Santal mud houses and brick houses in the same area within the same context and climatic zone. A comparative thermal comfort analysis of these two materials will be conducted with a computer base simulation software Ecotect v 5.2. This study also tries to find efficient building material in term of thermal comfort and energy efficiency by analysing hourly temperature profile, hours of discomfort, passive gains analysis and monthly load analysis.*

***Keywords****: Ecotect, Mud House, Simulation, Thermal Comfort.*

## 1. INTRODUCTION

Building materials play an important role in buildings from the energy efficiency and thermal comfort points of view **(Givoni, 1998).** Due to their inherent properties, different building materials respond differently to climatic conditions. The thermal properties of building components such as walls, ceiling and floors together determine the energy consumption patterns and comfort conditions in an enclosed space **(Olanipekun, 2002).** The traditional dwelling units in Dinajpur constructed with locally available materials, such as mud, bamboo, thatch, wood, etc**. (Rumana, 2007).** Construction and design of new houses in rural Dinajpur have changed considerably over the last decay due to increased affordability, wide spread availability, affordability & durability of brick and other materials. Flat roof and thin brick walled buildings of relatively low thermal insulation have replaced the old thick mud high walled houses which were said to have good thermal insulation and ventilation. Since temperature is one of the key weather variables affecting thermal comfort, Thermal performance of the brick and mud houses was evaluated on the basis of computer simulations only. Change in building material also effect energy consumption in long run. So, this study tries to compare the heating and cooling load for these two materials.

### *1.1. Purpose of Study*

The aim of the study is to investigate the thermal performance of both Santal mud houses and brick houses in the same area within the same context and climatic zone with the following objective,

To study the thermal performance of both mud wall building and brick wall building In Dinajpur.

To conduct a comparative thermal comfort analysis of these two Materials based on hourly temperature profile, hours of discomfort, passive gains analysis.

To find efficient building material in term of

thermal comfort and energy efficiency

### *1.2. Scope and Contribution of Study*

Two houses having similar type of plan, orientations, roofing material but different wall materials are the prime focus of study. Difference between the indoor and outdoor temperature and the comfort level of humans in both summer and winter season will be the main subject of study. The successful completion of this study may Influence the use of building material in this particular research area.

### *1.3. Limitation of the Study*

The study is limited in the two types of houses (mud wall building and brick wall building) in same area in Dinajpur, Bangladesh. This study is only based on computer generated data. Data collected from field based investigation on thermal comfort are not used in this comparative study.

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## 2. LITERATURE AND THEORY

According to **ASHRAE 55-2004** thermal comfort is a subjective response, and is defined as the 'state of mind that expresses satisfaction with existing environment', making it difficult to assign it a specific numerical value. The state of mind is widely driven by perception and expectation of the occupants **(Brager & Dear, 1998).** So, the same thermal environment may be perceived differently by different occupants, or different occupants may perceive the same thermal comfort sensation for different thermal environments **(Auliciems, 1981) (Rajasekar, 2010).** According to the research conducted by **Mallick (1994),** air temperature for comfort with no air movement and for people wearing normal summer clothing, engaged in normal household activity indoors are within the range of 24 °C and 32 °C and for relative humidity between 50% and 95% in still air condition, people feel comfortable even in higher humidity, which is expected response in a location where humidity is generally high for most of the years. With the introduction of airflow relative humidity up to 95% is tolerated.

All Previous researches on thermal comfort are mostly concentrated on the urban situations especially on Dhaka **(Ahmed, 1994) (Mallick 1994).** Some Recent studies by **Shahjahan. A** (2010), **Shahjahan. A** (2012), **Shahjahan. A & Ahmed Z.N.** (2016), **Ahmed S., Hossain K.A., & Zobaid N.** (2017) are concern about thermal comfort in rural and traditional houses of different areas of Bangladesh. The majority of the field survey discover that the international set up is either overestimated or underestimates the comfort condition .To predict the comfort zone in the climate of Bangladesh, **Ahmed(1987)** proposed **Humphreys & Nicols (1970)** neutral temperature model **(table 1)** which was found to be better fitted for our context.

*Table 1: Monthly comfort zones for Bangladesh*

| Month | Average temp (C) | Comfort Zone (C) |
|---|---|---|
| **Jan** | 18.7 | 16.0-20.0 |
| **Feb** | 21.2 | 18.2-22.2 |
| **Mar** | 26.0 | 22.4-26.4 |
| **Apr** | 29.0 | 24.6-28.6 |
| **May** | 28.9 | 24.6-28.6 |
| **June** | 28.6 | 24.3-28.3 |
| **July** | 28.6 | 24.3-28.3 |
| **Aug** | 28.6 | 24.3-28.3 |
| **Sept** | 28.7 | 24.4-28.4 |
| **Oct** | 27.2 | 23.1-27.1 |
| **Nov** | 23.4 | 20.0-24.0 |
| **Dec** | 19.7 | 16.9-20.9 |

*Source: Humphreys & Nicols (1970)*

## 3. METHODS

Method followed in this study is twofold. First a field based investigation was adopted, to select a study mud house in Dinajpur and to collect necessary data for analysis. Various building design parameters like numbers and dimensions of doors and windows, celling height, materials orientations were recorded carefully. Secondly, Thermal analysis calculations were performed using the software Ecotect v 5.2. Ecotect is a complete building design and environmental analysis tool that covers the broad range of simulation and analysis function. It couples an intuitive 3D design interface with a comprehensive set of performance analysis functions and interactive information displays

**(Marsh, 2003).** It uses a unique system of progressive data input to reduce user's burden. It initially, only needs simple geometric details. Work flow chart in **Figure 1** presents full Proses of the study. Other details of simulations and finding are describe in next chapters.

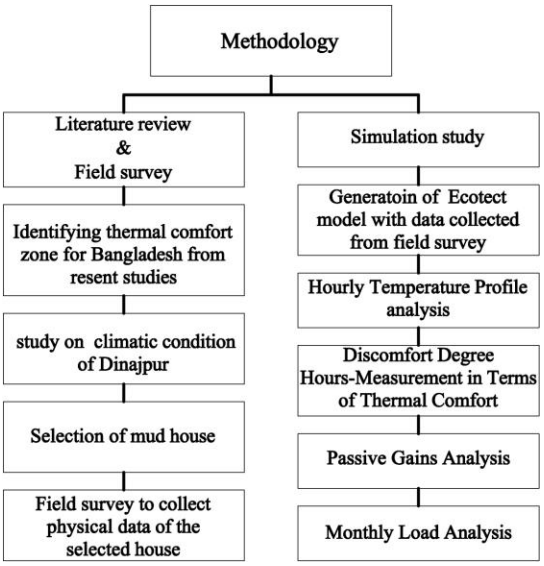


*Figure 1: Work flow chart*

### *3.1. Selection of Mud House*

An 'L shaped' mud house situated in Goraghat, Dinajpur was selected for the study. Both The external and internal mud walls of the studied house are 500 mm thick. The studied mud house has 90m$^2$ areas with 2 bed room and a store. Bed Room 1 is east-west elongated with measures 8.5 meters in length by 5 meters in breadth is main zone for analysis. 2 windows and a door 1 in each north and south, one window in west wall and one small void like opening is placed on the east wall of the room **(see figure 2).** Other building details measured in field survey are structured in **table 2.**

*Table 2: Details of studied house*

| | Wall | Door | Window | Roof | Floor |
|---|---|---|---|---|---|
| **Size** | 500mm thick | 950mm x 900mm | 750mm x 900mm | 5.4m from the floor | 42.5 m$^2$ |
| **Materials** | Mud finish | Wooden frame | Wooden frame | Corrugated sheet | Mud finish |

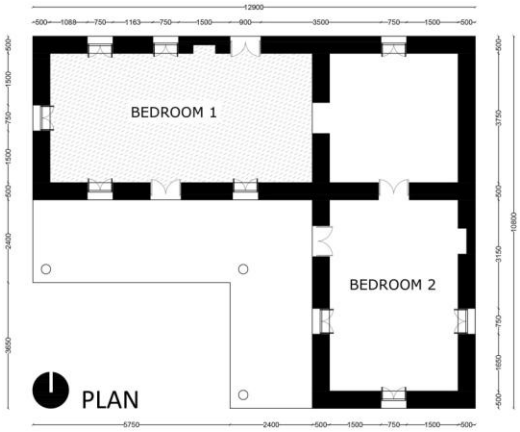


*Figure 2: Plan of studied house*

### *3.2. Climate of Dinajpur*

Dinajpur District located in between 25°10' and 26°04' north latitudes and in between 88°23' and 89°18' east longitudes, experiences a hot, wet and humid tropical climate. Under the Köppen climate classification, Dinajpur has a tropical wet and dry climate. According to **Ferdous & baten( 2011)** The district has a distinct monsoonal season, with an annual average temperature of 25 °C (77 °F) and monthly means varying between 18 °C (64 °F) in January and 29 °C (84 °F) in August **( see figure 3 & 4).**

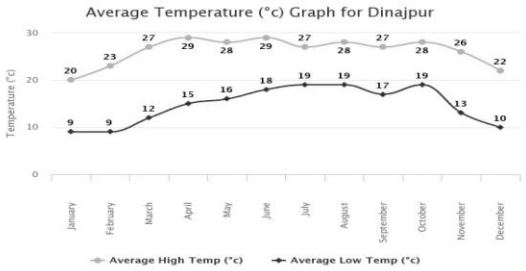


*Figure 3: Average of mean monthly maximum and minimum temperatures for Dinajpur (2000 to2012)*

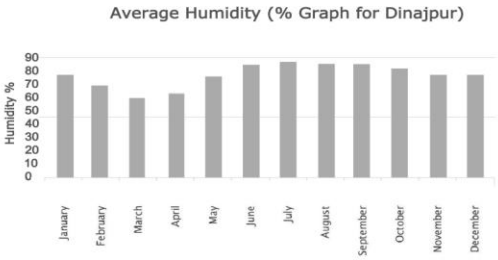


*Figure 4: Average Humidity % for Dinajpur (2000 to 2012)*

## 4. SIMULATIONS WITH ECOTECT

First the model of two houses was constructed. In order to ascertain the direct effect of wall materials on the thermal behaviour of the building, the material properties and details of the walls only were altered for each run. In other words, the materials and dimensions of the doors, windows, and roof and floor constructions were still the same. The scope is limited to two alternatives of the walls.

**Mud wall:** mud house is built with murrum mati, a locally available clayey soil and 500 millimetres thick. Plaster is made of very fine clay, mixed with cow dung and bits of straw or rice husk **(see figure 5).** The straw or husk serves to reinforce the plaster layer and prevents it from cracking and rain wash. From a study of **Gupta and Nathanz (2016** ), material property of mud wall are shown in **table 3.**

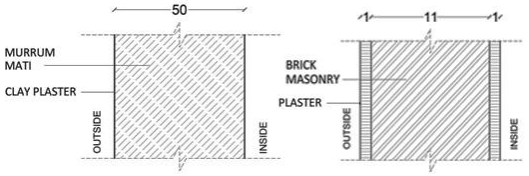


*Figure 5: sections of mud and brick plaster wall.*

*Table 3: Material prosperities for mud and brick plaster wall.*

| | Mud wall | Brick wall | |
|---|---|---|---|
| | Murram clay | Plaster (Molded Dry) | Brick Masonry |
| Width( mm) | 500 | 10 | 110 |
| Density[kg/m³] | 2600 | 1250 | 2000 |
| Specific heat capacity [J/kg/K] | 962 | 1088 | 836 |
| Thermal conductivity [W/m/K] | 41.84 | 0.431 | 0.711 |
| Admittance [W/m2K] | 5.850 | 4.3 8 | |
| Time lag [hours] | 12.12 | 3 | |
| Simplified U-value [W/m²K] | 3.020 | 2.62 | |
| Thermal decrement(0-1) | 0.18 | 0.7 | |

*Source: Gupta and Nathani, 2016 and field survey.*

**Brick wall**: The first layer is the external plaster with a thickness of 1cm. The density of the external plaster is higher than that in the internal one to afford the fluctuations of the weather. The second layer is the brick with 11cm as a thickness. The internal layer is the plaster with a thickness of 1cm as shown in **table 3 and figure 5.** Time lag is 3 hours and simplified U-value for these three layers is 2.62 W/m2K.

Thermal analysis was based on 50% occupancy during weekdays and 90% occupancy during Weekends. Number of inhabitants was assumed to be same for all the rooms. The thermal comfort analysis of the two houses was carried out for based on three parameters. Firstly, hourly temperature profile for the hottest day (May 28) and coolest day (10 January) for Dinajpur **(Ferdous & baten, 2011)** is analysed. Secondly, monthly discomfort hours i.e. total hours of discomfort for each type of wall is analysed. Thirdly, thermal comfort analysis is followed by passive gains analysis of rooms identified with specific thermal behaviour pattern.

### *4.1. Hourly Temperature Profile*

On the hottest day (May 28th), the Outdoor temperature ranges from 35.3 C at 10:00 AM to 28.7 C at 11.00 PM with high diurnal variation of 6.6C.

In mud house, inside remains cooler than outside during day-time, from 6 AM- 2PM but after 2PM inside temp is slightly higher than outside. In brick house inside is hotter than outside during day-time after 2pm. none of the house has comfortable temperature according to **table 4 (also see figure 6 & 7)** but in mud house inside temperature is lower than brick house in day time from 6AM-7PM.mud house has higher indoor temperature then brick house in night. This can be attributed to thermal time-lag of heat-conductivity of mud. The mud stores the heat gained during day-time and dissipates it gradually after 8 PM at night, after getting heated from 7 AM to 5 PM in summer (with peak heat gain during 9 AM in the morning to2 PM in afternoon), thereby demonstrating a thermal lag of more than 12 hours.

*Table 4: Hourly Temperature Profile for both mud and brick wall on a hottest and a coldest day.*

| Hour | Hottest Day (May 28) | | | Coldest Day (10 Jan) | | |
|---|---|---|---|---|---|---|
| | Outside temp C | Inside temp (mud) C | Inside temp (brick) C | Outside temp C | Inside temp (mud) C | Inside temp (brick) C |
| **00** | 28.9 | 32.1 | 31.6 | 13.7 | 19.1 | 18.5 |
| **01** | 28.9 | 32.1 | 31.6 | 13.7 | 19.1 | 18.5 |
| **02** | 28.9 | 32.1 | 31.6 | 13.7 | 19.0 | 18.5 |
| **03** | 31.1 | 32.0 | 31.7 | 17.6 | 19.1 | 18.3 |
| **04** | 31.1 | 32.0 | 31.8 | 17.6 | 19.1 | 18.4 |
| **05** | 31.1 | 31.9 | 31.8 | 17.6 | 19.1 | 18.4 |
| **06** | 33.5 | 32.0 | 32.4 | 23.1 | 19.4 | 19.4 |
| **07** | 33.5 | 32.1 | 32.5 | 23.1 | 19.5 | 19.6 |
| **08** | 33.5 | 32.1 | 32.5 | 23.1 | 19.5 | 19.6 |
| **09** | 35.3 | 32.3 | 33.1 | 24.5 | 20.1 | 20.8 |
| **10** | 35.3 | 32.3 | 33.4 | 24.5 | 20.2 | 20.9 |
| **11** | 35.3 | 32.3 | 33.5 | 24.5 | 20.3 | 21.1 |
| **12** | 34.0 | 32.2 | 33.9 | 19.2 | 19.4 | 22.1 |
| **13** | 34.0 | 32.2 | 33.8 | 19.2 | 19.3 | 21.3 |
| **14** | 34.0 | 32.2 | 33.9 | 19.2 | 19.3 | 21.3 |
| **15** | 30.9 | 31.9 | 33.5 | 16.5 | 19.0 | 20.1 |
| **16** | 30.9 | 31.9 | 33.4 | 16.5 | 19.0 | 19.9 |
| **17** | 30.9 | 31.9 | 33.3 | 16.5 | 18.9 | 19.8 |
| **18** | 29.3 | 31.7 | 32.5 | 16.5 | 18.9 | 19.0 |
| **19** | 29.3 | 31.8 | 32.2 | 16.5 | 19.2 | 18.8 |
| **20** | 29.3 | 32.0 | 32.0 | 16.5 | 19.2 | 18.8 |
| **21** | 28.7 | 32.0 | 31.7 | 14.6 | 19.2 | 18.7 |
| **22** | 28.7 | 32.1 | 31.7 | 14.6 | 19.2 | 18.7 |
| **23** | 28.7 | 32.0 | 31.7 | 14.6 | 19.3 | 18.7 |

On the coldest day (January 10), the Outdoor temperature ranges from 24.5 C at 11:00 AM to 13.7 C at 11.00 PM with high diurnal variation of 10.8C. In winter brick houses has temperature higher than comfort level in day time from 9AM-3PM. Indoor temperature of mud house is remain in comfort level in most of the time of the day (excepts 9AM-11AM).due to thermal lag of mud wall, The heat stored during day released at night helps to maintain a comfortable temperature inside the mud house at night**. (see figure 6 & 7)**

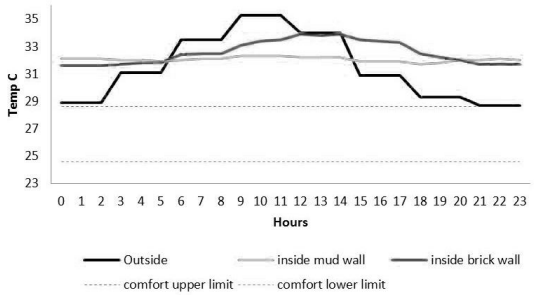


*Figure 6: Hourly Temperature Profile on Hottest Day (May 28)*

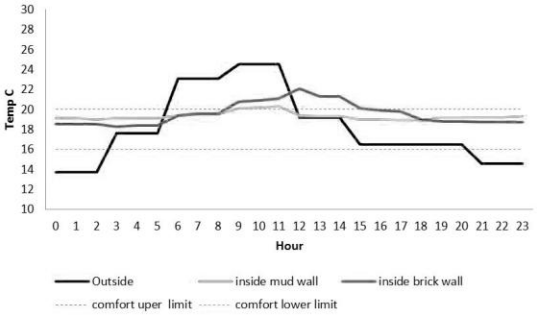


*Figure 7: Hourly Temperature Profile on coldest Day (January 10).*

### *4.2. Discomfort Degree Hours-Measurement in Terms of Thermal Comfort*

From the Discomfort degree hours graph, both mud and brick walled house is found to be comfortable for four months in a year namely January, February, November and December **(see figure 8 & 9).** March and October in mud house seems comfortable. For other months mud house is more comfortable than brick house as brick house has hotter hours than mud house.

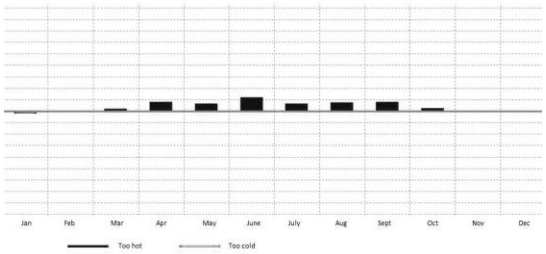


*Figure 8: Mud wall Monthly load discomfort; Discomfort Degree Hours too hot = 5830.7 too cool = 313.0;Total discomfort = 6143.7*

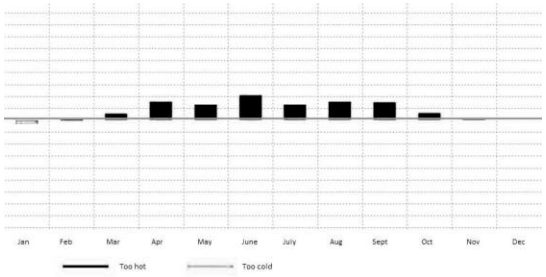


*Figure 9: Brick wall Monthly load discomfort; Discomfort Degree Hours too hot = 11488.8 too cool = 456.7;Total discomfort = 11945 5*

### *4.3. Passive Gains Analysis*

Passive gains breakdown graph of the two houses are shown in **Figures 10 & 11.** The passive gains breakdown graph maps gains and losses that occur via the various heat transfer mechanisms that occur within a zone. These mechanisms include conduction, sol-air, direct solar, ventilation, internal and inter-zonal gains and losses, indicated by the colors shown in the legend below the graph. Values above the horizontal **0** axis indicate heat gain; values below this axis indicate heat loss measured in Watts per hour per square meter to the right of the graph, the gains are presented as percentage values. These percentage values are relative to the total amount of heat gains and losses.

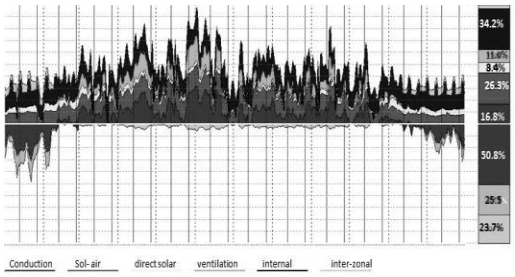


*Figure 10: Heat Gains Breakdown – mud wall 1st jan to 31th dec*

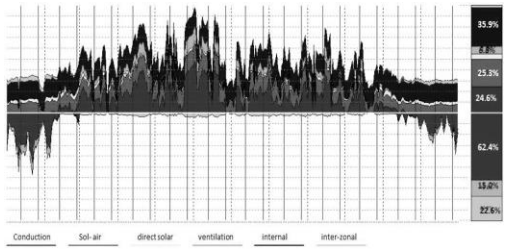


*Figure 11: Heat Gains Breakdown – brick wall 1st jan to 31th dec*

From **Figure 10 & Figure 11**, it is clearly seen that major heat gains in both mud houses occur via conduction and Indirect Solar (Sol-air) gains besides internal gain that occurs due to occupancy. Heat loss in summer is observed to occur only via inter zone loss. In winter, Internal Heat Gain is the primary cause of heat gain. Whereas, with respect to heat loss during winter, main heat loss is through building fabric, that is building skin. Due to thermal mass of mud, heat loss through conduction is less in mud house that provide more comfortable temperature then brick in winter.

### *4.4. Monthly Load Analysis*

To find load (heating and cooling) for both mud and brick house data of entire year is needed. The simulations were done for mud and brick house and summarized in **table 5.**

The total loads of brick house record the high value (2460679W) while the load of mud house is (1407180W).For mud house and brick house Load per m2 floor area is 53225 w and 93072w respectively. So mud wall saves 57% of the loads compared with brick wall due to the efficiency of walls in reducing gains and losses.

*Table 5: Comparison of Monthly loads (heating +cooling) between mud and brick walled house.*

| Month | Monthly loads (heating +cooling) for mud wall (W) | Monthly loads (heating +cooling) brick wall (W) |
|---|---|---|
| **Jan** | 21368 | 159309 |
| **Feb** | 2799 | 44009 |
| **Mar** | 85644 | 200008 |
| **Apr** | 201531 | 358955 |
| **May** | 205297 | 314311 |
| **June** | 291049 | 396187 |
| **July** | 161940 | 254771 |
| **Aug** | 184995 | 263537 |
| **Sept** | 174567 | 280517 |
| **Oct** | 77990 | 139453 |
| **Nov** | 0 | 15852 |
| **Dec** | 0 | 33769 |
| **TOTAL** | **1407180** | **2460679** |
| **Load per $m^2$ Floor** | **53225** | **93072** |

## 5. RESULTS

Hourly temperature profiles show that in winter mud house maintain a comfortable internal temperature within comfort band both in day and night. In summer internal temperature in both mud and brick house remain high than comfort band. Temperature in mud house is lower than brick house and maintained a steady profile.

From Monthly discomfort percentages both mud and brick walled house is found to be comfortable for four months in a year namely January, February, November and December. But for other month in summer brick house has 50% more discomfort hour than mud house.

Passive gains and losses breakdown analyses indicate that the majority of heat losses during winter or heat gains during summer occur via Conduction heat transfer (building envelope). Due to thermal mass and high time lag of mud, heat loss through conduction is less in mud house that provide more comfortable temperature than brick in winter

Monthly load analysis shows, mud wall saves 57% of the heating and cooling loads compared with brick wall due to the efficiency of walls in reducing gains and losses.

## 6. CONCLUSIONS

The building envelope is the main interface between indoors and outdoors and has a significant role in moderating variations in the outdoor weather conditions, providing thermal comfort for occupants and consequently determining the heating/cooling loads of the building. Therefore, this computer-based modeling and simulation study shows traditional mud houses provide better thermal comfort as well as better indoor environment both in summer and winter than brick houses. This study may play an important role in decision making and selection processes of building material particular in Dinajpur reason. This may increase environmental performance of building and occupants' thermal comfort as well as decrease future energy consumption in long run. Though this study is limited to only two building material further research on other available materials and may enrich the knowledge about thermal property and performance of material.

## ACKNOWLEDGEMENTS

I would like to thank all of the people who helped make this investigation possible, in particular Dr. Zebun Nasreen Ahmed (Professor, Dept. of Architecture, BUET), for her continuous guidance, valuable suggestions, generous help and valuable acumen. I would like to thank Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh and last but not the least Dept. of Architecture, BUET, Dhaka, Bangladesh for their technical support.

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# COMPARATIVE ANALYSIS OF THERMAL ENVIRONMENT IN UNDERGROUND AND ABOVEGROUND STRUCTURE IN TROPICS

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***Abstract:*** *Underground construction is perceived to be environmental friendly and sustainable as it is the higher protection against the climatic influences by constant surrounding soil temperature and a pleasant thermal comfort can be ensured with less energy in comparison to conventional aboveground buildings. Thermal environment of underground construction is different from the aboveground buildings since there is no direct influence from the solar radiation. The main objective of this research is to analyse and compare the indoor thermal environment of underground and aboveground spaces of a building, situated in Chattogram, Bangladesh. So that we can consider the differences when designing any underground workspace. In the first step of this study, the air temperature & relative humidity of underground and aboveground spaces in three different point of a building has been monitored for three days by using the infrared temperature monitoring sensor. 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 varies in underground spaces in comparison to aboveground spaces with a range of 0.2°C - 2.2°C. This study indicates the potential of underground buildings to reduce energy demand in comparison to aboveground buildings.*

***Keywords****: Air temperature, Relative humidity, Tropical climate, Underground Structure.*

## 1. INTRODUCTION

Today the urbanization process is advancing rapidly all over the world, the requirement of more space to accommodate increasing activities in metropolis is a world-wide phenomenon. Over the past years the urban underground space development offer interesting possibilities by different projects all over the world [1, 2]. There are many causes for rapidly development of urban underground space, such as environment, disaster prevention and population. In recent years, the use of underground space for subway, underground parking lots, underground shopping malls, underground museum, highly secured portion of politically important building, lifelines has been increasing in Bangladesh. An important feature of underground spaces is the higher protection against the climatic influences. The soil temperature follows the external changes with phase delay and with significant attenuation [3-5]. Since there is no direct influence from the solar radiation, the thermal sensation induced by direct solar radiation can be neglected [6, 7]. As a result, a pleasant thermal environment can be ensured with less energy in underground spaces [8, 9]. It is essential to understand the thermal environment of an underground space to ensure the sustainable underground development. Hence, the objective of this research is to analyse and compare the indoor thermal environment of underground and aboveground spaces of a building in Tropics. Thermal environment of underground buildings is largely affected by air temperature & the relative humidity RH (%). So, the analysis is based on thermal issues like indoor-outdoor air temperature ($T_{out}$, $T_{g}$, $T_{ug}$,) $^{o}$C, and relative humidity RH (%). The result of this research can aid better understanding of indoor thermal environment of an underground space which will play a very important role in planning, design, construction and maintenance of underground space.

## 2. CLIMATE CONSIDERATION

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

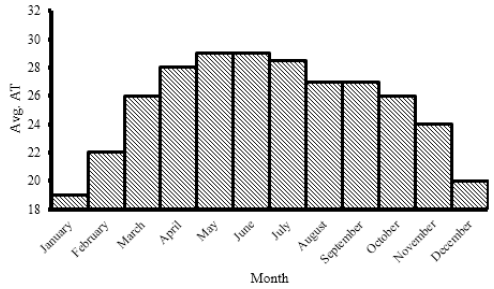


*Figure 1: Average AT in Chattogram, Bangladesh*

The cool and dry 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 Chattogram and the hottest months are March, April and May respectively. Fig.2 and 3 shows the average wind speed and relative humidity of Chattogram [10-12].

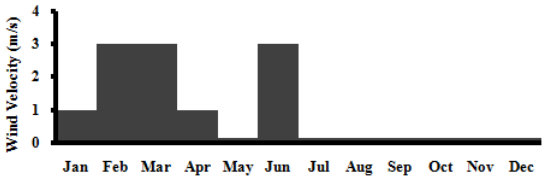


*Figure 2: Average wind speed ($ms^{-1}$) in Chattogram, Bangladesh*

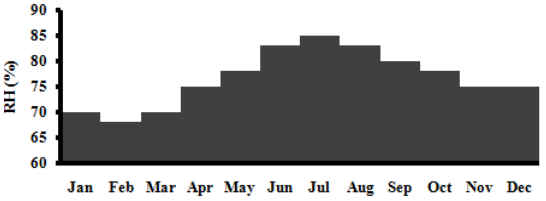


*Figure 3: RH (%) of Chattogram, Bangladesh*

## 3. METHODOLOGY

The field studies were conducted in a building with basement facility. In the first step of this study, the air temperature of three different point in underground and ground level of this building has been monitored using the infrared temperature monitoring sensor. In this step, indoor air temperature in underground level ($T_{ug}$), indoor air temperature in ground level ($T_g$), outdoor air temperature ($T_{out}$), and relative humidity RH (%) at each level in indoor and outdoor was measured in three different location of the selected building by using lutron LM 8102, environment meter. Fig.4 shows the multi-meter.

*Figure 4: Lutron LM 8102*

The field survey was conducted in a building with a floor area of 1400$m^2$ and located in Chittagong University of Engineering and Technology, Chattogram, Bangladesh. The survey data were collected for three different days in between 30-1-2018 and 4-2-2018. Each day $T_{ug}$, $T_g$, RH (%) was recorded at three different points of the basement and ground floor and $T_{out}$ at outdoor at two hour interval manually from 9.00am to 5.00pm. For the basement and ground floor, three points were selected for data collection. As the building is rectangular in plan & elongated to north-south direction, two points are chosen near exterior wall of north and south ends (10' from end wall) and another one at the middle of the building to measure the variation of data of previous two points. In case of outdoor, the points were at the west side, parallel to the indoor points at a distance 15' from the building outer facade.

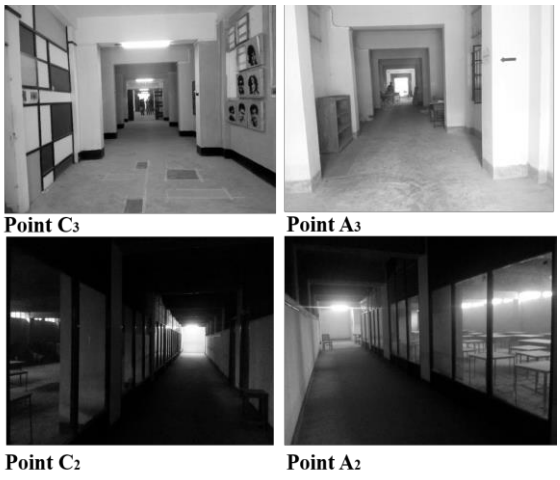


*Figure 5: Interior spaces of the selected points*

Fig.5 shows the Interior spaces of the selected points. The data collection was done manually with the device being 3' from floor level in a handheld position. In the second step, a comparative analysis of monitored data is conducted to evaluate the indoor thermal environment of underground and aboveground spaces.

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

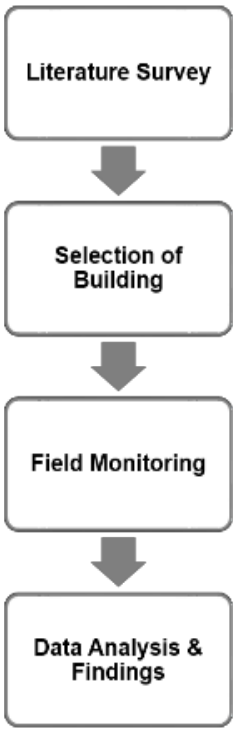


*Figure 6: Structure of the research work*

## 4. BUILDING SELECTION CRITERIA DESCRIPTION

New Academic Building in Chittagong University of Engineering and Technology, Chattogram was selected for this study. The reasons being, the building is East-West oriented with underground facility and having rectangular plan. Because of the orientation and plan shape, it was convenient for us to survey the difference of air temperature and RH (%) at north side, south side and west side of the building. Here, Fig.7 shows the site location of the building which is located at Pahartali, Raozan, Chattogram.

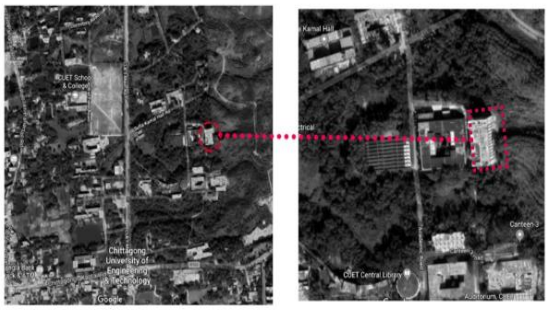

*Figure 7: Site location of the building*

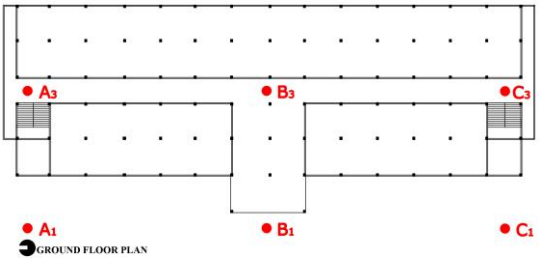


*Figure 8: Floor plan at ground level*

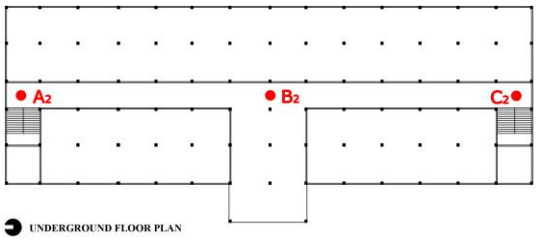


*Figure 9: Floor plan at underground level*

Fig.8 and 9 illustrate the typical floor plan for ground level and underground level respectively. It shows the 218' long corridor beside which the classrooms are grouped with stair at two ends. There are toilets and verandas at both ends of the corridor. The underground level was used as classroom and study purpose. Presently, it is abandoned for indoor discomfort and unhealthy situation. Fig.10 shows the exterior view.

*Figure 10: View of the building*

## 5. RESULT AND DISCUSSION

From the monitoring and data analysis, it has been appeared that $T_g$, $T_{ug}$ reach the peak points at 1.00PM to 3.00PM and falls gradually from that time keeping pace with $T_{out}$ and RH (%) reach the peak points at 9.00 AM. $T_g$, $T_{ug}$ and $T_{out}$ reach the minimum at 9.00 AM and RH reach the minimum at 3.00 to5.00 PM.

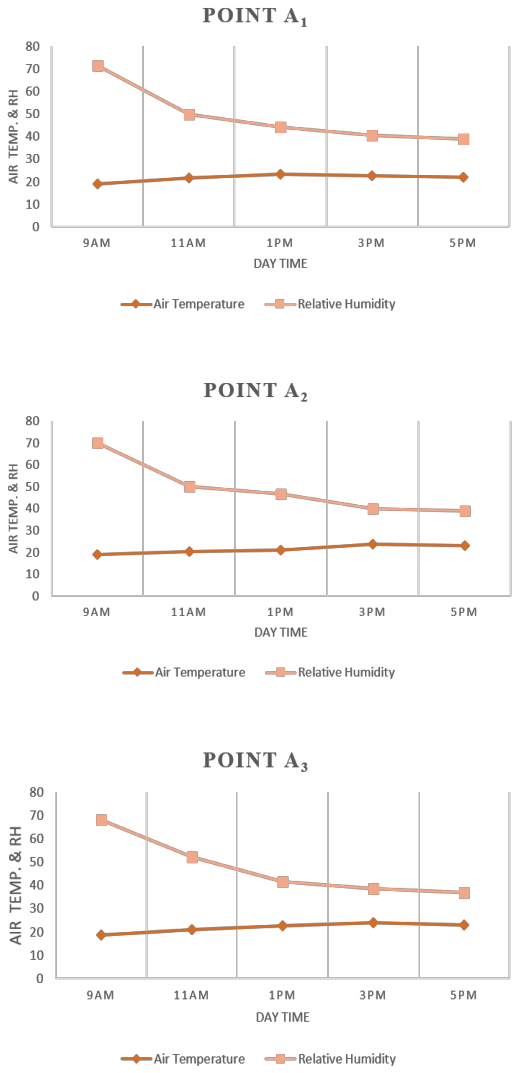


*Figure 11: Air temperature & RH (%) distribution of point $A_1$, $A_2$ and $A_3$*

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

The Fig.11 shows the $T_{ug}$ and RH at point $A_2$, $T_g$ and RH (%) at point $A_3$, $T_{out}$ and RH (%) at point $A_1$ at different period. All the points are in north side of the building. At the peak point (1.00PM), air temperature at $A_1$, $A_3$ and $A_2$ is 23.4°C, 21.5°C and 21.3°C respectively. At this point underground temperature is 0.2°C lower then temperature at ground level. At the lowest point (9.00 AM), temperature $A_1$, $A_3$ and $A_2$ is 19°C, 18.7°C and 18.3°C respectively. Underground temperature is 0.4°C lower then temperature at ground level. In the case of humidity, at the peak point(9.00AM), $A_1$, $A_3$ and $A_2$ is 71.3%, 68.4% and 70.1% respectively and it is found that underground humidity is 1.7% higher than ground level humidity at this point.

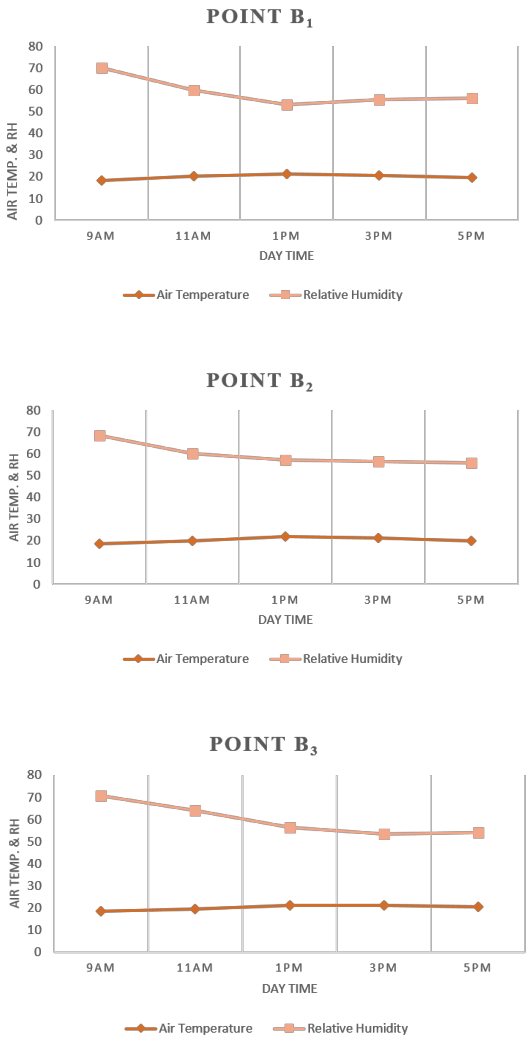


*Figure 12: Air temperature & RH (%) distribution of point $B_1$, $B_2$ and $B_3$*

Fig.12 shows $T_{ug}$ and RH (%) at point $B_2$, $T_g$ and RH (%) at point $B_3$, $T_{out}$ and RH (%) at point $B_1$ at different period. All the points are located at

midpoint of the building. At the peak point (3.00PM),air temperature at $B_1$, $B_3$ and $B_2$ is 23.9°C, 21.6°C and 21.2°C respectively. Underground temperature is 0.4°C lower then temperature at ground level. At the lowest point (9.00 AM), temperature at $B_1$, $B_3$ and $B_2$ is 19°C, 18.7°C and 18.3°C respectively. Underground temperature is 0.4°C lower then temperature at ground level. In the case of humidity, at the peak point(9.00AM), $B_1$, $B_3$ and $B_2$ is 70%, 68.5% and 68.5% respectively and it is found that underground humidity is almost equal to the ground level humidity.

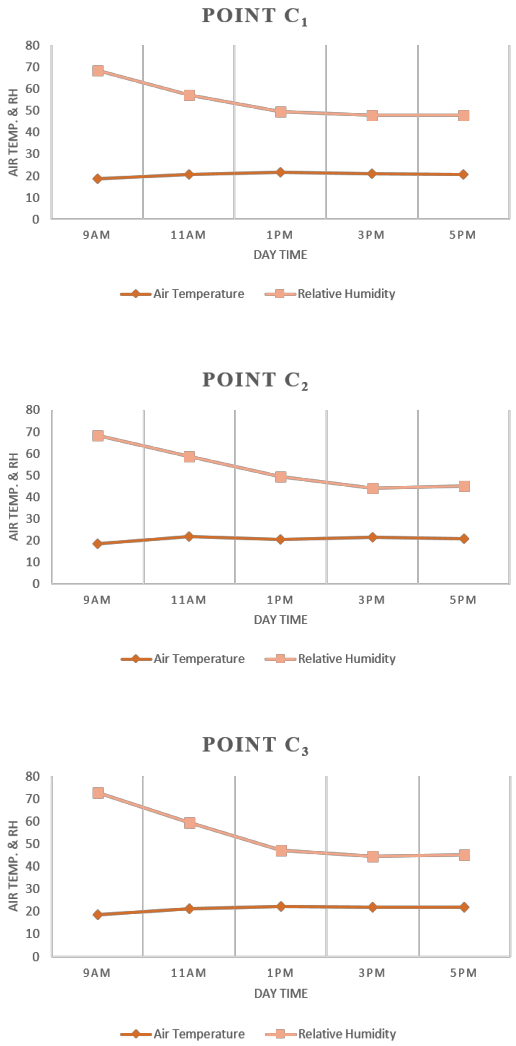


*Figure 13: Air temperature & RH (%) distribution of point $C_1$, $C_2$ and $C_3$*

Fig.13 shows $T_{ug}$ and RH (%) at point $C_2$, $T_g$ and RH (%) at point $C_3$, $T_{out}$ and RH (%) at point $C_1$ at different period. All the points are at south side of the building. At the peak point(3.00PM), temperature at $C_1$, $C_3$ and $C_2$ is 24°C, 22°C and 21.2°C respectively. Underground temperature is 0.8°C lower then temperature at ground level. At the lowest point (9.00 AM), temperature at $C_1$, $C_3$ and $C_2$ is 18.8°C, 18.6°C and 18.5°C respectively. Underground temperature is 0.1°C lower then temperature at ground level. In the case of humidity, at the peak point (9.00AM), $C_1$, $C_3$ and $C_2$ is 68.2%, 72.6% and 70.6% respectively and it is found that underground humidity is 2% lower than ground level humidity.

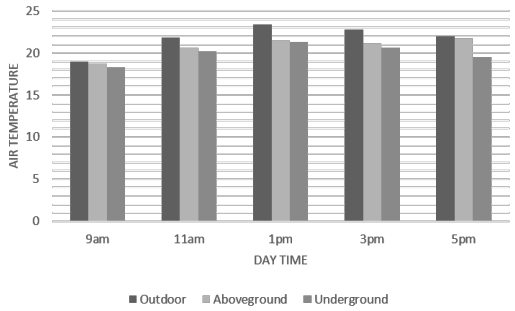


*Figure 14(a): Air temperature comparison at north side of the building*

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

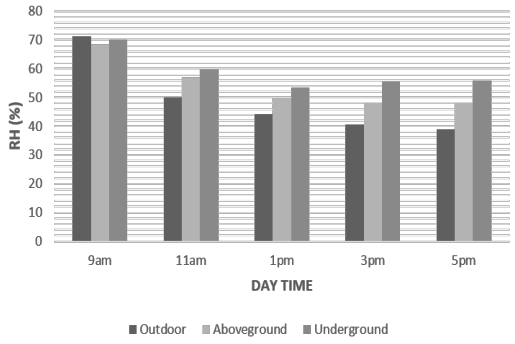


*Figure 14(b): RH (%) comparison at north side of the building*

[Here, Y Axis = Relative Humidity; X Axis = Day Time]

Fig.14 (a) indicates the comparison among outdoor air temperature ($T_{out}$), underground air temperature ($T_{ug}$) and aboveground air temperature ($T_g$) at point $A_1$, $A_2$ and $A_3$ respectively, at the north side of the building. The temperature ranges from 18.3°C to 23.4°C. The comparison indicates $T_{out} > T_g > T_{ug}$ in every case.

Fig.14 (b) indicates the comparison of RH (%) among outdoor, underground and aboveground at point $A_1$, $A_2$ and $A_3$ respectively, at the north side of the building. It shows that after 9.00AM indoor RH (%) is larger than outdoor RH (%) and RH (%) at underground is always larger than aboveground.

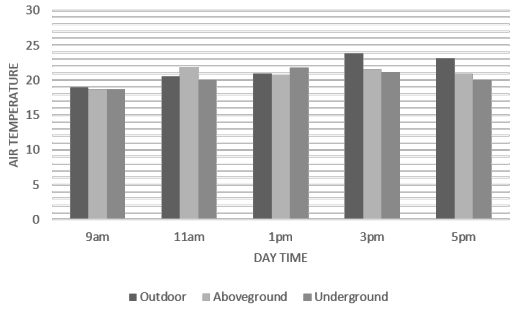


*Figure 15(a): Air temperature comparison at midpoint of the building*

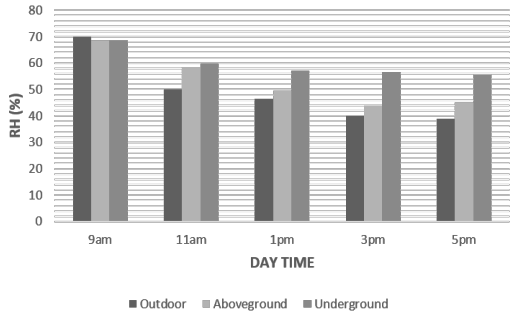


*Figure 15(b): RH (%) comparison at midpoint of the building*

Fig.15 (a) indicates the comparison among outdoor air temperature ($T_{out}$), underground air temperature ($T_{ug}$) and aboveground air temperature ($T_g$) at point $B_1$, $B_2$ and $B_3$ respectively, at the mid-point of the building. The temperature ranges from 18.7°C to 23.9°C. The comparison does not indicate $T_{out} > T_g > T_{ug}$ in every case. At 11.00AM and 1.00PM there is a difference. At 11.00AM $T_{out} < T_g$ and at 1.00PM the $T_g < T_{ug}$.

Fig.15 (b) indicates the comparison of RH (%) among outdoor, underground and aboveground at point $B_1$, $B_2$ and $B_3$ respectively, at the mid-point of the building. It shows that after 9.00AM, indoor RH (%) is larger than outdoor RH (%) and RH (%) at underground is always larger than aboveground.

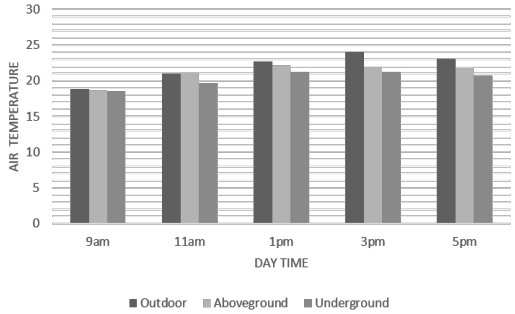


*Figure 16(a): Air temperature comparison at south side of the building*

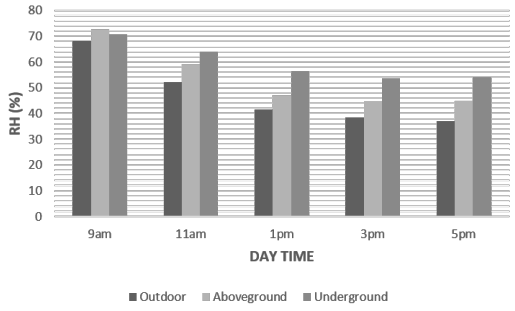


*Figure 16(b): RH (%) comparison at south side of the building*

Fig.16 (a) indicates the comparison among outdoor air temperature ($T_{out}$), underground air temperature ($T_{ug}$) and aboveground air temperature ($T_g$) at point $C_1$, $C_2$ and $C_3$ respectively, at the south side of the building. The temperature ranges from 18.5°C to 24°C. The comparison indicates $T_{out} > T_g > T_{ug}$ almost in every case.

Fig.16 (b) indicates the comparison of RH (%) among outdoor, underground and aboveground at point $C_1$, $C_2$ and $C_3$ respectively, at the south side of the building. It shows that after 9.00AM, indoor RH (%) is larger than outdoor RH (%) and RH (%) at underground is always larger than aboveground.

## 6. SCOPE & LIMITATION

In this study only air temperature and RH (%) have been considered for the research study. Some degree of uncertainty has been ignored. As it was conducted in winter season, the difference of air temperature and RH (%) between underground and above ground is very low. It was necessary to conduct the survey in different season and in different area to get more accurate result and to validate the result a simulation software could be used. Scope of this research is to consider the HVAC system, heating, cooling, ventilation, lighting issues, Acoustics, insulation, safety and security, to conduct survey in different season and indifferent area and using a simulation soft ware to validate the result.

## 7. CONCLUDING REMARK

As this study is based on measurement of one building, it is difficult to reach any conclusion. Hence, several findings about underground and aboveground from these experimental data were identified.

Based on the data analysis and result from the investigation described above, the followings major observations can be drawn:

a. At the north and south side of the building, $T_{out} > T_g > T_{ug}$ in almost every case.
b. At the mid-point of the building there is a difference. At 11.00AM $T_{out} < T_g$ and at 1.00PM the $T_g < T_{ug}$.
c. In the case of RH (%), after 9.00AM. indoor RH (%) is larger than outdoor and RH (%) at underground is always larger than aboveground.

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# PERFORMANCE EVALUATION OF WINDOW LOCATION AND CONFIGURATION TO IMPROVE DAYLIGHTING OF RESIDENTIAL APARTMENT BUILDINGS

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***Abstract:*** *Dhaka is a densely populated urban area, characterized by closely spaced houses in many of its parts, results poor daylighting condition in the central deep spaces, such as dining area in residential apartment buildings. Dining is the counterpart of rural Bangladeshi courtyard and most visually integrated central space. Because of its central location, dining is the critical one in the residential building design with respect to daylight inclusion. Users' physical and mental health largely depends on the quantity and quality of daylight in the interior spaces. Besides, energy consumption (due to excessive and continuous use of artificial lighting) is another critical issue in the context of Bangladesh and optimized use of daylighting is important to reduce energy consumption. The aim of this paper is to identify effective window location and configuration of the bed rooms to improve daylighting condition at dining spaces of the residential apartments in the context of Dhaka. Daylight simulation was used as a decision supporting tool for this study. The 3D model of the case residential apartment located at Dhaka city was created in ECOTECT to assess the availability and distribution of daylight in the dining space. Then the model was exported to DAYSIM to asses the annual daylight performance of the case space with dynamic annual climate based daylight performance metrics. Full height corner window opposite to the door of the adjacent bed rooms of the dining space was found as the most feasible window configuration among the studied options considering most of the dynamic daylight metrics. It is expected that the outcome of the study will generate guidelines for window location and configuration to improve the daylighting of the dining area of residential apartment buildings.*

***Keywords****: Daylighting, Residential building, Apartment, Simulation study, Window.*

## 1. INTRODUCTION

Dhaka as the capital of densely populated country Bangladesh, facing a crisis in the housing sector and the resultant is closely built high rise residential apartments on small lands with the lack of environmental facilities specially daylight. Because of increasing popularity of the walk- up apartments, closing of the joint family tradition and change in the urban landownership patterns, apartment building is now-a-days an integral part of city development (Nigar, 2012).

Dining space is the most visually integrated central space in a residential apartment that links the adjacent spaces, which is chronologically evolved from the rural concept of courtyard (Gomes and Nilufar, 2012). Courtyard is the most daylit space of a house that accommodates maximum of the day activities of the occupants. Apart from being a tropical city with direct daylight as a blessing, residential dining spaces of Dhaka often deprived from daylighting because of its central location in apartment planning layout, and side effect of unplanned urbanization.

Urban areas are characterized by loss of daylight, sunlight and solar gain because of obstructions (Littlefair, 2001). This character gaves rise to the use of supplementary artificial lighting and thus creating the energy crisis. Residential buildings consume 50% of the total energy of Dhaka and 41% of this consumption is for lighting purpose (DESCO, 2016). To save energy, it is necessary to increase the use of daylight and reduce the dependence on artificial lighting. Energy used for lighting purpose can be reduced by 25- 50% with advanced lighting

sources, design strategies and controls; and by 75% with the addition of daylighting (Clanton et al., 2004). Not only energy benefit but also daylight has an effect upon the users physiological and psychological needs.

Window design has an effect on the daylighting potential of a building. Fenestration and building envelope design significantly influence the amount of energy consumption by tropical high-rise buildings (Muhammad et al., 2005). Most common studies on window design are related to commercial and office building design. Experiments regarding window design of residential apartment are very limited and confined to daylighting of the bed rooms only. On a study Afroz et al. (2014) showed that both horizontal and vertical windows with same area gives same type of daylight penetration in case of bed rooms comprising 9.3 $m^2$ to 14 $m^2$. But vertical window on south facing residential rooms performs better than horizontal window if the space depth is 6 m and area of the room is larger than 14$m^2$. According to Chowdhury et al. (2011) vertical windows perform better than horizontal windows because of its geometry regarding the sun. Both studies were limited to south facing rooms and for specific time or seasons. At this point a sensible window configuration and location can be investigated to improve the daylighting condition inside the residential apartments of Dhaka city.

This paper aims to identify the best possible window location and configuration to incorporate daylight into dining spaces through the adjacent rooms and peripheral surfaces of the dining space in the context of Dhaka.

This paper has three major parts. First part is the literature synthesis which describes the importance of window design and illumination standards related to daylighting inside the residential apartments. The second part describes the research methodology. The third part describes the results study with conclusion.

## 2. LITERATURE SYNTHESIS

### *2.1. Codes and standards*

According to Bangladesh National Building Code (BNBC 2006) the recommended minimum illumination level for dining area of a residence is 150lux on the table top at 0.75m above the finished floor level. Supplementary lighting shall be used when illumination from daylight falls below 150 lux.

### *2.2. Dynamic daylight performance metrics*

Dynamic daylight performance metrics are an alternative way to the Daylight Factor (DF). It is based on time series (usually a whole calendar year) of illuminances or luminances within a building with respect to the external, annual solar radiation data for the building site (Reinhart et al., 2006). Following dynamic performance metrics are studied in this research.

- **Daylight Autonomy (DA):**

The daylight autonomy at a point in a building is defined as the percentage of occupied hours per year, when the minimum illuminance level can be maintained by daylight alone (Reinhart et al., 2006).

- **Continuous Daylight Autonomy ($DA_{con}$):**

Continuous daylight autonomy is another set of metrics where partial credit is attributed to time steps when the daylight illuminance lies below the minimum illuminance level (Rogers et al., 2006).

- **Maximum Daylight Autonomy ($DA_{max}$):**

Maximum daylight autonomy indicates the percentage of time when direct sunlight or excessively high daylight conditions prevail (Rogers et al., 2006).

- **Useful Daylight Illuminance (UDI):**

Useful Daylight Illuminance (UDI) is another method to analyse daylight which measures the occurrence throughout the year of a target range of illuminances (i.e. 100 to 2000 lux) achieved across the work plane. This range is considered to be useful for the occupant, neither too dark (>100lux) nor too bright (<2000lux) (Nabil and Mardaljevic 2005). The range could be further divided into following.

• Daylight illuminances less than 100 lux are

considered insufficient to be the sole source of illumination (UDI fell short)

• Daylight illuminances in the range of 100-500lux are considered effective either as the sole source of illumination or in conjunction with artificial light (UDI achieved- supplementary)

• Daylight illuminances in the range of 500-2000 lux are often perceived either as desirable or at least tolerable (UDI achieved/autonomous)

• Daylight illuminaces higher than 2000lux are likely to produce visual or thermal discomfort or both (UDI exceeded).

### *2.3. Window design and daylighting*

Window is an opening placed in a wall or any side of a building that admits light, air and provision of viewing. Orientation, placement, size and glazing characteristics of windows play a vital role in the daylit environment of a space. Window size and position on the wall determine the distance that adequate daylight will penetrate (Robertson, 2002) (Figure 1). Besides the interior illuminances, electric lighting demand also depends on window position, window size and shape (Bokel, 2007).

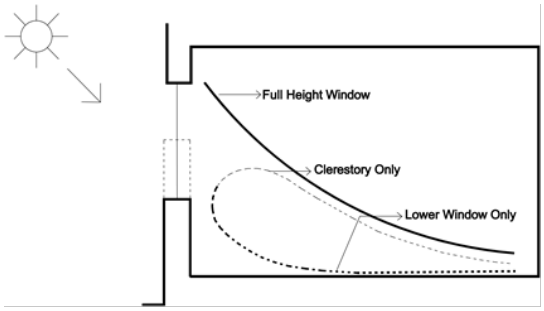



*Figure 1: Relative indicators of light levels with different apertures (AGS, 2000)*

There are three types of window positions: low, middle and high (Figure 2). The low window starts at the bottom of the façade, the middle window is situated exactly at the middle of the façade and high window ends at the top of the façade (Bokel, 2007). Corner window is another type that avoid excessively bright view and provides a large apparent source of a lesser luminance (Koenigsberger, 1975) (Figure 3).

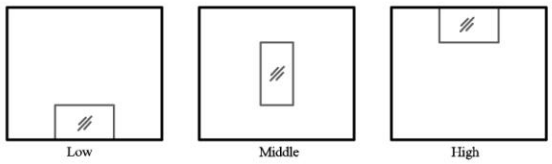



*Figure 2: Low, middle and high window positions (Bokel, 2007)*

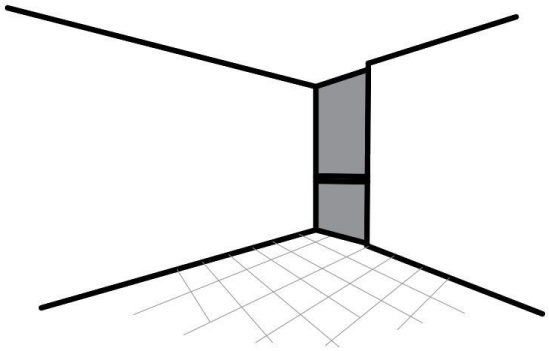


*Figure 3: The corner window (Koenigsberger, 1975)*

## 3. METHODOLOGY

### *3.1. Selection of the Case Space*

The criteria for selection of case apartment are following.

- The dining space should be located at the center of the apartment surrounded by other rooms and service spaces.
- There should be no window or aperture in the dining space of the apartment that opens directly outside and serve as a direct source of daylight.

A survey by previous researchers on 50 randomly selected residential apartments of floor areas between $74m^3$-$139m^3$ (represents middle income group) identified three types of living-dining layout based on the physical layout: separate living-ding; attached living-dining; and continuous living-dining (Gomes and Nilufar, 2012). From these 50 surveyed apartments, an apartment with attached living-dining layout was selected as case apartment (Figure 4) based on above mentioned criteria for simulation analysis.

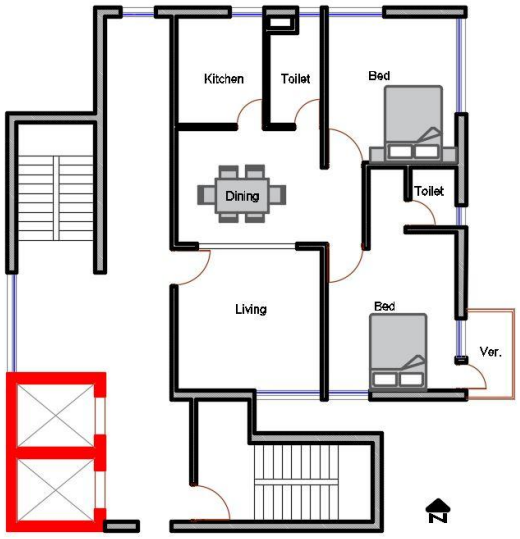



*Figure 4: Floor plan of the case apartment*

### *3.2. Simulation Method*

In this study, the initial simulation model is constructed using ECOTECT V5.20 simulation program. Then it is exported to RADIANCE based simulation tool DAYSIM 2.1P4. Simulations are performed to calculate the DF, DA, $DA_{con}$, $DA_{max}$ above 5%, UDI and illumination on the specific points of the case space on an hourly basis using an annual climate file. DAYSIM, validated successfully for daylight analysis (Reinhart et al., 2006), can calculate illumination level on any point as a function of outside daylight availability and can provide 8760 (365 x 24) hours data for each sensor point considering Perez all weather sky illuminance models (Perez et al., 1990; 1993)

### *3.3. Simulation Parameters*

For dynamic daylight simulation, DAYSIM calculations are performed for the whole year considering nine hours of daylight time from 8.00 to 17.00 hour for seven days a week without any lunch or intermediate breaks and daylight savings time. The minimum illuminance level is considered as 150 lux according to BNBC (2006). The parameters of dynamic daylight metric are shown in Table 1.

The non-default RADIANCE parameters are: 5 ambient bounces, 1000 ambient divisions, 20 ambient sampling, an ambient resolution of 300, a specular threshold of 0.15, a direct sampling of 0.0 (Reinhart et al., 2006).

*Table 1: Daylighting Simulation Parameters*

| **Parameters** | **Specifications** |
|---|---|
| **Location** | Dhaka |
| **Longitude** | 90.40° N |
| **Latitude** | 23.80° E |
| **Local Terrain** | Urban |
| **Precision** | High |
| **Time Zone** | +6 GMT |
| **Simulation Time** | 8.00 to 17.00 |
| **Date** | Whole year |
| **Sky Illumination Model** | Perez all possible sky model round the year(Perez et al. 1990) |
| **Unit of Dimension** | SI metric (m, cm, mm) |
| | Photometric dimension: SI (Lux, cd/m2) |

### *3.4. Case Space*

The case apartment (88$m^2$ area) is consists of two bed rooms, two toilets, a kitchen, an attached type living- dining space (area of dining 12.7 $m^2$) and one veranda.

The walls of the case space are considered to be plastered brick wall with white paint on interior and exterior surfaces, floor to ceiling height is 3.00m, wall thickness is 125mm, ceiling is 125mm thick plastered and white painted (inner surface) R.C.C (Chowdhury et al., 2011). The width of shading device is considered as 500mm according to RAJUK rules (DMBCR, 2008). The material properties for simulation are shown in Table 2.

Because of the synchronous impact of numerous variables in reality, it is hard to isolate the impact of one single variable or any changes of the variable on daylighting of a space. Daylight simulation allows studying the effect of one variable by keeping the others constant. To observe the daylight penetration into the dining by changing the window size and position, the case space is considered at ground floor and the surroundings are considered as vacant (Joarder et al., 2009).

*Table 2: Material properties for daylighting simulation*

| | Material Properties |
|---|---|
| **Wall** | Material: 110mm brick with 10mm plaster in both sides.<br>U Value: 2.620<br>Solar Absorption: 0.418<br>Thermal Decrement: 0.7 |
| **Window** | Material: Single pane of glass with aluminium frame (no thermal break).<br>U Value: 6.000<br>Solar Absorption: 0.94<br>Thermal Decrement: 1.74 (refractive index of glass) |
| **Roof** | Material: Concrete Roof Asphalt<br>U Value: 0.896<br>Solar Absorption: 0.9<br>Thermal Decrement: 0.58 |
| **Floor** | Material: 100mm thick concrete slab on ground.<br>U Value: 0.880<br>Solar Absorption: 0.467<br>Thermal Decrement: 0.3 |
| **Shading device** | Material: Concrete Roof with plaster<br>U Value: 0.896<br>Solar Absorption: 0.9<br>Thermal Decrement: 0.58 |

## 4. PERFORMANCE EVALUATION

Performance metrics is useful for comparative studies to guide building design. For simulation the total floor area of the dining was divided into 66 sensor points at 0.75m above the floor level representing the work plane height for the residential spaces of Dhaka (BNBC 2006). Intersection points were coded according to the letter and number system showing in Figure 5. There were 10 sensor axis on XX' direction and seven on YY' direction and an equal distance of 0.5m were maintained between them. Position of the dining table was considered at the centre of the dining area and six core sensor points were selected above the table top at 0.75m above the finished floor level. DF, DA, DAmax, DAcon, UDI value of the six core sensor points are evaluated.

Eight different configurations of windows were placed alternatively at the adjacent two bed rooms of the dining space to improve the daylighting of the dining space as shown in Table 3 and Table 4.

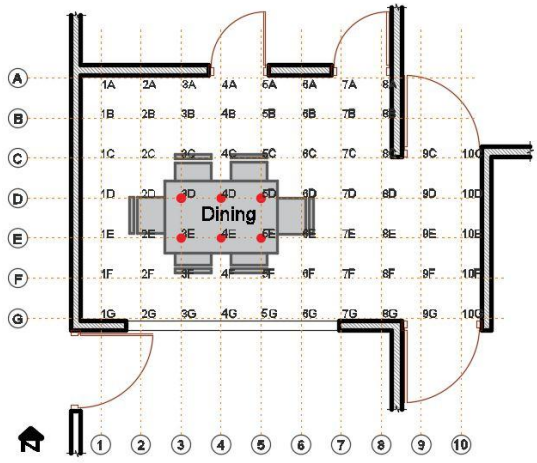



*Figure 5: Case dining space showing the sensor points*

*Table 3: Middle Window (MW) and Corner Window (CW) size and positions for simulation*

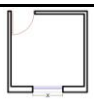
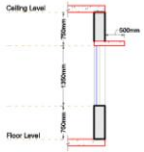
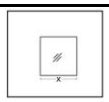
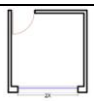
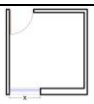
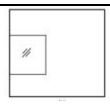
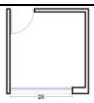
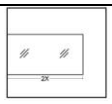
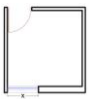
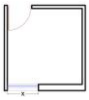
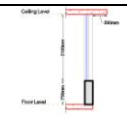
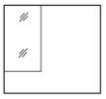
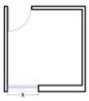
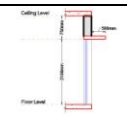
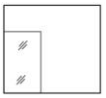
| | | Plan | Section | Elevation |
|---|---|---|---|---|
| **Middle Window** | **MW1** |  |  |  |
| | **MW2** |  | |  |
| | **MW3** |  | |  |
| | | **Plan** | **Section** | **Elevation** |
| **Corner Window** | **CW1** |  |  |  |
| | **CW2** |  | |  |
| | **CW3** |  |  |  |
| | **CW4** |  |  |  |
| | **CW5** |  |  |  |

*Table 4: ECOTECT modelling of case space with selected window locations and configurations*

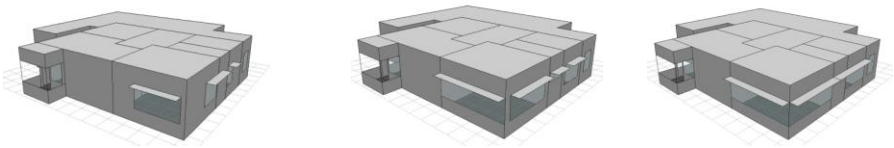
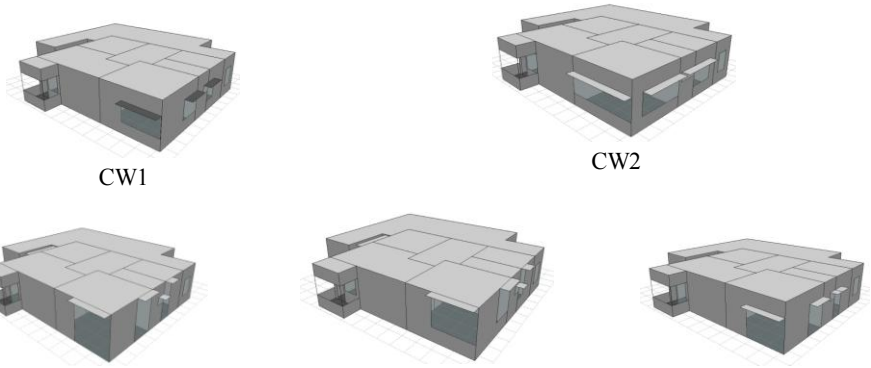
| Window Locations and Configurations | ECOTECT modelling |
|---|---|
| **Middle Windows** |  MW1 MW2 MW3 |
| **Corner Windows** |  CW1 CW2 CW3 CW4 CW5 |

*Table 5: Summary results of annual daylighting simulation of the window configuration*

| Category of Windows | Window Configuration | DF [%] | DA [%] | $DA_{con}$ [%] | $DA_{max}$ [%] | $UDI_{<100}$ [%] | $UDI_{100\text{-}2000}$ [%] | $UDI_{>2000}$ [%] |
|---|---|---|---|---|---|---|---|---|
| **Middle Windows** | MW1 | 0.10 | 0.00 | 28.67 | 0.0 | 95.83 | 4.17 | 0.0 |
| | MW2 | 0.17 | 0.33 | 37.17 | 0.0 | 88.00 | 12.00 | 0.0 |
| | MW3 | 0.20 | 2.50 | 45.33 | 0.0 | 76.50 | 23.50 | 0.0 |
| **Corner Windows** | CW1 | 0.12 | 0.00 | 28.00 | 0.0 | 99.17 | 0.83 | 0.0 |
| | CW2 | 0.18 | 2.83 | 41.33 | 0.0 | 82.33 | 17.67 | 0.0 |
| | CW3 | 0.35 | 28.17 | 64.50 | 0.0 | 50.83 | 49.17 | 0.0 |
| | CW4 | 0.27 | 8.33 | 55.67 | 0.0 | 59.50 | 40.50 | 0.0 |
| | CW5 | 0.15 | 0.00 | 30.67 | 0.0 | 99.33 | 0.67 | 0.0 |

*Table 6: Summary result of annual daylighting simulation of the window configuration*

| Category of Windows | Window Conf. | DF [%] | DA [%] | $DA_{con}$ [%] | $DA_{max}$ [%] | $UDI_{<100}$ [%] | $UDI_{100\text{-}2000}$ [%] | $UDI_{>2000}$ [%] | Ranking with rating points | Average rating points of category | Place |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Middle Windows** | MW1 | 0 | 0 | 1 | 7 | 2 | 2 | 7 | 19(6th) | 27.33 | 2nd |
| | MW2 | 3 | 1 | 3 | 7 | 3 | 3 | 7 | 27(5th) | | |
| | MW3 | 5 | 2 | 5 | 7 | 5 | 5 | 7 | 36(3rd) | | |
| **Corner Windows** | CW1 | 1 | 0 | 0 | 7 | 1 | 1 | 7 | 17(8th) | 31.4 | 1st |
| | CW2 | 4 | 3 | 4 | 7 | 4 | 4 | 7 | 33(4th) | | |
| | CW3 | 7 | 5 | 7 | 7 | 7 | 7 | 7 | 47(1st) | | |
| | CW4 | 6 | 4 | 6 | 7 | 6 | 6 | 7 | 42(2nd) | | |
| | CW5 | 2 | 0 | 2 | 7 | 0 | 0 | 7 | 11(7th) | | |

## 5. RESULTS

The results of dynamic daylighting performance metrics (DF, DA, $DA_{max}$, $DA_{con}$, UDI ranges) of the different window size and position at the two adjacent bed rooms of the dining space are summarized in Table 5. Full height corner window (CW-3) scored highest in DF, DA and $DA_{con}$ metrics. However, it scored highest in $UDI_{100\text{-}2000}$ and lowest in $UDI_{<100}$. $UDI_{100\text{-}2000}$ shows that windows with greater window head height and greater area effectively produce larger amount of daylight into the dining compared to other windows. According to DA, $DA_{con}$ and UDI metrics, CW1 scored considerably lower than the other window configurations.

It is easier to find the best possible window location and configuration using a rating system (Reinhart et al., 2006) between these eight configurations of two categories. Table 6 presents the rating system which was done considering the mean value of dynamic metrics of core sensor points for each window configuration. Rating points were considered as 7 point to 0 point, to suggest the configurations from 1st to 8th place.

Considering dynamic daylight metrics, corner location of windows was found superior than the middle locations when it was placed opposite to the bed room door. Corner windows achieved rating point range of 17- 47 and average of 31.4 points. On the other hand, middle windows were found as lower as it achieved the rating point range of 19-36 and average of 27.33 points. Full height corner window (CW3) was found as the most feasible window configuration among the studied options considering most of the dynamic daylight metrics. CW4 and MW3 were also found feasible as they acquire the 2nd and 3rd position (Table 6).

## 6. CONCLUSION

This simulation study presents the relationship between window configurations of the adjacent bed rooms of the dining space and daylight penetration into the deep central space of an apartment in tropical location. It was found that, the full height corner window opposite to the door of the adjacent bed rooms of the dining space is the most feasible configuration. Greater window head height and greater window area allow more daylight penetration. It is difficult to specify one category of windows as best among the studied options. Each category has its own advantages as well as shortcomings. Corner windows admit more daylight through the bed rooms into the dining than the middle windows. On the other hand, middle windows with greater area allows daylight into dining but can create glare in the bed room. It is expected that the findings of this paper will help the architects to design better apartment façade in terms of daylighting the dining.

## ACKNOWLEDGEMENTS

We would like to thank all of the people who helped make this study possible, in particular Dept. of Architecture, BUET, Dhaka, Bangladesh for technical support.

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# ASSESSING THE EFFECTS OF OPENING POSITIONS IN FACADE ON THERMAL COMFORT:

## A CASE STUDY OF THE UAP ARCHITECTURE BUILDING EXTENSION

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***Abstract:*** *Thermal Comfort of a built environment is a subjective issue that depends on a myriad of elements. It is dependent on climatic factors and designed factors which are closely interrelated. In a tropical climate like Bangladesh the thermal comfort level of a place is largely dependent on the solar radiation and wind flow, which have diametric opposite requirement in the design of the spatial configuration, opening and the envelope of the building . When a room is protected from direct solar radiation, the chance of unobstructed ventilation is reduced. On the other hand, opening for cross ventilation increases the solar penetration which increases the indoor temperature. The study investigates, which is more dominant among temperature and wind flow in influencing thermal comfort by assessing the opening configurations of a single building in a tropical climate.*

***Keywords****: Thermal Comfort, Solar Radiation, Wind Flow, Opening Configurations.*

## 1. INTRODUCTION

The quality of human life, to a very large extent depends on the quality of their indoor environments. Activities of human being can only be performed best when the environmental conditions are favourable within building enclosures. People show physiological reaction and psychological responses to the indoor climate that they are part of. Indoor temperature plays a significant role in the thermal comfort, which in turn impacts the human performance at both mental and physical levels [1]. Thermal comfort is achievable when temperature is under control. Szokolay (2004) underlines three sets of variables that affect thermal comfort. These are environmental variable, personal variable and contributing factors. Air temperature is the dominant environmental factor, as it determines convective heat dissipation. Air movement accelerates convection, but it also changes the skin and clothing surface heat transfer coefficient (reduces surface resistance), as well as increases evaporation from the skin, thus producing a physiological cooling effect [2]. For a building in tropical climate the widely practiced norm is to provide ample openings to permit the wind flow. Opening for cross ventilation increases the solar penetration which increases the indoor temperature On the other hand, when a room is protected from direct solar radiation, the chance of unobstructed ventilation is reduced.. This poses a dilemma for the designer to provide openings in a facade.

The study investigates which is more dominant of the two, temperature or wind flow in influencing thermal comfort. For this purpose an existing building needed to be studied in terms of its physical characters and environmental performance. By doing a questionnaire survey of the occupant the comfort conditions were identified and from that finding an assessment of the buildings fenestration has been done to determine its contributory role on the factors effecting thermal comfort.

For this purpose the UAP (University of Asia Pacific) Architecture Building was taken as case study. The steel extension of the renovated building which is 3 storied has rooms of similar configuration but with different opening conditions. This presents an opportunity to survey users of each room for comfort condition in a

given period. Based on the feedback and cross linking the measured climatic data through an anemometer, it can be determined how the opening configurations are effecting the indoor environment.

Due to the short duration of the study only winter months were available, so the comfort condition surveyed is not a clear representation of the comfort situation that are desirable in summer months in Bangladesh.

## 2. LITERATURE SURVEY

This literature review covers topics related to thermal comfort including bioclimatic charts, thermal comfort models, climate responsive building design, design-dependent elements and thermal performance studies in buildings.

**Thermal comfort:** Thermal comfort is a condition of mind that expresses satisfaction with the thermal environment. A definition most people can agree on, but also a definition that is not easily converted into physical parameter (Olesen, 2000).It is maintained when the heat generated by the human metabolism is allowed to dissipate at a rate that maintains thermal equilibrium in the body. Any heat gain or loss beyond this generates substantial discomfort. Human occupants are more sensitive to the variation of temperature rather than relative humidity (Hussein et al., 2002). Many research done by several researchers such as Agung Murti Nugroho (2011), Hussein and Rahman (2009) and Wafi and Ismail (2010) also indicate that thermal comfort does affect its occupancy. According to Fanger (1982), thermal comfort refers to metabolism levels that can be assessed by variables that include activities, clothing resistance, air temperature, relative humidity, air velocity, and mean radiant temperature. Two groups of personal physiological variables of metabolism are 1) result of activities and the thermal resistance of clothing; and 2) climate variables that include air temperature, air velocity, relative humidity and radiant temperature (Humphreys & Nicol, 2002).The second set of climatic variables are take into account for this research.

**Thermal Comfort Zone:** The range of acceptable comfort conditions is generally referred to as the comfort zone. Attempts have been made since the early 1900s to create a single figure comfort index. The latest comfort index now generally accepted, is the ET∗ (ETstar) or new effective temperature, and its standardized version, the CET

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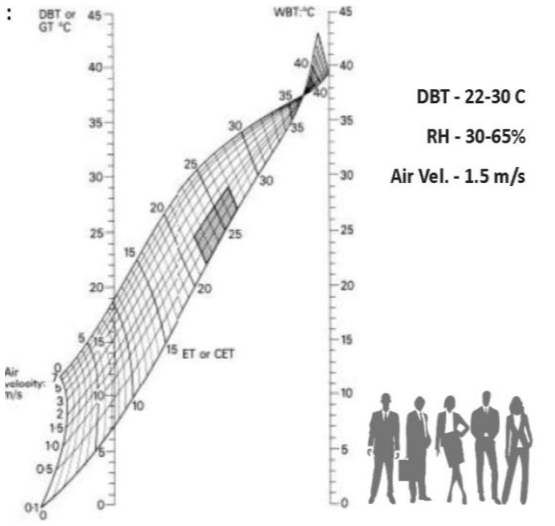


*Figire1: Corrected Effective Temperature Chart and comfort level in Bangladesh*

**Thermal Comfort Models (PMV):** People intuitively know what factors affect their comfort, but they have not been translated into metrics. The ASHRAE 55 comfort standard uses a formula to translate these six variables into a single output, called predictive mean vote (PMV). Through extensive testing, the PMV predicts what percentage of people will be comfortable at a given condition. PMV provides a clear, standardized specification for a building. Only using temperature in the specification is so widespread because it is a single, easily measured variable that can be monitored to verify the building meets its specification. It can encompass all possible combinations of the six variables and translate these into a single, easily modeled, specifiable value.

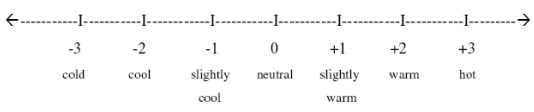


*Figure2: PMV scale*

**Comfort Zone in Tropical Climates**

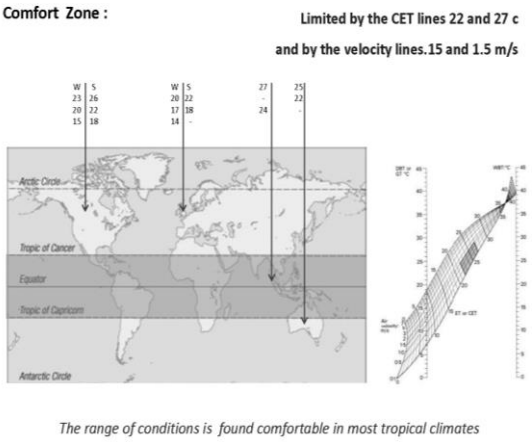


*Figure 3: Range of Comfort Level in Tropical Region*

**Impact of Envelope Design on Thermal Performance:** Building envelope is one of the most important components with respect to total heat gain of whole building. Despite of the availability of many experimental and numerical research studies conducted in some tropical warm and humid climates to investigate the impact of building envelope in internal thermal performance consumption, there is only a limited amount of research literature on building envelope fenestrations through the climate *responsive design requirements* to achieve energy-efficient building in hot and humid climate. In this paper, the relevant literature in the above aspects will be reviewed. Windows, doors, and skylights have a significant impact on the thermal performance of the building envelope. Windows can also have a strong influence on the use, productivity, and comfort of the people who occupy the building. Study reported by Jinghua Yu (2006) showed that heat gain through the exterior window accounts for 25-28% of the total heat gain, They allow natural light, offer a visual communication with outdoors, reduce a structural load and enhance aesthetic appearance of buildings (Datta, 2001; Al-Saadi, 2006). A proper selection for the optimal area of the glass and applying natural ventilation system can reduce the negative effect of solar radiation in increasing the indoor air temperature (Al-Tamimi, N. and Syed Fazil, 2010).

## 3. INFORMATION AND COLLECTED DATA

The study was carried out on the Department of Architecture building in the UAP campus in Dhanmondi road no.4/A. Materials were the case study building, temperature and humidity data collected from concerned rooms, and Anemometer used for this data collection. Measurements of the windows and photos from exterior were other related materials in the study. In addition to all, monthly temperature data for Dhaka in September 2015 was obtained from Meteorological office.

### *3.1. Climatic Data Source:*

Meteorological Dept.

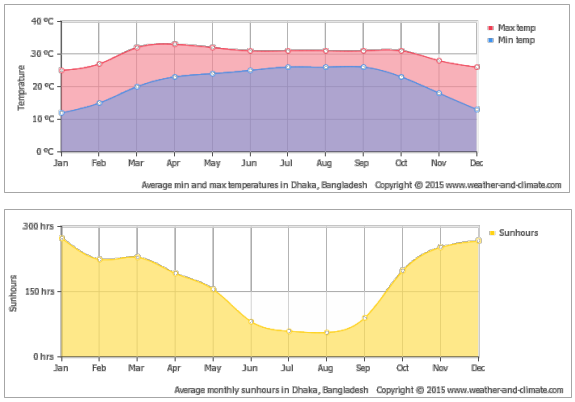


*Figure 4: i) Avg Max & Min Temp Chart & ii) Sunhours in Dhaka*

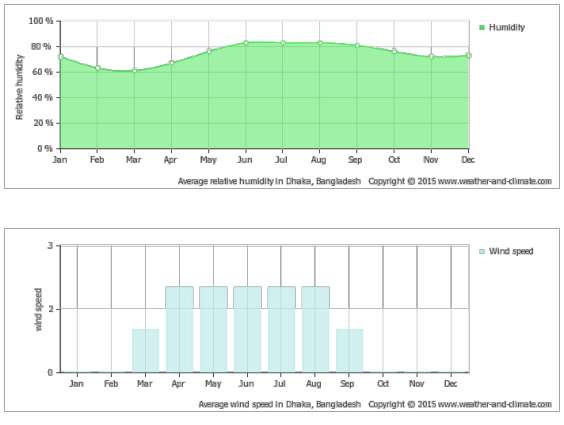


*Figure 5: Avg Relative Humidity of Dhaka ii) Avg Wind Speed of Dhaka*

### *3.2. Anemometer and collected data:*

| | Location | Outdoor temp | Indoor temp | R/H | Wind speed |
|---|---|---|---|---|---|
| A | GF | 28.5 | 25 | 75 | .6 |
| B | 1st | | 27 | | 1.2 |
| C | 2nd | | 28 | | 1 |

*Figure 6: Anemometer and data collected*

| | Location | Outdoor temp | Indoor temp | R/H | Wind speed | DBT | WBT | CET | Comfort Range |
|---|---|---|---|---|---|---|---|---|---|
| A | GF | 28.5 | 25 | 75 | .6 | 30 | 26 | 27.5 | uncomfortable |
| B | 1st | | 27 | | 1.2 | 30 | 26 | 26 | Comfortable |
| C | 2nd | | 28 | | 1 | 30 | 27 | 27 | Just in the limit |

*Figure 7: CET and comfort scale*

### *3.3. Data Evaluation:*

The collected data shows that the outdoor air temperature is 28.5° Celsius and its not changing in different floors. The indoor temperature is changing and in ground,1$^{st}$,and 2$^{nd}$ floor, the temperature is 25°, 27°, 28° Celsius respectively . The RH is constant ( RH value reading as found in Anemometer ) but the wind velocity in the interior is different in each room. The change in wind speed could be caused due to the positional change of window and the depth of the room.

From another set of data, the WBT and the DBT are measured and from that the CET (Corrected Effective Temperature) can be derived. and crosschecking using the CET chart the comfort level of the prevailing wind flow is predicted.

The user feedback was gathered through simple questionnaire survey, The survey will determine the PMV equivalent. The predicted comfort feedback are then compared with the feedback from the user. If the both feed backs are found to be similar then it could be concluded that the corresponding window positions are adequate to ensure Thermal comfort or not.

*3.3.1. Location and Key Plan*

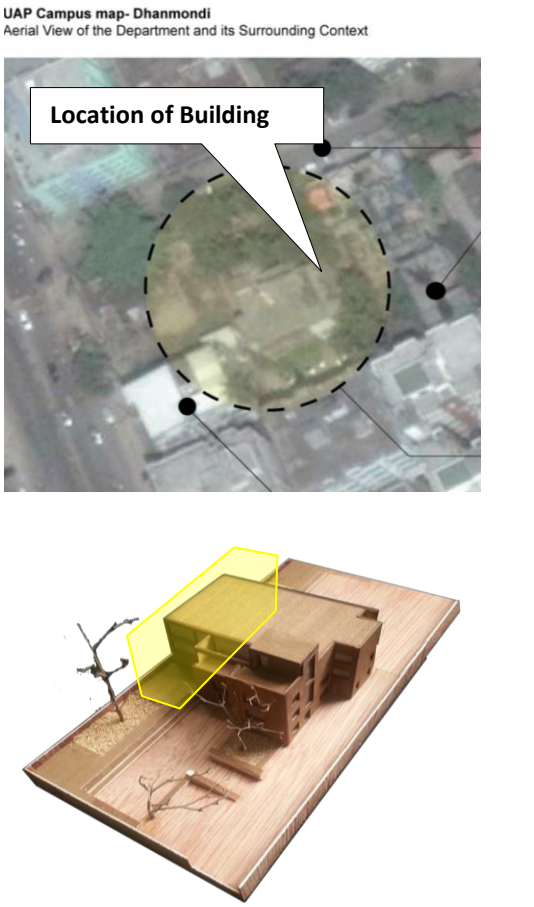


*Figure 8: Case Study Building Location extension part of the building*

*3.3.2. Building Floor Plans*

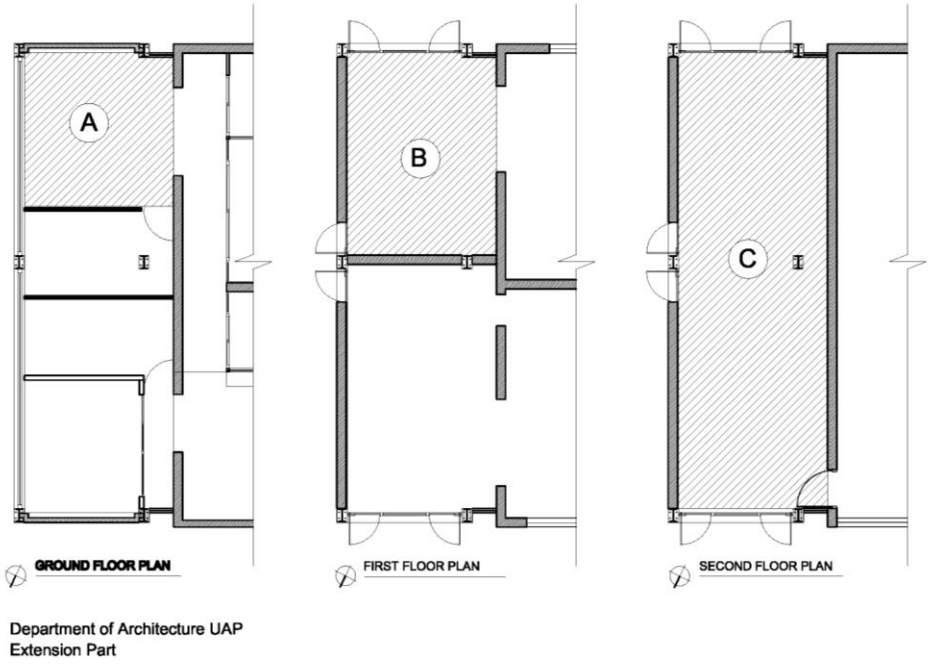


*Figure 9: Building Floor Plans*

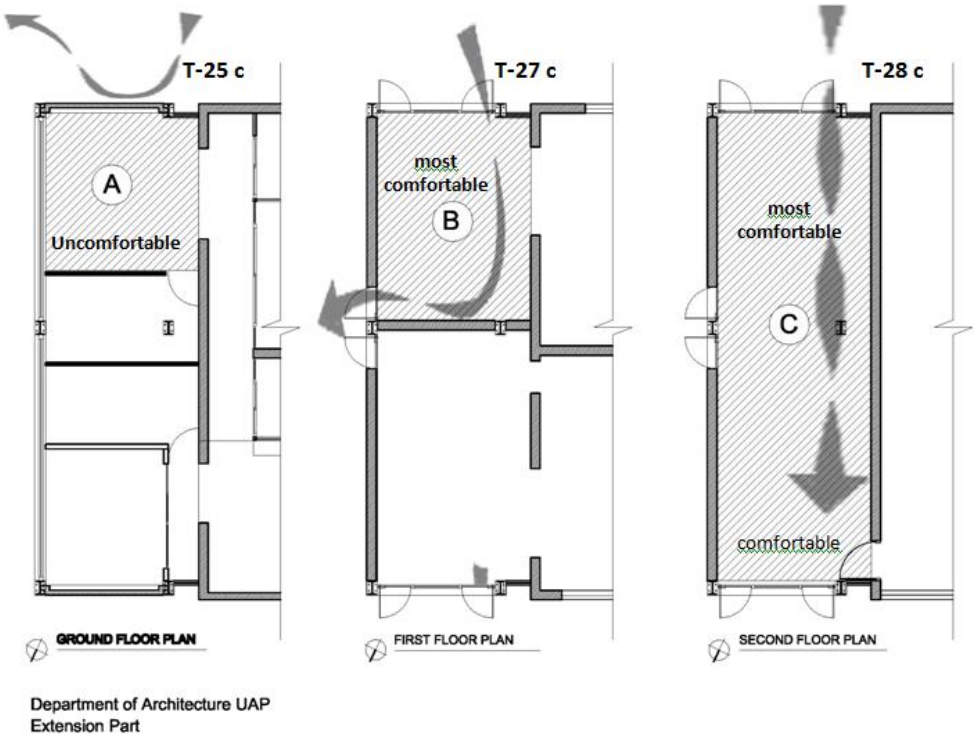


*Figure 10: Effect of opening position on wind flow*

## 4. ANALYSIS AND RESULT

The openings in the building allow different type of air flow at different floors. In the ground floor there are no openings on the south side, so there is no ventilation on the Room A. but the indoor air temperature is low due to less solar penetration. In the second floor the Room-B is shorter in depth than Room -C , and it has opening on the side, This allows for the air to circulate at a relatively higher velocity. Where as in Room -C, the room has opening on both sides but the air velocity is reduced during direct cross ventilation, Thus the area near the south window is more comfortable than its near the north.

From the questionnaire survey of the 3 rooms it was found that the participants on the ground floor felt uncomfortable. Occupant of the B and C rooms when near the south window felt comfortable. Only the occupants at the northern side showed dissatisfaction.

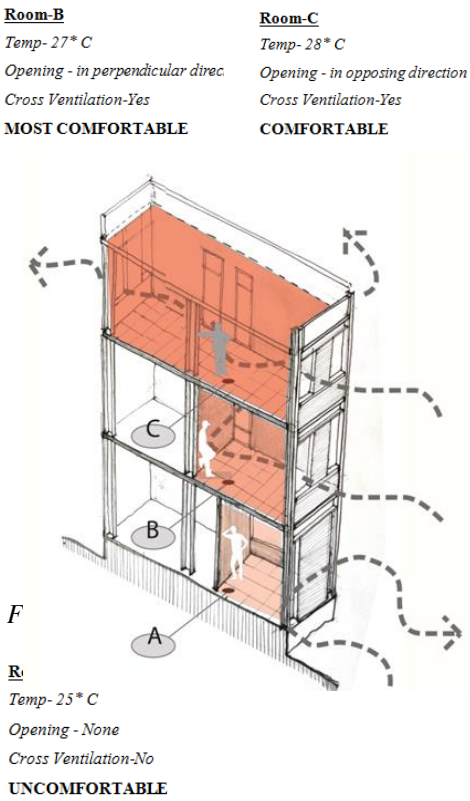


*Figure 11: Interior Axonometric*

## 5. CONCLUSION

This study reveals that the effect of opening position on the thermal comfort of a building. It can be seen that because of air circulation in an area it gives a sense of comfort where the RH and the temperature is higher than accepted comfort temperature. And in tropical climate the sensation of wind flowing through the skin gives the most comfortable feeling. For that reason, rooms that has greater indoor air change rate and velocity feels most comfortable than a room with less cross ventilation but with lower temperature. In this regard it can be concluded that the position of opening which effects ventilation plays an important role than measures taken to lower heat gain for the thermal comfort of any building.

Further study in this regard might be carried out to find out the suitable opening size in the building as well as the relative positioning of the opening to ensure maximum natural ventilation and as a result maximum thermal comfort.

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# AN INVESTIGATION OF THERMAL ENVIRONMENT IN RESIDENTIAL BUILDING DUE TO ORIENTATION CHANGE IN DHAKA

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***Abstract*****:** *Dhaka, decades of population influx has led to demands for rapid urbanization. Urban densification modifies its microclimate, which influences thermal performance of internal spaces. Comfortable internal environment is fundamental requirement for efficient living. Thermal comfort is the basic expectation and achieving thermal comfort in domestic space is extremely important issue. Passive design strategies are more effective solution in the context of developing countries. Thermal performance of an internal space is largely depends on building orientation. This paper concerns about the existing thermal performance in domestic spaces. The aim of this paper is to evaluate thermal performance of four identical living spaces (bedrooms) in a residential apartment building due to orientation difference in the Dhaka city. The study based on field investigation, which has been carried out in cool dry month (January) of the year. Differences in indoor air temperature of the space is the measuring parameter of thermal performance of the space. The findings reveal notable differences in indoor air temperature due to orientation change. Moreover, neighboring structures showed significant impact on ambient microclimate which modulate thermal performance of internal space.*

***Keywords:*** *Air temperature, Microclimate, Neighboring structure, Orientation, Thermal Performance.*

## 1. INTRODUCTION

Rapid population growth in urban area of developing countries with tropical climate have dragged enough attention due to its extensive effects on microclimate. As a consequences, the ambient microclimate of a build form is being a major concerning phenomenon (Erik Johansson 2006). The ambient microclimate of a residential area is a decisive matter of thermal performance of an interior space and energy consumption. Because of wide-ranging use pattern of domestic spaces are very delicate in character. Thus, thermal performance of a domestic space is very important for healthy and efficient living (F.H. Mallik 1995). Cities like Dhaka often fail to fulfil its energy supply and mechanical means of cooling or heating are generally out of reach for most of its population. Therefore, passive climatic means would be more efficient solution for achieving thermal comfort in urban residential area (Roy, 2010). It is evident from many studies that among other passive control strategies, orientation is one of the major design strategy which affects thermal performance of the interior space (K.S.Ahmed 1995). Therefore, the aim of this paper is to investigate the thermal performance of interior space of an apartment building due to orientation change in dense urban context.

## 2. PROBLEM STATEMENT

The world temperature has been risen and the effcts are profoundly visible in countries in the tropics. Bangladesh is one of the climatically vunarable country (Huq, S., 2001). Unlike other developing cities, passive climatic strategies are more advantegeous than mechanical solutions.In domestic building, thermally comfortable environment is the basic human requirement. Orientation of the building is a primery passive means of achieving indoor thermal comfort . It can modify any space unfit to use and consume maximum energy for cooling or heating. To take advantage of the ambient micro climate,

orientation of the structure is a highly influencial factor. Moreover, in the dense urban cities the gap between neibouring structures are often insufficient. This situationresults in affecting ambient microclimate like casting deep shadow, creating air tunnel etc.

## 3. OBJECTIVE

-to evaluate thermal performance of living space (bed rooms) of a residential apartment building due to different orientation and

-to understand the impact of neighboring structures on ambient microclimate.

## 4. LITERATURE REVIEW

Dhaka is the capital of Bangladesh, facing huge population influx in urban areas. As a result residential development is taking place at high rate to cater the need of increasing population. To do so new lands at the city fringe areas are being developed both in public and private sectors, large plots are being sub-divided into smaller plots and one-unit houses are being replaced by multi-unit and multi-storied residential buildings (Roy, G.S., 2010).This dense urban developments have produced significant changes to the ambient microclimate (Landsberg, 1981, Oke, 1982).

Thermal Performance of interior space is an important issue in the context of sustainability in urban areas (Ahmed, K.S., 1995). Residential space are always been crucial to deal due to multiple uses for 24 hours. One of the important aspects of living in a house is to feel a desired level of thermal comfort. It has no absolute standard as humans are able to live and survive in a range of climatic conditions from very hot areas to cold ones (Darby and White, 2005). It is defined by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard as "that condition of mind which expresses satisfaction with the thermal environment". The environmental parameters which influence thermal comfort are air temperature, mean radiant temperature, humidity, relative air velocity and personal parameters: clothing and activity (Fanger1972).Studies found that air temperature, air humidity and wind velocity varies depending on the density of the surroundings built forms,(Ahmed, 1995). Wind velocity does not affect the indoor air temperature because of high dense situation.

The first European passive house was built in Darmstadt, Germany in 1991.According to German Passive House Institute "A passive house is a building, for which thermal comfort (ISO 7730) can be achieved solely by post-heating or post-cooling of fresh air mass, which is required to fulfil sufficient indoor air quality conditions (DIN 1946) – without a need for recirculated air."

It is evident from many studies that among other passive strategies, orientation is one of the important strategy which affects thermal performance of the interior space (K.S.Ahmed 1995). Orientation of a building decides which surface of the structure is gaining most solar radiation and heat through the windows and wall, (Szakolay, 2008) and also affects cross ventilation through the building. When orientation is properly designed the need for extra heating and cooling is dramatically decreased (Hansen and patnaikuni, 2014). A study in hot and dry climate elaborates that the major decision about orientation, resulting in reduction of solar heat gain on building surface in summer. (Ahuja and Rao 2005). In warm humid climate, north facing spaces shows best performance among all, while West facing spaces found lowest in performance (Ahmed 1994).

### *4.1. The Climate and Location*

Bangladesh is recognized as one of the most climatically vulnerable countries in the world (UNDP 2007).The climate of Bangladesh, based on the classification by Atkinson (Koenigsberger, 1973) may be placed in a zone of 'composite or monsoon climate'. According to Hossain and Nooruddin, meteorologically the climate of Bangladesh is categorized into four distinct seasons Winter (cool dry), Pre-Monsoon (hot dry), Monsoon (hot and wet), Post-Monsoon (hot and wet), where Winter months (December to February) temperature 21-26°C, Pre-Monsoon (March to May) temperature max 34°C, Monsoon (June to September) avg. 31°C, Post-

Monsoon (October to November) temperature bellow 30°C (Ahmed, 1996). Average Relative Humidity is 60-80%. Radiation on a horizontal surface 5.00 kWh/ m2 and Air Flow 4.1 m/s (Ahmed, 1996). Shown in Table 1. The cool dry season is characterized as short and mostly dry, having mean monthly maximum temperature of approximately 26°c and mean monthly minimum temperatures varying between 11°-13°C and relative humidity is approximately 70% to 80%, skies remain blue and clear (Ahmed 1987). Furthermore, Dhaka lies just north of the Tropic of Cancer, displaying characteristics of "Composite" climate, with approximately one-third of the year being hot-dry (mean max 33.6 ºC), two thirds warm-humid (mean max 31.3ºC), and there is a short cool-dry season (UNDP 2007).

*Table 1: Classification of the seasons and weather condition of Bangladesh,*

| Bangla Calendar Month | Traditional Seasons | Meteorological Seasons | Gregorian Calendar Month |
|---|---|---|---|
| Chaitra | Bashanta | Pre-monsoon (hot-dry) | March |
| Baishakh | Grisha | Pre-monsoon (hot-dry) | April |
| Jaishtha | Grisha | Pre-monsoon (hot-dry) | May |
| Ashaar | Barsha | Monsoon (hot-wet) | June |
| Srabon | Barsha | Monsoon (hot-wet) | July |
| Bhadra | Sharat | Monsoon (hot-wet) | August |
| Ashin | Sharat | Monsoon (hot-wet) | September |
| Kartik | Hemanta | Post-monsoon (hot-wet) | October |
| Arahayon | Hemanta | Post-monsoon (hot-wet) | November |
| Poush | Sheet | Winter (cool-dry) | December |
| Magh | Sheet | Winter (cool-dry) | January |
| Falgun | Bashanta | Winter (cool-dry) | February |

*Source: (Ahmed 1995)*

## 5. METHODOLOGY

Literatures, relevant to this study have been studied to derive the investigation base. Within the limited period of time for the study, single residential apartment building with easy accessibility to each apartment was selected for the investigation. Moreover, the centrally placed core with four apartments outward makes the opportunity to investigate the effect of orientation directly on the living space (Image-2). The building consists of a mirror symmetrical arrangement of four apartments. The position of the apartments can be denoted as South East A, South West B, North West C, North East D (Figure-2). Master bedrooms of each apartment had been chosen to conduct the investigation as it is the most comfort zone of any domestic functions. At each spot, measurements of air temperature were recorded at same positions (middle of the room)from 10am to 2 pm in two hours intervals, keeping 1m distance from the floor. Indoor/ outdoor Thermometer with Hygrometer, accuracy of (+1) and Mini Thermo Anemometer (EXTECH,Model45118) were used to conduct the survey. The survey day was characterized by clear skies, dry weather, low solar altitude angle, low solar intensity and lesser duration of sun-shine in January 2017, the cool-dry period of the year. The measurements of indoor air temperature was examine in usual pattern of closed windows and doors of the cool season. The study was primarily based on, field data measurement, observations, comparison and analysis. However, the noticing fact was that the neighboring buildings on the west of the surveyed building were over 20 storied, which creates an impact on overall microclimate.

### *5.1. Description of the Example Building*

The example building is a rectangular shape apartment building, consisting 50 flats with centrally located core. It is a 14 storied building, elongated with the North -South axis and the approach road on the South. And there are two empty plots on the North and the East. The combined effect of road and open spaces on the South, East and North respectively, creates opportunities for prevailing wind in the summer and winter. Though, the surveyed building is located in dense urban context of Dhaka, the distance between the building and the neighboring buildings are minimum 3m (Figure-1). There are two neighboring high-rise building of 20 and 22 storied respectively on the West. Which creates profound shadow effect on the


*Image 1: Location of the building in satellite image*

*Image 2: Image of the building*


*Figure1: Site Surrounding of the Building*

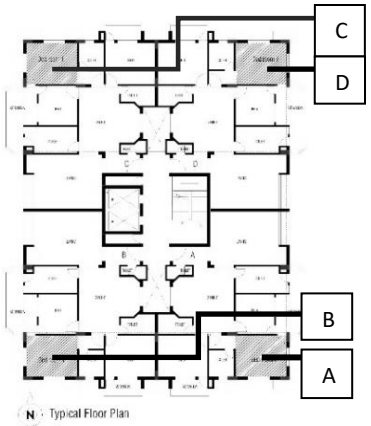



*Figure2: Location of the Bedrooms*

ambient microclimate. Microclimate can be manipulated by presence of neighboring structures and the qualities of the surfaces can be predicted from shading pattern (Ahmed 2002).The representative building is a frame construction, infill with combination of 250 mm and 125 mm hollow brick, plastered on both faces and white-washed. All openings, doors and windows have security grilles and they are provided with sunshades, which cut off some of the solar radiation and also protect the openings from rain(Image-2). Each flat, of the example building is exactly identical in terms of functions, area, glazing windows and materials of roof and walls, only orientation of selected bedrooms are different. The surveyed master bedrooms have attached toilet and a door opened to the common verandah. The position of the flats can be marked as South East A, South West B, North West C, North East D (Figure-2).

## 6. FIELD INVESTIGATION

At each spot both indoor temperature and surface temperature were recorded from 1m above from floor. Table 1 shows the temperature readings of both indoor and surface of flat A, B, C, and D. It was observed that the relative humidity of air was ranging from 55% to 60% during the investigation period and the indoor wind speed was unchanged and negligible.

*Table 2: Temperature reading*

| Time | A | | B | | C | | D | |
|---|---|---|---|---|---|---|---|---|
| | Indoor temperature | Surface temperature | Indoor temperature | Surface temperature | Indoor temperature | Surface temperature | Indoor temperature | Surface temperature |
| 10:00 AM | 25.6 | 25.1 | 25.1 | 25 | 24.7 | 24 | 24.6 | 25 |
| 12:00 PM | 25.4 | 27.1 | 26 | 27 | 24.9 | 24.7 | 24.9 | 25.5 |
| 2:00 PM | 25.3 | 26.5 | 25.6 | 26.8 | 24.6 | 24.9 | 25 | 25.1 |
| Average | 25.4 | 26.2 | 25.5 | 26.3 | 24.6 | 24.5 | 24.8 | 25.2 |

*Source: Field Survey Data by Author*

## 7. DATA ANALYSIS

Table 1, shows data of chaging temperature pattern of indoor and surface temperature. The result shows that at the flat A, indoor

temperature was little higher than surface temperature at 10AM. The surface temperature was higher than the indoor temperature at 12AM and at 2PM surface temperature was dropping with noticeable difference, while indoor temperature was not showing much difference. For the flat B, the indoor and surface temperature both were changing in a same pattern but at 10 am the difference between indoor and surface was not noticeable. In the case of the flat C, it shows different pattern among others. At 10AM surface temperature was lower than indoor temperature, then the surface temperature went higher with the time but the indoor temperature remained almost same with little variations. The reason of this exception at flat C could be the shadow effect ofthe immediate 20 storied building on the ambient microclimate. At flat D, the changing pattern of temperature in indoor were consistent with surface temperature changing pattern. At the 12PM the difference

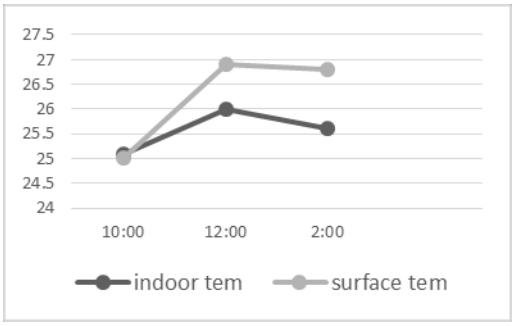



*Chart 1: Changing pattern of indoor and surface temperature of Flat A*

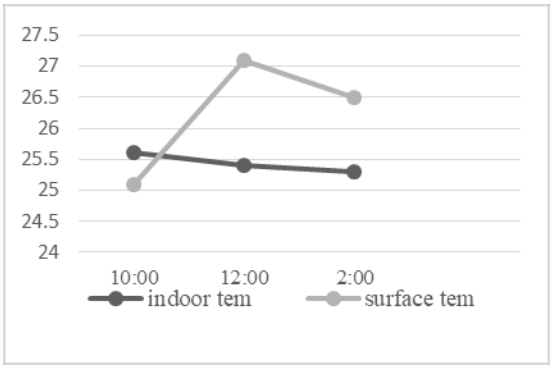



*Chart 2: Changing pattern of indoor and surface temperature of Flat B*

between indoor and surface temperature was

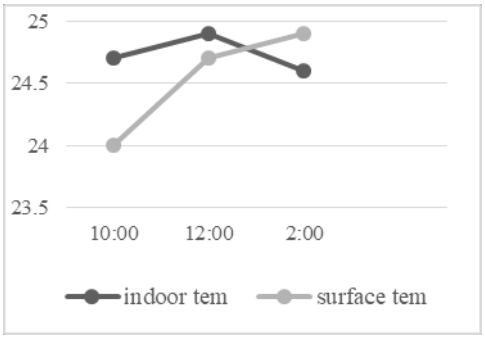



*Chart 3: Changing pattern of indoor and surface temperature of Flat C*

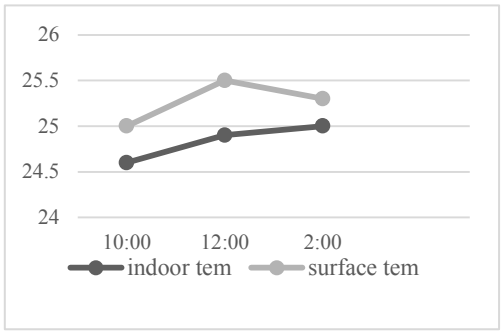


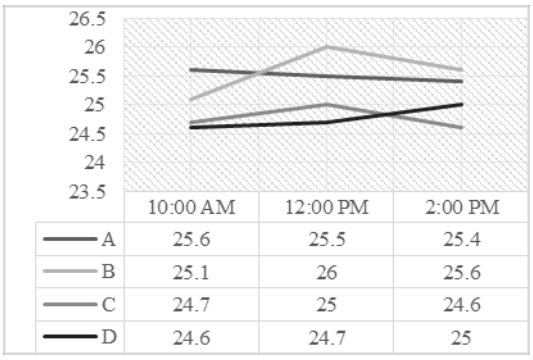

*Chart 4: Changing pattern of indoor and surface temperature of Flat D*

noticeable than at other measurements. Chart 1, Chart 2, Chart 3, Chart 4 are showing changing pattern of indoor and surface temperature of flat A, B, C, D.

### *7.1. Comparative Analysis*

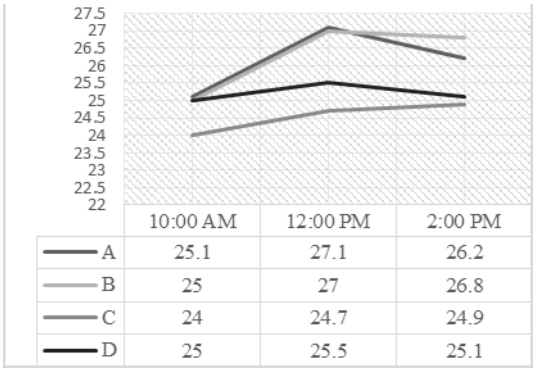
The thermal performance of each bedroom due to orientation change were judged by the changing pattern of indoor and surface temperature. Chart (1-4), showing the result of the temperature differences among all bedrooms. The comparison analysis shows that the bedroom at flat B, located in the south west position displayed highest temperature change in indoor and surface and the difference of indoor and surface temperature was of 1.2°Cat 2:00PM. Bedroom at flat A, locate at south east position displayed second highest temperature changing pattern but the indoor temperature was higher at 10:00AM where surface temperature was higher at 12:00PM and the temperature differences between indoor and surface was of 1.7 °C at 12:00PM. Bedroom at flat C in the northwest position displayed lowest temperature changing

pattern the indoor temperature was higher at 12:00PM and surface temperature was higher at 2:00PM with highest temperature difference between indoor and surface was of 0.7 °C at 10:00 AM, as it was always remain in the shadow zone of neighboring 20 storied buildings. Bedroom of flat D displayed



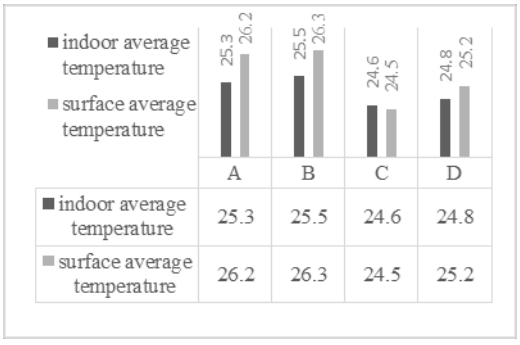

| | 10:00 AM | 12:00 PM | 2:00 PM |
|---|---|---|---|
| A | 25.6 | 25.5 | 25.4 |
| B | 25.1 | 26 | 25.6 |
| C | 24.7 | 25 | 24.6 |
| D | 24.6 | 24.7 | 25 |

*Chart 5: Temperature changing pattern ( Indoor)*




| | 10:00 AM | 12:00 PM | 2:00 PM |
|---|---|---|---|
| A | 25.1 | 27.1 | 26.2 |
| B | 25 | 27 | 26.8 |
| C | 24 | 24.7 | 24.9 |
| D | 25 | 25.5 | 25.1 |

*Chart 6: Temperature changing pattern (surface)*




| | A | B | C | D |
|---|---|---|---|---|
| indoor average temperature | 25.3 | 25.5 | 24.6 | 24.8 |
| surface average temperature | 26.2 | 26.3 | 24.5 | 25.2 |

*Chart 7: Average temperature difference*

consistent in temperature changing pattern of indoor and surface with highest difference of 0.6 °C at 12:00AM.The location of the bedroom of flat D was in northeast corner of the building (Chart 5, Chart 6, and Chart 7).

## 8. RESULT AND DISCUSSION

From the above analysis the result reveals that the master bedroom of flat B displayed highest temperature changing pattern of indoor and surface. That means solar heat gain was highest on the south west bedroom. The bedroom at flat A showed second highest temperature changing pattern where the location of the bedrooms was on the southeast position. Northeast bedroom of flat D ranked in third position with noticeable lower changing pattern of indoor and surface temperature. Bedroom on Northwest position, flat C showed lowest changing pattern of temperature, thus this bedroom got lowest solar heat gain and the shadow effect of neighboring high-rise was prominent (Chart 8 and Chart 9). Undoubtedly the flats positioning in the south side were displayed higher solar heat gain because of direct sunlight beam and there were no shadow effect of neighboring structures.

Sun path, angle and the shadow effect of neighboring high-rises, the bedrooms in the north side flats displayed less solar heat gain and

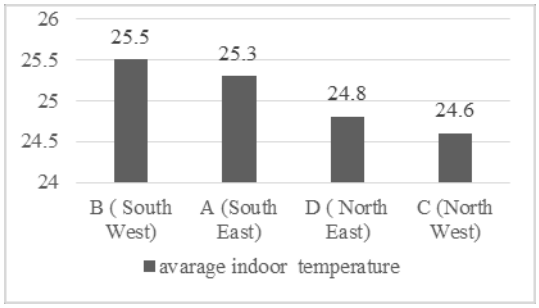



*Chart 8: Ranking of indoor temperature changing pattern*

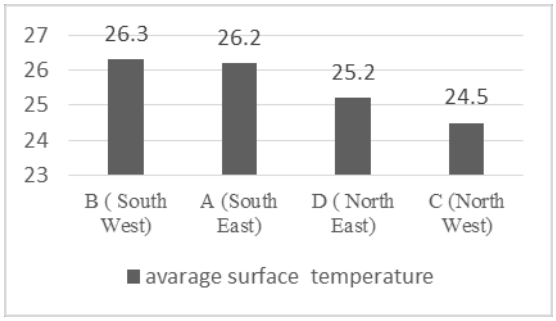



*Chart 9: Ranking of surface temperature changing pattern*

lower temperature changing pattern both in indoor and surface.

This paper illustrated that the solar heat gain is significant in the south east and south west and less in the northeast and northwest oriented bedrooms. Because of existing location and surroundings of the surveyed residential apartment building orientation is the significant variables to regulate thermal performance of the indoor. To achieve thermal comfort, the spatial zoning of the domestic functions largely depends on orientation. Moreover, the height, width and location of neighboring structures also have influencing effect on the orientation thus, modifying ambient microclimate in dense situation.

## 9. SCOPE AND LIMITATIONS

- Similar kind of study can be done in different parts of the city with various type of situation and functional buildings.
- The field investigation was done in the winter season (January) only. There is a scope of conduct similar studies in different season of the year. The results may varies in the other seasons.
- This study was conducted as a partial requirement of M.Arch course, ARCH 6101 Thermal Environment and Built Form. As the time was limited for the investigation thus, the scale and the number of the case of the study were limited.

## 10. CONCLUSION

The study aimed to investigate the thermal performance of the residential building in the context of Dhaka regarding orientation change and the result established that there is a significant changes in thermal behavior pattern on south and north oriented interior space. While designing a residential building, proper orientation can be a game changing factor to take advantage of ambient microclimate.

This study shows that for design purpose, if the building has to be thermally comfortable, some influential factors are describe below;

- Consider the path, angle of the sun for proper orientation.
- In the case of residential building the layout of functional space require proper orientation, thus, living spaces gain less heat.
- As the south oriented bedrooms gain more heat than north oriented bedroom, therefore placing all the bedrooms on the north do not solve the problem because we also require south air for thermally comfortable indoor.
- For the orientation of windows, the south bedrooms require windows with deep shading on the other hand, bedrooms on the north do not require much shading as south because of the sun orientation.
- Site surroundings also have influential effects on building orientation. Therefore it is also important to take design decision about orientation which is advantageous for that particular situation.

Country like Bangladesh often scares in energy supply thus, it is important to concentrate on the passive solution for the buildings during the design phase. Proper orientation of a building would be greater in achieving thermal comfort and sustainable in energy consumption. However, it is often difficult to deal in this dense urban context where benefits of orientation are minimal.

## ACKNOWLEDGEMENTS

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# INFLUENCE OF WINDOW CONFIGURATION ON INDOOR COMFORT AND HEAT STRESS

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***Abstract:*** *This paper presents a parametric study of thermal performance and heat stress in indoor environment depending on window size, number and their orientation in tropical climate. First, the window orientation on different façade of wall was simulated and the number of windows performance was evaluated by indoor air temperature (AT), relative humidity (RH), air velocity (AV), indoor wall surface temperature and heat loss rate. During the next phase of the study, heat stress such as wet bulb globe temperature (WBGT), predicted mean vote (PMV) and Predicted Percentage of Dissatisfied (PPD) were predicted based on established formulas. Using dynamic simulation, modelled by Energy plus, Google sketch up and Open studio plugging, the assessment was carried out by predicting indoor condition. Typical metrological year (TMY) data of Dhaka, Bangladesh was used for the simulation, based on energy plus weather (EPW) file. Fifteen types of window orientation was simulated (one, two, three and four windows, with different orientations on a cubicle model room). Result shows that only one window at north side shows higher indoor temperature, and four windows at four walls show better performance according to thermal comfort index. Four-window model reduce indoor temperature around 2-3 °C than just a single window at one surface. For WBGT it's about 2-2.5 °C temperature reduction and less heat stress in four window models. Assessment of PMV is higher in single window rooms and it's about +1. Four-window room's PPD is about 40% less than the single window rooms and its quite significant for the indoor inhabitant's thermal comfort.*

***Keywords****: Heat stress, Thermal comfort, Tropical climate, Window configuration.*

## 1. INTRODUCTION

Windows are one of the key elements that influence the indoor comfort and enhance building performance (Amaral, 2016). It is an important architectural design parameter which configuration can modify indoor heat gain and heat loss as well as ventilation pattern (Olgyay, 2015, Chand, et al, 1998, Raja, et al, 2001). Especially, in tropical countries, such as Bangladesh, which climate is characterized by elevated temperature and high relative humidity, needs to restore indoor thermal comfort (Prianto, et al, 2003). Thermal comfort is the state of mind, which express satisfaction in thermal environment (Fanger, 1970). This paper describes an investigation on indoor air temperature (AT), relative humidity (RH), wall surface temperature and heat loss through window by computer simulation. A cubicle room of four perpendicular walls has considered for the simulation, with different window orientation. For calculating indoor environment, outdoor climatic condition of Dhaka, provided by energy plus weather (EPW) was used. Prediction of heat stress was also conducted by several heat stress index, wet bulb globe temperature (WBGT), predicted mean vote (PMV) and Predicted Percentage of Dissatisfied (PPD). Summarized objectives of the study are:

- Find out the thermal condition in a standard size model room with different window orientation (simulation model developed by Google Sketch up, Energy Plus and Open Studio) and compare with recommendation of ASHRAE standards (ASHRAE, 2013).
- Exploring most widely used heat index, wet bulb globe temperature (WBGT) (ISO, 1989; Budd, 2008) to find out the discomfort range in different models.

- Analysis predicted mean vote (PMV) and Percentage of dissatisfied (PPD) as per ISO 7730, to evaluate occupant's satisfaction level (Fanger, 1970; Fanger, 1984; ISO, 2005)

## 2. METHODOLOGY

The experiment was carried out by illustrating a series of computer generated energy simulation model to figure out indoor thermal condition. Thermal comfort index WBGT, PHS and PMV was predicted from the simulated data to find heat stress on occupants and thermal comfort.

### *2.1. Building simulation models*

All tested three dimensional (3D) energy simulation models were developed during the research work by using Google sketch up, Energy plus and Open studio to make a comparison depending on window orientation. For comparison, a room of 3.05m x 3.05m x 3.05m was considered (typical residential room size). All window size was 1.21m x 1.21m, elevated 0.9m from the floor, placed at center of the facade. Construction type and material considered based on local construction system. 127mm thick brick wall with plastering and reinforced cement concrete (RCC) for floor and roof was considered. Table 1 shows the detail construction information of wall, floor and roof including window for simulation. Here windows were considered as open swing window for cross ventilation. After Figuring out architectural dimensions and features of the study zone, models were developed with basic thermal properties of common used building materials in Bangladesh (Table 2) (Chowdhury, et al, 2017). Here buildings were at ground floor where floor was touched with the ground. According to simulation all tested models can be categorized with the following criteria:

1. Models 1-4, have only 1 window at 4 walls with different orientation started with north side, south side, east side and ended with west side (Figure 1-2).
2. Models 5-10, have combination of 2 windows at 4 walls with different orientation.
3. Models 11-14, have only 3 windows at 4 walls with different orientation.
4. Models 15 have 4 windows at 4 walls with different orientation.

Figure 1 shows the plan of all tested models and Figure 2 shows 3d simulation model images.

In this study, the "conduction and convection heat transfer function" heat balance algorithm has been applied for simulation. For zone ventilation, general cross ventilation (.25-4: air change/hour, ASHRAE, 2013) was considered for the analysis.

### *2.2. Climate consideration and comfort measurement*

Bangladesh is a hot humid tropical country, here mostly three seasons are prominent, hot-humid summer, rainy monsoon and cool winter (Ahmed, 2003). In summer time it faces adverse climatic condition for elevated temperature and high humidity. For evaluating heat stress comparison, simulation has been conducted in the hot-humid seasons (April-July) in the capital city of Bangladesh, Dhaka, which latitude is 23.8103° N, longitude is 90.4125° E, elevation 4m and time zone +6 GMT. Generally, during summer time temperature remains here around 25-34° C and RH fluctuates between 70-90%. Specially in daytime scenario of indoor environment is more critical and creates health hazards like dehydration, heavy sweating, heat cramps, heat exhaustion, heat stroke etc. In this study for comfort calculation, metabolic rate was assumed light activity while seated or standing, 1.1 met in indoor condition. The clothing insulation was taken .55 clo, which is standard for tropical condition (Prianto, 2003).

*Table 1: Construction properties of building for simulation.*

| | Wall | Floor | Roof | Window |
|---|---|---|---|---|
| **Construction** | 127mm brick wall with 12.5mm both side plaster | 152mm brick soling + 127mm RCC concrete with 25.4 mm clay tiles | 152mm RCC with 12.5 mm both side plaster | Swing window, 3mm clear glass |

*Table 2:* Thermal properties of building material *for simulation.*

| | Thickness (mm) | Thermal Conductivity (W/m.K) | Density (kg/m$^3$) | Specific Heat (J/kg. K) |
|---|---|---|---|---|
| **RCC** | 152 | 1.34 | 2487 | 750 |
| **Brick** | 127 | 0.55 | 1200 | 1150 |
| **Plaster** | 12.5 | 0.43 | 2374 | 700 |
| **Tiles** | 25.4 | 1.12 | 1763 | 1200 |
| **Glass** | 3 | 0.9 | 2500 | 837 |

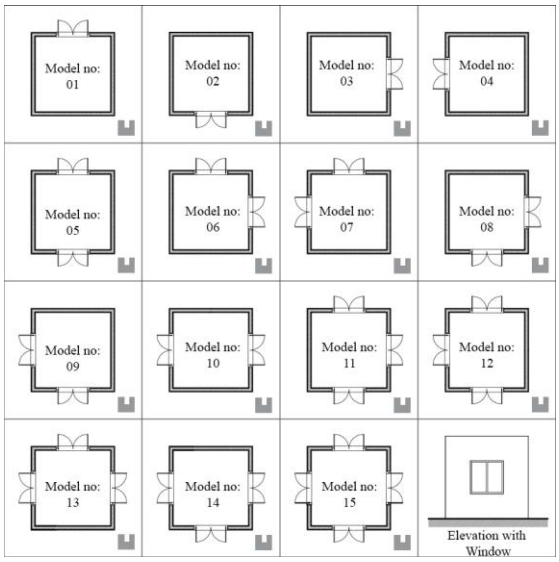


*Figure 1: Plan of simulation models with windows*

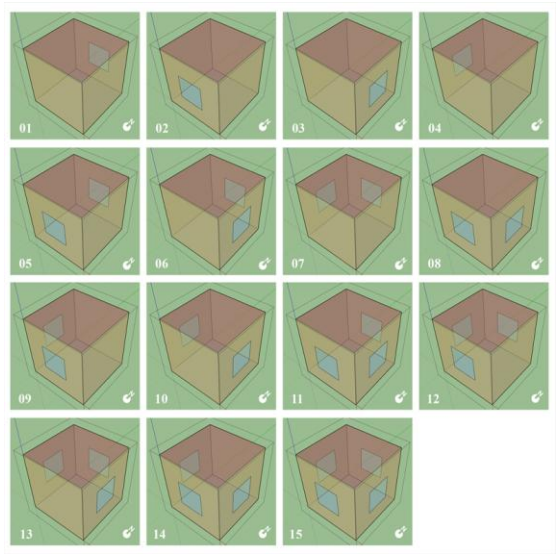


*Figure 2: 3d view of simulation models (1-15)*

## 3. RESULT ANALYSIS AND DISCUSSION

From the EPW data, it has been observed that the daily average outdoor temperature reach at around 30-34°C during April-July, at the same time RH is near about 70-90% during day time (Figure 3). For heat stress this time is more threatening than other months. For analysing the health risk index this month's value were predicted. During this time, outdoor wind speed is near about 1.5-2.5 m/s (Figure 4). It effects significantly on indoor climate and shows window demands for ventilation and heat loss process.

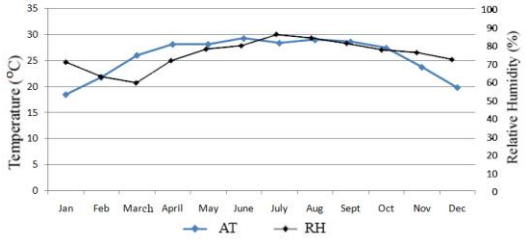


*Figure 3: Outdoor annual mean AT and RH*

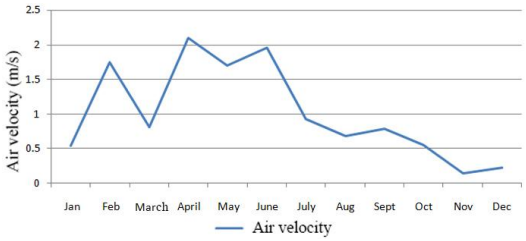


*Figure 4: Annual mean Air velocity*

### *3.1. Indoor AT, RH comparison*

For predicting heat stress, AT, RH and AV have been simulated in indoor condition. Figure 5 shows indoor mean AT. It clearly indicates that during the summer season temperature goes higher continuously. One thing is identical that for one-window models (1-4) shows 1.5-2°C elevated temperature than the four-window models during the whole year. And also indoor air temperature decreases gradually by increasing window numbers. So according to indoor mean temperature, windows at all facades perform better than the other ones, in hot humid condition during summer time. Figure 6 represents the RH for all of the simulated models. It shows that one window models keeps 5% less RH than the four window models. Country like Bangladesh, this impact is a little because of high humidity during the whole year. During summer time, it is near about 65-70% in indoor.

### *3.2. Wall surface temperature*

During the simulation period all models construction parameters were same. So heat transfer by conduction process can be considered as same, but convection heat transfer occurs because of open windows and air flow. Figure 7 represents wall surface comparison between model 1 and model 15. It shows that, Wall surfaces at model 1 is warmer (2-3 ° C) than the model 15 and it's significant for comfort analysis.

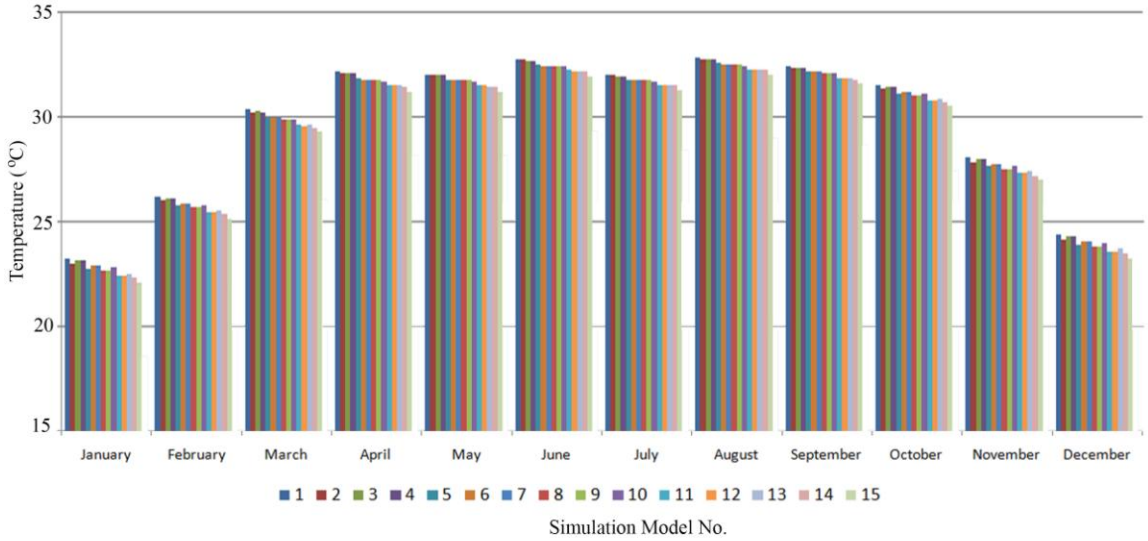


*Figure 5: Indoor air temperature (AT) comparison among 15 simulated models.*

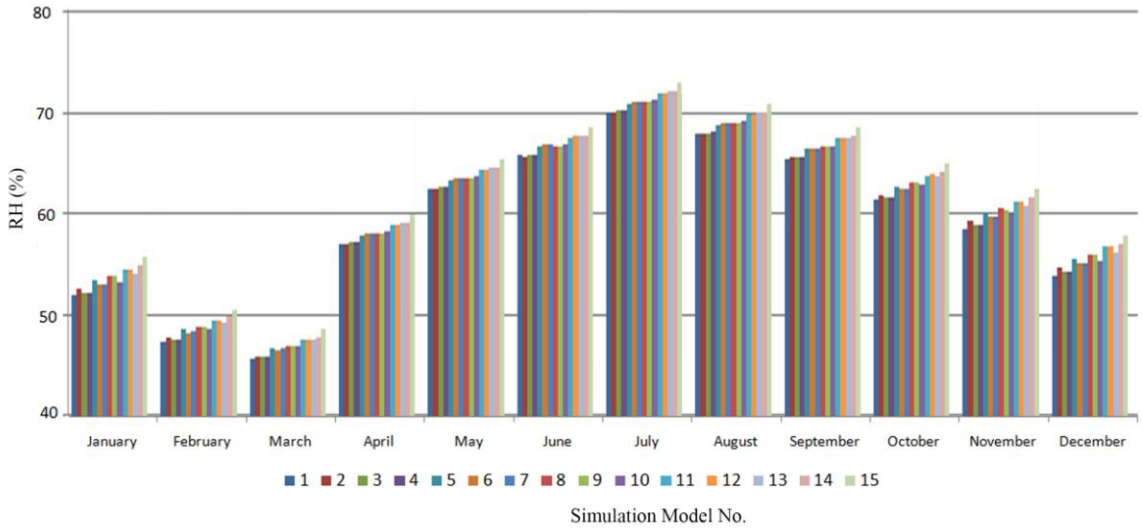


*Figure 6: Indoor relative humidity (RH) comparison among 15 simulated models.*

### *3.3. Heat loss comparison.*

In hot humid condition, it is important to lose heat rather than heat gain from window side. Our indoor generates heats from different electrical equipment, reflection of solar radiation and from living elements. Therefore, reduction is necessary for the comfort in indoor condition. Figure 8 shows the heat loss comparison between one-window models with four-window model. It shows that model 15 heat loss rate is around 120-160 W, where model 1 have a much lower rate around 40 W during the whole year.

For heat loss rate, analysis following equation has considered (Serth, 2014):

$$Q/t = hA\ (T_1-T_2) \quad (1)$$

Here, Q/t =heat loss rate, h = heat transfer coefficient, $T_1-T_2$ = temperature difference.

### *3.4. WBGT prediction*

In this study WBGT has been analyzed, it is one of the mostly used heat stress index derived from a series of field monitoring during 1920 [Parsons, 2006]. It is a combination of air temperature, relative humidity, solar radiation and air velocity in a single value to predict the heat

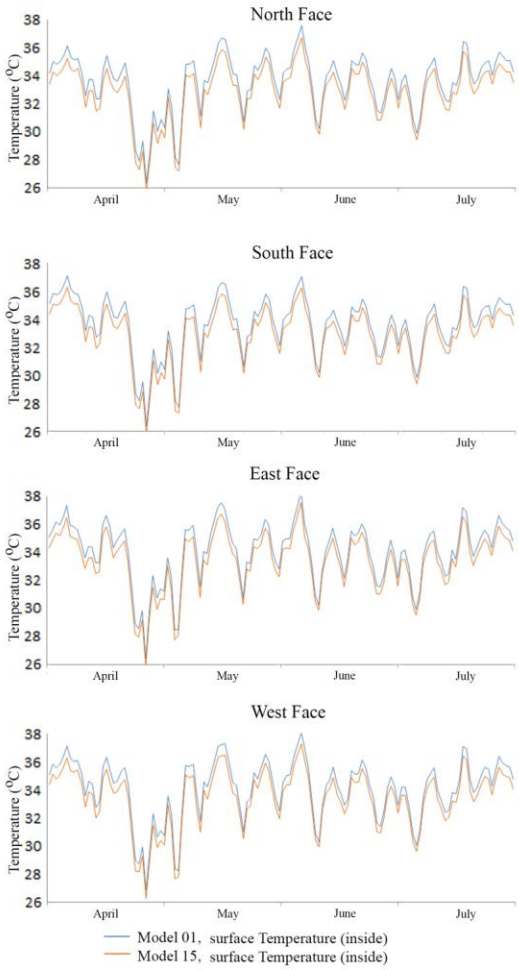


*Figure 7: Indoor wall surface temperature comparison between model 1 and 15*

stress. In case of indoor condition, solar radiation is negligible and following formula has considered: [Moran, et al, 2001; OSHA 1999]

$$WBGT = 0.7\ T_{nwb} + 0.3\ T_g \quad (2)$$

When air velocity is $v \geq 0.25\text{-}3\ ms^{-1}$, $T_w = T_{nwb}$; $T_g = T_a$ [Fanger, P. O., 1970]. Here, wet bulb temperature ($T_w$) was derived from AT and RH by the following equations: $T_w = (((0.00066 \times P) \times T_a) + ((4098 \times E)/((T_{dc} + 237.7)^2 \times T_{dc}))/((0.00066 \times P) + (4098 \times E)/((T_{dc} + 237.7)^2$ (3)

Here, $T_{dc} = ((T_a - (14.55 + 0.114 \times T_a) \times (1-(0.01 \times RH)) - ((2.5 + 0.0007 \times T_a) \times (1- (0.01 \times RH)))^3 - (15.9 - 1.117 \times T_a) \times (1- (0.01 \times RH))^{14}))$ (4)

$E = 6.1078 \exp ((17.269*T) / (237.3+T))$ (5)

All the calculations were formulated by ISO 7243.

*Table 3: WBGT risk factor index*

| WBGT (°C) | Risk Factor | Metabolic Rate, M Limit) |
|---|---|---|
| **≤ 26.6 (°C)** | Lower | Very High Activity M>260 |
| **26.7 - 29.3 (°C)** | Moderate | Moderate to High Activity, 200 < M ≤ 260 |
| **29.4 - 31.0 (°C)** | Moderate to Risk | Moderate Activity, 130 < M ≤ 200 |
| **31.1 - 32.1 (°C)** | Risk | Light Activity, 65 < M ≤ 130 |
| **≥ 32.2 (°C)** | High Risk | Very Light Activity, M ≤ 65 |

*Table 4: PMV index*

| Scale | Prediction |
|---|---|
| **+3** | Hot |
| **+2** | Warm |
| **+1** | Slightly warm |
| **0** | Neutral |
| **-1** | Slightly cool |
| **-2** | Cool |
| **-3** | Cold |

From the obtained data of AT, RH and AV it was observed that WBGT criteria for the dwellers become worse during the month of April to July. At this summer time, in operational period it indicates health risk in the scale of WBGT. From analysing the risk factor criteria of WBGT (Table 3) it was detected that for hot temperature and high humidity, April-July is the extreme condition in this particular region. From figure 9, mean WBGT is in moderate zone for all the models. But in case of maximum measure, for single window models it sometimes reaches to high risk zone (over 32.2° C), where four windows generally in moderate to risk zone (29.4 - 31.0° C). So for WBGT criteria, in hot humid condition several windows perform better than just a single window. Among single windows, south side windows showed good result than the other ones. Cross ventilation reduce the risk factor due to WBGT index.

### *3.5. PMV and PPD prediction*

For prediction of thermal comfort, PMV is mostly used function now days for its wide range

both in hot and cold environment. Table 4 shows the PMV scale where it runs from cold (-3) to hot (+3). 0 represent neutral condition for the subjects. Fanger's thermal comfort model was used to

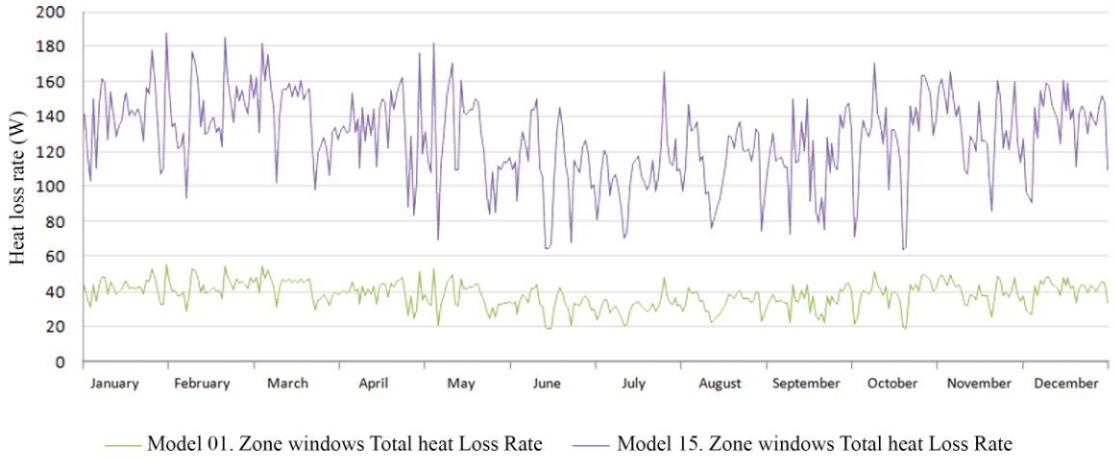


*Figure 8: Heat loss rate comparison between model 1 (one window) and model 15 (four windows)*

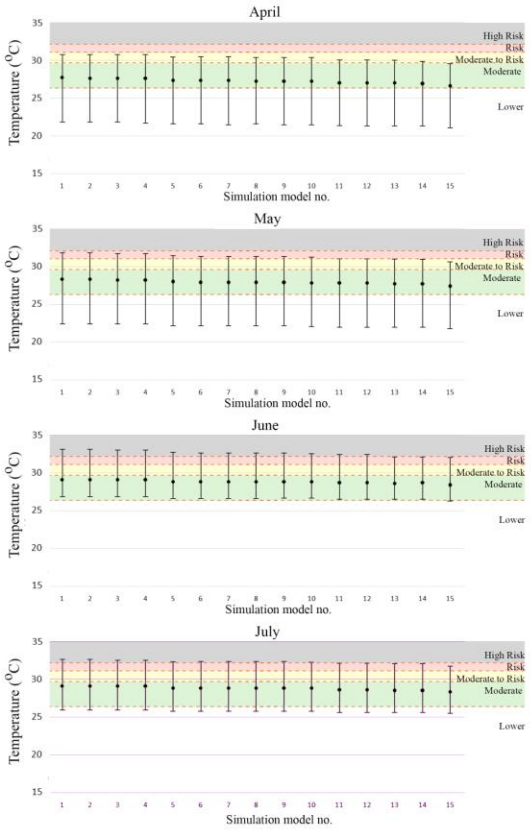


*Figure 9: WBGT comparison (model 1-15)*

calculate PMV in the following equation according to ISO 7730.

$$PMV = [0.303e^{-0.036M} + 0.028]\{(M - W) - 3.96\ E^{-8}\ f_{cl}\ [(t_{cl} + 273)^4 - (t_r + 273)^4] - f_{cl} h_c\ (t_{cl} - t_a) - 3.05$$

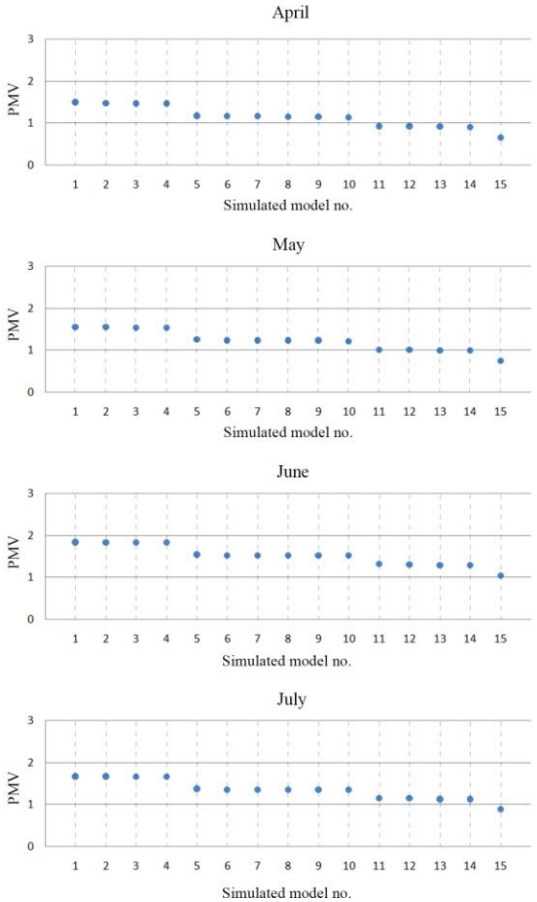


*Figure 10: PMV comparison (model 1-15)*

$$[5.73 - 0.007(M-W) - p_a] - 0.42[(M-W) - 58.15] - 0.0173M(5.87 - p_a) - 0.0014M(34 - t_a)\} \quad (5)$$

Here, $f_{cl} = 1.0 + 0.2\, I_{cl}$ , $1.05 + 0.1\, I_{cl}$ (6)

$t_{cl} = 35.7 - 0.0275(M-W) - R_{cl}\{(M-W) - 3.05$

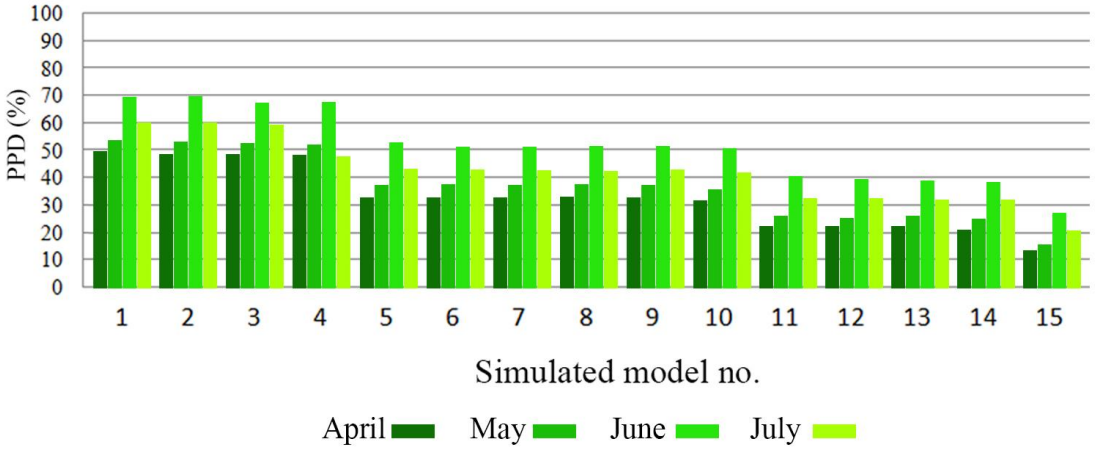


*Figure 11: PPD comparison (model 1-15)*

$$[5.73 - 0.007(M-W) - p_a] - 0.42[(M-W) - 58.15] - 0.0173M(5.87 - p_a) - 0.0014M(34 - t_a)\} \quad (7)$$

$R_{cl} = 0.155\, I_{cl}$, , $h_c = 12.1\,(V)^{1/2}$

Here, e = Euler's number (2.718), $f_{cl}$ = clothing area factor, $h_c$ = convective heat transfer coefficient (W/ $m^2$. $^oC$), $I_{cl}$ = clothing intrinsic clothing insulation (clo), M = metabolic rate ($W/m^2$), $p_a$ = vapor pressure of air (kPa), $R_{cl}$ = thermal resistance of clothing ( $m^2$. $^oC/W$).

$t_a$ = air temperature ($^oC$), $t_{cl}$ = surface temperature ($^oC$), $t_r$ = mean radiant temperature ($^oC$), V = air velocity (m/s) and W = external work (0.0). From the simulation, mean PMV during April-July is around +1 to +2 for all 15 models. For single windows models normally it fluctuates slightly warm to hot range, two windows models in slightly warm range, three windows models in neutral to slightly warm range and for four windows model it is in neutral zone. So performance elevated when the number of windows increase.

PPD is a function of PMV, and it can defined as,

$$PPD = 100 - 95e^{[-(0.3353\,PMV^4 + 0.2179\,PMV^2)]} \quad (8)$$

From figure 11, percentage of dissatisfaction level goes down for increase of window numbers. Single window models shows 50-70% dissatisfaction, two windows 30-50%, three windows 20-40% and four windows is 10-25%.

## 4. CONCLUSION

This study was conducted to find out the indoor thermal condition and comfort of the occupants in Bangladesh according to window configuration on wall facades. Heat stress criteria were observed for the hottest month April to July. The environmental parameter influenced a lot on thermal comfort and finally, the following precise conclusion has been drawn from that:

a) From the study, at Dhaka region indoor mean AT is around 30-34$^o$C in summer season and RH is continuous like 65-70%. For one window models it is about 2-3$^o$C elevated temperature than the four window model.

b) Indoor wall surface temperature comparison shows that maximum windows reduce surface temperature around 2-3$^o$C than just a single window.

c) Heat loss process from the windows increase by rising window numbers.

d) From measurement and prediction WBGT, PMV and PMV deflect from the comfort level at mid of the daytime, during summer.

e) In the perception of WBGT, mean WBGT is quite similar for all of the models. In case of maximum value record, more windows perform better.

d) PMV goes neutral to warm to hot zone, when window numbers reduced from four to one.

e) For PPD criteria, four-window model is around 40-45% less dissatisfactory level than

single window models.

It is a clear indication that, in hot humid condition indoor climate largely depends on building openings. It increase ventilation and heat loss process. This study is based on computer simulation; real environment evaluation can be conducted for further evaluation to find the exact condition. Still this result can be a good example for Architects and Engineers to find the importance of room openings in hot-humid condition.

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# IMPACTS OF GREEN WALLS ON URBAN HEAT ISLAND AND THERMAL COMFORT IN DHAKA CITY

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***Abstract:*** *Dhaka was ranked as the 11th largest megacity of the world in 2014 and is expected to become the 6th largest megacity by 2030. The predicted enhanced rate of urbanization due to both increase in population and built-up area along with the looming increase in temperature due to global warming would in future further deteriorate the already precarious present urban microclimate. Hence, for sustainable urbanization, there is an urgent need for mitigating the urban heat island (UHI) and conservation of energy required for cooling and ventilation. The temperature based assessments show that the decrease in temperature in Dhaka city by installing green walls of the buildings of the canyons would be approximately $4^0$C and the cooling load is expected to decrease by 40%. Analysis of thermal comfort by computation of thermal heat index (THI) value shows that at present the comfort condition is 'uncomfortable' for almost 100% of the people. By introducing green wall, the computed THI indicates that thermal condition can be made comfortable for 50% to 100% of the people, depending upon the decrease in temperature by $2^0$ C and $4^0$ C, respectively. The analysis of the decrease in cooling load (energy requirement for cooling) by using 'cooling degree days' concept shows that the energy requirement for cooling may be reduced by 22% to 44% with decrease in temperature by $2^0$ C and $4^0$ C, respectively.*

***Keywords:*** *Green wall, Urban heat island, Thermal comfort, Dhaka City*

## 1. INTRODUCTION

Dhaka, the capital of Bangladesh is one of the fastest growing cities of the world and is ranked as the 11th largest city with a population of about 17 million. It is predicted to be the 6th largest city of the world by 2030 with a population of about 27 million (United Nations, 2014). The unplanned and often unauthorized urbanization in the past has caused a significant decline in the wetlands and agricultural lands with a consequent manifold increase in the built-up area.

Along with pollution, urbanization has also negatively affected the microclimate – the change in climate of an area with respect to the surroundings. The urban heat island (UHI), which refers to the increase in localized temperature of a city or parts of it with respect to the surroundings due to decreased vegetation and lowered albedo (reflected sunlight), is a direct effect of urbanization. The increase in temperature due to UHI lowers thermal comfort in both indoor and outdoor urban environments and consequently increases the demand for thermal cooling. Thus, with the predicted future increase in urbanization, the urban heat island effect and the pollution scenarios are going to worsen, unless mitigation measures are adopted alongside the development work. It has become imperative that for sustainable development, a harmonious balance is maintained between the rate of urbanization and the restoration of the environment. 'Green Architecture' which is a concept that advocates sustainable use and conservation of energy and design of building and built environment with due consideration of its impacts on the environment, is a step in that direction and is the way forward. The 'green wall' is a wall of a building that is partially or completely covered with vegetation that are either freestanding or stand with support. In the context of greening of a city, the green coverage by walls can potentially be much more than the green coverage during the pre-existing state of

urbanization. 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. Although a number of studies on green walls in the developed countries have positively asserted their role in cooling and energy conservation, there is a general lack of such studies in the developing countries like Bangladesh. This study is an attempt in that direction, but it is in no way comprehensive and holistic, and can only be considered as indicative.

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 walls are going to work on a pre-existing building and what impacts they would have on the microclimate and thermal comfort.

## 2. IMPACT OF GREEN WALL

Considering the plants' ability to provide shade, intercept solar radiation and carry out photosynthesis, which all act together to reduce the temperature, it is comprehensible that green walls would reduce the heat across the building surface. The cooling effect by the green walls during the summer has been studied by a number of researchers, mostly in the Europe and some in Asia (mostly in China and Singapore). 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, and in summary, have mentioned four key issues for consideration; climate, construction system, species used and operational mechanism. They have concluded that the reduction in summer temperature varied from $1.7^0$ C to $13^0$ C, in warm temperate climate. In another experimental study in the UK (temperate climate), Cameron, (2014) has observed that the green walls can cool the air around the walls by $3^0$ to $5^0$ C during the summer. Studies in Hong Kong (sub-tropical climate) by Chu (2014), observed that the temperature difference between living and bare walls varied from $3.8^0$ to $6.4^0$ C.

Apart from reducing the exterior wall temperature, green walls have also been effective in reducing the indoor temperature with a consequent savings in energy. Raji et. al., (2015), have reported as much as 50% reduction in energy consumption during the summer due to air conditioning. The saving was mainly attributed to absorption of solar radiation by the green wall and the consequent reduction in indoor temperatures. In the US, Tilley et. al., (2012), observed the mean indoor temperature difference of $4^0$ C during the summer. From an experimental study in the hot and humid region of China, Chen et al., (2013), measured interior walls and indoor temperature reductions of $7.7^0$ C and $1.1^0$ C, respectively. In a summary of effects of green wall on energy savings with respect location, Raji et. al., (2015) have concluded that green walls would be more effective at high latitudes than at low latitudes.

### *2.1. Urban heat island reduction*

As green surfaces have a higher albedo (20% to 30%) compared to bare wall (less than 10%) and also helps in replacing the hot urban air by Oxygen rich air from the green walls, they can be effective in mitigating the urban heat island (UHI). Study by Akbari et al., (2001) shows that through greening (roofs, walls and trees) the energy consumption for cooling in the US can be reduced by 20% with a consequent mitigation of the UHI. In a review paper on UHI, Shishegar (2014), has shown that temperature reduction in UHI can reach up to $4^0$C. Alexandri and Jones (2008) conducted a quantitative study on cities in different climates and have shown that green walls can reduce the UHI temperature by an average of $9.1^0$ C in Riyadh and $8.4^0$ C in Hong Kong. They concluded that generally, the hotter and drier the climate, the greater the effect of vegetation on UHI reduction. Study by Mazzali et al., (2013) show that such reduction in temperature the Mediterranean climate due to green wall can vary from $6^0$ to $9^0$ C.

It is evident from the preceding literature review that there is a consensus among the architects/researchers on the definitive role of green walls in reducing the exterior wall temperature of a building, and consequently, as a passive tool for reduction in energy consumption and improvement of thermal comfort. Moreover, the impact of decreased exterior temperatures on mitigating urban heat island effects (when extrapolated from a building level to canyon or city scale), is also well recognized.

## 3. THE STUDY AREA

With a present area of about 360 $km^2$ and population density of about 45,000 per square km, Dhaka is one of the densest cities of the world. The 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). The land cover change due to urbanization during the 1989-2010 period is shown in Table 1. The table shows that during

that period, the 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%. The built up area in 2010 was about 36% of the total city area. 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).

*Table 1: Land cover change in Dhaka city during 1989-21010 period (Source: Raja and Neema, 2013).*

| Land Cover Type | Year | |
|---|---|---|
| | 1989 ($km^2$) | 2010 ($km^2$) |
| **Water body** | 76.0 | 35.2 |
| **Vegetation** | 105.2 | 87.9 |
| **Built up area** | 59.4 | 129.9 |

The change is land cover, especially the dramatic increase in built up area, has advertently affected the microclimate. Figure 1 shows the increase in temperature over different land covers of the city during the 1989-2009 period (Ahmed et. al., 2013). It can be seen from the figure that the city area did not experience any temperature above $30^0$C before 2009. In 2009, about 5% of the city area experienced temperatures above $30^0$C. If the present trend of urbanization continues into the future, then it is estimated that the area experiencing temperatures above $30^0$C would increase to 56% and 87% of the city area by 2019 and 2029, respectively (Ahmed et. al., 2013). The increase in urbanization has also negatively affected the UHI, and in a recent study, Das and Karmakar (2015) estimated the UHI intensity of Dhaka city to vary between $2.5^0$C to $7.5^0$C. In a study on comfort and quality of indoor and outdoor spaces in two communities of Dhaka city, Hafiz (2004) observed that the outdoor temperature in the summer is uncomfortable for 85% of the people. 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.

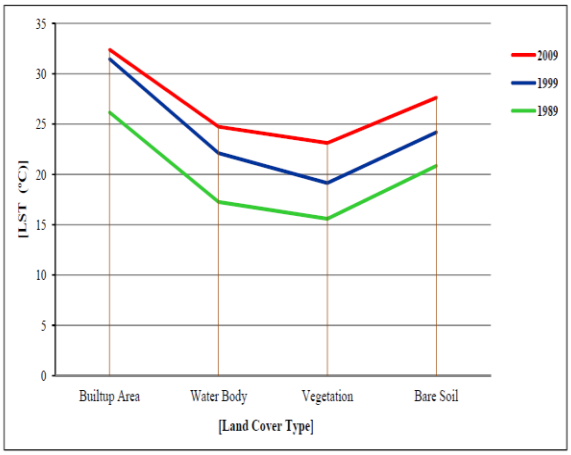


*Figure 1: The variation of mean temperature over different types of land cover in Dhaka city (Source: Ahmed et. al., 2013).*

## 4. ASSESSMENT OF IMPACTS OF GREEN WALL ON THERMAL COMFORT AND UHI

As there are no experiment based field data available on the effect of green walls on cooling of the ambient air temperature for Dhaka city, the effect of green walls in nine cities across the world, conducted by Alexandri and Jones (2008) was used to estimate such cooling effect. Their study was based on two dimensional micro-scale model describing heat and mass transfer in a typical urban canyon. The walls of different geometries (heights and widths) inside the canyon were fully covered with vegetation. They concluded that the temperature decrease by a green wall is dependent on the amount and geometry of the green wall and not the orientation of the canyon. In general, the larger the solar radiation a green wall receives, the larger is the decrease in temperature. The study concluded that if green walls are applied to city scale, they could bring temperatures down to comfortable level in hot climate and achieve energy savings for cooling from 32% to 100%.

Out of nine cities studied by Alexandri and Jones (2008), Mumbai, India ($18.55^0$ N and $72.5^0$ E) and Hong Kong ($22.16^0$ N and $114.12^0$ E) are in the tropics with similar mean monthly summer temperatures of $28.9^0$ C and $29.5^0$ C, and humidities of 77.1% and 69.5%, respectively. Dhaka ($23^0$42'N, $90^0$ 22'E), is situated in the tropics and is located between these two cities in terms of longitude. The energy savings in the nine cities due to green wall are shown in Figure 2. The figure shows that the maximum temperature decreases for Mumbai and Hong Kong are $4.4^0$ C and $3.9^0$ C, respectively. Since,

the climate of Dhaka is similar to these two cities (average temperature during the summer months of March – June of $29^0$ C and average humidity of 70%), through interpolation it can be expected that the temperature decrease due to green façade in a canyon of the city would also be similar and

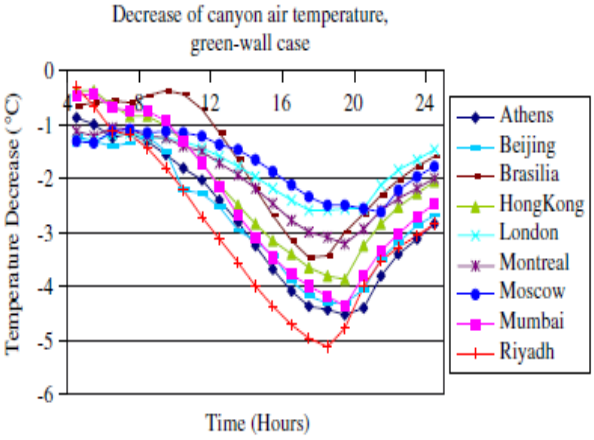


*Figure 2: Temperature decrease in canyon when only walls are covered with vegetation (Source: Alexandri and Jones, 2008).*

The thermal comfort in a city can be estimated by the Temperature Humidity Index ($T_{hi}$) as suggested by Emmanuel (2005). $T_{hi}$ can be expressed as (Kakon et. al, 2009):

$$Thi = 0.8\ Ta + (Ta \times RH)/500 \qquad (1)$$

Where: $T_a$ = air temperature in $^0$C and RH is the relative humidity.

The thermal comfort can be determined from the value of $T_{hi}$ as:

$21 \leq T_{hi} \leq 24$ =100% of the subjects feel comfortable

$24 < T_{hi} \leq 26$ = 50% of the subjects feel comfortable

$T_{hi} > 26$ = 100% of the subjects feel uncomfortably

Considering the average temperature of Dhaka city during the summer months of March – June as $29^0$ C and average humidity of 70%, the $T_{hi}$ value is more than 27, which is uncomfortable for almost 100% of people. Kakon et. al., (2009) also determined the $T_{hi}$ value ($T_{hi} > 26$) for three canyons of Dhaka city as 100% uncomfortable. If the temperature of a canyon can be decreased by $4^0$ C (as discussed earlier) by green wall then the $T_{hi}$ value will come down to 23.5, which is comfortable for 100% of people. Even if the temperature is decreased by $2^0$ C, the $T_{hi}$ value will be 25.5, which is comfortable for 50% of the people.

Thus, introduction of green wall would have positive effect on the thermal comfort of the people living in Dhaka city. The assessment of the decrease in temperature and the computation of $T_{hi}$ show that the green façade would have significant impact in reducing the UHI of Dhaka city.

### *4.1. Impact on cooling load*

An assessment of the impact of green walls in decreasing the cooling load (energy saving) was made based on the concept of 'cooling degree days' (CDD), which may be expressed as (EPA, 2014):

$$Dcd = \Sigma(To - Tb)/24 \qquad (2)$$

Where: $D_{cd}$ is the daily cooling degree day for one day of a month (in $^0$C day) and $T_o$ and $T_b$ are the hourly outside and base temperatures (in $^0$C), respectively. The higher the CDD, the higher is the energy requirement for cooling.

Considering the average outside temperature of Dhaka city ($T_o$) during the summer month as $29^0$ C and the base temperature for cooling comfort ($T_b$) as $20^0$ C, the average CDD for the summer months can be calculated as $270^0$ C day by using equation 2. If it is assumed that the green wall would decrease the summer temperature by $4^0$ C, then the base temperature cooling comfort ($T_b$) can be $24^0$ C. By using equation 2, the CDD can then be calculated as $150^0$ C-day, with a CDD saving of $120^0$ C-day by the green facade or a saving of 44.4%. Similarly, if it is assumed that the green façade would decrease the outside temperature by $2^0$ C, the CDD savings would be 22%. As the energy demand for cooling is directly proportional to the CDD, the energy savings due to green wall is also expected to be similar (Mourshed, 2011). In a model based study on green walls in Dhaka city considering the cooling effect due to evapotranspiration from the green wall, Saleh et. al., (2017) estimated the energy savings from green wall during the summer months to be about 31% of the total energy consumption. In a model based study carried out by Alexandri and Jones (2008), the decrease in cooling loads by green walls in Mumbai and Hong Kong were estimated as 35% and 66%, respectively.

Thus, depending upon the decrease in outside temperature by the green wall (as shown

in Table 2), the energy demand for cooling may be reduced by 22% to 44%.

*Table 2: Estimated energy saving (in CDD) by green wall during the summer months (for average outside and base temperatures of $29^0$C and $20^0$C).*

| Average Green Wall Temp.($T^0$C) | Average CDD ($T^0$C) | Average Savings (%) |
|---|---|---|
| No green wall | 270 | _ |
| 24 | 150 | 44 |
| 22 | 210 | 22 |

A major limitation of this study has been the lack of real life (field) data on the impact of green walls on the cooling (decrease of ambient temperature) of the surroundings. But, model studies carried out on Dhaka city by Das and Karmakar (2015) and Saleh Saleh et. al., (2017) show that green walls have the potential to lower the UHI and improve the thermal comfort. Hence, the results of this study are indicative and further research is needed for the validation of the model studies with real life (field) data.

## 5. CONCLUSIONS

From the impact analysis presented in the preceding articles, the positive role of green walls in decreasing the ambient temperature and energy savings from cooling is evident.

The temperature based assessments by interpolation show that the decrease in temperature in Dhaka city due to green wall would be about $4^0$ C. Similarly, the cooling load is also expected to decrease by 40%. Analysis of energy savings by computation of CDD shows that if the ambient temperature decreases by $4^0$ C, then the saving would be 44%. Thus, there is not much discrepancy in the estimation of energy savings by the two approaches.

Analysis of thermal comfort by computation of THI value shows that at present the comfort condition is 'uncomfortable' for 100% of the people. But, by introducing green wall, the computed THI indicates that thermal condition can be made comfortable for 50% to 100% of the people, depending upon the decrease in temperature by $2^0$ C and $4^0$ C, respectively. The assessment of the decrease in temperature and the computation of THI show that the green wall would have significant impact in increasing the thermal comfort and reducing the UHI of Dhaka city. The findings of the study could not be validated due to lack of field data and further research is needed on collection of field data on the impacts of green walls on the environment.

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# STUDY ON THE IMPACT OF LANDSCAPING ON CARBON FOOTPRINT:

## CASE STUDY ON A RURAL SCHOOL CAMPUS IN BANGLADESH CONTEXT

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***Abstract:*** *To response to the environment and Sustainability issue, landscape is now considering as one of the important architectural tools. As a major part of Landscape Plants have role in configuring carbon footprint through carbon sequestration and reducing carbon emission. This study is aimed to investigate the role that landscape play in overall carbon footprint. at present the carbon offset by the landscape is not a major portion of total carbon footprint of the overall community, but the factors including green area, tree biomass, and also the construction and maintenance of the landscape can influence the scenario . The measure of landscape sustainability such as the issues surrounding green, water, materials, energy, biodiversity, community and economics have not been well known yet. Therefore, make the landscape planning a better carbon sink should be taken into consideration by expanding green zone, growing tree planting, and ensuring proper construction and maintenance works for existing landscape. This paper will cite the findings that will be compiled based on related reference study available in hard and soft media. As a pilot study this research also focus on the effect of green plantation on carbon balance (carbon emission and carbon offset) of a small study site. Carbon needs to be one of the baseline for sustainable architecture. The findings reconfirm the preferences of Greening and plantation that aware for the carbon costs and carbon figure for Architects' projects and also produce consciousness for architects preparing the policy how landscape will be effective to carbon minimization and offset.*

***Keywords****: Landscape, carbon landscape, carbon footprint, sustainable environment, green architecture.*

## 1. INTRODUCTION

There are 50% of the world's population inhabit in 2% of the world's land area. Cities are now found as the hotspots of climate change effect (*Grimm et al., 2008*). How to strengthen urban greening by landscape planning, such as the green space, carbon sink, increasing the urban ecology function, , and to improve the wellbeing and comfort of the residents has got the focus of urban planning in the governments. (*Niemela et al,.2010*;) Furthermore, after signing the kito protocal by all the nations the low-carbon concept is highly concerned to mitigate the green house gasses. How to develop effective policies to construct the low-carbon and eco-friendly environment become an important issue in architectural landscape design as well as an opportunity towards a low-carbon city and the green economy.

The carbon footprint analysis has been extensively used for decades in products and labors, but not so concerned in urban environment and planning. There are few literature that review the carbon footprint of urban green landscape. there are also few researches about the value of the urban green ecology. *Strohbach & Haase* (2012) were the first one who shows extensive interest in reviewing the city's green carbon footprint. The life cycle assesment includes the three stages of landscape - construction, maintenance and tree biomass.

## 2. METHODOLOGY

The scope of this study is to investigate the different component of Landscape that can play role to configure the carbon footprint. To explore the research topic combination of literature review and case study is conducted where literature review get the preference to clarify the theoretical issues on landscape and its effects on carbon

footprint. Case is experimented to explore the potentials for a specific entity. There are three main parts of the method conducted in order to achieve this aim as follows:

### *2.1. Literature review*

The principal part of the study is literature review. The basic concept of Landscape and Carbon footprint, and detail of its elements, potentials, and process are deeply studied through available resources. Books, Journals, seminar procedings, thesis papers and also valid online resources were investigated to reach the information on research topic.

### *2.2. Case study*

Author have conducted a pilot study on a small school campus located at a rural area as a sample case. The case is selected in a rural area because the great potentialities of Landscape in Bangladesh context is preferably found in rural setting. The study area was surveyed and Data on the Landscape was collected. The Land and its surroundings , land use pattern, the landscape features and elements as like plants , water body, lives, build form etc are recorded. The climate of the site area is checked from literature.

### *2.3. Carbon footprint Calculation*

Using the data collected through field survey and the synthesis process guided by literature survey, the calculation of carbon footprint have prepared. There are three sequential stages for considering and calculating carbon footprint:

- Lists the direct and indirect source of carbon emission and carbon sequestration
- Measures carbon that created and consumed in site and reduced by the components on site,
- Summarize the opposite data and found carbon footprint status of the site area.

## 3. DISCUSSION: LANDSCAPE AND CARBON FOOTPRINT

The *Carbon footprint* is one of the curtail measuring standard for low carbon research and actions. It derived from the concept of ecological footprint That can be relevant with communities, urban developments, organizations, even specific persons or products etc. (*Gao, Liu, & Wang, 2014*) there are few literature assessing the carbon footprint of urban green landscape. In landscape study, carbon footprint focuses on carbon dioxide emissions and sequestration in a ecological area generated by the overall consumption of materials and energy, vegetation and other components, as well as the direct and indirect emissions (Wiedmann *et al 2008)* to analyze the net carbon dioxide emissions of the entire area. In broad sence It is a measure to evaluate the activity or entity's contribution to climate change. when carbon sequestration activities achieve zero carbon footprint of a particular activity, it's contribution is remarked as *carbon neutral* status.

### *3.1. Landscape and its' potentials*

A content of landscaping is sometimes less than the whole of its visible components. Primarily the identity of landscape is determined by expression of form. *Passarge* (1920) defined landscape as "*A correct representation of the surface form, of soil, and of surficially conspicuous masses of rock, of plant cover and water bodies of the coasts and seas, of a really conspicuous animal life and of the expression of human culture*." Perception of landscape varies and is sometimes determined by assessors interest. In architectural research concentration focuses on the in the part of the areal scene which concerns as the design and construction components.

Land and water is the fundamental element for configuring the earth and its surface. Both are basically reservoir for organic carbon which accumulate from carbon dioxide in atmosphere through green trees in a biogenetic process. Tree is the natural resource that ornaments and differentiates the earth surface and Conceptually act as great terrestrial Carbon sink *(Houghton et al., 1998)*. The combination and organization of these three elements in different approaches and scales create variation and diversity in landscape. Therefore Landscape mostly influences the carbon sequestration while carbon is emitted through land and users activity. The production and consumption of food, fuels, manufactured goods, materials, buildings and roads, transportation and

other services causes the emission of carbon. Estimating the carbon Elements of landscape is typically categorized according to their morphological organization and different calculation standard of carbon estimation is established by the researchers.

*Sea* / The review of *Cebrian* (2002) states that various types of biotic communities in tidal regions sequester considerable amounts of carbon. Marine grasses, marshes, mangroves are act as organic carbon traps .Carbon sequestration at any submerged location grows ever larger. (*CO2 Science*, 2017) Due to sea level rises coastal wetland evolves from high marsh to low marsh" . At that time carbon is being sequestrated into soils *(Choi et al*.2001)

*Waterbody*/ Inland waters show positive correlations between carbon dioxide (CO2) emissions and organic carbon concentrations. (*Premke, et. al* 2016 ) Most inland large lakes are supersaturated with CO2 (*Cole et. al*.1994) It can also arise from discharging groundwater supersaturated with CO2. ( *Marce et. al* , 2015 ) In major case natural small water bodies act as depressional wetlands and comprise effective Organic Carbon trap. Furthermore people would be expected to construct more artificial reservoirs and the trend is increasing. These man-made reservoirs contain more organic carbon each year than natural lake. (*Einsele et al*.2001). After all, Urban and peri-urban water bodies and wetlands play a significant role in carbon sequestration and long term storage of atmospheric carbon. Conserving water bodies and wetlands is now drawing attention due to their ability to capture atmospheric carbon. *(Ghosh, Bardhan & Roy,2017)*

*Soil* / Soil itself is documented as a potential carbon sink that plays imperative role in mitigating climate change effect. *(Ghosh, Bardhan & Roy,2017)* The carbon sink capacity of the world's agricultural and degraded soils is 50 to 66% of the significant carbon loss. The rate of soil organic carbon sequestration depends on soil texture and structure, rainfall, temperature, farming system, and soil management. Carbon sequestration also has the potential to offset fossil fuel emissions by 0.4 to 1.2 gigatons of carbon per year, (*Lal, R. 2004*.) The soil Carbon sequestration is a truly win–win strategy. It restores degraded soils, enhances biomass production.

*Peat lands* / peat lands, defined as wetlands with a rich organic soil layer cover 3% of the global land surface. These peat lands typically connect terrestrial and aquatic ecosystems. According to research by *Limpens et. al*. (2008) peat lands are estimated to store one-third of the world's soil Carbon. Therefore, perfect peat lands play essential role within the global Carbon cycle as terrestrial long-term CO2 sinks. as a result, Direct gas flux measurements of peat lands have exposed that net Carbon losses vary, on average, 10 times higher than the carbon dioxide sequestration rates. (*Couwenberg et. al*. 2011).

*Croplands and Grasslands* / Cropland and grassland ecosystems cover ~12% & ~22%.of the ice-free surface of the earth, (*Ramankutty, et. al* 2008). croplands and grasslands can play dual role as CO2 source and CO2 sinks. This feature is developed for their creation on former forest or grassland sites for a period up to 120 years.( *Poeplau & Don*, 2013 )Since the onset of agriculture, soils have lost 40,000–90,000 Tg Carbon globally through cultivation. On the other hand, Corpland also act as carbon sink due to land use activities such as fertilization for agriculture. In the long run, as *smith* (2014) notes, grasslands are neutral on an average (neither carbon sink nor carbon source) but with respect to the soil Carbon stock it is often higher than croplands. The reason is that, grasslands are currently much more widespread in areas of high rainfall and, lower temperatures than croplands.( *Leifeld & Fuhrer 2009* )

*Plants and Forests* / Plants are highly influential landscape components that play vital role in reducing carbon and modifying carbon footprint. It offen consider as secondary element in landscape design but indivisual plant has the capacity to direct minimize the amount of carbon

in environment and create balance by increasing oxygen. Most strategies being proposed to mitigate global climate change include increasing carbon storage is plant systems. This is often referred to as "terrestrial carbon sequestration." (*Hong, Lee & Hsu,2014*) If large amounts of $CO_2$ are removed from the atmosphere by photosynthesis and then held in stable plant material or soil organic matter, it could help offset $CO_2$ generated by fossil fuel use. Plant uptakes the carbon dioxide and stores the carbon in the plant tissues by *photosynthesis*.

By the way, Forest ecosystems cover ~30% of the earth's land surface and are among the most important terrestrial Carbon sinks globally, estimated to fix 30% of all CO2 emitted from fossil fuels and deforestation worldwide. (*Canadell & Raupach, 2008*). In addition, forest biomes are the major reservoirs for terrestrial Carbon storage both below and above ground.( *Malhi & Baldocchi, Jarvis 1999*). Around 46% of the total Carbon stocks is contained by tree biomass( *Dixon et. al 1994*). The annual net primary production (NPP) of forest ecosystems varies among tropical, temperate, and boreal biomes.

### *3.2.Carbon Sequestration and Landscape, Bangladesh Context*

Bangladesh is a plain land with natural vast green and specialized forest zone. The availability of water reaches the greenness of land with great potential of carbon sequestration. The bay of Bengal in the southern part of the country and other Inland waters itself have positive impact on carbon reducing. No more research on carbon storage of water is published so that specific data is not available In Bangladesh context but soil is proved as positive to carbon storage. National average of soil organic carbon content was 182.94 tone/hec (*Jha et al. 2003*) The organic carbon concentration and storage under vegetated land uses were significantly ($p < 0{\cdot}05$) higher than those in the degraded hill areas.,

Forest and plants is significant to specialize the country landscape. 367 tones of carbon per hector is stored by the tree tissues in the forest of Bangladesh. (*sohel et al. 2009)* Study results showed that about 17 million megagram carbon (MgC) could be sequestered by plants in the hill areas of Chittagong by *akshmoni* tree (*Barua, and Haque, 2013*). Forests alone still absorb more carbon than the total carbon produced in the country(Mukul, 2007) though we are under Threats to carbon deposits as a result of world deforestation.

Bangladeshi forests is classified in three major categories. Mangrove forest, Hill forest and inland forest such as sal forest etc. Mangrove plantation also consider as a sub category in consideration of variation of carbon density. table-1 shows the carbon density and carbon stock for all types of forests

*Table 1: Soil carbon storage in different forest type in Bangladesh (FAO, 2007)*

| Forest type | Carbon density* (Mg $ha^{-1}$) | Carbon stock (Million Mg) |
|---|---|---|
| Hill forests | 49. 5 | 33.2 |
| Mangrove forests | 88.2 | 52.9 |
| Mangrove plantation | 19. 6 | 2.6 |
| Sal forests | 34.5 | 4.2 |
| Total | | 92.9 |

*The rate of carbon sequestration* depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood. The Effectiveness of specific plants material in climate control also depends up on the form and character of the plant and the climate of the region. *(Robinette, 2009)*. Thus native plants and trees have importance in consideration Mangroves are amongst one of the efficient in carbon sequestration. It is estimated that 251.8 million Mg of carbon stored in Bangladesh forest ecosystems, 49.4% stored in the mangrove forests alone.

*Image 1: Mangrove forest at the southern part of Bangladesh*

The fresh water zone shows the highest ecosystem carbon stock (336.09 ± 14.74 Mg C

$ha^{-1}$) followed by moderate and strong salinity zones. (*Rahman, Khan, & Fazlul Hoque, 2015*) The mean rate of carbon sequestration for Whole WHS is 3.93±1.38MgHa-1year-1( 14.44±5.07MgHa-1year-1 for CO2)

*Hill forests and Inland Forests* also have high potential for forest carbon sequestration. according to the study (*Alamgir, 2005*) The forest area of Chittagong (South) forest division can sequester 1.9 million tones of organic carbon per year.

*Image 2: Chittagong hill forest;*

Roadside plantations in Bangladesh also participate in the carbon mitigation and adaptation mechanism, We estimated a biomass carbon of 192.80 Mg $ha^{-1}$. (*Rahman, et al 2015*)

*Image 3& 4: Roadside Plantation*

## 4. CASE STUDY : CARBON FOOTPRINT OF A SMALL SCHOOL COMPLEX AT RURAL AREA

Though the carbon footprint has been widely used in products and labors, however, there are few literature assessing the carbon footprint of green landscape. In the part of the study South shakokathy model academy is selected to conduct a pilot experiment of carbon footprint analysis in Bangladesh context.

### *4.1. Context of the study area*

The case studies of this research was selected at Gauranadi Upzilla in Barisal City, Bangladesh. It is located at latitude 22.93 North and longitude 90.17 East (Image-3). There have two single storied build form in 'L' shaped arrangement but The landscape of the site is mainly characterized by green field with informal arrangement of trees and a small peat land.

*Image 5: Satellite image of site location (Source: Google maps) and Image 6: aerial view.*

The summer season occurs between March till September when the peatland is wet and sometimes filled by water under the influence of moonsoon climate with a rainy environment during a short period. The winter season occurs from october till January. The effect of climate on the landscape is minor to consider.

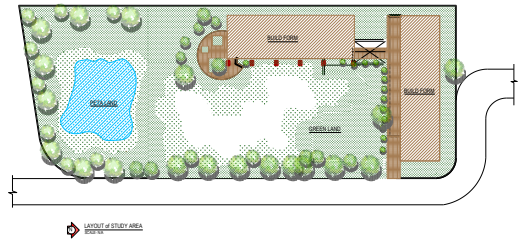

*Image 7: Study Area layout.*

A conceptual layout of the research area including existing building, lands, plants, water sheets are defined. User activities and energy uses are investigated separately. The survey on peoples activity was carried out in pick working hour of South Shakokathy Model Academy in day time. Geological Data is collected during the field measurement. Climatic factors were also measured as supplementary works.

### *4.2. Calculation of carbon footprint*

Total footprint of the study area is found after summarizing the two opposite data . Since it is very difficult to calculate the carbon footprint of specific project. In case study the study area is considered as isolated example on which no external effect is valid. The work has done as pilot study from which a conceptual result may collect about the relationship of landscape and carbon footprint.

In the study 1(one) year carbon sinks of the landscape is estimated and then projected amount of carbon emission also estimated based on the activity and user. There have a water body which is considered as peatland . Due to the high uncertainty, the study neglect the carbon sinks of the tree root biomass (*Strohbach and Haase, 2012).* the carbon footprint of the landscape is calculated in the following way:

*4.2.1. Carbon sequester*

*A. Carbon sinks of trees* / The school complex researched in this study is under rural management. Therefore the tree mortality is suitable to refer to the natural growth patterns. approximately 3.5 meter above the ground. Carbon sinks for tree is calculated by *Vishnu and Patil* (2017) that found that 1068.33 Carbon from 3916.81 kg of Carbon dioxide is sequestred by a mature mahagoni tree. and The amount of carbon from 214.31 kg CO2 is 58.455kg / year for teak chambol tree.

*B. Carbon sinks of shrubs* / There are 12 medium size native ornamental shrubs, with slower growth rate. Their everage heights 1 meters and width 0.6 meters, multi-branched without major trunk. It is assumed that the shrubs are naturally grown and any trimming work would not be performed. The carbon sink is estimated to be the one-thirds of the tress as mentioned.

*C. Grassland* /Other features of carbon sequestration is Grassland and a small peatland. During the growing season, per square meter Grassland taken 1.85 grams CO2 from the atmosphere on average *(Frank, A.B., and A. Dugas, 2001)*

*4.2.2. Estimation carbon Emission*

The active source of carbon emission of the study area is human breathing. Human produces about 0.7 kilograms CO2per day, or 255 kilograms by year. (*Berkow et al., 1997)* Indirect emissions associated with the consumption of purchased electricity for electric fan, water pump and light for occasional use. A total of 1115 kWhr of grid electricity is consumed on yearly basis which translates into a carbon emission of 497kg of CO2. carbon estimate for Grid Electricity is 0.446 Kg CO2 / kWhr

*4.2.3. The net carbon footprint in the research area*

Based on the calculation as mentioned, total Carbon footprint is estimated comparing the carbon emission and the carbon sequestration of the study area.

*Table 2 & 3: Comparative result on Carbon sequestration and carbon emission.*

| **Carbon sequestor** | | **sq rate kg/tree** | **total nos** | **carbon sequestered /year** |
|---|---|---|---|---|
| **1** | **Mahagony tree** | 3916.80 | 23 nos | 90086.40 kg |
| **2** | **Teak Chambol Tree** | 214.31 | 1nos | 214.31 kg |
| **3** | **shrub** | 1305 | 12 nos | 15660 kg |
| **4** | **Grass land** | .675 per sqm | 1000 sqm | 675 kg |

| **Carbon Source** | | **emission rate kg/unit** | **total unit** | **carbon emitted /year** |
|---|---|---|---|---|
| **1** | **Human body** | 255Kg /person | 65 | 16575 kg |
| **2** | **Electricity consumption** | .446 kg/kWhr | 1115 kWhr | 497.29 kg |

The result shows that when other factors and parameters are constant the carbon sequestration is more than five time larger than carbon emission. It has happend only for the presence of mahagony tree which have a great sequestration rate. Thus the landscape has a influential role on reducing carbon and modifying the carbon footprint

## 5. CONCLUSION

The concentration of CO2 in the atmosphere has been increased tremendously in the last couple of decades. Bangladesh is not out of global environment. The climate change impact also major concern though we are not the cause of the problem. Huge amount of carbon in the atmosphere, however, should be removed. This

study shows that landscape design can significantly influence environment and energy efficiency. If Landscape architects are to promote themselves as the solution provider for sustainable urban and open spaces we need to develop an understanding of our environment impact and the best ways to mitigate them.

If the definition of sustainability is considered and applied to the profession of landscape architects then Yet this is not the way we perceive ourselves; we are a green discipline; we are responsible for the care of the land and communities. Our tools are plants and ecological systems, we create spaces of beauty with trees and lawns . at the same time Value of carbon sink and carbon neutral by landscaping has gradually overridden its traditional function of beauty nature. The potential advantage of carbon sequestration offers an opportunity for the landscape industry .It also offers its clients to become concerned to maintain required Carbon footprints through effective urban landscape (*Rufty, Rees and Hamon, 2010*).

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# AN ANALYSIS OF INDOOR ENVIRONMENTAL CONDITION AND POSSIBLE COMFORT GUIDELINES FOR INDUSTRIAL BUILDING:

## A CASE STUDY ON METAL INDUSTRY, CHATTOGRAM

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***Abstract:*** *Bangladesh Metal Industry has emerged as one of Asia's leading positions in markets. Labour based industry in Bangladesh has been heavily criticized over the last 30 years for the working conditions. The indoor condition of the factory is very poor. Indoor working environment is intolerably hot because of high internal heat gains from artificial lighting and equipment. This paper identifies the existing condition of this poor environment through analysis of factory in Chattogram. It also discussed about rules and regulation of industrial building standards. Data was collected through field survey which consisted of environmental measurement and thermal comfort information gathered from industrial workers by questionnaire or interview format. Finally, this study briefly explains indoor working condition and also analyses acceptable guidelines to achieve indoor comfort for industrial buildings.*

***Keywords:*** *Environment, Indoor comfort, Industrial building, Working condition.*

## 1. INTRODUCTION

Bangladesh has achieved a tremendous growth rate in its industrial production. In present time's most of these industries are highly criticized for workers who spend most of their daily lives. Besides, Extensive working hours (10-12 hours/day) become most intensive during summer, when production increases to meet the year end demand (Naz, 2008).

Industrial buildings have some distinguished features which causes huge impact on worker's health like inappropriate ventilation and internal heat gains (De Angelis, Saro and Truant, 2017).
The occupancy pattern and artificial lighting affect the thermal conditions inside the building. Cooling solution generally consists of ceiling and exhaust fan which neglects the potentiality of natural ventilation (Naz, 2008). Moreover, excessive noise, indoor air pollution, damp environments have long term health risks. To ensure worker's health and comfort, the indoor air quality and thermal comfort must be appropriate (Errico, 2014).

China, India, Korea, Russia, United States are the leading steel producing countries. In addition, they are working hard on improving indoor working condition to increase ultimate production.

Bangladesh had almost 400 mills across the country in 2012. Those mills play great role in economic sector. Most of them are located in Chattogram; the largest sea port of the country (Wikipedia, 2018). With limited scope, a metal factory of Chattogram has been taken as a case study for this research.

This paper focuses on indoor comfort criteria, lighting, temperature, ventilation, relative humidity, and noise level by comparing the case study with the standards. And to provide guidelines for achieving indoor comfort which ensure the safety and health issues of workers.

## 2. LITERATURE REVIEW

In Bangladesh planners and designers, in many cases, design and construct projects without

following the rules and regulations of the government.

In detail area plan (DAP) there are standards for designing an industrial building. City Corporation and Chittagong Development authority (CDA) permission is needed for final design confirmation (Development, 2009). Bangladesh gadget has some criteria; which is important to follow when designing.

Bangladesh has a hot and humid climate, with an average mean annual temperature of 26.5°C. The maximum summer temperature is 37°C and minimum winter temperature is 6°C. Ground temperature can be assumed to be around 26.5°C (average annual outdoor air temperature), at depths over 10 meters below grade, which is not low enough to provide a powerful heat sink for cooling. Due to geographic location relative humidity ranges, between 50-90% throughout the year. During the summer (June – September) cloud cover averages above 40% (Naz, 2008).

Adequate, well balanced levels of illumination are essential in establishing safe and productive working conditions. Optimizing industrial lighting, requires consideration of work tasks, environmental conditions and economic considerations. Due to the deep floor plan and small windows, which again are not correctly orientated, artificial lighting and lack of natural ventilation occur. Most of the windows are not shaded and in many cases are shut to prevent drafts.

Most factories have ceiling fans for interior circulation. Fan and exhaust fans are usually used for a 1-2 ACPH (Air changes per hour) per person, but in many cases those are randomly placed. As a result those are turned off to avoid creating strong breezes in the wrong direction, which may disrupt the work (Naz, 2008).

Dust and weld fumes are common challenge in manufacturing. In order to protect worker's health, contaminants must be controlled. There occurs symptoms of common problems due to these contaminants — such as depression, bipolar disorder, attention deficit hyperactivity disorder (ADHD), and anxiety (Eroglu S., Toprak S., Urgan O, MD, Ozge E. Onur, MD, Arzu Denizbasi, MD, Haldun Akoglu, MD, Cigdem Ozpolat, MD, Ebru Akoglu, 2012).

Poor Indoor Air Quality (IAQ) may develop when not enough fresh air is introduced to reduce contaminant concentrations. The HVAC system should not only control contaminants, it must also provide a comfortable environment. Factors such as temperature, humidity, lighting, noise and personal and work-related stress can affect occupants' perceptions of indoor air quality.

## 3. METHODOLOGY

In case study, information is collected through the process of observation, reconnaissance survey and focus group interview. In the surveying process direct observation helped to understand the present situation of the area, people's activity and participations. Problems and related data have been recorded in the form of photographs, sketches and writing records, which were documented and received. The secondary data on industry adjacent areas and related aspects were collected from various published sources.

The objective measurements were conducted using Environment monitoring tool (5 in 1) (Fig.1) is used to collect the temperature, humidity, noise level, thermal comfort ,light rate in industrial building. It help to analyse the present situation and for further proposal process. The subjective assessment was formulated into was formulated into questionnaire form and interview format. Policies and ideas have given by analysing situation through stages.

All the collected data presented with the help of Google earth, MS Word, MS Excel, Adobe Photoshop, PDF Converter etc.


*Figure 1: Environmental Monitoring tool Lutron LM 8102*
*Source: Author (Photo credit).*

## 4. STUDY AREA AND EXISTING SITUATION

Chattogram is the major coastal seaport of Bangladesh with 2.5 million populations according to 2011 census (Wikipedia, 2018). The Chattogram Port is the principal seaport of Bangladesh handling about 92% of import-export trade of the country (Chittagong Chamber Of Commerce & Industry, 2018). As the busiest port in South Asia it is the centre of Industrial revolution in Bangladesh. More than 40% factories of the country are located in Chattogram (Wikipedia, 2018).

Multi Steel Casting Ltd is the case study of metal industry which is located at Textiles circle, Bayazid Bostami, road, Chattogram. The way towards Textiles circle to the industry is showing with red dotted line in (Fig. 2).

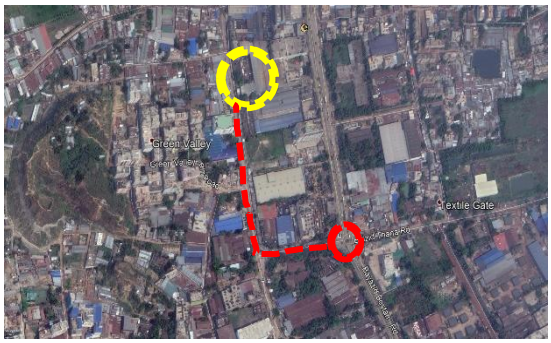


*Figure 2: Road network from Textiles circle to Industry.*
*Source: Google Earth.*

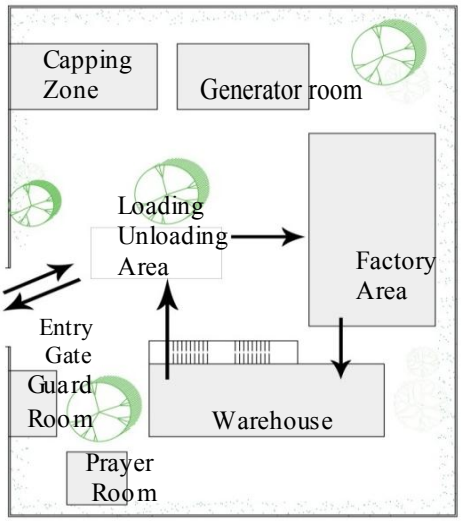


*Figure 3: Industry Master Plan*
*Source: Author*

The Metal industry has a functional chain of zoning (entry gate > loading unloading > factory area > warehouse > loading unloading > entry gate), which helps to distribute production (Fig. 3). Loading unloading zone has some safety issue as workers have to carry the materials manually.

Every industry has proper production cycle to run the industry. The chain of production is shown in (Fig. 4).

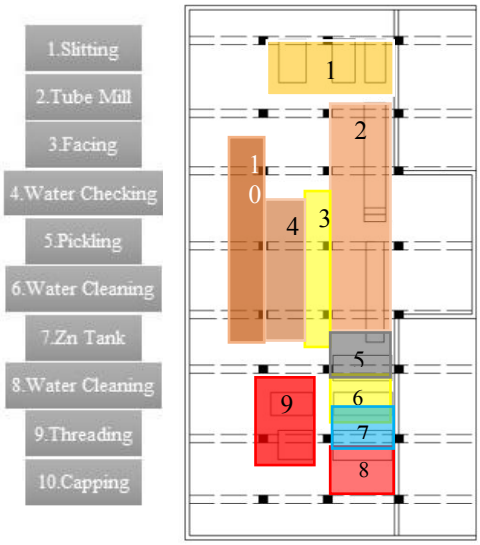


*Figure 4: Industry Production Chain.*
*Source: Author*

Among working process areas, slitting is the zone with horrible sound condition. Workers in this section may have severe hearing damage in the long term. Another problematic zone is Zn tank where extreme heat is produced. As ventilation system is very poor, workers feel maximum discomfort in this zone. Workers are suffering from different health hazards such as Hearing impairment, Bronchitis, Asthma etc.

In terms of building material, roof is comprised of tin and steel which make it more heated during summer time. Provision of natural ventilation is totally neglected in this industry. Small high windows are inadequate for lightening and are fully dependent on artificial lightening (Fig. 5).

There are insufficiency in terms of working condition and workers facilities. In addition, there are absence of proper wash zone facilities and resting spaces (Fig. 6).

*Figure 5: Inadequate natural light.*
*Source: Author*

*Figure 6: Workers resting space.*
*Source: Author*

## 5. RESULT AND DISCUSSION

Field analysis helps to understand the actual condition of the space. It also clarifies issues more closely. Field observation in different times provides a better understanding of possible strategies of spaces. It has also added a visual glance of workers relationship with environment. With the help of Environment monitoring tool ( 5 in 1) Lighting, temperature, air velocity, noise level, relative humidity data were collected (Fig. 7, 8).

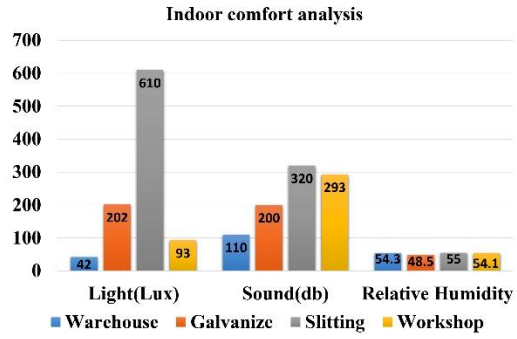


*Figure 7: Indoor comfort analysis (Light, Sound, RH)*
*Source: Author*

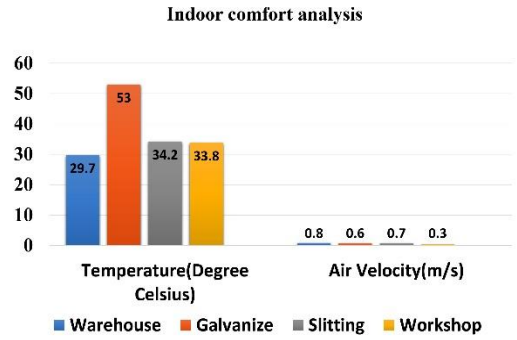


*Figure 8: Indoor comfort analysis (Temperature, Air Velocity)*
*Source: Author*

## 6. RECOMMENDED GUIDELINES

The findings show that poor working condition is created because of the lack of environmental considerations in design. Following are the recommended guideline for indoor comfort in Industrial Buildings.

- They need to follow the rules and regulation in designing an industrial building.
- Sound absorption material should be used for reducing high level of noise, which may cause hearing impairment.
- Natural lighting and ventilation system should be developed.
- Worker and staff facilities should be developed.
- Lighting has to be 500 lux in workshop (Table 1).
- Recommended air temperature ranges between 24° C and 28° C for Comfort and between 28° C and 32° C for Moderate (Table 1).

- Recommended humidity is < 65% for thermal comfort (Table 1).
- Recommended air speed is 0.6 m/s (Table 1).
- In the working environment, for noise levels above 90 dBA, the exposure is restricted. For noise level of 85 dBA, exposures should be averaged over an 8 hour working day (Table 1).
- Temperature should not more than 35° C (Table 1).
- In industry production chain seperation is needed between high internal heat gain spaces to create void between them.
- Introducing high and low level windows will increase cross ventilation.
- The analysis proves that natural daylight can be utilized by using optimized window design. If it is possible to turn off artificial lights, during 50% of the working hours, it will reduce the lighting demand (Naz, 2008).

*Table 1: Indoor Comfort Chart.*

| **Indoor Comfort parameter** | **Comfort value** |
|---|---|
| **Comfort temperature range** | Comfort (24–28)° C ,Moderate (28–32)° C (Chowdhury, Ahmed and Hamada, 2015) |
| **RH** | <65% (Chowdhury, Ahmed and Hamada, 2015) |
| **Air velocity** | 0.6 m/s (Chowdhury, Ahmed and Hamada, 2015) |
| **Light** | 500 lux for workshop (CIBSE, 1989) |
| **Sound** | 85 dBA (Osha, 2011) |

- General guidelines for achieving good IAQ include:

a. Ventilation should be in accordance with the current guidelines established in the American Society of Heating, Refrigerating and Air - Conditioning Engineers (ASHRAE) Standard 62.1, Ventilation for Acceptable Indoor Air Quality.

b. Significant emission sources, such as large copy machines, should be separated from occupied spaces and air intakes.

c. Major sources of chemical or biological contamination should be promptly identified and controlled.

- Molten metal also emits electromagnetic radiation in the furnace and pouring areas. This emission should be controlled in proper way.
- Workers of zinc tank zone are exposed to direct flame; they need to be protected against this flame. Truly non-flammable protective fabrics (as opposed to purely flame-resistant fabrics) offer the highest level of protection.

## 7. CONCLUSION

The population of urban cities regularly suffers from lack of proper planning in industrial area. Urbanization requires more concern before building any industry. As industrial workers play vital role in economic development, their health and safety should be the prime concern. In this study, the basic indoor condition of the production spaces and workers resting space has been studied and a limited number of strategies have been discussed with the help of literature resources. The study identifies strategies that can be adopted as basic design guidelines in the vital work spaces in an industry in order to attain a comfortable working environment. Such strategies can be implemented in the context of local region.

To undertake this research further, building materials can play a vital role in case of indoor comfort. Analysis of building materials via simulation tools can be effective for further study to achieve indoor comfort. Selection of materials can also be emphasized on the basis of seasonal changes to build a sustainable working environment.

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# A CRITICAL REVIEW OF THE MAIN CHALLENGES TO SAFE AND SUSTAINABLE URBAN CITIES

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***Abstract:*** *Gradually there is a budding attention between national governments and international organizations in the involvement of urban centres to sustainable development. Nevertheless, this should not surpass the point that sustainable development does not only finish with environmental agitations but also shields social and economic fields that are reconciled through physical spaces and built form. The paper summaries the innovative global agendas to monitor this: the Sustainable Development Goals, the Paris Agreement and the New Urban Agenda. Then it points out the crucial challenges and opportunities for urban governments across the Commonwealth in executing these agendas and succeeding comprehensive, nonviolent, robust and sustainable cities. This is troubled with substantial infrastructure shortfalls and a deficiency of funding. After delineating the pledges approved by national governments in these comprehensive agendas, this study deliberates the dynamic part in meeting those of city governance, funding and investment, urban planning and indigenous economic progress. This requires proficient and responsible urban governments functioning thoroughly with local people and society, and the redistribution of public funds and improvement support to make them sustainable.*

***Keywords****: Urbanization, Urban growth, Sustainable urban cities*

## 1. INTRODUCTION

The 21st century is recognized as the urban era with further than half the world's population existing in towns and cities. In the South, however, the demographic alteration to a mainstream urbanized state is anticipated to be touched before 2020 (WUP 2005) and in Africa not earlier 2030. Such trend, nonetheless, is vibrant with 'the urban' constantly expanding 'the rural'. In the upcoming two eras, towns in the developing world will captivate 95% of urban progression (UN Habitat 2006). Additionally, the hasty rates of urban growth have directed to the growth of megacities of over 10 million in developing states. In 1975, there were only three megacities in the world: Tokyo, New York and Mexico City. But now in 2005, there were 20 such cities, 16 of which were situated in the developing parts (WUP 2005). Fay and Opal (2000) claimed that the rate of urbanization is not essentially connected with economic growth in cities but that it has a converse bond to the level of urbanization in a country, mostly in the African context. Based on their study of 187 cities in 100 countries, they have pertinently defined this process as urbanization without growth. Marking from a viewpoint critical of conventional neoliberal expansion, Atkinson (2004) approached to a related deduction mentioning that, in southern countries, only about 10% of the people arriving the workforce discover engagement in the formal sector. The enormous majority of the urban populations in these countries are making a living through numerous forms of informal service – a little portion of it safe and well compensated.

## 2. CITIES AS PROCEDURES OF DEVELOPMENT

In current times, cities and towns are known as essential for growth. Cities aid up to 55% of gross national product in low-income nations, 73% in middle-income countries and 85% in high-income countries (UN-Habitat 2006). At the same time, in some circumstances, the influence of a single megacity, for example, Sao Paulo or Bangkok can be as high as 40% of the gross national product but covering only 10% of the population of their particular countries. The part of cities in the progression of national economies is possibly best exemplified in China where development is an overt government policy for hastened economic development. In a parallel

way, local city governments have developed the related demand for housing and property development to immensely increase their revenues through the trade of land use privileges to private developers (Cao and Keivani 2007). The economic character of cities has enlarged even more connotation in the recent time of economic globalization (Keivani *et al*. 2001, Sassen 2001): they assist as focuses for finance and producer facilities; they are areas of modernization and leading the centres of manufacturing and consumer markets. The acute density of people that permits for accumulation economies delivers bigger occasions for reflexivity, material and information sharing, social interactions and more active provision of amenities, mostly health and education. Cities are centres of political power and administration too. The nearer contiguity to the seat of control, their higher meditation and enhanced delivery of their demands through civil societies have intended that in the main urban citizens have better chances for persuading policy-making and setting progressive outlines equally local and national stages.

## 3. RAPID URBAN EVOLUTION

Economic globalization has endorsed for a different international partition of labour and local concentration based on current and developed viable benefits. This research has perceived speedy de-industrialisation in numerous municipal cities in the North and an equivalent progress of greater value corporate facility, knowledge-based and ingenious industries. In London, for instance, concerning 1971 and 2003 the involvement of the manufacturing sector to the city's economy abridged from 25% of total employment to about 6%, while the stakes of business and financial services augmented from 16% to 33% (Harris 2006). In this process, many cities of the South are emerging as international business and industrial nodes, attracting much of the relocated lower value-added industries because of the comparative advantage of their low labour costs and the development of infrastructure and transport capacities for supporting decentralised production and access to the world markets (Sassen 2002, Keivani and Mattingly 2007). Other evolving inclusive cores from Bangalore, to Bangkok and Shanghai to Sao Paulo, are also ensuing suit with diverse grades of accomplishment as regional centres, placing themselves to attain the similar sort of global purposes. Globalisation is extremely prevalent distressing not only the huge accumulations but also several minor cities, towns and even villages and peri-urban zones. Major examples can be comprehended in the economic reformation in villages and small towns adjoining main capitals. Leaf (2002), for instance, emphasised the conversion of agronomic villages around Guangzhou in China and Hanoi in Vietnam to one or the other upper income residential domains for the new middle classes or small-scale industrial centres feeding production in the central urban zones. Equally, this study can also take agricultural share in rural farms in Zambia and Mozambique by stakeholders from Zimbabwe and South Africa or the enlargement of major rural eco-tourist purposes appealing visitors from across the world. Conceivably even more intensely, any can communicate current large-scale agricultural investments by the United Arab Emirates in Sudan to confirm an amount of food security in indefinite market circumstances in the Persian Gulf (Sudan Tribune 2008). Further vital considerations in relation to the influence of globalization on cities contain large scale labour relocation and remittances. This can either be local or global. The up-to-date World Bank data for 2008 specify that international remittances belong to developing countries as a total accounted for $338 billion amounting to almost 1.9% of GDP in these countries (World Bank 2009a, 2009b).

## 4. TOWARDS SUSTAINABILITY OR NOT?

### *4.1. Enormous growth of population*

The circumstance that cities generate wealth, allow universal economic purposes and propose better life prospects for their residents does not contradict the encounters they pose for sustainable expansion. On the social front, cities are disposed to vast intra-urban social dissimilarities. In the 2005 Bristol Accord, the European Union positioned the growth of sustainable communities at the core of its urban policy highlighting between other things inclusivity, impartiality, equality, good governance, security and convenience (ODPM 2006, Colantonio 2007). All of these apprehensions also relate with many cities of the South but they are also challenged with the far more austere context of relative and total levels of poverty and segregation. There are nearly a billion people existing in slums in cities throughout the developing world – one out of each three city inhabitants (UN-Habitat 2006). The rate of development of the world's urban population assessed at 2.24% is unevenly equivalent to the rate of growth of slums projected

at 2.22%. The same facts for Sub-Saharan Africa are 4.58 and 4.53%. In addition, this study observing what Nicholas You (2007) defined as the urbanization of poverty where the urban population is possible to grieve from malnourishment, disease and hunger as their rural equivalents. A main apprehension in many cities that also highlights economic inadequacy and the environmental side effects of speedy urbanization is the often impervious, special and inexplicable grace of urban governance and management foremost to tilted and exclusive decision-making. However, such social and communal complications are being addressed in several cities at diverse stages and by dissimilar institutions. Favourable initiatives can be recognized in the current shifts in slum upgrading towards more united methods. For example, in Brazil, inclusive slum upgrading programmes relate employment and income generation with physical revitalisation and the combination of slum neighbourhoods into the city fabric.

### *4.2. Economic circumstances*

On the economic base many cities in both the North and South are encountered with austere challenges for sustainable economic growth. Cities in the North are belligerent with the later impacts of large-scale economic rearrangement in a speedily globalizing period that has perceived loss of main industries and earlier economic characteristics. Many have been efficacious in revolving around their chief economic base (e.g. Birmingham, Barcelona). Related concerns are also apparent in cities of the South. Concentrating severe stages of income poverty through constant policies for local economic expansion and income-generating chances for low-income households is of direct significance to both social and environmental enlargement in cities of the South. Positive involvements comprise new advanced schemes for better operating corporate social accountability initiatives and participatory budgeting to better mark what is really required on the ground and to substitute community possession. The principal example of this is perchance seen in Porto Alegre that founded participatory budgeting in 1989 and according to some evaluations it has currently been accepted in over 1200 municipalities globally in both southern and northern cities (Wikipedia 2010).

### *4.3. Environmental concern*

Based on environmental issue, this study confronted with numerous different but interrelated issues with diverse grades of impact in northern and southern cities. First are the universal anxieties over the discharge of greenhouse gases (GHG) and their effect on the global climate. However, this is an inclusive problem that necessitates a worldwide solution. A latest research by Urge-Vorsatz and Novikova (2008) showed that the highest economic prospective for mitigating $CO_2$ emissions in buildings deceits in developing countries. It is possible because of many of the low-cost prospects for $CO_2$ diminutions have already been taken in the more developed economies because of advanced policies in place. Moreover, it is also essential to deliberate the ability of actors to efficiently impose the appliances of environmental policy. Lastly, reminder must be reserved for more critical arguments highlighting typical alterations from what is measured to be the present overriding neoliberal development model mostly based on constant growth and extreme depletion to more organized growth and community-oriented development options (Atkinson 2004, 2007). Another concern is the adverse impact of climate change on human settlements which perceived in current floods, increased heat waves and frequent hurricanes in Europe, the Caribbean and North America. These have imposed adaptation actions for facilitating cities to survive better with a progressively impulsive climate and other natural hazards. With this study it can be addressed that the extreme destructive impacts of environmental change and natural hazards are found in the informal settlements of the South which are often based on unstable construction, acutely sited and under-serviced and are mostly disposed to austere climatic and natural circumstances (Wilbanks *et al*. 2007). Further concerns connect with overall environmental pollution, supply management and damage of agricultural land due to massive urbanization, urban sprawl and industrial events. This has certain quality in northern cities but the key concerns exist in developing countries chiefly because of weaken institutional ability to implement guidelines and accomplish natural resources. For example, in China more than one third of industrial wastewater and two thirds of municipal wastewater is unconfined into waterways without any treatment action (Wen 2005). This reveals that about 60% of the country's major rivers are currently considered as incongruous for human interaction. Similarly, several Chinese cities observe austere air pollution and with some researches appealing that it states some 300,000 lives precipitately (Wen 2005). Several study also illustrate that though

pollution primarily rises but with increasing incomes and high economic progress the authentic rate of pollution really lessens and is ultimately overturned which has been renowned in the decreasing drifts in the invention of particulate air pollution throughout the 1990s in Chinese cities, Mexico City and Cubatao in Brazil which was identified as the valley of death previously because of its austere industrial air pollution (Wheeler 2000). Nevertheless, all the examples more or less focus the negative impacts of restricted attitudes to sustainable development and environmental security.

### *4.4. Access to services and basic infrastructure*

This study discovers the findings from Werna (2009) that in various southern cities, lack of access to basic services is not only a key disorder to sustainable economic growth and efficiency but also a main reason of urban imbalance and poor well-being (Werna *et al*. 2009). Even with current international data that specify that 95% of urban populations in developing nations have basic access to drinking water (World Health Organisation/UNICEF 2006). In various circumstances, access can refer communal taps rather than genuine household connections. Furthermore, half or one-third of those that are linked just acquire sporadic access. In India, for instance, a research based on 35 urban foci signifying 15% of the urban population of the country initiated that water was delivered on average only 7 hours per day (Nickson and Franceys 2003). Obviously, ascending to the level specified is a colossal task in various developing countries as there is lack of material, financial and human capitals. Normally, it develops even more intimidating to contemplate that a huge portion of the population in developing towns live in slums and squatters informally where local authorities face disappointments in providing services because of the unlawful prominence of the settlements or due to hazardous locations and unintended layouts that make allowance of services so tough even if governments were ready to encompass them (Nickson and Franceys 2003). Sometimes poor households need to pay merchants more than a few times the unit price compensated by related non-poor households to the service (Gulyani *et al*. 2005). The state with access to electricity, sanitation and waste collection is perpetually shoddier than that of water. These have main inferences for social and economic enlargement as well as aggravating environmental effluence because of practise of exposed ground or unlined pit latrines for sanitation or insufficient removal of household and industrial garbage in some cities (Werna *et al*. 2009). Subsequently, more responsiveness requires to be ensured to precise policy and technical methods that offer more instant resolutions that contain the prospective for ascending up to mark a palpable influence on the condition of the low-income clusters especially in developing cities. For example, Christoph Lüthi *et al*. claim for merging Household-Centred Environmental Sanitation and Community-led total Sanitation in responding the encounter of sanitation in such a sustainable way in urban and peri-urban extents. All of these are perceived to amalgamate the paybacks of both a community led and a structured planning method carrying into behavioural change and multi-stakeholder participation required for delivering additional sustainable interpretations.

### *4.5. Sustainable urban development*

Urban form and spatial expansion have foremost consequences on the sustainable development including not only environmental concerns but also focus on social and economic features. The notion of green and sustainable city development targets to improve energy use, endorse renewable energy sources, deliver combined transport networks with a emphasis on augmenting public transport and bi-cycle lanes, make sure to transform the tradition of energy and resource depletion and rise social attachment (Jenks and Jones 2010). Eventually, with those actions would also boost up economic efficiency from better connectivity and saving of resources. A significant deliberation under this captions the effect of key urban development and infrastructure projects commenced by both the public and the private divisions along with straight concerns on all features of the sustainability standard. These enlargements are sometimes foreign direct investment focused and universally persuaded intended at growing city effectiveness but must unexpected and incapable externalities. In southern towns, nevertheless, they frequently impact on informal low-income communities with perilous tenure privileges and income-generating prospects or labourer groups (Keivani and Mattingly 2007, Werna *et al*. 2009). The fact is they can make direction to key social rigidities, mostly as a consequence of enforced shift with insufficient social and financial reimbursement, depriving of local necessities and daunting leading governance practices. For example, such effects can be observed cities in both the North and the South though the rate of

improvements and the range of displacement have inclined to be much greater (Swyngedouw *et al*. 2002, Keivani and Mattingly 2007, Werna *et al*. 2009). However, they can improve the city economy too and have the latent for local economic expansion promoting the lower income clusters and small and medium local initiatives. The vital concern is to create the suitable institutional framework and good governance practices for overall policy-making and implementation that would permit for further stable and pro-poor attitude to urban spatial institute, land use and reasonably priced housing augmenting both global and local evolving paybacks. Moreover, speedy and vibrant urban development in developing cities sometimes heads to different shapes of accumulation in peri-urban zones with their individual exclusive social and economic encounters, prospects and developmental significances. The negative factor is circled with the enormous evolution of gated communities for the middle and higher income clusters that often impose on marginal land engaged by poor slum tenants and peri-urban rural communities and generate certain problems of social segregation and so unfit within the wider urban material. A predominantly austere instance of this can be perceived in the Metropolitan Area of Buenos Aires where Thuillier (2005) pointed out that there are approximately 350 gated communities, covering 300 km2 of land, and holding approximately 50,000 long-lasting inhabitants. This can contain advanced sociotechnical tactics that can pursue to offer both helpful institutional outlines and financial and technical provision for an extent of processes including physical promotion and renovation, advanced and low-cost manufacturing resolutions and green adaptation encircling both energy convertible actions and reasonable renewable energy skill.

### *4.6. Good governance practice and institutional capability*

According to the earlier discussion, urban governance and institutional capability are underlined as crucial necessities for covering the main encounters for urban sustainability. Governance mentions to the procedure of conveying government through the insertion of non-government actors (Jones and Evans 2006, Werna *et al*. 2009). From a multi-scale governance viewpoint, vital contemplations are (i) the capability and synchronization between the upright stages of government and (ii) straight levels of governance including both the intercontinental and intra-city connections and outlines of governance between diverse city government constructions and also the power associations and networked interface among diverse public, private and community actors in judgement creating and policy background at local and municipal levels and the approach that they nourish into upper levels of decision-making process (McGuirk 2000, Rakodi 2004a, 2004b, Corfee-Morlot *et al*. 2009). Any sort of conversation of governance must reflect the impact of strategic development for permitting bendable reactions to ambiguous urban prospects principally in the circumstance of overall economic globalization and frequent climate change. This attitude has been accepted in the towns of the North since the initial 1980s in their exertions to flourishing themselves in the context of austere economic catastrophe and loss of their further traditional activities. This has directed to a propagation of numerous short to long-term economic and development policies at mutually metropolitan and city district stages. Partially based on this involvement and acknowledgment of the multi-faceted complications of economic and physical progression in cities, since 1998 the World Bank and later the Cities Alliance have promoted the implementation of city development strategies (CDSs) in developing countries as a solution of delivering a all-inclusive planned method for countering the core alleged challenges. The detailed goals of a CDS are:

- improving city economies,
- lessening poverty,
- defending the environment,
- developing indigenous revenue-raising capability and city fiscal supervision.

In 2009 more than 200 CDSs had been expressed and applied in diverse cities across the globe with different grades of achievement. Some critics have claimed that CDSs and tactical planning intended at reinforcing economic affordability are local solicitations of the 'Washington consensus' and the neoliberal growth archetype that will strengthen historical configurations of social and spatial segregation. At the same time, a further optimistic and practical view claims that except city leaders have a planned indulgent of the faults, asset and capacities of their cities and where they suit much inside the wider national and regional economies they cannot really receive operative accomplishment to address their inadequacies. According to this standpoint CDSs and strategic urban planning must have a part to play and are

really important for delivering such a planned perception which can monitor follow-up activities.

## 5. CONCLUSION

In this paper, this research tried to highlight the main encounters that the world faces in terms of urban sustainability. This study highpoints the multi-faceted context of the sustainability argument in different towns and cities where huge deliberations of people and events have generated a innumerable of multifarious social and economic encounters with habitually austere environmental significances containing the extreme impact to atmospheric, water and ground contamination. However, cities also deliver the maximum capacity and latent for encountering several of these problems. The similar attentions of people that trigger the encounters also deliver the accumulation economies for more competent use of assets and endowment of facilities and the space for better modernization and efficiency. In the recent time of speedy global assimilation, both the intimidations and prospects for attaining more sustainable cities have enlarged. From one perspective, for instance, cities and towns are disposed to risks related with augmented worldwide economic instabilities, encounters between local requirements and global capital necessities in terms of access to city assets and public venture, enlarged threat of social and cultural estrangement and hasty growth in energy practise and effluence as an outcome of enduring inclusive economic development. On the other perspective, economic globalization can also enhance city economic enactment with further prospects for engagement and local economic growth. The point to which native population and inferior groups can assistance from these fluctuations mostly relies on good governance policy and decision-making that can accomplish the procedure to boost up local profits and offer a well stability between global and local significances. Furthermore, although the appearing disappointment of the 2009 Copenhagen Summit in background fresh officially binding goals on GHG decreases, global and regional environmental governance arrangements are being advanced. Such as Adrian Atkinson has illustrated in his input to this matter of IJUSD, the achievement of such governance constructions is basically reliant on the valour of the political leaders and definitely their capacity to encounter with what is essential to control and converse the threats of global warming. Such types of governance arrangements deliver the base for sophisticated policy discussion on the theme that can have an actual impression at the local stage, e.g. Rio and Kyoto contracts on $CO_2$ lessening goals. However, some countries have decelerated $CO_2$ discharges that sanctioned the contract, delivering the recognized framework for evolving and executing operative and obligatory antipollution actions at the very local stage. Subsequently, Williams categorizes two foremost encounters that must support future investigation: (i) realizing 'what the sustainable city is and its context' and (ii) 'how to carry out overall sustainable urban development'. These encounters demand the consideration of diverse viewpoints on urban sustainability that possibly will help to change the traditional mind set of city leaders and policy makers that are related with urban development. This is precarious for shifting towards larger compromise on basic explanations and evolving further operative policy and sociotechnical resolutions to exact concerns. Extensive distribution of the arguments across diverse sectors will support to accomplish cultural modifications too among academic, specialist and public participant clusters which can be key modules for additional fundamental typical changes. It is to be noted that millions of urban inhabitants within the Commonwealth have very insufficient earnings and survive in meagre class, overloaded housing which are basically lack of adequate infrastructure and facilities.

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# BIOMIMICRY INSPIRED ROOF DESIGN FOR DAYLIGHTING MULTIPURPOSE HALL

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***Abstract:*** *In institutional buildings multipurpose hall is often the single large interior space that relay majorly on artificial lighting while conducting functions during day hours which mostly coincide with daylight hours. Maximum use of daylight in building design is necessary to reduce the energy demand created by artificial lighting during day hours. Studies show that electrical lighting energy use can be reduced by 25-50% with advanced lighting sources, design strategies and controls; and by 75% with the addition of daylighting. Modification of the multipurpose hall roof inspired by Biomimicry concept which is based on the study of nature´s models (designs and processes) as an inspiration to be replicated to solve human problems, could be an effective option for daylighting to ensure energy savings and visual comfort. The aim of this paper is to explore the opportunities of creating biomimicry designs of a multipurpose hall roof and analyse the effectiveness of different biomimicry inspired roof configurations to ensure maximum use of daylight to ensure energy savings and visual comfort of users. The 3D models of case multipurpose hall with different biomimicry inspired roof strategy were first generated in the ECOTECT. Then, the decisions were verified with DAYSIM simulation program to ensure the compliance of the decisions with dynamic annual climate-based daylight performance metrics. A roof configuration based on morphodesign approach, (i.e. generated from shapes and structures of Dolichopteryx Longpipes fish eye) was found as most superior biomimicry inspired configuration among the four studied options for multipurpose hall in educational building in context of Bangladesh. It is expected that, the findings of this research will inspire architects and designers to adapt the concept of biomimicry in improving design especially for proper daylight distribution in architecture design through the roof.*

***Keywords:*** *Biomimicry, multipurpose hall, roof configurations, daylighting, simulation*

## 1. INTRODUCTION

Architecture is one of the major biomimetic fields demanding to learn from the nature to enhance and improve living environment. This approach helps in discovering new techniques and concepts that can enhance the building systems (Debnath, 2014). In terms of design application, biomimicry often considered as a way of understanding the process of creative thinking and creative problem solving (Looker, 2013), through the mechanism of traducing principles of a living organism function and turning it into a solution of a problem (Volstad and Boks, 2012).

The term 'biomimicry' first appeared in scientific literature in 1962 and grew in usage particularly amongst material scientists in the 1980s. Some scientists preferred the term 'biomimetics' or, less frequently, 'bionics' (Pawlyn, 2011). Vincent (2006) defines it as 'the abstraction of good design from nature'; while for Benyus (1997) it is 'the conscious emulation of nature's genius'. It starts with study of figures, propositions, forms and structure. It was not until the end of the 20th century it became possible to adopt natural processes and ecosystems in built environments (Bar-Cohen, 2011). This approach helps in discovering new techniques and concepts that can enhance building systems. This area of research struggles to define the discipline as 'mimicking the functional basis of biological forms, processes and systems to produce sustainable solutions'. In order to ensure a

sustainable development, now-a-days many researchers have focused on biomimicry (Yanez, 2014; Volstad and Boks, 2012).

On the other hand, the use of daylight as the principle light source is an integral part of sustainable buildings, because daylighting has been recognized as a useful source of energy savings and visual comfort in buildings (Sharmin, 2011). Designers often tend to rely on electric lighting due to lack of daylighting provision in the buildings. Multipurpose halls in academic buildings are primarily used for seminars, conferences, debate competitions, workshops, juries, exhibitions and similar functions, where individuals in the room rightfully expects to get the clear vision of the event or performance. Preliminary observations show that, most of the time multipurpose halls located in different universities of Bangladesh function under artificial means. This not only fails to provide a stimulating environment for better visual communication 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 the compact urban context of Bangladesh fail to provide adequate daylighting during daytime into the multipurpose halls (Figure 1). Artificial lighting becomes necessary in the rooms to run the events. Without having adequate daylight, usage of artificial lighting for a longer period can create serious damage to human body and productivity. Strategies for improving luminous environment in multipurpose halls should be established for incorporation in the design process. This paper proposes and analyses concept of biomimicry and biomimicry inspired roof configurations for getting maximum utilization of sun power. Simulation programs (ECOTECT and DAYSIM) were used to analyse different roof strategies by mimicking nature to indicate suggestions for improving day lighting in the multipurpose hall.

*Figure 1: Multipurpose halls at different private Universities in Bangladesh.*

This paper consists of three major parts. The concept and importance of biomimicry 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 biomimicry philosophy and develop methodologies to apply biomimicry in daylit building design.

## 2. LITERATURE SYNTHESIS

The Biomimicry Institute (founded by Janine Benyus in 2006) created a design spiral methodology to help designer to adopt and practice biomimicry (Figure 2). Research held in Georgia Institute of Technology by Michael Helms, Swaroop S. Vattam and Ashok K. Goel, at the Design Intelligence Lab in 2006, also defined this approach through six definite steps, which are very similar to those defined by the Biomimicry Institute (Helms et al. 2009):

- Step 1: problem definition
- Step 2: reframe the problem
- Step 3: biological solution search
- Step 4: define the biological solution
- Step 5: principle extraction
- Step 6: principle application

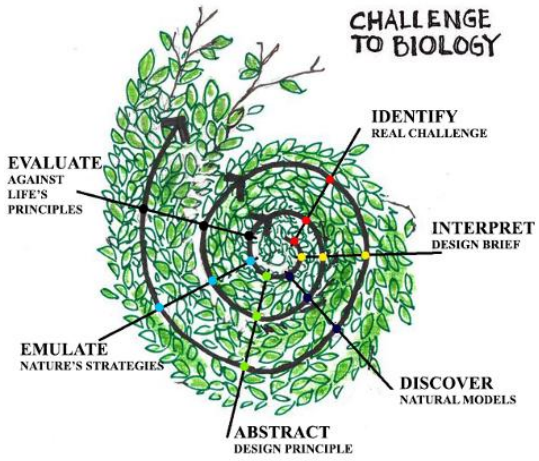



*Figure 2: Biomimicry Institute's Design Spiral methodology (after, Yowell, 2011)*

The importance of an appropriate visual environment for knowledge sharing tasks deserve careful consideration of appropriate daylighting to develop learners' behaviour, stimulates learning (IESNA, 2000) and thus promotes 20% improvement in performance (Jackson, 2006).

The minimum maintained illuminance on desks for regular work is recommended as 500 lux (CIE, 2004), however the 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 (2000) for space with both computer task and regular paper tasks is 300 lux to 500 lux. According to Bangladesh National Building Code (BNBC, 2006), the recommended illumination levels for multipurpose hall in educational buildings in the context of Bangladesh are 150 lux (general) and 300 lux (lecture, examination, platforms and similar functions) respectively.

Buildings in general e.g. office, school and industry use 40% of the total consumed energy for lighting (Lechner, 2001). Bangladesh is a developing country with shortage of energy supply. As most of the educational buildings operate during the daytime and multipurpose hall in educational building is always an active place; therefore, daylighting can reduce high energy consumption for lighting purpose in educational buildings.

## 3. METHODOLOGY

### *3.1. Case Room Selection*

The criteria for selection of the 'Case Multipurpose Hall' were following.

- Location of the hall would be in the urban context.
- The case hall room should be designed or renovated for multipurpose hall purpose.
- The hall room should be located at the top floor of the building and have the provision of allowing daylight to enter through roof.
- There should be no shadows on the roof top caused by surrounding (tall) buildings that can obstruct daylight to enter from top.
- The activity pattern and internal layout of the hall room should represent current practice of multipurpose hall design in a typical academic building of Bangladesh.

Considering the above criteria, the multipurpose hall located on the top floor at Premier University (PU), Chittagong, Bangladesh (Figure 3) was chosen as the case hall (Figure 4 and 5). The hall is a rectangular 208.7 sqm (21.3m x 9.8m). Major problem seems that there is no window in this hall and due to exterior design purposes side windows were not recommended but during daytime light is often necessary for different kind of programs such as seminars, workshops, conferences, debate competitions and academic meetings (Figure 5). During physical survey, following was recorded.

- **South facade:** Solid; Material: Blue painted wall.
- **West facade:** Solid; Material: Blue painted wall.
- **East facade:** Solid; Material: Off-white painted wall and a white board
- **North facade:** Solid; Material: Blue painted wall.
- **Interior Walls:** Brick with Plaster.
- **Floor:** 21,000 mm long and 10,000 mm width with Glazed tiles.
- **Ceiling:** Solid; Material of false ceiling: gypsum board.
- **Stage (East):** 5700 mm X 4200 mm.
- **Height of the hall:** 3000 mm.


*Figure 3: Premier University (PU) with surrounding context.*

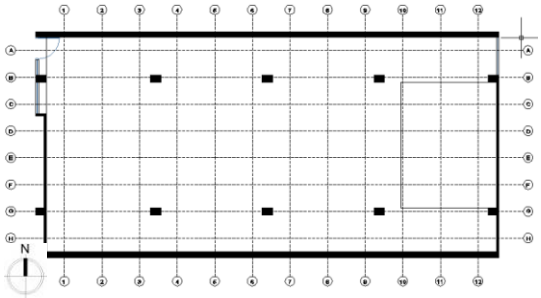


*Figure 4: Plan of PU Multipurpose hall*

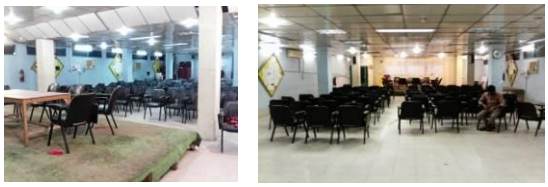


*Figure 5: Case multipurpose hall at PU*

### *3.2. Generating design concepts*

Two kinds of design concepts can be applied for the case hall: a morphodesign that is related with shapes and structures; and physiodesign that is related with function and materials (Yanez, 2014). As this research is focused on architectural design, it is more sensible to approach for morphodesign. Investigated options of the design of the roof of case hall was evolved from shapes and structures of the eye of a fish (Dolichopteryx longpipes) and materials (i.e. mirror) and functional aspects are not considered as described below.

***Dolichopteryx Longpipes:*** This fish (Figure 6.a) has an interesting ocular system; the main eyes are supported by a structure called diverticulum (Figure 6.b) that allows capturing light to recognize objects from horizontal and below directions, in the diverticulum, there is a cell mirror that reflects light aiming to the retina (Figure –6.c) (Wagner, 2008; Yanez, 2014).

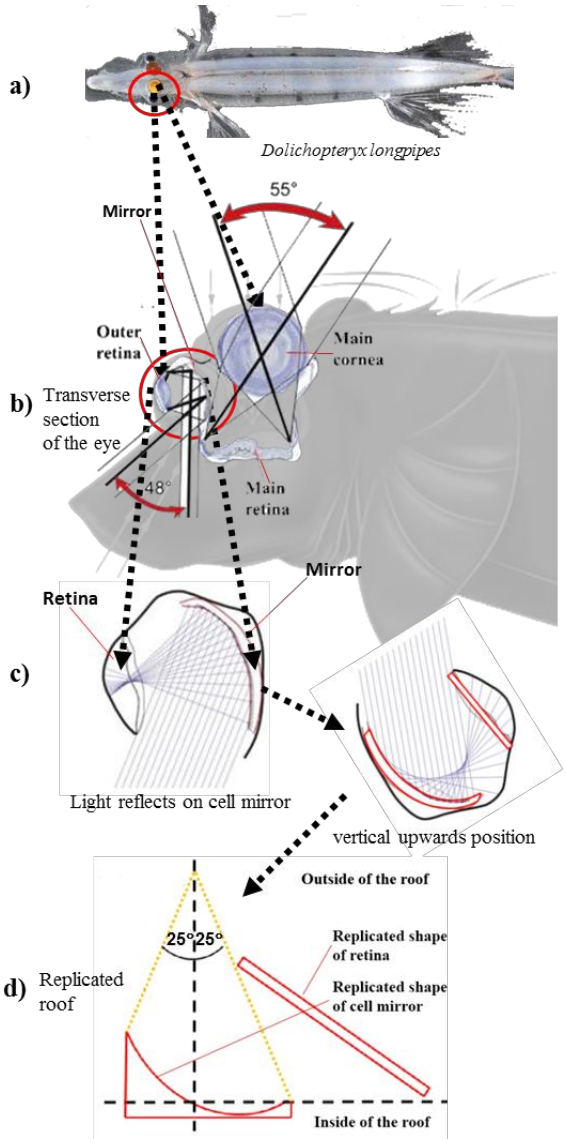



*Figure 6: Concept of replicating the cell mirror on a rooftop (after Wagner, 2008 and Yanez, 2014).*

### *3.3. Modelling Parameters*

The sun on the orientation north and south covers 50° (Yanez, 2014) and the mirror can receive a range of 48° (Figure 6.b). The same mechanism could be used as shown in replicated roof (Figure 6.d) as biologically and geographically the range of angle is similar (48° vs 50°). Based on this principle of work of previous researchers (Wagner, 2008; Yanez, 2014) by mimicking the retina study of the Dolichopteryx Longpipes and the cell mirror study (Figure 6) for the case hall model, four roof

configurations were proposed in this paper (Morpho 01 – 04: Figure 7) and were analysed through simulation study. The height of each configuration is 900 mm and the opening sizes considered for each configuration are: 650 mm upper level and 750 mm adjacent slab level (Figure 8).

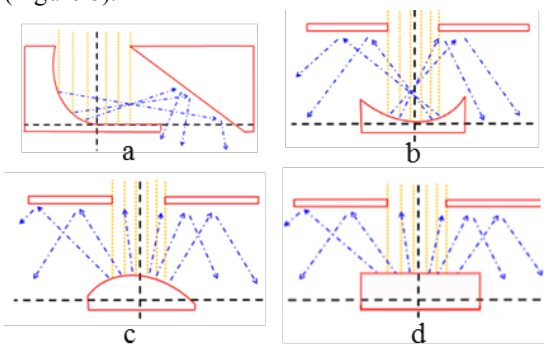



*Figure 7: a) Morpho 01: concept of replicating the cell mirror with vertical position b) Morpho 02: design with horizontal position c) Morpho 03: design with divergent; and d) Morpho 04: flat platform (Yanez, 2014).[ Sun rays are colored as yellow and reflected light as blue].*

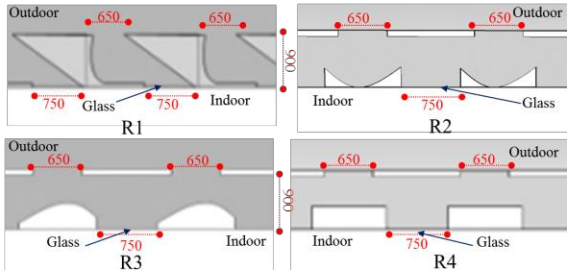



*Figure 8: Four roof configurations (R1, R2, R3 and R4) of case hall of PU for the simulation study generated from Morpho 01 - 04 (Figure 7).*

### *3.4. Climatic Parameters*

For the simulation, the quantitative and qualitative assessments for the different design configurations were based on the following parameters.

- Location: Chittagong, Bangladesh (91.48 E; 22.22 N).
- Calculation settings: Full Daylight Analysis.
- Precision: High
- Local terrain: Urban.
- Window (dirt on glass): Average,
- Duration for dynamic simulation: Whole year.
- Illumination threshold: 300 lux (BNBC, 2006).

### *3.5. Simulation Tools*

Through the process of applying biomimicry to technical designs, one of the most helpful and powerful tools, is the modelling of designs to test them using software (Yanez, 2014). 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 (2002) showed in his research that the mean error of the estimated results of ECOTECT is less than 2%, indicating a reasonable degree of accuracy. On the other hand, DAYSIM allows users to model dynamic facade 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), Maximum Daylight Autonomy (DAmax), and Useful Daylight illuminance (UDI) can be measured by DAYSIM.

### *3.6. Evaluation Process*

For the simulation study, four morpho design concepts (Figure 8) generated from literature synthesis was considered by incorporating biomimicry inspired roof configurations of case multipurpose hall. 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 difference of the impact of the different roof configurations being assessed. Floor of case room was divided into 77 intersecting grid points to analyse the daylight levels on horizontal surface, at 450 mm (18 inch) above floor level (Figure 4). For the evaluation, specified sensor points were coded as 3E to 10E (Figure 4). Firstly, the models were generated by 'ECOTECT' software. Then, the models were exported to DAYSIM simulation exercise for getting hourly daylight data for the whole year, generated at each specified sensor point (Figure 4). Finally, the impacts of different biomimicry inspired roof configurations were

evaluated. Finish materials were used in the model for simulations as found during the field survey (Section 3.1).

## 4. RESULTS

Table 01 presents the performance of R1 (Figure 8). The average DA level for points, 3E to 10E is 89.4%, average DA max is 13.6% and average UDI below 100 lux is 2.8%, between 100 lux-2000 lux is 71.8% and over 2000 lux is 26%. The DA value is around 90% i.e quite satisfactory but the UDI value over 2000 lux is 26% i.e. too high.

*Table 01: Dynamic performance of model R1*

| Sensor points (lux) | DA [%] | DA max [%] | $UDI_{<100}$ [%] | $UDI_{100-2000}$ [%] | $UDI_{>2000}$ [%] |
|---|---|---|---|---|---|
| 3E | 83 | 0 | 4 | 95 | 2 |
| 4E | 93 | 9 | 2 | 70 | 28 |
| 5E | 95 | 23 | 2 | 60 | 39 |
| 6E | 96 | 24 | 2 | 58 | 41 |
| 7E | 95 | 25 | 2 | 59 | 40 |
| 8E | 94 | 19 | 2 | 60 | 38 |
| 9E | 90 | 9 | 2 | 78 | 20 |
| 10E | 69 | 0 | 6 | 94 | 0 |
| Average | 89.4 | 13.6 | 2.8 | 71.8 | 26 |

The performance of R2 (Figure 8) shows the average DA level for points, 3E to 10E is 89.1%, average DA max is 4.9% and average UDI below 100 lux is similar to R1 which is 2.8% and quiet satisfactory. UDI value between 100 lux-2000 lux is 77.3% and over 2000 lux is 20.3% (Table 02) i.e. still too high.

*Table 2: Dynamic performance of model R2*

| Sensor points (lux) | DA [%] | DA max [%] | $UDI_{<100}$ [%] | $UDI_{100-2000}$ [%] | $UDI_{>2000}$ [%] |
|---|---|---|---|---|---|
| 3E | 82 | 0 | 4 | 96 | 0 |
| 4E | 94 | 1 | 2 | 74 | 24 |
| 5E | 94 | 9 | 2 | 65 | 34 |
| 6E | 94 | 11 | 2 | 67 | 32 |
| 7E | 94 | 11 | 2 | 65 | 33 |
| 8E | 94 | 7 | 2 | 68 | 30 |
| 9E | 89 | 0 | 2 | 89 | 9 |
| 10E | 71 | 0 | 6 | 94 | 0 |
| Average | 89.1 | 4.9 | 2.8 | 77.3 | 20.3 |

The DA performance of model R3 (Figure 8) is better than previous models i.e. 91.6% but the other values are not satisfactory especially DA max is 19.3% and UDI>2000 is 31.1% i.e. higher than R1, R2 and have possibilities of glare and heat problems (Table3).

*Table 3: Dynamic performance of model R3*

| Sensor points (lux) | DA [%] | DA max [%] | $UDI_{<100}$ [%] | $UDI_{100-2000}$ [%] | $UDI_{>2000}$ [%] |
|---|---|---|---|---|---|
| 3E | 86 | 7 | 3 | 88 | 9 |
| 4E | 95 | 20 | 2 | 61 | 37 |
| 5E | 96 | 28 | 2 | 56 | 42 |
| 6E | 96 | 32 | 2 | 51 | 48 |
| 7E | 96 | 30 | 2 | 53 | 45 |
| 8E | 95 | 25 | 2 | 58 | 41 |
| 9E | 91 | 10 | 2 | 74 | 24 |
| 10E | 78 | 2 | 4 | 93 | 3 |
| Average | 91.6 | 19.3 | 2.3 | 66.8 | 31.1 |

Model R4 (Figure 8) is resulting much more satisfactory result compare to R1, R2 and R3. The DA value is more than 90% and DA max is only 2.5% and UDI <100 is 3.8%, UDI is in between 100-2000 lux is almost 90% and over 2000 lux is only 6.3% (Table 04).

*Table 4: Dynamic performance of model R4*

| Sensor points (lux) | DA [%] | DA max [%] | $UDI_{<100}$ [%] | $UDI_{100-2000}$ [%] | $UDI_{>2000}$ [%] |
|---|---|---|---|---|---|
| 3E | 82 | 0 | 6 | 94 | 0 |
| 4E | 94 | 3 | 3 | 93 | 5 |
| 5E | 94 | 4 | 2 | 87 | 11 |
| 6E | 94 | 4 | 2 | 84 | 14 |
| 7E | 94 | 3 | 2 | 88 | 9 |
| 8E | 94 | 3 | 2 | 90 | 7 |
| 9E | 92 | 3 | 4 | 92 | 4 |
| 10E | 80 | 0 | 9 | 91 | 0 |
| Average | 90.5 | 2.5 | 3.8 | 89.9 | 6.3 |

Table 5 shows comparison of average dynamic daylight metrics for the studied four configurations (R1-R4: Figure 8). Use of rating system for the simulated performances, presented in Table 6 shows the ratings of the four options considering different metrics. From 1st to 4th place ratings, points were considered as '3' to '0' points respectively (Reinhart et al., 2006).

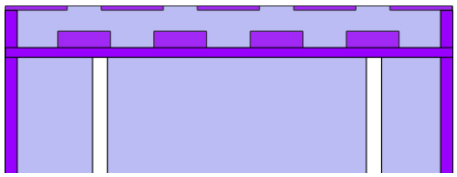
*Table 5: Comparison of dynamic daylight simulation mertics (average).*

| Sensor points (lux) | DA [%] | DA max (%) | $UDI_{<100}$ [%] | $UDI_{100-2000}$ [%] | $UDI_{>2000}$ [%] |
|---|---|---|---|---|---|
| R1 | 89.4 | 13.6 | 2.8 | 71.8 | 26 |
| R2 | 89.1 | 4.9 | 2.8 | 77.3 | 20.3 |
| R3 | 91.6 | 19.3 | 2.3 | 66.8 | 31.1 |
| R4 | 90.5 | 2.5 | 3.8 | 89.9 | 6.3 |

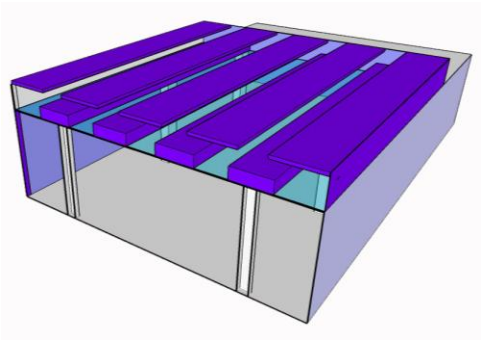
After summing the ranking (Table 6), it can be stated that R4 configuration generated from morpho 04 (Figure 9) room was found as most superior biomimicry inspired roof configuration among the four studied options for the case hall.

*Table 6: Rating of the options provided with different biomimicry inspired roof configurations.*

| Code of Roof | DA [%] | DA max (%) | $UDI_{<100}$ [%] | $UDI_{100-2000}$ [%] | $UDI_{>2000}$ [%] | Rating and Ranking |
|---|---|---|---|---|---|---|
| R1 | 1 | 1 | 2 | 1 | 1 | **3rd (6)** |
| R2 | 0 | 2 | 2 | 2 | 2 | **2nd (8)** |
| R3 | 3 | 0 | 3 | 0 | 0 | **3rd (6)** |
| R4 | 2 | 3 | 0 | 3 | 3 | **1st (11)** |



*a) Section*



*b) Perspective*

*Figure 9: Model R4, the superior biomimicry inspired roof configuration among the studied options for the case hall.*

To understand and to interpret how nature works is not an absolute truth nor there is one way to do it. The biomimicry design process is based on the natural principles but it should not be a limitation to modify the characteristics of the design if they are ineffective to meet the design aims, therefore the designers should adapt the principles to their own necessities in the design goals (Yanez, 2014). Same mechanism has been used in this paper. The original idea is not conceived in that way, the position of the mirror is vertically downwards so the fish can collect light from the bottom of the sea but the replicated shape is considered as vertically upwards so that it can receive lights from outside of the roof (Figure 6.b and 6.d). Later the shape is considered as horizontal position and converted to divergent and flat platform sequentially (Figure 7).

## 5. CONCLUSION

This reserach is an investigation of biomimicry to maximize the use of daylight during the day for a multipurpose hall in educational building and presents the development of a design method based on biological principles that are applied and correlated with morphogenetic computational design. Results from dynamic simulation indicate that, a roof configuration based on morphodesign approach, (i.e. started with shapes and structures of Dolichopteryx Longpipes fish eye) as the most superior biomimicry inspired configuration among the four studied options for multipurpose hall in educational building in context of Bangladesh. Thus, roof configurations inspired from natural principle can achieve suitable daylighting for a multipurpose hall. It is expected that, the findings of this research will inspire architects and designers to adapt the concept of biomimicry in improving design especially for proper daylight distribution in architecture design through the roof.

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# SUNDARBAN VILLAGE IN DINAJPUR:
## A CASE TO EXPLORE INDIGENOUS MATERIALS AND BUILDING TECHNOLOGY FOR SUSTAINABLE RURAL DEVELOPMENT

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***Abstract:*** *The need to promote local technology with local resources comes from the desire to make long term sustainable development by holding onto local culture. Materials such as, mud, thatch and bamboo are available in the rural areas of Bangladesh. Rural people are used to build their houses with these indigenous materials in a traditional way. The sustainable and vernacular tradition of homesteads went through major transition in the last century and the natural materials have been replaced with artificial and energy inefficient materials e.g. corrugated iron (CI) sheet, burn brick and cement. Manufacturing and production of these artificial materials contribute to pollution, deforestation and depletion of fertile top soil. On the other hand, simple strengthening improvements of mud and bamboo construction houses can increase 25% of the total construction cost, in return will increase the longevity by five times. The paper demonstrates innovative and practical intervention of contextual construction technique by a NGO, step by step that could be used in the rural areas of Bangladesh, especially in the northern portion of the country for constructing a complete house as one of the sustainable option emerged from locally available raw materials and equipment. It is expected that the application of demonstrated method will help to eliminate CI sheets, burn bricks from construction process and promote compressed earth blocks, and treated bamboo which will contribute to reduce carbon emission and decrease deforestation in the long run. The intention of this paper is to present a brief documentation for integration of local tradition with comparatively newly developed localized technology as an improved house building techniques and sustainable environmental initiative.*

***Keywords****: Indigenous materials; local technology; sustainable development; simple strengthening; tradition.*

## 1. INTRODUCTION

Architecture does not involve only people, it also has a very strong relation with nature, in particular while choosing materials. The construction of a house can be assumed as a kind of negotiation between the short term cost benefit from the builders'/owners' perspective and long term benefit of environment and health of the locality including the users of the house. Natural resources are often used without considering its after effects. The relationship between nature and its use emphasised the fact that if individuals are not aware enough then it might end up with hurting the nature and cause harm to the community including individuals such as almost 80% of the total area of Bangladesh is prone to flooding and North and North-western regions of the country are suffering because of extreme temperature problem (Kabir and Mallik, 2005). Each building has a relation with the nature. Relevant technical personnel must be well aware with the selection of materials while making a structure. The advantages of using indigenous materials are many as following.

- These materials are mostly naturally and locally available in specific area.
- Can be produced near a construction site.
- Usually reduce construction costs and wastes.
- Often helps to boost local economy.

Statistics shows that almost 87% of rural houses in Bangladesh are made of bamboo, wood,

and corrugated iron (CI) sheet while 13% are made of brick and cement (Wahed, 2015). It is important to search and study alternate construction materials and techniques in order to build sustainable houses without creating any adverse effect to nature.

## 2. METHODOLOGY

As part of a B.Arch final year thesis project titled, 'Towards Green Architecture Research and Learning Center of Indigenous Materials' an initial survey with the help of Simple Action for the Environment (SAFE) foundation was done by first Author during one of SAFE project titled, 'Building for Safety Workshops and Demonstration Houses' on July - September 2016 at Sundarban Village, Dinajpur. SAFE is an NGO, based in Dinajpur region of Bangladesh, which has been officially operating since 2009 with support from Housing and Hazards (www.housingandhazards.org); an international group of building professionals working to promote affordable hazard resistant housing. Before starting the field survey a thorough literature review was done which helped to conduct the field survey. A reconnaissance survey was conducted at the beginning to understand the environmental and geographical context of the settlement. The main survey was based on the studies and comparison of building age, material, size, occupancy and aspects of five small areas (paras) to identify the housing style of the village. Problems with the traditional building technology were identified from the survey; and comparatively new and less popular bamboo and mud treatment process were investigated as alternative option.

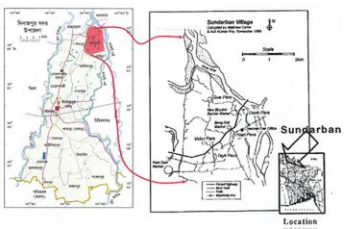



*Figure 1: Position of Sundarban Village in the map of Dinajpur.*

## 3. STUDY AREA

Sundarban is a village located in Dinajpur region, the far northwest of Bangladesh, with a population of approximately 30,000 inhabitants lying midway between the towns of Saidpur and Dinajpur town (Figure 1).

Economy of Dinajpur depend largly on agriculture. Approximately 40% of the population are landless labourers (SAFE, 2014). Although Dinajpur does not suffer from severe storms that affect the southern coastal region of the country, localised flooding does often occur and strong winds in September and October regularly cause damage to property (SAFE, 2014). In parts of north Bengal, mud or mud bricks are used in floors and walls as the land level is on higher elevation above flood level and soil characteristics (Plasticity Index (PI) less than 15% which is suitable for cement stabilization) are favourable for mud construction (Hodgson and Carter, 1996). Bamboo is used in construction frequently due to its availability. The traditional techniques are self-built houses using mud and untreated bamboo with thatched roof or CI sheet (Figure 2). This makes households vulnerable to natural hazards such as strong winds and earthquakes that happen several times in a year (IA, 2013). Therefore, need emerged to explore indigenous techniques for building construction suitable for the village to resist against natural hazards.

*Figure 2: Existing building construction practice of local people.*

## 4. EXISTING SCENERIO OF BUILDING CONSTRUCTION

The construction of houses in Sundarban Village is determined largely by the socio-economic condition of the family and supply and cost of available construction materials. The riches used to build their houses with burnt brick and cement. However, most of the people are not financially solvent. Unless the low cost

technology is provided or credits (with low interest) are available for them, the poor families often cannot afford even the cheapest imported technology, such house design with processed bamboo and compressed earth block (CEB).

At present the walls are mainly constructed with wattle and daub technique. In this technique bamboo lattice is made by weaving strips of bamboo together and fixed to the outside of the frame. Mud is then applied in layers on both sides of the wall up to 50mm thick (approximately). The single sloped roof (EKCHALA) is made with a bamboo frame and CI sheet. A layer of bamboo matting is usually placed directly below the CI sheet roof to provide some insulation from the heat during day hours.

## 5. PROBLEM STATEMENT

The main problem of existing popular construction process is that the houses do not sustain for more than 3-10 years depending on annual perspiration. As the local people use the materials without any treatment process, mud houses get cracked and bamboo shows poor resistance to fungi and bacteria. As a result individuals need to alter their houses in every two to three years. Because of this temporary nature of untreated mud and bamboo, individuals if achieve financial solvency, try to switch from mud and bamboo to brick and cement construction (Figure 3).

*Figure 3: Decay of untreated mud and bamboo (left) result popularity for brick and cement construction (right)*

Rural people are hardly aware of the advantages of using new techniques that can increase the durability of the existing houses. Even though the villagers get to know the technology and their advantages, they are unwilling to pay the extra money needed for those treatment processes.

## 6. POTENTIALITY OF BAMBOO AND CEB IN BUILDING CONSTRUCTION

Bamboo is a versatile, strong, renewable and environment friendly material. Bamboo is the fastest growing woody plant producing a mature fiber for use within three years. Bamboo is an extremely strong fiber with twice the compressive strength of concrete, and roughly the same strength to weight ratio of steel in tension. In addition, testing has shown that the shape of bamboo's hollow tube gives it a strength factor of 1.9 times over an equivalent solid pole (Janssen, 1997). The strongest bamboo fibers have a greater sheer resistance than structural woods, and they take much longer to come to ultimate failure (DeBoer, 2004). The structural advantages of bamboo are its strength and light weight whereby properly constructed bamboo buildings are inherently resistant to wind and earthquakes. Bamboo is susceptible to attack by fungi and insects and untreated bamboo have a life expectancy of not more than five years. The purpose of treatment is to remove the starch and other carbohydrates (soluble sugars) that attract fungi and insects and replace it with chemicals in the cells of the bamboo thereby increasing the life of the bamboo. Treated bamboo has a life expectancy of 50 years without losing its structural properties (DPD, 2010).

*Table 1: Comparison between regular and treated bamboo (Fawaz 2014).*

| | Regular Bamboo | Treated Bamboo |
|---|---|---|
| **Cost** | 100-150 taka per piece | 170-200 taka per piece |
| **Termite Resistance** | No termite resistance | Termite resistance. |
| **Availability** | Widely available | Not widely available |
| **Processing Time** | Can be used directly after cutting | Need to cure for at least 3-4 weeks. |
| **Longevity** | 3-10 years depending on annual perspiration | 20-50 years depending on maintenance. |

In Dinajpur, available types of bamboo are as following.

- Barua (bambusa balcooa) locally known as 'borak' bash.
- Muli (melocanna baccifera) locally known as 'makal' bash.

It is found from a project report that naturally occurring bamboos are dominated by the muli (melocanna baccifera) variety that grows all over Bangladesh with following particulars (SAFE, 2014).

- Average height: 8.5 – 10 m (25'- 30')
- Useable for structure: 8 m (24')
- Height of typical rural bamboo houses: 2.5m (7'-8')
- Standard depth of room: 4 m (12')

### *6.1. Treatment and Joinery of Bamboo*

There are several indigenous treatment systems e.g. lime wash and smoking of bamboo, whereas chemical treatments are known to have longer effect against fungi and insects. The use of water as a solvent to carry the preservatives into the cells of the bamboo (Figure 4) is recommended (DPD, 2010). Water-soluble salts are dissolved in water. On treatment the water evaporates leaving the salts (i.e. boric acid, borax and copper sulphate) inside the bamboo. Boron salts are effective against borers, termites and fungi (except soft rot fungi). High concentrations of salts have fire retardant properties as well. These are not toxic. The preservatives and treatment process are listed in Appendix A.

*Figure 4: Treatment of bamboo is going on in tank and then under shade.*

Treatment is intended to add following extra features to bamboo.

- Extend durability and lengthen useful life.
- Capture and delay degradation.
- Preserve dimensional stability and retain strength.
- Impart properties e.g. fire resistance and lustre.
- Improve aesthetic qualities.

Selection of the treatment method depends on the following factors.

- State of bamboo: green or dry.
- End applications: in ground contact, exposed to atmosphere, undercover, structural/non-structural.
- Scale: quantity to be treated and time available.
- Potential causes of decay: biotic (fungus/insects) and abiotic.

Bamboo structure is based on four types of lashing (i.e. Clove hitch, Square lashing, Shear lashing, and Diagonal lashing) and three types of shear (i.e. Post with plinth band, 'T' and 'L' Junctions, and Cross Junction) keys (Figure 5 – 7) (Schroder, 2009). Mainly different types of lashing (Figure 8) with dowels (Figure 9) are widely used in rural areas. Dowel is a pin made of wood or bamboo with fibers in longitudinal direction of 10 mm. diameter inserted right through the pole.

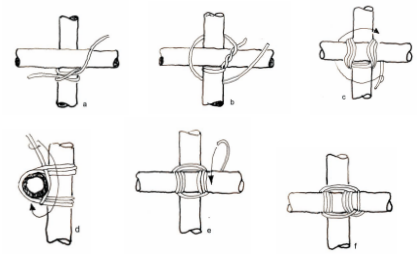


*Figure 5: Square lashing of bamboo* (Schroder, 2009)

*Figure 6: Shear lashing of bamboo* (Schroder, 2009).

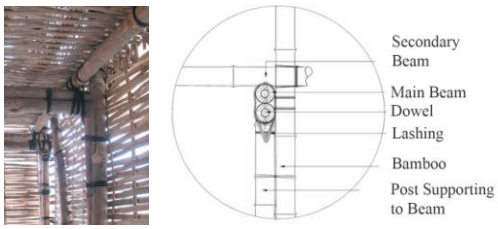



*Figure 7: Joinery with T and L Junction Shear Key* (Schroder, 2009).

*Figure 8: Different types of Bamboo joints.*

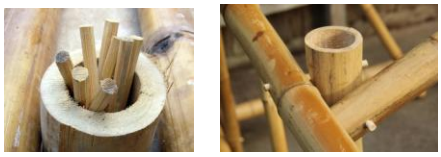


*Figure 9: Bamboo dowels.*

Bamboo has nodes to use (Figure 10). In construction, properly using bamboo nodes is very important. Bamboo columns or beams need to have a node at both ends or as close as possible towards the ends. If not, the pressure of a structure on the joint may crush the bamboo. Often it is not possible to find bamboo of the required length with both end nodes in place. When this occurs, a wooden cylinder with appropriate diameter or a fitting piece of bamboo with a node is inserted (Schroder, 2009).

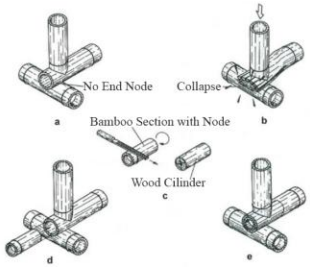



*Figure 10: Use of bamboo nodes.* (Schroder, 2009)

### *6.2. Preparation of CEB*

In Bangladesh, at present over 8000 brick factories produce nearly eight million tons of carbon emission every year. Corrugated iron industry adds another six million tons of $CO_2$ in the air (Fawaz, 2014). The new method of construction aims to reduce carbon emission. A better alternative of untreated mud and brick is CEB. Table 2 shows comparison between regular fired brick and CEB.

A small mobile unit of CEB machine can be made on site to produce the bricks. The machine can be made locally from free source design material available on the internet. The machine can produce on an average 1000 bricks per day. The main ingredients for the bricks are 5% cement, 40 -50% sand and 50 - 55% earth (Roy, 2013). The technique for brick production was taken from proven methods of United Nations Human Settlements Programme (UN-Habitat), German Organisation for Technical Cooperation (GTZ), and various experiments are being performed by other organizations in Bangladesh, e.g. Housing and Building Research Institute (HBRI) to get the most durable and strong bricks.

*Table 2: Comparison between regular fired brick and CEB* (Fawaz, 2014).

| | **Regular Kiln Fired Bricks** | **Compressed Earth Blocks** |
|---|---|---|
| **Cost** | 7-10 taka per piece | 5-7 taka per piece (based on 1000 bricks per day) |
| **Water Resistant** | Yes | Yes |
| **Environmental Impact** | 8 million tons of carbon emission in Bangladesh every year | Very minimal. CEB's are made with 5% cement stabilization, therefore carbon emission should be considered. |
| **Heat** | 1000 - 1500ºF required to produce 1000 bricks | No heat required. |
| **Mortar requirement** | Cement Mortar is required for laying bricks and wall plastering. | Mortar is only required to make internal columns. |
| **RCC columns requirement** | Columns required at every 10-15 feet interval for brick filling. | No columns required. Walls are load bearing and internal columns are inserted through the bricks. |

Mud blocks are made of a mix of mud sand and cement in a ratio of 20:3:1. Firstly, the mud is dried for 5 days, and also netted if required to ensure thinness and uniformity. Then it is crashed to powder and mixed manually with sand and cement and a minimum amount of water has to be added to mix them together. The mixture is placed inside the pressure machine (Figure 11) that has the mold to give them shape with dimensions of 25mm x 150mm x 75mm (1’ x 6” x 3”). The block should be dried for 24 hours before curing which is done under a plastic cover with spraying water for one

week. After that it needs another week for drying just before it is used in construction. The mortar that joins them together in walls is prepared with the same proportion of mud, sand and cement (SAFE, 2014). The presence of two circular holes inside them allows the possibility of adding vertical sticks for reinforcement in the corners or edges of windows (Figure 12).

*Figure 11: Mixing of mud and machine of compressed earth blocks.*

*Figure 12: Size of CEB and regular brick.*

## 7. COST ANALYSIS OF CONSTUCTION

It is a challenge to coin new methods in the market, regardless of how good it is. Strong mind set about existing construction methods are hard to alter and new materials often fail to gain trust. Moreover, individuals often do not want to take risks with their hard earned savings in new and unproven matters. In addition, cost is a significant factor in the rural areas of Bangladesh. Inhabitants are attracted to cheaper yet better materials.

The fact is, the people of Sundarban Village are familiar with the mentioned technology and its advantages; still they are not convinced to build their houses with treated bamboo and CEB because the initial construction cost is higher than the houses made of widely used untreated mud and bamboos. Table 3 compares the cost of a single storey house made of regular and treated bamboo.

*Table 3: Comparison between regular and treated bamboo* (unit size 8ft x 12ft).

| | Regular bamboo | Treated bamboo |
|---|---|---|
| **Plinth** | Mud | Stabilized earth |
| **Structure** | Bamboo | Bamboo |
| **Roof structure** | Bamboo | Bamboo |
| **Wall** | Bamboo | Bamboo |
| **Roof** | CI sheet | CI sheet |
| **Cost*** | 31565 tk | 39755 tk |
| **Extra cost : 8190 tk** | | |

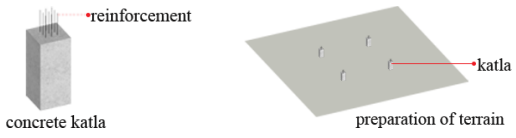
*including transportation and labour cost.
Source: SAFE foundation, Bangladesh (2016).

According to Table 3, an initial 25% extra cost is required, that can increase the life expectancy of the building five times or more (SAFE, 2014). There are already a few buildings in Sundarban Village area which are made of stabilized earth, CEB and treated bamboo and these buildings are proving their expected results with the passage of time. The two storey office building of SAFE foundation and a single storey online school building are some shining examples that are made of treated mud and bamboo (Figure 13). It is expected that these buildings will provide inspiration for common people to come forward and make this evolution a success.

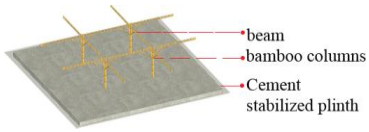
*Figure 13: Local online school building and office building of SAFE foundation, Bangladesh.*

## 8. PROCESS OF A BAMBOO AND CEB HOUSE DESIGN

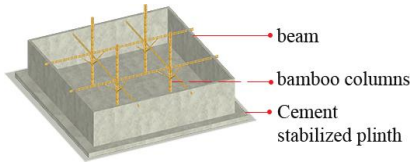
The materials and the way of their processing are discussed in previous sections. The simple steps of constructing a two storey building are illustrated in this section. Here stabilized earth (mixture ratio same as CEB) is used in foundation, CEB for ground floor wall and treated bamboo for first floor wall (Figure 14).



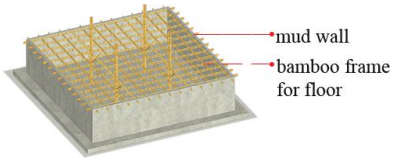

**Step 01:** The terrain is prepared and concrete katla (small pillars) are placed where bamboo columns are going to be provided. Concrete kalta is used so that the bamboo is not in direct contact with ground.



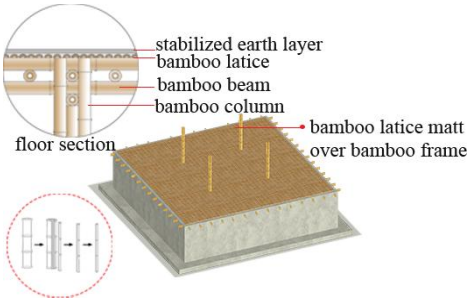

**Step02:** A bundle of bamboos are used as column and placed on katla. Bamboos are also used simultaneously as beams.



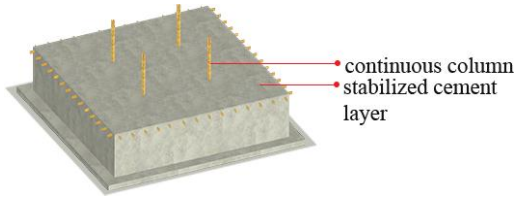

**Step03:** Wall are then made with CEB.



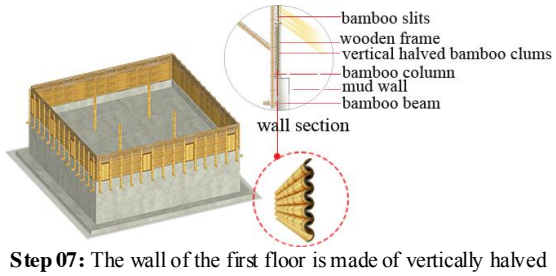

**Step 04:** A bamboo frame is made for providing support for the upper flooring.



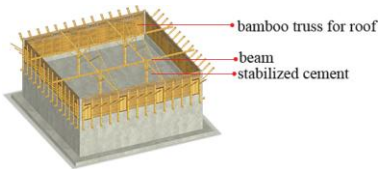

**Step 05:** A matt of bamboo lattice is spread over the bamboo frame. Detail is provided in the image above.



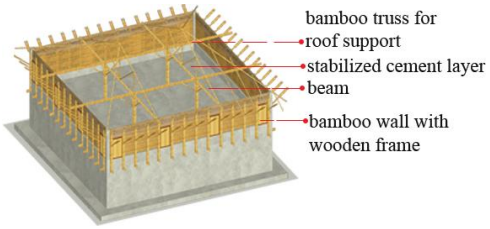

**Step 06:** A thin layer of stabilized cement is provided on the matt for a fine finished look and comfortable use.



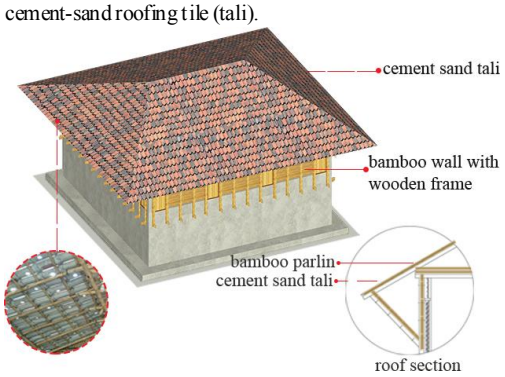

**Step 07:** The wall of the first floor is made of vertically halved bamboo clumps. Windows are also made with the same material.




**Step08:** Bamboo trusses are used for supporting the roof.




**Step 09:** A bamboo frame is made to provide support for cement-sand roofing tile (tali).




**Step 10:** Finally, cement-sand tile is used on bamboo purlin for roof.

*Figure 14: Steps of Building a two storey house with mud and bamboo.*

As cement-sand roofing tile is used for roofing, an overall bamboo frame is needed to support. Cement-sand roofing tile provides better heat insulation than CI sheet; however, in general CI sheet is used widely in rural areas of Bangladesh.

## 9. CONCLUSION

According to the World Bank, rural population in Bangladesh was reported at 64.96% of total population in 2016 (TE, 2018). Integration of local tradition with local technology (material and construction techniques) has a huge potential in rural Bangladesh. Furthermore, carbon emission could be significantly reduced if existing traditional method is replaced with the treated method and eventually should be resulting in a positive environmental impact. Bamboo and mud are indigenous materials in the northern part of

Bangladesh similar to most of the rural areas of the country. These materials are losing their appeal with time as people want more durable materials for making houses. There are some easy methods of treatment for these materials which will increase their durability and will minimize the existing problems to a great extent. Moreover, once the new methods enter into the mainstream construction, more masons and entrepreneurs will be interested to follow the methodology.

The main purpose of this paper is to provide a quick guide for the construction of rural houses with treated bamboo and mud (block), and documentation of the process with pointing out some limitations. Firstly, the methods and treatment process stated here are mostly based upon the equipment and raw materials available in the locality (Sundarban Village, Dinajpur). Still, there are scopes of improving the technology to ensure a better sustainable community.

**ACKNOWLEDGEMENTS**

We would thank Ajit Roy, Coordinator of SAFE foundation, who helped thoroughly during the study with survey information. Thanks to local people of Sundarban Village who helped cordially with every possible information, and Dept. of Architecture, BUET for technical supports.

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**APPENDIX A**

Chemical Preservatives for Treatment of Bamboo (Schroder, 2009)

i) Boric acid and borax (BB)

ii) Boric acid and borax shall be mixed in ratio 1:1.5.

iii) Acid-Copper-Chrome (ACC) composition: A typical composition comprises 1.68 parts of Chromic Acid ($Cr_2O_3$) (equivalent to 2.5 parts of sodium dichromate), 50 parts of Copper Sulphate ($CuSO_4.5H_2O$) and 47.5 parts of Sodium Dichromate ($Na_2Cr_2O_7.2H_2O$); conforming to IS 10013 (Part1)

iv) Copper-Chrome-Boron (CCB) composition: A typical composition comprises of Boric Acid ($H_3BO_3$), Copper Sulphate ($CuSO_4.5H_2O$), and Sodium or Potassium Dichromate ($Na_2Cr_2O_7.2H_2O$ or $K_2Cr_2O_7.2H_2O$) in the proportion of 1.5:3:4, conforming to IS 10013 (Part 3)

v) Acid- Cupric- Chromate (ACCH) Composition: A typical composition comprises of 1.68 parts Chromic Acid ($Cr_2O_3$) (equivalent to 2.5 parts of sodium dichromate), 50 parts of Copper Sulphate ($CuSO_4.5H_2O$) and 47.5 parts of Sodium Dichromate ($Na_2Cr_2O_7.2H_2O$); conforming to IS 10013(Part 1)

Above mentioned are the basic chemicals needed for treatment process of bamboo. The requirement has been minimized a little for the

convenience of the rural people and the present method is going on smoothly. The method is stated briefly below.

Before the materials are placed into the tank, they would need to be drilled in both sides of every natural joint, to allow the water come in and out. The treatment of bamboo clumps against insect and fungal attack takes place in a prolonged soaking water bath. The proportion would be 1kg borax and ½ kg boric acid, in each 35 liters of water. The concentration would have to be a 1% and the density would be 1.04 kg/liter.

The tank of bamboo soaking measures 25' long and 6'7" wide and it is filled up between 2' and 3' depth. It will be usable after 3 weeks of soaking and 1week of drying under a shaded roof.

# AN ASSESSMENT OF PREVAILING NOISE LEVEL IN A READY-MADE GARMENTS FACTORY SPACE LOCATED AT MIRPUR, DHAKA

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***Abstract:*** *Noise pollution can cause serious health hazard. Occupational noise hazard is detrimental for the health of workers. Same goes for the workers of ready-made garment (RMG) industries of Bangladesh where the issue of exposure to noise for long hours at workplace is far beyond the consideration of the garment factory owners and the assessing authorities. In recent times, there have been surveys and assessments by government authorities as well as private entities on various safety issues like structural stability, fire safety, electrical safety, hygiene etc. in RMGs located in Dhaka and elsewhere in the country. But the existing noise levels are not yet in their consideration. This paper shows the study on existing noise level in a randomly picked RMG factory space (the sewing section) situated in Mirpur, Dhaka and finds out whether it is within the permissible range or not. The paper tries to figure out the noise distribution pattern within the space and the reverberation time of the space. The study finds that although most of the machines produce sound within the permissible range, the factory authorities use sound masking principles in a faulty way that causes more harm than good to the workers. Lastly the paper suggests some probable solutions to reduce considerably high noise levels in that RMG factory space. As a whole, the basic intention of the study is to start raising awareness regarding necessary assessment and control of high noise levels in RMG sector and promote the importance of architecture acoustics in built environment.*

***Keywords****: acoustics, industrial noise pollution, noise related hazard, RMG industry*

## 1. INTRODUCTION

Noise pollution causes hazard for human health. Noise is an unwanted sound that interferes with the function in a given space (Talukdar, M., K., 2001). In other words, noise is defined as undesired excessive sound that usually results in annoyance and health hazards like hearing loss and other physical ailments. This noise can be produced from both occupational or non-occupational sources. Extraneous noise not only creates health problems; it can also have adverse social repercussions. (Jayawardana, T., S., S., et al, 2014). It is not easy to define noise as it is somewhat a relative issue but regardless, excessive noise can cause severe physical and psychological damage to human beings.

Any noise rating above 80 dBA produces physiological effects and any long exposure at above 90-100 decibels will produce permanent damage to a person's hearing. An increase of 10 dBA is a doubling of loudness with respect to the human ear (Talukdar, M., K., 2001). Noise induced hearing loss (NHL) is a process of permanent metabolic cochlear damage caused by incessant exposure to loud sound levels between 90dB to 140dB (Haider, Y., M., et al, 2008). Adverse effects of noise include acoustic trauma, noise induced temporary or permanent threshold shift, cardiac and cardiovascular changes, stress and fatigue, disturbance in sleep, deterioration of InMotor and psychomotor functions, violent behaviour etc. (Agarwal, S., 2013).

It is evident that rapid urbanization along with mass industrialization and developed transportation system play a vital role behind the increase in noise levels and noise pollution worldwide (Salehin, S., et al, 2014). So, noise or excessive noise should be one of the crying environmental concerns in cities like Dhaka

where unplanned urban, industrial and traffic growth have taken place.

Dhaka is filled with a huge number of ready-made garments (RMG) factories unplanned in nature. After some recent accidents and disasters regarding fire and structural collapses that have brought immense misery and life loss of the workers, notable steps have been taken by the Government and private entities to assess the internal and external working conditions of the RMG factory spaces. Several institutions such as the Bangladesh Accord on fire and building safety, the Alliance for Bangladesh worker safety and national plan of action have been designed to improve building and fire safety of these factories (Kumar, K., 2016). The assessed RMGs are bound to follow the regulations and corrections provided by the authorized assessment teams. But unfortunately, the prevailing high noise levels in some of the working areas are not among the concerns. This might be because noise pollution is a slow killer and unlike other apparent disasters its adverse effects cannot be readily seen.

More than 78% of Bangladesh's export earnings come from the garment industry (Ahmed, F., 2012). The garment industry of Bangladesh currently consists of 5600 factories of various sizes and about 4.4 million people, mostly women work in this sector. (Kumar, K., 2016). So, undoubtedly their working condition and occupational health should be a vital concern of the employers for their wellbeing as well as better productivity.

Noise and especially industrial excessive noise have been a common concern of a large number of studies and researches internationally and also in Bangladesh. For example, M K Talukder, 2001, India, T. S. S. Jayawardana, et al, 2014, Sri Lanka, Md. Yusuf Haider, et al, 2008, Bangladesh, have similar studies on noise pollution and noise control in textile industries. E. Atmaca, et al, 2005 have a study that focuses on overall impact of industrial noise on human health including textile, iron and steel, cement and concrete industries. Sirajus Salehin, et al, 2014 conducted a study on Nasirabad Industrial area, Chittagong, Bangladesh where the noise levels of three industrial zones comprising of steel, aluminium and garments industries were studied and noise levels were logged at location, entry, and premise and inside the industries. It was seen that the noise levels were higher than the noise permissible in the respective industrial zones. The study focused on comparing maximum and minimum sound levels of industrial zones with standard permissible industrial noise levels worldwide. A study conducted by Dr. N. R. Khan, et al, 2015, on occupational health hazard among garment factory workers of Dhaka city depicts that among the respondents of the research, 33.8% workers complain about noise pollution in the workspace. 51% workers suffered from head-ache and shoulder pain. Insomnia was common in 20% respondents. Among the respondents, 65.3% workers said they have headache problems due to noise in their workplace. These along with similar studies portray that noise related problems exist in RMG factory workspaces and can be detrimental for workers' health as well as productivity. Yet, no detailed study on major noise sources, the sound pressure level distribution, duration of noise exposure etc. in an RMG factory workspace in Bangladesh could be found till now.

As it can be seen that there is a gap in existing information and studies regarding actual sound pressure levels and noise distribution pattern and the degree of graveness of the existing noise conditions in the RMG factory spaces, the focus of this paper is to find out the prevailing noise level of a randomly picked small RMG factory space (the sewing section) located in Mirpur, Dhaka. As per the contract of this brief survey with factory authority, the original name and detail address of the factory and their BGMEA serial number will not be disclosed here. In this paper, the factory is given a generic name as "X Garments". The intention of the survey was to observe if there is excess noise and propose noise attenuation measures if necessary.

In this study, it is observed that the noise generated from the machinery is somewhat mostly within the permissible range according to guidelines of BNBC 2015 Draft, but the unique observation is that the authority uses sound masking techniques within the sewing section in a seemingly faulty way. Traditionally, sound masking is used in office spaces in order to attain speech privacy among co-workers. Appropriate

masking sound is necessary for reaching acceptable speech privacy in open offices, especially between nearby workstations (Hongisto, V. O, 2008). But in 'X Garments' (also observed in many other garments factories located in Mirpur area during observational survey), the authority uses loud speakers to play loud music and songs in order to mask the machine noise and to prevent workers from talking to each other. With plain ear, the sound level seems quite high and harmful. To find out whether the noise is truly excessive or not, the noise distribution pattern across the sewing section (the space that generates most of the noise) is observed from the sound pressure levels at a number of points of the workspace. In this study, it is found that this faulty sound masking is actually hazardous regarding excessive noise level and should be a vital concern of the authority as well as the regulatory bodies. The paper also presents a calculation of the Reverberation Time(RT) for the factory space and seeks necessary measures to solve the existing problems regarding high noise level in the sewing section of the RMG factory space.

## 2. METHODOLOGY

At the beginning of the study, a reconnaissance survey was conducted to search for a common range of noise levels in RMG factories located in the area between Mirpur Section 11 and 12, Dhaka. There are quite a large number of unplanned RMG factories in rented spaces of different buildings located in this area. Assessment authorities had already visited these factories and they had apparently made necessary changes regarding day-lighting, ventilation, fire safety, cleanliness etc. But the issue that needed to be investigated is that what was majorly the prevailing sound level or noise level in those factories and how they dealt with the problem. In all the visited factory spaces, the ambient noise level of the sewing section was measured by a Sound level meter (LUTRON 4023 SD) and the A weighted measurement was taken.

For the detailed survey, "X Garments" was chosen as it had a noise level that represents most of the existing RMG units and also had the common practice of masking machine noise with loud music present in quite a few RMG factories visited. Only the sewing section was chosen for assessment of noise level and sound pressure level mapping. The RT of the factory space was also calculated for further understanding of the acoustic condition of the space.

At first, all the sound generating sources were logged in a chart. These sources included about fourteen types of sewing machines among which nine types are prominently in use. There were also ceiling fans and human noise and most importantly the noise of the loud music and songs from loud speakers located at two separate points of the sewing section. The sound levels generated from the sources were measured individually from a horizontal or vertical distance of 1m at the time of lunch hour with the assistance of an attendant from the factory. Figure 1 shows the detail layout and interior working condition of the sewing space.

With a LUTRON 4023 SD sound level meter, sound pressure levels were measured at twenty-six different points in a 3mx3.6m grid-like pattern over the sewing section space. After that, the RT of the space was calculated from measured elevations and plan with the following theory (BNBC Final Draft, 2015):

$$\mathbf{RT_{(60)} = 0.16\ V/\ (A + xV)} \quad \text{.....(i)}$$

Where,

$RT_{(60)}$= the time (in seconds) required for the sound pressure level in a room to decrease by 60 dB after the sound is stopped

V= Room volume, $m^3$

A= Total room absorption, $m^2$- *sabin*

x= air absorption coefficient (generally omitted to simplify calculation)

So, the equation used here is as follows:

$$\mathbf{RT_{(60)} = 1.6\ V/A} \quad \text{.....(ii)}$$

The found data from the sound level meter was then compared with BNBC standard of permissible industrial sound levels following the BNBC Final Draft, 2015. The RT value was used to assess how long the sound pertains in the room before dying down.


*Figure 1: Plan, sections and interior photographs (from camera position C1, C2, C3) of the RMG space*

## 3. RESULT

According to the survey, the sound sources included 14 types of different sewing machines among which 9 types are more frequently used. According to the authority, generally 100 machines are simultaneously used every day. Thirty ceiling fans operate over the sewing section. Sound level of each operating ceiling fan from a 1m vertical distance is 70 dBA. The names, sound levels (from 1m horizontal distance) and images of nine types of frequently used sewing machines are given below in Figure 2.


*Figure 2: Nine types of machines (with sound pressure level from 1m horizontal distance) that are frequently used in the sewing section of the surveyed RMG*

The distribution pattern of the sound sources across the RMG space including the sewing machines, loud speakers and the ceiling fans, is shown in Figure 3. Among the measured sound pressure levels at 26 different points of the sewing section space, the highest sound level found was 99.3 dBA and the lowest was 73 dBA. The distribution pattern of sound levels is given in Figure 4.

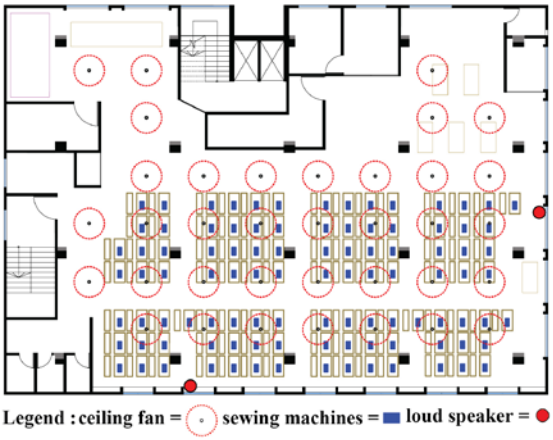


*Figure 3: Plan of "X garments" showing the distribution of mechanical sound sources*

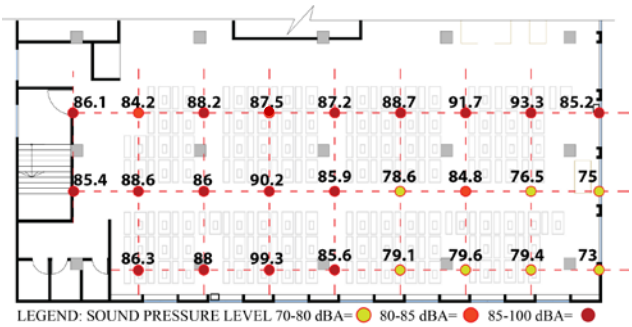


*Figure 4: Partial plan of the sewing section showing the measured sound pressure levels at 26 different points in a 3m x 3.6m grid pattern*

From Figure 3 and Figure 4 it can be seen that the sound pressure level is notably higher near the two loud speakers. Among the 26 points, 6 points are within the range of 70-80 dBA, 2 points are within 81-85 dBA and 18 points are within 85-100 dBA.

The average ambient noise level is approximately 85.13 dBA in the fully occupied sewing space (with 100 machines and approximately 100 workers functioning) and 51 dBA in empty room (with all machines shut down and all workers gone for lunch break). At the time of survey, through a brief interview with the supervisor, it was found that the workers generally work for 8hrs per day and 50% of them work for 5hrs as overtime. So 50% workers stay there for 13hrs. According to the floor manager of "X Garments", there are 120 workers in total working in the factory space. From the survey, it was apparent that the workers did not have any awareness regarding harsh impacts of excessive noise for long hours and were not using any kind of protective measures like individual ear-plugs or so. The workers didn't have any opinion for the loud music as well because it was actually the decision of the authority.

From the measured plan and elevations using equation (ii), the $RT_{(60)}$ of the factory space was calculated for various frequencies of sound. Spectrum analysis is done on log frequencies in X-axis and amplitude in Y-axis.

The analysis shows that the frequencies range from 43 Hz to 20104 Hz of different amplitude. We may find highest amplitude of -29.4 dB at 474 Hz. However, frequencies at or above the amplitude level of -36 dB are found within a range from 100 Hz to 1 kHz (Figure 5)

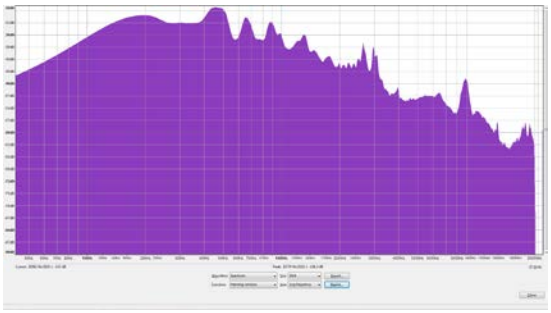

*Figure 5: Spectrum analysis of recorded ambient noise during full occupancy and activity with loud music*

Figure 6 shows the comparative analysis of RT for different frequencies.

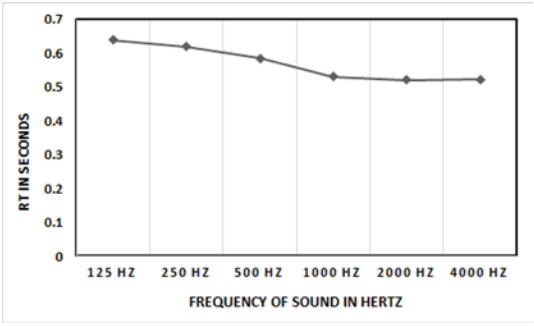


*Figure 6: $RT_{(60)}$ for sound frequencies ranging from 125 Hz to 4000 Hz.*

According to the BNBC 2015 final draft, musical sound frequency can range from 50 Hz to 8500 Hz, for an average dynamic range of about 75 dBA. Figure 5 shows that from 125 Hz to 4000 Hz, the RT can range from 0.64 seconds to 0.52 seconds.

## 4. DISCUSSION

To find out whether the existing noise level in "X Garments" is within the permissible range or not, the existing standards and permissible noise levels should be sought. BNBC 2015 Final Draft states that the permissible noise exposure for 85 dBA noise is 16:00 hours and for 86 dBA noise is 13 hours 56 minutes per day. For higher level of noise, the duration of permissible noise exposure gradually reduces and it is seen that for 99 dBA of noise, the permissible exposure time is only 2 hours 15 minutes.

According to the above standards, the average ambient noise level (85.13 dBA) of "X Garments" for daily 8 hours' work and additional 5 hours' over-time is within the acceptable range. Then again, according to the sound pressure level assessment, it is seen that among 26 points distributed over the space, 17 points correspond to a sound pressure level higher than 85 dBA and even reach upto 99 dBA which could be extremely dangerous for the workers' health who are located near the points of excessive noise. The range that is given in the standards is the maximum point of any permissible range which can also be harmful in certain cases. The basic approach for noise control should be considered as an effort to keep noise level well below the allowable exposure range.

### *4.1. Possible noise attenuation strategies and protective measures*

Following are some probable noise attenuation strategies that can be adopted in RMG industrial units like "X Garments":

- The garments authority should be strictly prohibited to use loud music (out of permissible range) as a sound masking mechanism via regulatory policies by quality assurance authorities. Routine assessments should be conducted so that the factories avoid this practice. The garment owner authorities as well as the workers should be made aware of the dangerously adverse effect of excessive noise on their overall health condition.

- For factory spaces with high mechanical noise, active noise control (ANC) is an effective technique that uses sound field cancellation through a system of sensitive devices but is not used commercially and widely due to high capital cost and complications in installation (Talukdar, M., K., 2001).

- Passive measures include blocking airborne sound, absorption of airborne sound, vibration damping etc. can be adopted (Talukdar, M., K., 2001).

- As the calculated RT value is between 0.52 to 0.64 seconds, in "X Garments" factory space, the noise that generates there pertains in the space for more than half a second. Thus it aids to increase the overall ambient noise level due to reverberation. In the factory space, there are only bare minimum finish materials in the interior surfaces and thus they reflect sound at a higher amount. Lining the walls, floor and ceiling with materials that have greater absorption coefficients can help lessen the RT and reduce noise. Even by only lining two parallel long walls with composite good quality absorptive materials and lining the floor with washable absorptive floor finishes, the RT value can be reduced notably. One important thing should be considered while interior treatments; the walls should only be lined with a combination of such materials that absorb less dust.

- Individual ear protectors can also be one of the most effective and cheap way to reduce noise at receiver's point (Talukdar, M., K., 2001). It could also easily be implied in any factory and would also raise awareness among the workers regarding occupational noise hazard. Even if the noise level is barely within the acceptable range, still it is useful to wear ear plugs because they can reduce stress and unnecessary fatigue with sounds and bring more concentration in work.

## 5. CONCLUSION

From all the above discussion it can surely be said that excessive noise is a silent menace. It is truer in the context of Dhaka city and Bangladesh as most of the general people are not yet familiar to the problems associated with noise pollution and are not at all concerned. Similar reluctant situation pertains in the RMGs which have a lion's share in our national economy. The workers' occupational health should be one of the major concerns. So, the paper has only tried to bring up that issue regarding noise levels in RMGs by a small case study of "X Garments". The major intention was to evaluate the situation from a very arbitrary and small scale view but this could be a starting point of a greater and more thorough study. There could be further research on an effective and safer system other than sound masking with overly loud songs, to ensure smooth production and less chaos. Also research could be conducted on the specification of interior absorbent materials that catch less dust, are durable and are also cheap so that owners are willing to implement the intended designs. Also, the mapping of noise levels can be done with appropriate software and more effective pin-point solutions can be found. Even new type of acoustically favourable design ideas can be proposed for RMG units ensuring better productivity in a safer working environment that can be implemented in pilot projects. The major goal is to raise awareness in this particular issue and save the valuable workforce from the adverse impact of noise pollution.

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# PROSPECT OF GREEN BUILDING IN BANGLADESH:
## A CASE STUDY ON LARGE GARMENTS FACTORY IN BANGLADESH

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***Abstract:*** *Green Building (GB) is becoming the popular research area nowadays. In Modern age, the demand for sustainable building construction has experienced significant growth. Nowadays developed countries are trying to be a GB based country; whereas in developing countries like Bangladesh, although the practice is still low, the rate of interest about GB is rising. Till now, very few studies have done in the context of Green Building in Bangladesh. Based on the primary and secondary data the study sought to understand the prospect of Green Building in Bangladesh. The primary data of this research are mainly opinions from specialists of Bangladesh Green Building Academy and design2occupancy(D2O) through "Workshop on Green Building" in KUET and an" Industrial Tour" at AKH ECO Apparels in Dhamrai about the prospect and overview of Green Building in Bangladesh. Green Building has the ability to optimize site potential; minimize non-renewable energy consumption; protect and conserve water; enhance indoor environmental quality; optimize operational and maintenance practices through rainwater harvesting, maintain passive system, active system and hybrid system, wastewater recycling, radiant heating and cooling, passive heating and cooling, building massing and orientation and HVAC simulation. This paper also focused on LEED (Leadership in Energy and Environmental Design) rating system according to opinions from green specialists in Bangladesh. Finally, Result drawn from this research will be useful for people of Bangladesh who have an interest in Green Building field to build up an environmentally friendly building construction and also helpful for the future researchers, builders and environment specialists in the similar geographic area.*

***Keywords****: Bangladesh, Green Building, LEED, Sustainability, USGBC.*

## 1. INTRODUCTION

Green Building is a type of Building which is energy efficient, water efficient, provides better indoor Environment and hence better-living conditions, uses environmental friendly sustainable materials, produces less waste, has lesser transportation requirement and protects or restores habitat. An increasingly popular goal for According to U.S. Green Building Council (USGBC), Green Building is achieving Net Zero Energy. Commercial and Residential buildings consume almost 40% of the primary energy in the United States or Europe, nearly 30% in China and approximately 32% in Bangladesh (Deng, S., Wang, R. Z., & Dai, Y. J. 2014). In order to reduce dependency on the primary energy for buildings, a number of studies on energy -saving technologies have been done worldwide. On the other hand, renewable energy utilization was regarded as reasonable solution to global warming, air pollution, and energy security. Sustainable design seeks not only to reduce negative impacts on the environment but also to preserve the health and comfort of building occupants, thereby improving building performance. Net zero energy commercial Building initiative supports the goal of net zero for all new commercial buildings by 2030. The California Public Utilities Commission of the USA has an energy action plan to achieve net zero energy for all new residential construction by 2020 and net zero for all new commercial

construction by 2030 (Deng, S., Wang, R. Z., & Dai, Y. J. 2014). The main environmental concerns today are climate change, depletion of resources, ozone depletion, land pollution, water pollution and air pollution. There is a common perspective that industries are responsible for the major part of greenhouse gas emissions. Buildings directly contribute towards all the environmental pollution. Green building can be a major part of the solution to these environmental issues. In Bangladesh, various businesses are inter-related with real estate business, such as garment, rod, cement factory, stone, and brick industry, still mills and so on. In Many ways, construction create a huge employment opportunity to in Bangladesh. It also negatively effects on energy sector concerning consumption of the rate. It is explicit that housing is the fundamental requirement and real estate business is paying for it in a big way. A huge amount of investment and cash flow happen in this sector than other available industry. So we should build up this part thinking about its present esteem and Government has taken up the Palli Janapod Project which is under process (Dailystar, 2015).

Although a number of researchers worldwide have conducted research on the Green Building; however, there is no specific guideline and work on the Green Building in the context of Bangladesh. Following those potentialities in this field of GB, this paper describes importance and prospect of Green Building in Bangladesh through literature review and in-depth interviews from Green Building Specialists in Bangladesh.

## 2. RESEARCH METHODOLOGY

### *2.1 Case Study Area*

We, the 40 students and honorable teachers of Building Engineering and Construction Management department have visited "AKH ECO Apparels" (23.9181° N, 90.1133° E) 495 Balitha, Shah Belishwer, Dhamrai, Dhaka-1800, N5, by the side of Dhaka-Aricha highway at 10th August 2017 (figure-1). We have spent there almost 2 hours to observe the whole project. AKH has built up this eco-friendly project strictly applying the Gold Classification prerequisites of Leadership in Energy & Environmental Design (LEED), which are officially recommended by the U.S. Green Building Council.

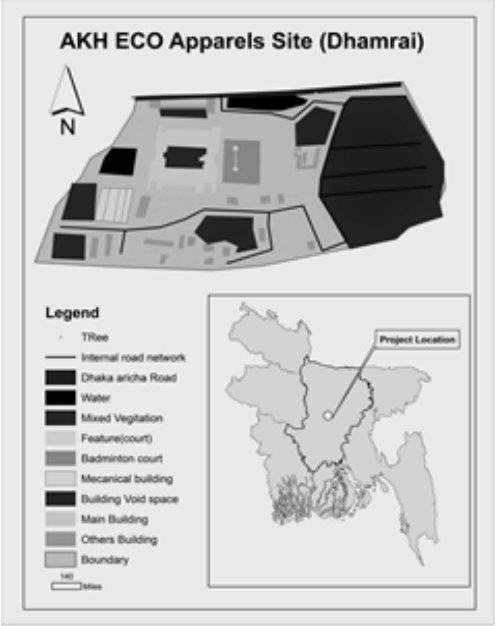


*Figure 1: Case study area*

### *2.2 Workshop and Interview*

Primary data, such as the opinions from green specialists were collected through in-depth interviews with LEED Consultants like Al-Emran Hossain of Bangladesh Green Building Academy and Lukan Alamgir, project manager/director at ARCHETYPE LIMITED which is working as a Green Architectural consultant, through a "Workshop on Green Building" at the Department of Building Engineering and Construction Management (BECM), Khulna University of Engineering and Technology KUET, Bangladesh at 1st December 2017 (figure-2) and Kushagra Juneja, LEED AP and Santanu Dattagupta, Indian Green Building Council (IGBC) AP(Accredited Professional) from design2occupancy services, India. All-important data related to Green building activity and LEED Certification projects and activity were noted from observations and interviews.


*Figure 2: Workshop on Green Building at KUET*

## 3. ANALYSIS AND FINDINGS

The main outcome through this research is to find out ways and means to reduce consumption of non-renewable resources, minimize waste and create healthy, productive environments. As it is a questionaries' research, we have asked many questions like how many projects registered in LEED online from Bangladesh, how many projects already get certificate, how many projects are LEED Platinum, how many Projects in LEED Gold, how many projects in Silver in Bangladesh? They told us about 402 projects registered in LEED Online from Bangladesh, 63 Project already get certificate, 17 projects are LEED Platinum, 15 Project in Gold, 9 Project in Silver and rest of Certificate. They also told us about passive design strategies which is used for ambient energy sources instead of purchased energy like electricity or natural gas. These strategies include daylighting, natural ventilation, and solar energy. If a structure is designed well, the consumption of energy will automatically be reduced. And there is a scope of energy saving by adopting proper and longer policy as well. If we start eco-friendly building design we can protect 20%- 30% energy.

Even we can protect the cost of one quick rental capacity (small power plant) plant per year if we follow green building policy. From the interview, we can conclude that through passive system, active system and hybrid system we can reduce consumption of non-renewable resources. We can also follow building massing and orientation system properly. That is how we can feel visual comfort and daylight. Passive heating uses the energy of the sun to keep occupants comfortable without the use of mechanical systems. Using simulation tools and software, we can estimate how much energy the building will utilize, making changes in accordance with the building systems, and compare amongst these to decide the optimal configuration. Also, we additionally take after radiant heating and cooling system. Be that as it may, radiant heating and radiant cooling systems are not quite the same as ordinary HVAC systems since heat or cool surfaces oppose to air. Water-efficient fixtures and equipment's may be the most effortless approach to reduce consumable water utilize. Rainwater harvesting can save water for reuse.

Below the table-1 which indicates LEED rating system from the interviews. Here, we see that many categories of LEED rating which indicates the parameter of Green Building. It comprises of an integrated process, area and transportation, water proficiency, energy and atmosphere, materials and resources, indoor natural quality, advancement and regional priority. Here we see that the importance of energy and atmosphere is greater than any other categories. It indicates 33 points out of 110 points (Todd, J. A., Pyke, C., & Tufts, R. 2013). Buildings use energy, materials, water, and land to create the right environment for its occupants. All of these things cost money and all of them have an environmental impact.

*Table 1: LEED Rating System*

| Category | Prerequisite | Credits | Points |
|---|---|---|---|
| **Integrated process(IP)** | None | 1 | 1 |
| **Location and Transportation(LT)** | None | 8 | 16 |
| **Sustainable sites (SS)** | 1 | 6 | 10 |
| **Water Efficiency (WE)** | 3 | 4 | 11 |
| **Energy and Atmosphere (EA)** | 4 | 7 | 33 |
| **Materials and Resources (MR)** | 2 | 5 | 13 |
| **Indoor Environmental Quality(IEQ)** | 2 | 9 | 16 |
| **Innovation(IN)** | None | 2 | 6 |
| **Regional Priority (RP)** | None | 6 | 4 |
| **Total** | 12 | 48 | 110 |

*Source: Based on interview*

We have visited AKH ECO Apparels at Dhamrai, Dhaka, Bangladesh (Figure-3). Here we have gained the practical experience of prospect of Green Building in Bangladesh. It is at Dhamrai by

the side of Dhaka-Aricha highway, on a 13-acre land, AKH has developed this eco-friendly project strictly applying the Gold Category requirements of Leadership in Energy & Environmental Design (LEED), which are officially prescribed by the U.S. Green Building Council. It has 480,000 sft of constructed area. Adequate space and scope for fresh air, rainwater storage and use, wastewater managing as well as recycling and reusing, reduction of carbon emission, use of efficient and renewable energy, and use of heat-resistant and carbon emission free building materials are a few of the major features of this green project (AKH Has Gone Green, 2017). About 4500 workers can work here in the most pleasant indoor and outdoor environments. The factory building, which will never rise beyond 3rd floor ever, does have all measures and features to ensure safety, security and good working environment for the people working in it. Open terrace with grass carpeting and rooftop gardens add to its pleasant and healthy ambiance (AKH Has Gone Green, 2017).

*Figure 3: AKH ECO Apparels at Dhamrai, Bangladesh.*

According to Green Building Information Gateway below (Figure 4) the position of LEED certification activity of Bangladesh comparing other countries in the world. We can see that 76 LEED Certification projects and 57 LEED Certification activity is in Malaysia. There is no LEED Certification project and LEED Certification activity in Nepal. The LEED Certification projects and LEED Certification activity are higher in India than Bangladesh. About 801 LEED Certification projects and 567 LEED Certification activity in India. There are 13 LEED Certification projects and 11 LEED Certification activity in Pakistan. From the site visit, interviews, secondary data, workshop and personal observation and analysis we have found that there are about 63 LEED certification project and LEED Certification activity in Bangladesh.


*Figure 4: LEED Certificate and LEED Certificate activity in different countries*

## 4. CONCLUSION

According to interview, LEED rating system has been explained in this research and it focused on the importance of energy and atmosphere category which importance is greater than any other categories. It indicates 33 points out of 110 points of LEED rating system. We should consider the opportunity at design phase to energy efficiency and atmospheric protection like reducing building energy use, using less harmful chemicals for refrigerants, generating renewable energy on site, providing for on-going energy savings and purchasing green power for project use. We should consider materials and resources consideration like providing for recycling, reusing existing buildings, reducing construction waste generation, using salvaged and recycled content materials, using rapidly renewable (agricultural) materials and certified wood products. It is also may consider to indoor environmental quality like improving indoor air quality, increasing outside air ventilation, managing air quality during construction, using only non-toxic quality finishes, carpets, and composite wood products, reducing exposure to toxic chemicals during building operations, providing individual comfort control and maintaining thermal comfort standards for the betterment of sustainable green building technology. The number of LEED certification Building is very low. Only 63 buildings of Bangladesh have LEED certification. For the development of green construction sector, there is no alternative way without energy efficient

building. By implementing this green building technology, it will be a great relief for the government and the future generation from energy problem. The architect and engineer should think over it at design phase. A shower tap from which water discharge will be little quantities. It can be energy efficient equipment and ultimately it will convert the building a green building. The results coming out from this such as energy demand will be decreased and it will be beneficial worldwide majorly for Bangladesh. If we ensure to implement the green building policy we can save electricity (energy), environment and social interaction which is equal to a smart green power plant, sustainability, and social imbalance.

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# AN ASSESSMENT OF NOISE LEVELS IN MEDICAL AND SURGERY WARDS OF A NATURALLY VENTILATED HOSPITAL

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***Abstract:*** *High noise level in hospitals is harmful for the wellbeing of patients and staff. For patients, it may induce stress, discomfort, restlessness resulting need for more medications than normal, even slowing down healing process and subsequent increase of length of stay. It has become a universal concern since the noise levels in hospitals are on constant rise exceeding the World Health Organization guidelines (WHO). This study aims to presents the results of a comprehensive noise survey of two surgery and one medicine ward in a naturally ventilate teaching hospital in Dhaka, Bangladesh. Through a field survey, quantitative data was collected through continuous noise monitoring over three days from 8:00 AM to 8:00 PM in wards, corridors and nurse stations. The study also identified the common noise sources present in the wards and their respective intensity. The daytime levels within these wards ranged from 48–63 dB $L_{Aeq}$ which was higher than the Bangladesh National Building Code (BNBC). Noise levels were not correlated with ward size, number or gender of patients, but were highly dependent on the ward layout with respect to noise source. Overall noise levels were related to Reverberation Time (RT) and to the numbers of high level noise events. Analysis showed that most of the noise sources are avoidable either partially or totally. Noise levels can be reduced to a great extent by eliminating or reducing noise sources, using hospital friendly high performing acoustic materials, use of quieter equipment, awareness and motivation programmes, proper management, policy enforcement and behaviour modification programmes of staff and patients. It will change the trend of noise levels rising in wards and help to improve the acoustic environment in hospitals effectively.*

***Keywords****: Acoustic Conditions, Hospital Wards, Noise control solution, Noise level*

## 1. INTRODUCTION

In recent times, high sound levels is a significant concern in hospitals, which have been a frequent phenomenon in hospitals since the time of Florence Nightingale. It is considered as one of the top complaints by patients and staff in a hospital. Along with environmental noises (such as traffic noise from road, air or railways, building with heavy machinery, construction activity, loudspeakers, and healthcare facilities e.g. ambulance, delivery vans and refuse collection), abundant sound sources are present inside the hospitals (BNBC, 2015). Sometimes, these sound sources are mobile such as, people, staff, trolleys and medical equipment. Constantly changing density of people inside the hospital and their various activities is another major reason for high noise levels in hospital (MacLeod et al., 2006).

Unwanted sound or noise can be harmful to the wellbeing of patients and staff (Joseph and Ulrich, 2007). Due to noise disturbances, patients are often disturbed during their rest which can negatively affect patient's health (Topf, 1985; Freedman et al., 1999; Parthasarathy et al., 2004). Due to stress in higher noise levels, patients sometimes require more pain medications than normal. Also, it can increase the length of stay (Fife and Rappaport, 1976) and sometimes slow down the healing process (McCarthy et. al, 1991). Also, sound levels in hospital affect patient's perception of the quality of care provided.

Beside annoyance, increased stress, and fatigue, high sound levels cause emotional exhaustion and burnout among the staff of a hospital. According to Joseph and Ulrich (2007), noise inside hospitals make it difficult for the staff to communicate clearly and due to speech

intelligibility of the space, it can lead to medical errors.

This constantly increasing noise levels in hospitals and its impact on the users are a serious concern. It is absolutely necessary to keep the noise levels in hospital wards in check and under the recommended levels. The standards and guidelines for the sound level within wards can be shown in Table 1.

*Table 1: Noise level standards in hospital wards*

| Standards | Recommended Sound Pressure Level |
|---|---|
| WHO (Berglund et al., 1995) | 35 dBA at Day Time<br>30 dBA at Night Time |
| ANSI (1999) | 25 – 40 dBA<br>NCB: 25-40 |
| International Noise Council [Cited in (Konkani and Oakley, 2012)] | 45 dBA at Day Time<br>20 dBA at Night Time |
| BNBC (2015) | 33- 48 dBA<br>NCB Curve: 25-40 |

Earlier studies on noise levels in hospitals were conducted by physicians or nurses with little information regarding the measurement methods or detailed analysis of noise (Christensen, 2005; Richardson et. al., 2009; Yoder et al., 2012). However, these literatures suggested that noise has become a significant problem which is just getting worse with time. Although in later periods many papers were published with proper acoustical studies, most of them focused on areas such as intensive care units (ICUs). Less attention was given to general wards where patients stay for treatment and recovery from a few days to several weeks. But the results of recent studies also showed consistency with the previous research (Elliott et. al, 2010; MacKenzie and Galbrun, 2007; Ryherd et. al, 2008; Xie and Kang, 2012).

After reviewing studies of diversified medical units and different hospitals of different countries worldwide from 1960 to 2005 Busch-Vishniac et al. (2005) found that none of the reviewed studies could find a hospital which complied with the 35 dBA recommendation by WHO (Berglund et al., 1995). They also found that the sound levels in these wards were increasing continuously since 1960, on average 0.38 dBA per year for daytime and by 0.42 dBA per year for night time. It was also mentioned that the average A-weighted $L_{eq}$ in hospitals has increased to 72 dBA from 57 dBA for daytime and to 60 dBA from 42 dBA for night time since 1960. Although there was inconsistency between methodologies and reporting of the data in different surveys, the author concluded with the statement that hospital noise is a universal problem.

Little research was found regarding this topic in the context of Bangladesh and this study aimed to fill that gap. The main focus was to measure noise levels in different ward layouts of a naturally ventilated Government hospital. However, due to the limitation of time, one particular case study was selected which has a common ward layouts of currently designed hospitals in Bangladesh. The objectives of this study were as followings.

1. To identify noise levels in adult wards for daytime and prepare noise maps
2. To find out common noise sources present in these wards
3. To highlight various factors that can affect the noise level in the wards
4. To recommend noise control solutions for reducing noise sources and noise levels in hospital wards

## 2. METHODOLOGY

### *2.1. Selection of a case study*

From the last decade, the architects are following a prototype design for government teaching hospitals of Bangladesh. Although they often vary in heights, orientation and functions according to their respective sites and need of their areas, most of the wards bear similar features. One particular teaching hospital of this prototype in Dhaka was selected to conduct this field survey, where the wards were placed in two or more parallel blocks in north-south orientation and were connected by corridors or waiting areas.

Among the surveyed wards, two surgery wards (Figure 1) were on the 6th floor while one medicine

ward (Figure 2) was on the 8th floor. Each of this ward blocks consisted of rooms with 8, 10 or 12 beds in double loaded bays. The wards were designed around a central nurse station, long corridors on both sides of Nurse Station, with patient accommodation, generally situated on one side, and staff rooms, kitchens, and healthcare resources on the other.

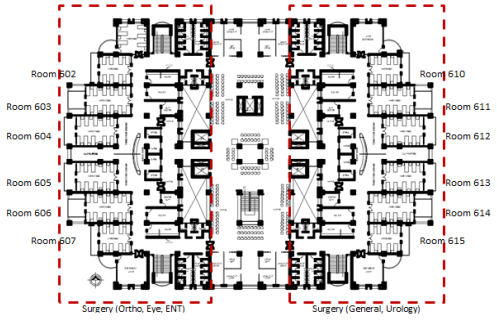



*Figure 1: 6th Floor Plan (Surgery wards-1&2)*

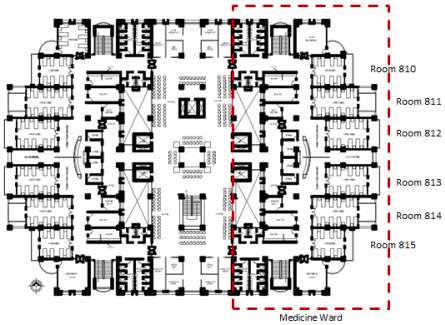



*Figure 2: 8th Floor Plan (Medicine ward)*

The ward rooms had hard plastered ceiling and tiles flooring. The 3.3 meter wall consisted of ceramic tiles till 1.4m height and hard plaster after that. Each ward rooms had two wooden doors, one facing the corridor and another facing the outdoors via balcony. Again each ward room was consisted of two Thai aluminium sliding glass windows at the east and west wall, on both sides of wooden doors. Each room was furnished with a patient's bed and a metal cupboard per patient.

### *2.2. Data Collection*

Measurements were taken at each room, nurse stations and respective corridors for three consecutive days and for 12 hour period time (8.00 AM to 8.00 PM) with a portable Lutron SL-4012 sound level meter after selecting 'fast' time constant as required by WHO guidelines (Berglund et al., 1995). For each space, the A weighted and equivalent noise levels were measured manually for every 2 hours from a point near the centre of the room and at a height of roughly 1.2m in a way that the Hawthorne effect was minimum (Shield, 2016). "A-weighting is a standard frequency weighting that deemphasizes low-frequency sound similar to average human hearing response and approximates loudness and annoyance of noise. A-weighted sound pressure levels are frequently reported as dBA" (Charles, 1998). Also, sources that were causing noise were identified through observation and the sound level was measured individually by the sound level meter after each incidence.

### *2.3. Data Analysis*

The study tried to analysis the current acoustic condition or noise levels in the wards during the daytime, identified common noise sources in these wards and presented the result of this survey by discussing the positive and negative factors responsible for influencing the quality of the acoustic environment. Also from the literature review, the study tried to provide noise control solutions to reduce noise levels in hospital wards to ensure a better acoustic environment for its users.

## 3. RESULTS

### *3.1. Noise Levels*

The noise levels found in every ward are presented in Figure 3(a, b, c) against the 12 hour time periods. The graphs showed that most of the ward rooms, except the empty ones (Room 602 and 610) or those with patients without guardians (Room 607), had high noise level and it is over 50 dBA. They were about 15 dBA higher than the WHO 35 dBA recommendation guidelines (Berglund et al., 1995). Even within empty rooms, the noise levels were ranged from 40 to 50 dBA. The reason behind this high noise level even in empty rooms were the presence of corridors which were often used by patients of caregivers for other types of facilities e.g. kitchen and toilets. The noises generated at the nurse stations also transmitted through the corridor. As it is a naturally ventilated hospital, the doors were remained open most of the times. As a result, the sounds produced at nurse station and corridors easily travelled in the

wards and made them noisier. The figure reveals that the noise levels in the medicine ward were above 53 dBA and were higher compared to the noise levels in surgery wards. The overflow of severely ill patients, their multiple caregivers and ever busy nurse station were the very reason behind this high noise level in medicine wards. High density people and the presence of busy adjacent corridors, these wards were always noisy. Same goes for ward rooms with highest patient - caregiver density and wards near Nurse Stations. It could be observed that the noise levels were low in the morning but still over 45dBA. The wards became noisiest during launch time and visiting hours in the afternoon, which were ranged from 55 dBA to 67 dBA.

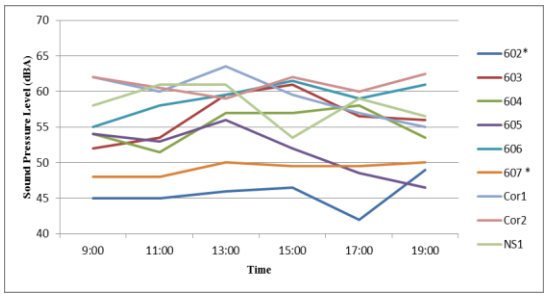



*Figure 3a: Measured noise levels during daytime in different rooms of surgery ward-1*

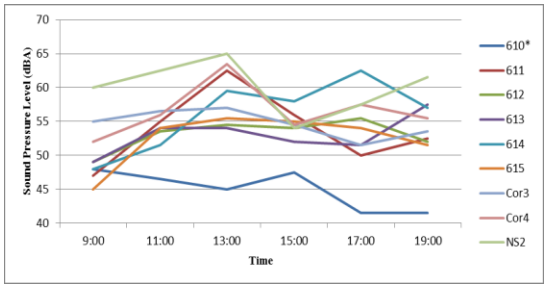



*Figure 3b: Measured noise levels during daytime in different rooms of surgery ward-2*

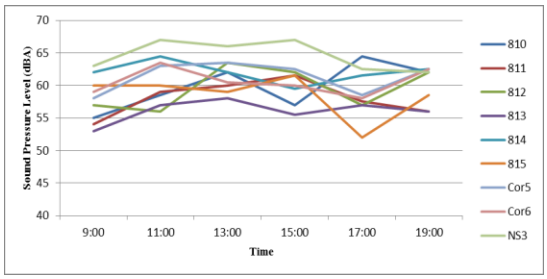
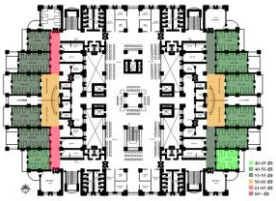
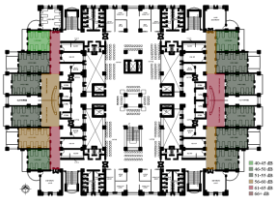
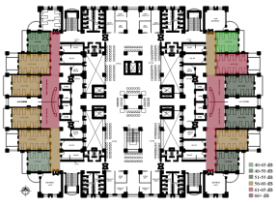
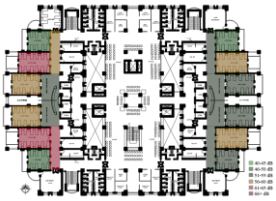
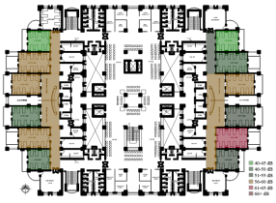
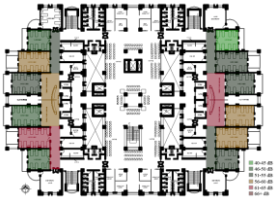
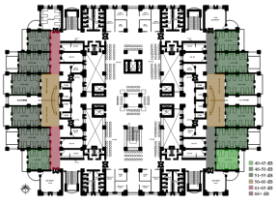



*Figure 3c: Measured noise levels during daytime in different rooms of medicine ward*

*Table 2: Noise map of surveyed wards at different time*

| Time | Surgery wards | Medicine ward |
|---|---|---|
| 09.00 |  |  |
| 11.00 |  |  |
| 13.00 |  |  |
| 15.00 |  |  |
| 17.00 |  |  |
| 19.00 |  |  |
| $L_{Aeq}$ Scale<br>40-45 dB<br>46-50 dB<br>51-55 dB<br>56-60 dB<br>61-65 dB<br>66+ dB |  |  |

Noise maps (Table-2) also reveals that the medicine ward was noisier than surgery wards and surgery ward-1 was noisier than surgery ward-2. The exposure to environmental noises, such as railway station and heavy road traffic, had the potential to influence the overall noise level. The nurse station of the medicine ward always showed a higher noise level (above 31 dBA) and over 66 dBA from 11.00AM to 3.00PM. The sound level in the corridors of medicine ward was always over 56 dBA which was higher than the noise levels found in surgery wards. Depending on the time the sound levels in the wards can be different. For example, during doctors round at morning, mealtimes and visiting hours were the noisiest period of time.

### *3.2. Overall $L_{Aeq}$ Values*

The $L_{Aeq}$ values of the three wards over the 12 hour time period are presented in Figure 4. The sound levels were ranged between 45-65 dBA and were higher than WHO standards (Berglund et al., 1995). Another reason besides the people density in the wards was the interior materials of the wards. The hard plastered wall and plastered ceilings worked as a reflective surface as well the use of highly reflective tiles for floor and half of the wall. These reflective materials trapped the noises inside and caused them to echo and linger around. As a result, although some activities did not produce that much noise e.g. people conversation itself, but due to the trapped condition the noise keeps lingering inside which caused an annoying acoustic environment for users. Noise map for $L_{Aeq}$ shows a similar pattern of noise levels as discussed before.

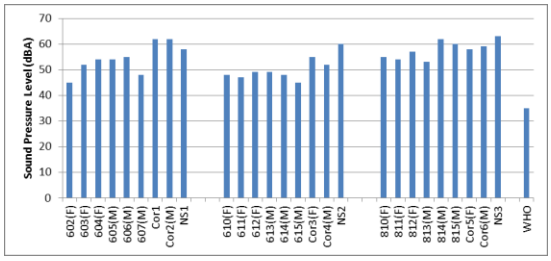



*Figure 4: Logarithmic average A-weighted sound pressure level ($L_{Aeq}$) measured in all wards compared to WHO guidelines*

### *3.3. Noise sources*

Noise events with $L_{Amax}$ greater than 60 dBA were recorded through observation and presented in Table 3 with their intensity. It can help to identify, avoid, reduce or control these high noise sources. No general patterns can be found behind these events. These events were highly dependent on the condition, time and type of patient or caregiver of a particular ward. For example, high noise from food trolleys, the rate of an object dropping and moving in the corridor are quite high during meal times. Other studies (Shield, 2016) on high noise events showed similar noise events which ensure the validity of these high noise sources. Most constant noises were people noise (Such as conversation, phone ringing and talking on phone), which can range between 60-80 dBA. Other sources have occurred without any fixed pattern.

*Table 3: Commonly occurred noise sources and their typical levels*

| Type of Noise | Noise of source | Measured Noise level $L_{Amax}$ |
|---|---|---|
| **Ward equipment** | Moving food Trolley | 65+ |
| | Moving medical supply trolley | 70-76+ |
| **Ward furniture** | Door closing | 76+ |
| | Metal cupboard door and drawer | 50-66+ |
| **People Noise** | Footsteps in the busy corridor | 60-64 |
| | Patient's coughing | 70-74+ |
| | Patients groaning or crying out | 70-80 |
| | Phone ringing | 60+ |
| | Talking on phones | 66+ |
| | People conversation in high voice | 62-65+ |
| | Conversation between nurse and caregivers | 64-74 |
| **Others** | Object dropping on floor | 70+ |
| | Object dropping on trolley | 78+ |
| **Noise from Surrounding** | Train Horns | 64+ |
| | Traffic (Horns) | 69+ |
| | Construction Site | 70+ |

### *3.4. Factors affecting noise levels*

Presence of loud noise sources (e.g. mechanical equipment, staff conversation and noise generated by visitors or patients) and use of sound reflecting materials on surfaces were the main reasons behind the high noise level in these hospital wards. This section discusses the above results to examine relationships between noise levels and various design, operational, and acoustic factors.

#### *3.4.1. Room size*

Noise levels were higher in both large and small rooms. So, it can be assumed that noise level of a room is not directly related to its size. Factors like the number of patient's caregiver and activities around patients highly influence noise levels.

#### *3.4.2. Ward Type*

Despite having a similar layout and hospital routines, the noise level in medicine ward was higher than the sound level in surgery ward-2 due to the difference of patient load, the density of people, the type of patients and care provided. Presences of more acutely ill patients, who were crying or groaning, were another underlying reason behind the high noise level in medicine wards.

#### *3.4.3. Ward design*

Although the wards were identical, analysis of noise level revealed that a considerable amount of noise occurring in the patient accommodation was associated with these ancillary spaces. Especially noise from nurse stations contributed to high noise levels in those rooms nearest to the nurse stations.

#### *3.4.4. Reverberation Times (RTs)*

Use of sound reflecting materials on surfaces (e.g. wall, ceiling and floor) is the main reason behind the high noise level, which caused sounds to echo, overlap, linger or have long reverberation times within the wards. High RTs can lead to less smooth communication between users as well as cause speech intelligibility for users which can lead to medical errors. Although RTs could not be calculated due to time restrictions and complications, many staff agreed to the speech intelligibility and less smooth communication with doctors, caregivers or patients due to the lingering noise in wards.

### *3.5. Noise Control*

The noise survey, findings, and analysis showed that many of the noise in hospital wards can be easily avoided by control of noise source, careful design, planning of patient accommodation and staff training (Shield, 2016). From earlier research (BNBC, 2015; Evans and Philbin, 2000; Joseph and Ulrich, 2007; MacLeod et al., 2006; Wiese and Wang, 2011; Zimring et al., 2004) the following measurements can be recommended as solutions for controlling the high noise levels in these hospital wards.

#### *3.5.1. Eliminating or reducing noise sources*

Loud conversations were identified as one of the main sources of high noise levels in hospital wards. By conducting group conversations in an enclosed space, educating patients and caregivers about maintaining a low sound level within wards and educating staff about the importance of talking quietly, maintaining a quiet environment etc. can minimize this problem (Baevsky et al., 2004; Bailey and Timmons, 2005; Buelow, 2001; Joseph and Ulrich, 2007; Slevin et al., 2000).

#### *3.5.2 Sound-absorbing ceiling tiles*

By installing high-performance sound-absorbing ceiling tiles and panels can help to solve the ambient noise problem to a great extent. Along with the reduction of noise levels, perceptions of noise and perceived work pressure among staff, this solution can improve speech intelligibility (Berens and Weigle, 1996; Blomkvist et al., 2007; Hagerman et al., 2005; Joseph and Ulrich, 2007; MacLeod et al., 2006). The ceiling-tile can help to reduce reverberation times and sound propagation. The sound absorbing materials must meet the hospital standards (e.g. inflammable, free from smoke generation, cleanliness, dust free, health hazard free etc.) and should be covered with antibacterial fabric (MacLeod et al., 2006).

#### *3.5.3. Other recommendations*

- Installation of door closers and resilient material strips put along edges of doors' frames can eliminate the noise from outside (MacKenzie and Galbrun, 2007).

- Instead of large metal trolleys, use of plastic trolleys, as well as plastic cover strips at the edges can avoid noises during moving or clashing between metal equipment (MacKenzie and Galbrun, 2007).
- Using resilient material strips along the edges of doors and drawers can eliminate the noises from cupboard door or drawers (MacKenzie and Galbrun, 2007).
- Behaviour modification programmes or different interventions can also help to control the high noise levels in these wards. Such as- educational noise reduction programme for staff, raising awareness in visitors and patients, policy enforcement, introducing music etc.

## 4. CONCLUSION

The noise levels measured in the wards of the surveyed surgery and medicine departments were above the recommended WHO guidelines and the 12-hour equivalent noise levels were in the range of 48–63 dBA. The noise sources, which were mostly responsible for the high noise level inside the wards, were general activity and talking. The occurrences were generally well distributed amongst the less common sources and building services were not identified as potential noise sources.

The noise survey included wards of different sizes and found that noise levels were not related to room size or the number of patient beds as some smaller wards had very high noise levels compared to larger rooms. Also, this study found that noise levels were highly dependent on the ward layout as the ward rooms near nurse station or service facilities. These findings were very similar to earlier studies (Shield, 2016).

This study revealed that most of the noise sources are avoidable while some of them are partially avoidable by eliminating or reducing noise sources, use of quieter equipment, proper management, policy enforcement and behaviour modification programmes of staff and patients. Noise could be further reduced by careful design of hospital wards in a way so that there is no direct sound path of noisy areas such as kitchens or services to patient areas and using hospital friendly high performing acoustic materials (wherever needed) as ceilings and wall panels can reduce reverberant noise significantly. High performing acoustic ceilings together with a more spacious design of corridors contribute to the lower noise levels (Shield, 2016).

Due to unavailability of other running hospitals of the same prototype in the city and time constraints, only one teaching hospital of Dhaka was studied. Further investigations should be conducted in more similar type of hospitals by following similar methods to have a better understanding of the overall acoustic conditions of hospital wards in Bangladesh. This study suggests that introduction of more standards for the acoustic design of hospitals; improved physical design can help to improve the acoustic environment in hospitals effectively and can challenge the rising of noise levels in wards.

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# RETHINKING RELATIONSHIP BETWEEN CHILDREN'S PLAY AND CONFIGURATION OF URBAN PHYSICAL ENVIRONMENTS IN DHAKA

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***Abstract:*** *Global awareness on children's right to play in the urban neighbourhoods has increased more than any other time in history. However, scholars argue that urban spaces are getting worse for children's outdoor play. It is a timely issue to rethink the way we see potentials of urban spaces in creating opportunities for children's play, most importantly in the rapidly urbanizing South Asian cities. This study explores play and spaces of play from children's (aged 7 to 15) perspective in Dhaka and develops a spatial analytical tool (SAT) to study children's play in the urban spaces. The paper then employs SAT to test whether the configuration of urban physical environments affects children's location preference for play, measured in terms of intensity of children's play in the play spaces (ICP). Methodologically, the study employs a mixed methods research approach and uniquely integrates ethnographic, spatial, and statistical analyses. Data were collected through questionnaire survey and interviews of children and their parents, and systematic observation of play spaces and streets in three urban areas, Sutrapur, Dhanmondi and Uttara, in Dhaka. Results reveal how children relate play to happiness in their everyday life. Children's play and play spaces in Dhaka are spontaneous and unstructured in contrast to structured games and managed playgrounds in the west. SAT shows high potential for comprehensive assessment of urban play environments. Statistical regression confirms the configuration of a play space ($R^2$ = 0.212, $p < 0.000$) and its surrounding streets and land-uses ($R^2$ =0.216, $p < 0.000$) significantly affect ICP. Discussion of results highlights the urgency importance of considering children's differential voices; prioritizing use-value of urban space; and rethinking the limitations of the 'playground' concept. This study informs policy makers and spatial design professionals who appreciate participatory, differential, and evidence-based approaches to make cities green and livable for all.*

***Keywords****: Children's Play, Configuration of Urban Physical Environment, Dhaka, Play Spaces.*

## 1. INTRODUCTION

Over the past few decades, researchers have exposed the diminishing pattern of children's outdoor play in urban areas (Hillman, Adams et al. 1990, O'Brien, Jones et al. 2000, Shaw, Watson et al. 2010). Besides having negative impact on physical health and wellbeing of children (Wen, Kite et al. 2009), lack of outdoor play affects social sustainability and urban resilience (Freeman and Tranter 2011, Bates and Stone 2014). Children's outdoor play is also an important source of joy and beauty (Huizinga 1949, Lefebvre, Stanek et al. 2014). The United Nations Convention on the Rights of the Child (UNCRC 1990) recognizes the importance of play by specifically mentioning children's right to play in Article 31.1:

> *"States Parties recognize the right of the child to rest and leisure, to engage in play and recreational activities appropriate to the age of the child..." (UNCRC 1990, Article 31.1).*

Paradoxically, despite awareness about children's right to play increased more than any other time in history, process of exclusion of children from the urban public realm continues, and even getting faster (Karsten 2002). Many cities lack equitable and accessible infrastructures for children's play (Hart 2011).

This problem is severe in urbanising South Asia. More than 500 million people live in different urban centres in this region. Among them, 163 million are children aged below 18 (UNESCO 2014). Rapid urban growth transforms the configuration of buildings, street network, and open spaces and demands context-sensitive urban management and plans. However, spatial planning in South Asian cities often replicate abstract pedagogical models developed in western contexts (Sargin and Savas 2012, Bertuzzo 2009). Among other aspects of children's play research in South Asia, issues such as children's differential views on play and the dialectics of play spaces remain unaddressed in most studies (Freeman, Tranter et al. 2017, Lefebvre, Stanek et al. 2014, Ahmed 2011). Consequently, wide gap exists between the actual users of urban play spaces, i.e. children, and the managers of those spaces.

This study fills the above-mentioned gaps

in the context by exploring the constructions of play and play space from children's perspectives in Dhaka and developing a measurable spatial analytical tool (SAT) to study dialectical relationship of urban physical environments and children's location preference for play.

Located in South Asia, Dhaka is a rapidly urbanizing and reportedly the densest mega-city in the world (UN-Habitat 2018). Little research has been done on the relationship between the configuration of physical environments and children's location preference for play in Dhaka (Islam 2009, Monsur, Mansur et al. 2016). Past studies, which are very few in number, have addressed children's play and the configuration of urban physical environments as separate issues (Islam 2009, Ahmed 2011, Monsur, Mansur et al. 2016, Ferdous 2012). In order to influence real change in the ground, urban studies must integrate both software and hardware aspects of urban spaces and develop organizational strategies for the future (Cho, Trivic et al. 2015). This study thus discusses its outcomes by highlighting their implications for current urban planning practices, particularly concerning children's play and wellbeing in high-density and urbanizing cities.

## 2. METHODOLOGY

The study has applied a mixed methodological research approach, where a qualitative strand preceded a quantitative strand. As part of qualitative strand, this study explored constructions of play and play space by adopting grounded theory approach (Glaser and Straus 1967). Constructions of play and play spaces have been explored with reference to themes such as children's perceptions and preferences of play and play spaces, degree of independent mobility, use-pattern of urban play spaces, and perceptions on neighbourhood environments etc. These themes have been analysed with reference to children's individual and social profiles such as age (aged 7 to 9, 10 to 12, and 13 to 15), gender (boys and girls), locations (places and path-networks in three study areas), family income (BDT'000/month: 0 to 5.9, 6 to 13.9, 14 to 24.9, 25 to 49.9, 50+) and length of stay (0 to 10 years and, more than 10 years).

Building on the results from the qualitative strand and with reference to literatures in advanced urban spatial analytics (Batty 2017), the quantitative strand of this study developed methods to measure configuration of urban physical environments of play considering children's play behaviour in Dhaka. The study then empirically explained the impact of urban physical configuration on children's location preference for play by testing specific hypothesis using statistical correlation and regression models. Children's location preference for play has been measured in terms intensity of children's play (ICP). ICP is the average number of children directly observed within a unit area of a play space. Systematic observation (10 minutes each) of children's play activities was conducted by the author four times a day, from 7am to 6:59pm with three hours interval, separately for weekdays and weekends.

Empirical studies have been conducted in three selected residential areas, namely Sutrapur (S), Dhanmondi (D), Uttara (U) in Dhaka from September, 2015 to October, 2016. The selected areas are characterized with both planned and unplanned settlements (Figure 1). Primary data collection process included i) questionnaire survey of children (n=308) and ii) their respective parents (n=168) in 8 schools; iii) follow-up interviews and drawing exercises with children (a subset of *i*); iv) systematic observation (n=208) of 21 play spaces and iv) interviews with children (n=201) in the play spaces and v) systematic observation of street segments (n=212).

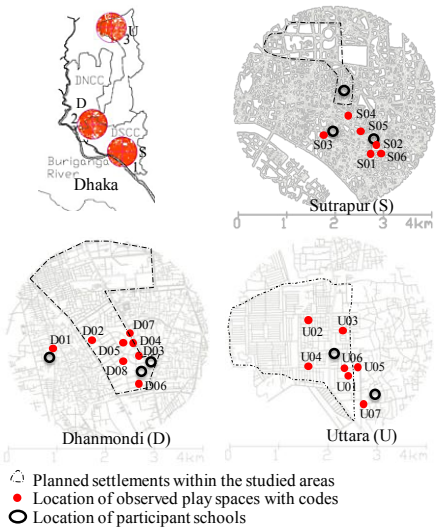


*Figure 1: Location of study areas and data collection sites in Dhaka*

Data collection instruments, such as survey questionnaires, interview guides, participant information sheet etc. have been approved by the relevant institutional ethics board (NUS-IRB), local authorities and consents have been taken from all participants before collecting any subjective data.

## 3. RESULTS

### *3.1. Differential constructions of children's play*

Grounded theory analyses of subjective data confirm both heterogeneity and homogeneity of children's play across gender, age, locations, income and length of stay in Dhaka. When asked what comes to their mind when they hear words such as 'play' (*khela*) most children referred to wellbeing aspects such as happiness and fun (55%), social aspects such as different forms of games, friends and families (34%), and space-time aspects such as names of play spaces, play times etc (19%). (Figure 2).

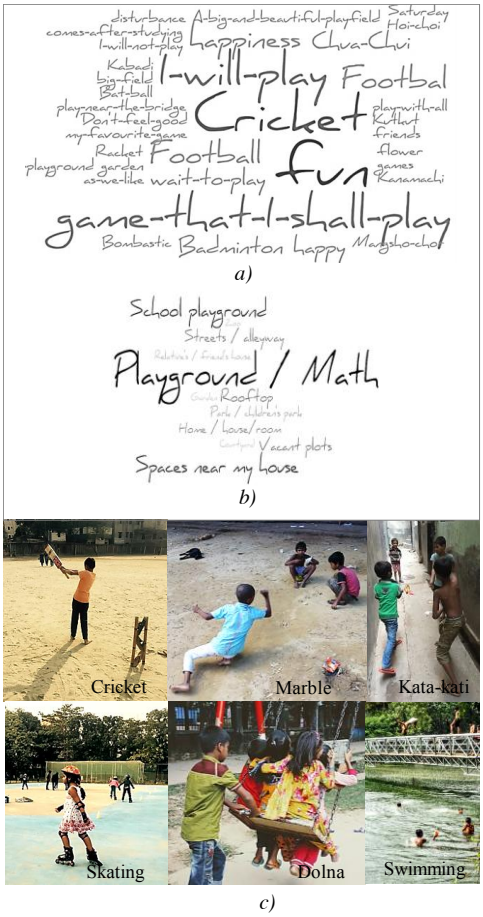


*Figure 2: Word-cloud showing children's perceptions on 'play' (a) and 'play spaces' (b). Photos depicting examples of children's play in Dhaka (c). (Source: author).*

Concepts of play and play space bear different meaning among different age and gender groups of children in Dhaka. In terms of forms of play, boys like to play cricket and football most, whereas girls prefer to play *kanamachi* and *chuachui*. Children's preference for outdoor play varies significantly across gender (girls prefer less than boys do) and income group (high-income group children prefer to play outdoors more than low-income group) (Figure 3). Children's preference for outdoor play and forms of play show homogeneity across study areas, age groups, and length of stay.

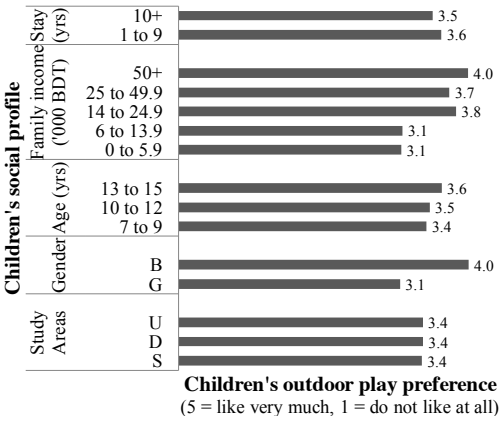


*Figure 3: Children's outdoor play preference and their social profile*

Children, and their respective parents highlighted the importance of provision, proximity, and car-free safe access routes to play spaces (Table 1). They expressed low satisfaction about the current state of these environmental aspects. In their dream play spaces, children highlighted natural environments, boundary conditions of play spaces, play equipment, furniture etc.

*Table 1: Degree of importance and satisfaction for the elements of physical environments concerning children's play*

| Elements of physical environment | Satisfaction* (1=lowest, 5=highest) | Importance** (1=lowest, 5=highest) |
|---|---|---|
| **Availability of play spaces** | 2.33 | 4.16 |
| **Proximity of play spaces** | 2.5 | 4.14 |
| **Cars on the way** | 2.42 | 4.22 |
| **Strangers in the outdoors** | 2.43 | 4.25 |

*Children's response, ** Parent's response

Intensity of children's play (ICP) in the studied play spaces varied from 0 to 478 (in persons/acre/10 minutes) (Figure 4). Average ICP in the studied play spaces for all observations (n=208) was 24 children per acre per 10 minutes. ICP varied Average intensity of use or play spaces by boys (19 boys/acre/10 minutes) was significantly higher than girls (1.7 girls/acre/10 minutes).

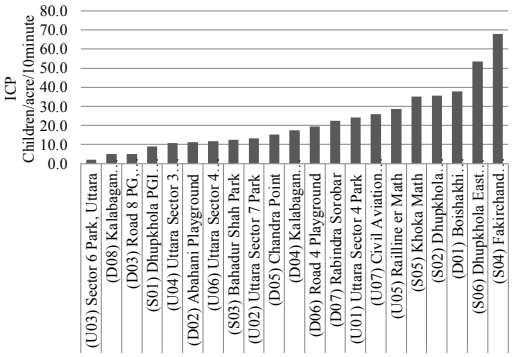


*Figure 4: Intensity of children's play (ICP) in the observed play spaces.*

Use of urban spaces and streets by children as play spaces varies significantly across types of streets. Results show that ICP is fewer in the planned area streets (less than 1 child in 100m) compared to unplanned area streets (more than 6 children in 100m). This finding is interesting since, planned residential areas are home to economically well-off families in Dhaka (Choudhury and Chiu 2013).

Results suggest that besides some similarities, such as play as a preferred form of activity by children, children' play and play spaces in Dhaka are significantly different from that in western urban contexts. They are different in terms of where and how children play. Children in Dhaka play in the playgrounds and available green spaces near home that are mostly unstructured (Figure 2). Children's play is mostly spontaneous in the urban spaces and streets of Dhaka, in contrast to structured games in western contexts (Rudner 2012).

### *3.2. Development of a spatial analytical tool*

Results from ethnographic explorations informed development and application of a context sensitive spatial analytical tool (SAT) to measure the configuration of urban physical environments of play. SAT measured urban physical environments of play in terms of micro- (MiSQ) and meso- (MeSQ) spatial qualities, referring to morphological and accessibility aspects of a play space and its surrounding environments respectively. In order to analyse MiSQ of the three study areas, this study defined and measured 17 MiSQ indices under eight sub-categories. These categories were developed based on the findings from the ethnographic studies and also with reference to earlier studies in urban morphology (Caro et al. 2016, Ahmed 2011, Islam 2008, Ewing and Clemente 2013, Mehta 2007, Jacobs 1961). The sub-categories of the MiSQ indices are as follows:

1) Co-presence of others: i) Co-presence of younger children (0 to 6 years), ii) Co-presence of adults (19 to 60 years), iii) Co-presence of elderly (61 years and above).
2) Size: i) Relative area of a play space, ii) Width (average) of a play space.
3) Surface quality: i) Green surface area of a play space (%), ii) Green foliage cover (%) of a play space
4) Amenities: i) Relative diversity of amenities within a play space.
5) Enclosure: i) Visual enclosure (%) of a play space.
6) Front-road geometry: i) Front road width, ii) Street frontage length.
7) Front-road diversity of use: i) Front road small business intensity, ii) Front road medium business intensity, iii) Front road big business intensity
8) Front-road traffic: i) Front road non-motorized vehicular traffic intensity, ii) Front road non-motorized vehicular traffic intensity, iii) Front road pedestrian traffic intensity.

Drawing on the graph theory (Euler, 1741), two types of spatial analytical units were used for MeSQ analysis: a) pedestrian street network segment line (NS), and b) pedestrian street network segment line and associated land-uses (NSL) (Figure 5). Two types of distance measurement systems, namely metric and topological, have been developed by representing urban spaces as i) point-locations (Porta et al. 2006a; Porta et al. 2012; Sevtsuk, 2014) and ii) lines (Hillier and Hanson, 1984; Hillier, 2012) respectively. In total, 63 MeSQ indices were measured and tested within 400m and 800m radii from studied play spaces.

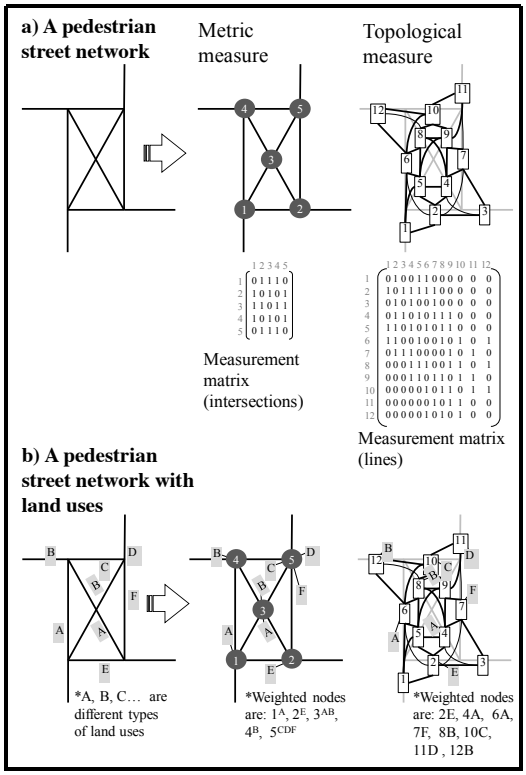


*Figure 5: Types and measurement techniques of MeSQ indices for hypothetical urban systems. Source: Author)*

### *3.3. Configuration of urban physical environments affects children's play*

Using the developed SAT tool, this study tested a hypothesis that both MiSQ and MeSQ qualities of a play space affect children's location preference for play, measured in terms of ICP. Regression studies confirm that ICP is influenced by both morphological ($R^2$ = 0.212, $p < 0.000$) and accessibility ($R^2$ =0.216, $p < 0.000$) attributes of a play space.

A number of MiSQ and MeSQ indices were significantly related to ICP. Notable MiSQ indices related to ICP are enclosure ($r = 0.326$, $p < 0.01$) and small business intensity ($r = 0.40$, $p < 0.05$). Higher enclosure of a play space (i.e. higher degree of visual opaqueness from the adjacent streets) and the higher rate of small businesses in the front street were associated with higher ICP in the studied play spaces.

Statistical regression involving MeSQ indices show that both metric (such as, land-use reach to medium volume vehicular intersections within 400m radius) and topological (such as, place syntax accessibility to vehicular intersections within 400m radius) measures are significantly correlated to ICP. Among all the MeSQ indices, space syntax choice within 400m radius (topological measure) showed the highest predictive strength ($r= 0.273$, $p < 0.01$) (Figure 6). MeSQ indices involving both network segments (NS) and network segments plus land-uses (NSL) are significantly correlated to ICP. These results extend current debates in urban morphology about the primacy of metric and topological distance measures (Hillier and Penn 2004, Ratti 2004), particularly in assessing children's play environments in the city and highlight the need for methodological integration of spatial analytical models in spatial analysis.

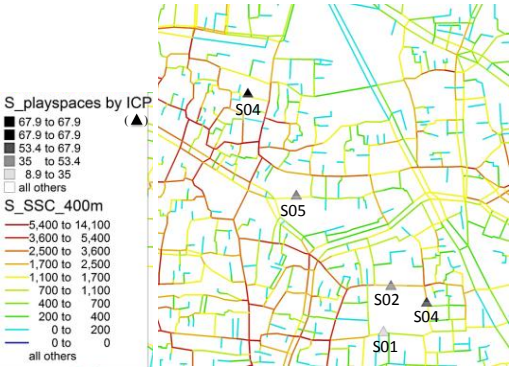


*Figure 6: Map showing relationship of a Space Syntax Choice of pedestrian network within 400m and ICP of play spaces in Sutrapur.*

## 4. DISCUSSION OF RESULTS AND RECOMMENDATIONS

### *4.1. From exchange-value to happiness-value of urban space*

Children highlighted happiness and joy while describing play and play space. Happiness is an important dimension of wellbeing that is materialized through the *use* of space. Ironically, urban spaces have historically evolved as sites for exchange and profit-generating machines friendly for working-adults only (Lefebvre, Stanek et al. 2014). Findings from this study suggest that we must reconsider use-value of urban spaces, in this case 'happiness-value' linked to children's play, to ensure children's wellbeing. Since, knowledge at early stages of human life is significantly shaped by space (Piaget and Inhelder 1948), urban streets and open spaces must act as continuous learning environments for children as they grow up.

### *4.2. Children's differential views on play and play space matter*

Inclusion of children allowed this study to reveal differential meaning of play and play space in Dhaka. Children mentioned that they felt valued seeing their opinions matter. Children were attentive and cooperative. Most of them were able to express their opinions in writing and showed high competencies in reading maps. All these suggest that school-age children in Dhaka are able show to express their opinions, if asked. However, children also reported that their views on play and play spaces have never been considered in the urban policy, planning and design discourses in Dhaka. This is evident in very limited supply and provisions for children's play compared to actual demand in the ground. Only 4% of urban land is designated as parks, playgrounds and open spaces in Dhaka (Ahmed 2011) and most of those spaces are large city parks serving only a small fraction of city dwellers. This study recommends that in the making of children's play environments, children's voices must be included. In contexts such as Dhaka, urban authorities must go beyond western standards and develop plans that are sensitive to local children's actual preferences. In the process of reducing gaps between actual demands and supply of play spaces, it is also important to consider both homogeneity and diversities of children's play. Results from this study show that children from different age, gender and income groups face different degree of exclusion concerning play. Such results also disclose social contradictions evident in the context and question traditional practices of urban development concerning children's wellbeing.

### *4.3. From playground to Playpolis*

Using advanced spatial analytical methods, this study assessed spatial qualities of the studied play spaces and streets at different spatial levels. Regression results suggest that both morphological and accessibility factors influence children's location preference for play in the play spaces. Such results highlight limitations of traditional concept of 'playground' and suggest a need for a more inclusive and robust spatial planning concept called *Playpolis* that considers play spaces and the street network together. The term 'Playpolis' has been derived from Middle Dutch *pleien* for 'leap for joy' and Greek *polis* for 'city state' (Figure 7). The concept of 'playground' as spatial settings of play provided by planners goes back to the 'playground movements' during the industrial revolution (1760s to 1840s) in the West (Curtis 1917). Playground movements at that time sought to protect children from the evils of urbanization and contributed to the development of 'playground' typology in many cities. Rationales of playground movements are still relevant in the emerging Asian cities. However, over the last two centuries urban streets, open spaces, and patterns of children's independent mobility and play have changed significantly all over the world (Shaw, Watson et al. 2010). Planned and standardized playgrounds for children, typically fenced and alienated from other urban spaces, seldom consider actual behaviour and mobility pattern of children (Rudner 2012). In such context, it is important to rethink the concept of playground in order to ensure each child's right to play in the urban streets and open spaces.

Playpolis calls for a renewed emphasis on the integration of at least three key elements of a city: a) *people* (i.e. in this case, perceptions and preferences of children, their family, friends and other social agents), b) *places* (all potential urban spaces, both designated and undesignated), and c) *paths* (all potential path network). Such integration must be considered at multiple spatial levels (in this case, micro- and meso- spatial levels) simultaneously.

Potential implication of the above recommendations is high in policy and planning contexts in South Asia and most importantly in the studied context of Dhaka. For example, equitable distribution of urban play opportunities is recurrently reported as an important public welfare issue in local newspaper reports and public protests in Dhaka (such as Save Dhanmondi Playground Movement 2015). The recently developed Dhaka Structure Plan 2016-2035 (RAJUK 2015, Chapter 10) sets space standards for of 4.5 acres of children's park and local play areas for 12,500 inhabitants. However, the plan does not suggest how these spaces could be equitably accessed by different groups of children. Learning from this study suggests that multidisciplinary and participatory research involving children; appreciation of differential

spatial opportunities for play; and evidence-based spatial provisions can be an important move towards equitable and accessible Playpolis.

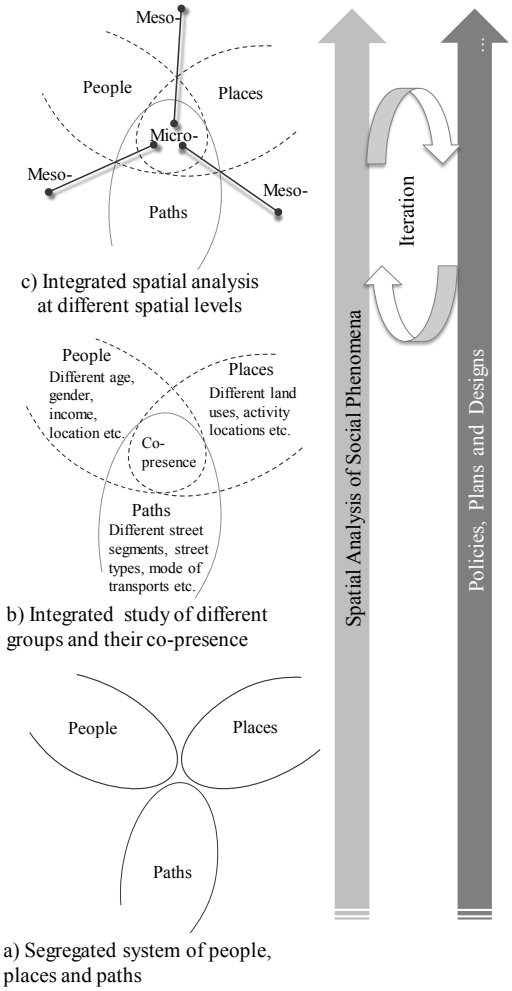


*Figure 7: Differential people, places, paths as integrated elements of analysis in a Playpolis*

## 5. CONCLUSION

In order to achieve sustainable development goals, a particular focus on inclusive, socially responsive and functionally appropriate urban spaces and infrastructural system is important. Understanding dialectics between social and spatial aspects of children's play and developing spatial analytical methods to address children's play through planning and designing of urban open spaces are two important steps in this direction. Outcomes from this study furthers our understanding on children's play and play spaces in a highly-dense and rapidly urbanizing global south urban context. Interpretation of results suggests application of integrated spatial analytical methods and context-sensitive planning approaches to address children's play in cities.

While applying the results and recommendations in real cases, limitations regarding external validity of spatial analysis, small sample size, and subjective bias in children's reports must be considered. Children's play spaces are not isolated places in an urban spatial system. Rather they are part of greater discourses of urban resilience and planning for green urban spaces and infrastructures for all age groups in the city. Future studies should overcome these limitations while incorporating inter-generational spaces and conducting comparative assessment of play environments across cities.

## ACKNOWLEDGEMENTS

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## ABBREVIATIONS

ICP: Intensity of Children's Play
MeSQ: Meso- Spatial Quality
MiSQ: Micro- Spatial Quality
NS: Network Segments
NSL: Network Segments and Land-uses
SAT: Spatial Analytical Tool

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# SUITABLE SITING OF A PARK IN KHULNA CITY:
## A GIS BASED MULTI-CRITERIA ANALYSIS

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***Abstract:*** *Liveable environment is the right of all human beings as well as all other beings. Parks and Green spaces provides that for us. Khulna city is rapid growing city and the parks and open green space is not sufficient for the people living there. Khulna is the third largest city in Bangladesh having a population of 1.4 million (BBS, 2011) According to Bangladesh Government's Standard, minimum land requirement for park has been set to 1.5 acres per 10000 people. (GoB, 2004) To maintain that standard, Khulna City needs at least 210 acres of park and open space but only has 54.0 acres. (Islam, W. et al. 2012) So, existing parks are not sufficient for fulfilling the minimum govt. standard for parks. Additional parks are required to fulfil the need. In Open space proposal (Chapter 8) of KDA Master Plan 2001-2020, a total of 2008.00 acres of open space was proposed in which 234.70 acres of land was proposed for Metropolitan and Community Level Parks in total KDA jurisdiction area including Khulna City but most of them are not yet implemented. (KDA, 2001) It may not be possible to fulfil all the demand of parks and open space at a time but this study intended to find out a suitable site for a park in Khulna city to help minimizing the problem at some extent.*

***Keywords****: Liveable City, Parks, Urban Green Space, GIS, MCA*

## 1. INTRODUCTION

According to the World Health Organization (WHO), people who use public open spaces are three times more likely to achieve recommended levels of physical activity than those who do not use the spaces. (Wolf, 2008). Parks can be a good platform for storm water collection because unpaved surface absorbs water, trees and grass are much more efficient and less expensive for managing storm water than concrete sewers and drainage ditches. So, to maintain a sustainable city environment for the community of people living there, sufficient number of parks and open space is required.

Khulna is the third largest city in Bangladesh. There are several recreational parks in Khulna City namely: Linear Park, Nirala Residential Area Park, Mujguni Park, Sonadanga Solar Park. But, still they are not enough to serve the entire population of the city. In Private House Land Development Rule, 2004, minimum land requirement for park has been set to 1.5 acres per 10000 people. (GoB, 2004) The current population of Khulna city is 1.4 million (BBS, 2011) so, according to that rule, there should be minimum 210 acres of Parks and open space but there is only 54.0 acres available which is only 0.48% of the total area of Khulna city. (Islam, W. et al. 2012) so, existing parks are not sufficient for fulfilling the minimum govt. standard for parks. Additional parks are required to fulfil the need. Khulna Development authority proposed a number of new parks to meet the issue. Chapter 8 of KDA Master Plan states that the existing Open/green Space (Park, stadium, Urban Green, etc.) in the total KDA jurisdiction area (including Khulna City) is only 128.00 acres which is approximately 0.31 percent of the total land use where Industries occupied 4.55 percent of the total land. (KDA, 2001) which is clearly not good for maintaining a healthy living environment. In 1961, Khulna City had only 37.10 acres of Green Space that is 0.40 acre per 1000 population. To improve the scenario, KDA Master Plan 1961 proposed 4 acres/1000 Population but in KDA Master Plan 2001, the amount was reduced to Minimum 2 acres/ 1000 Population based on two major issues, first, future requirement of space

and second, availability of vacant land. On the other hand, Zila/Upazila Master Plan, 1985 proposed 1 acre/1000 Population and in Dhaka Metropolitan Development Plan, 1995 the amount was only 0.16 acre/1000 Population. (KDA, 2001) so, it is clear that in their master Plan, KDA intends to preserve more green Space in comparison to other major Development plans of the country. In Open space proposal (Chapter 8) of KDA Master Plan 2001-2020, a total of 2008.00 acres of open space was proposed in which 234.70 acres of land was proposed for Metropolitan and Community Level Parks. Other than park and play areas, 1846.58 acres have been proposed as green areas in the form of road side green, river front green and urban forest. (KDA, 2001) Insufficient amount of park and open space is acting as a barrier to achieve the better living standard in Khulna city. In this paper, a GIS based multi-criteria analysis technique has been used to find out a suitable location for new park in Khulna City and the location has been justified in relation to proposed Park locations of KDA Master Plan.

## 2. METHODOLOGY

### *2.1. Study Area*

Khulna City is located in between 24°45' and 24°54' north latitudes and in between 89°28' and 89°35' east longitudes. The city is bounded by Dighalia Upazila and Batiaghata Upazila on the south Khan Jahan Ali Thana on the north, Rupsa and Dumuria Upazila on the west and Dighalia Upazilas on the east. (Palit, 2014). Figure 1 shows the location of the study area.

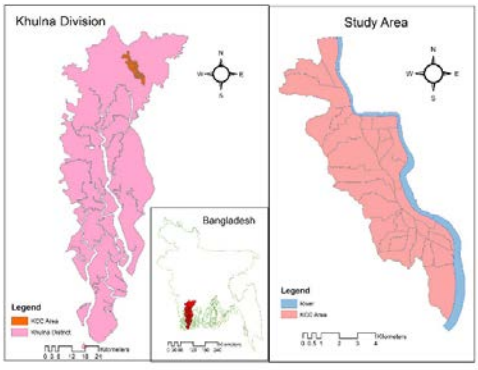


*Figure 1: Location of the Study Area*

### *2.2. Data Collection*

Land use data (ArcGIS shape file) including educational zone, residential area, water bodies, commercial area, industrial area, recreational facilities, urban green space, roads, vacant lands, and parks has been collected from Khulna Development Authority (KDA) 2001, Khulna Master Plan and Elevation points were collected from Google Earth. Land use map of Khulna city is shown in Fig. 2.

### *2.3. The criteria for site selection*

Different criteria were set following:

a) Site must be close to a street at least with a buffer of 10 m.

b) The site shall not be closer than 30 m from existing residential development.

c) The site shall not be closer than 200 m from existing commercial zone.

d) The site shall not be closer than 100 m from existing educational institutes.

e) There should be a minimum distance of 30 m between site and the existing green space like playground.

f) There should be a minimum distance of 200 m between site and existing recreational facilities.

g) The site shall not be closer than 300 m from the river.

h) The slope of the sides of the Site must construct in such a manner that little or no erosion occurs.

i) There should be a minimum distance of 100 m between site and any existing Park

(Lashari, Z et. al, 2017).

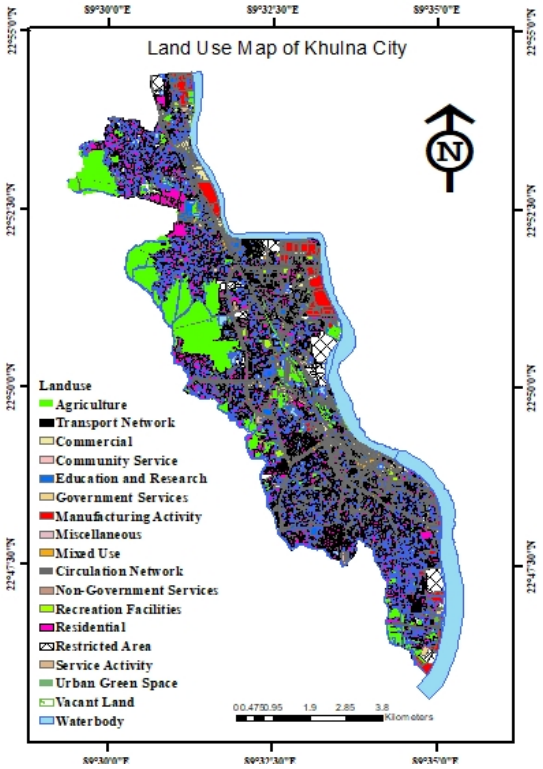


*Figure 2: Khulna City Land Use Map*

### *2.4. Data processing and analysis*

At first, several maps were generated showing the existing location of existing parks, roads, educational institutions, recreational facilities, residential area, commercial area, river, urban green space, and DEM of the study area which represents the spatial distribution of the infrastructures and different physical features in the study area. The process was done by ArcGIS Modeler, the model is shown in fig. 03

Then, according to the criteria, a 100 m buffer has been made from the existing parks in order to get quantitative proximity information of the existing parks location. Subsequently, 10 m buffer from Roads, 30 m buffer from both Residential area and existing green space like playground, 100 m buffer from existing educational institutes, 200 m buffer from both existing commercial zone and existing recreational facilities like cinema hall, Theatre, etc. and 300 m buffer from the river has been made using 'Buffer' tool from ArcTool box. Then, the slope of study area has been prepared from DEM data using 'Slope' tool from ArcTool box. All these maps have been shown in Figure 4.

According to the criteria, the park should be located closer to the Residential area and Educational institutions to ensure the maximum accessibility of people from different age group at a walking distance. And there should be a good

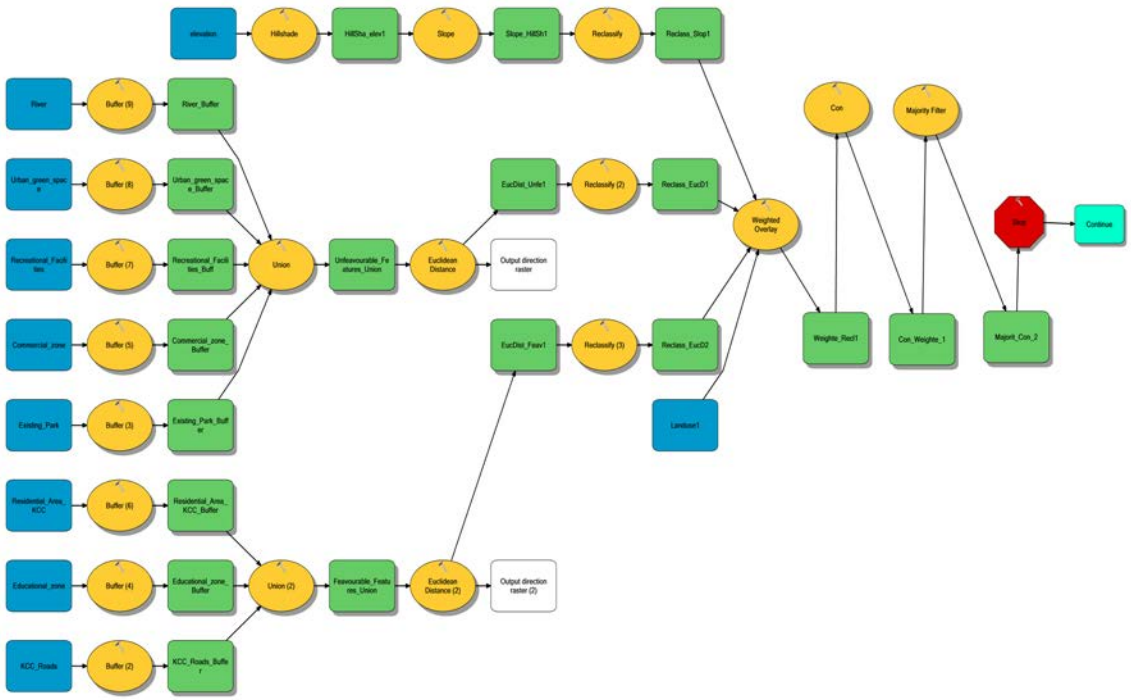

*Figure 3: MCA Model in ArcGIS Modeler*

linkage of roads to ensure proper connectivity. So, a union has been made taking buffers of Road, residential area and educational institutions to indicate the locations of favourable feature for the park using 'Union' tool as shown in Fig. 5. The park should be located far from existing parks, recreational facilities, and existing urban green space in order to maximize the utility of the park.

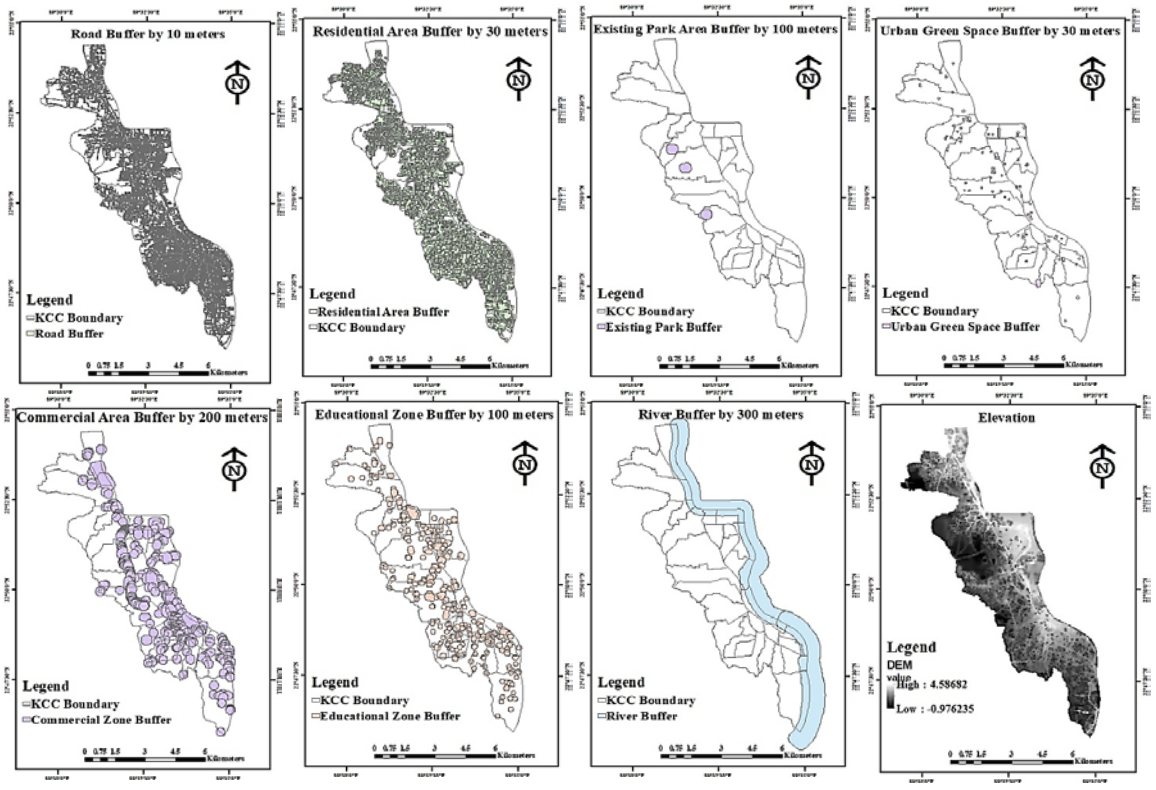


*Figure 4: Criteria Maps for suitable site selection for a municipal park in KCC Area*

Moreover, a park should not be located too close to a river in order to avoid the threat of being over flooded and water logged during rainy season, river bank erosion and another natural phenomenon.

Commercial area like CBD and shopping centres are also not considered as a good site for the development of parks because people usually go there for shopping and business purposes that makes the place noisy and overcrowded. As people go to park to find a place for refreshment and recreational purposes, people may not like such a place for that purposes. So, these are the unfavourable locations for a park and altogether, their locations have been identified by making a union of their buffers as shown in Figure 6.

Final sites could be selected just by erasing the unfavourable features from the favourable features but in that case, it would be difficult to select just one location from the other potential locations because each of the location would have equal importance. In this study, to avoid that problem weighted overlay was performed to assign weight in the basis of their relative advantages which makes it easier to select only the best one among all the alternatives.

Euclidean distance has been measured from the union of both favourable and unfavourable features buffer to indicate the existing distances in straight-line, from a particular feature to the rest of the field by dividing into a number of same distance bands in a visual and colourful way using 'Euclidean distance' tool from ArcTool box. The Euclidean distance tool describes each cell's relationship to a source or a set of sources based on the straight-line distance and helps to identify the closest distance areas from a particular object.

In this study, this tool was needed to identify

the nearest areas and the areas far from any particular feature. Now, it is needed to assign weight for every criteria map to perform weighted overlay, so that the most suitable locations for the site can be identified. Before assigning weights, the value range of all the distance images were normalized to a common range of 1 to 9 using 'Reclassify' tool from ArcTool box. In the case of favourable features, Normalization was performed by considering the highest value 9 for closest distance and the lowest value 1 for the place of highest distance. But in the case of unfavourable features, the rule was just the opposite.

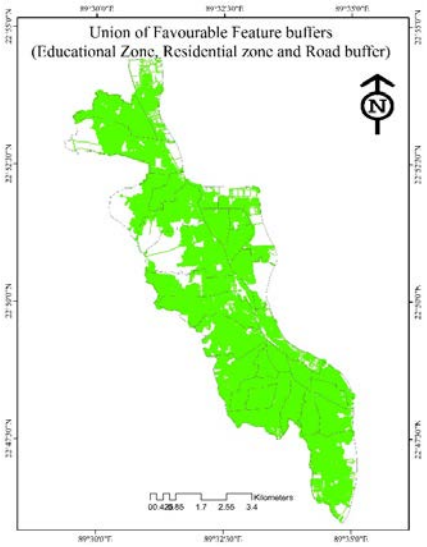


*Figure 5: Union of favourable features buffer*

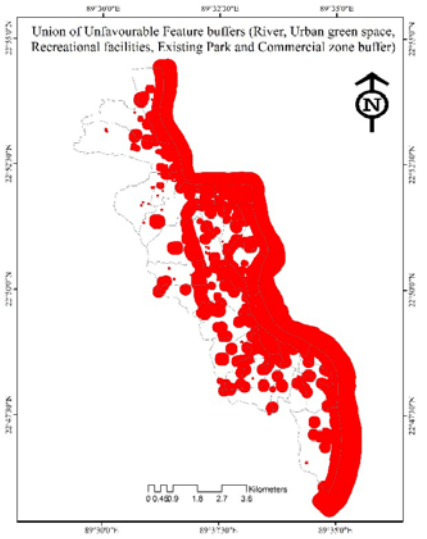


*Figure 6: Union of unfavourable features buffer*

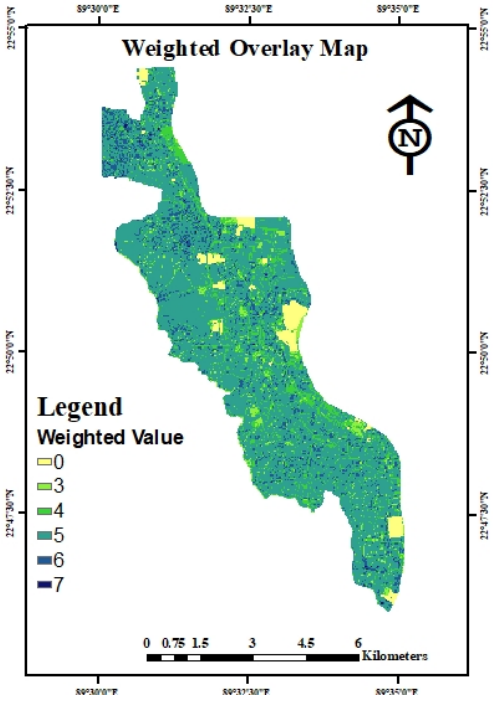


*Figure 7: Weighted overlay map*

Finally, weighted overlay was performed by incorporating all the normalized maps along with the raster layer of Khulna cities land use. Equal influence had been considered for all the factors. From the weighted overlay operation, all the cells obtained a weighted score which is shown in Figure 7.

Next, to identify the best possible locations for the park site, 'Con' tool was used to filter the cells containing the highest value, in this case, 'value = 7'. Figure 8 shows the generated map.

By applying this condition, the potential locations for the site was identified but still all of those locations were not the best option for the site because there are many single cells representing optimal locations. These 30 m cells are too small for the park site. A park needs much more larger space than that. So, it was needed to clean up the result, removing those small areas, using the Majority Filter tool in Spatial Analyst toolbox. Majority Filter replaces cells in a raster based on the majority of their contiguous neighbouring cells. In this study, 'Four' neighbouring cells method was used in the kernel of the filter. Going through this filter, the most suitable location for the park site was identified. Figure 9 shows the final suitable

location for the proposed park in Khulna city.

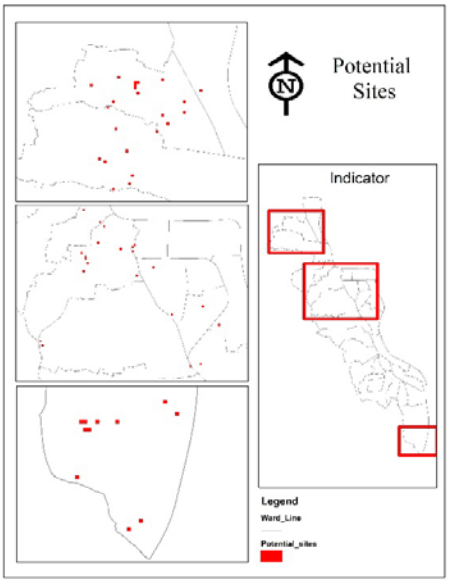


*Figure 8: Potential Sites for the new park*

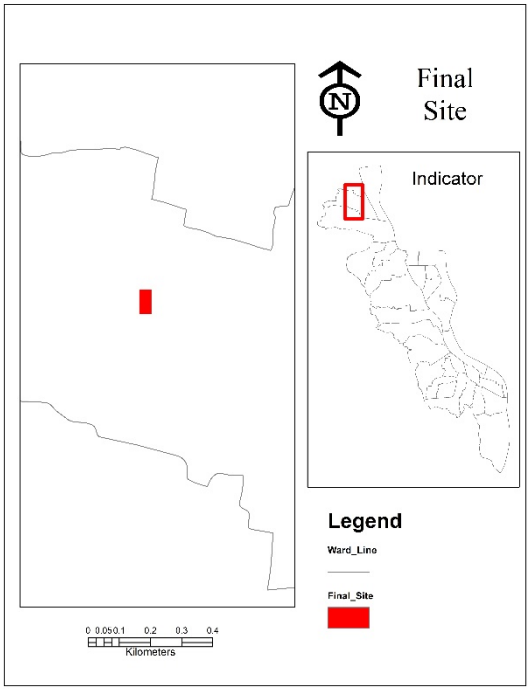


*Figure 9: Final site for the new park*

## 3. RESULTS AND DISCUSSION

Ensuring the proper accessibility by road network was one of the most important criteria for selecting suitable site for a new proposed park in Khulna city corporation area. In the map showing in Figure 10, giving the evidence that, the selected site is well connected with the surrounding area and a road is crossed over the site.

Figure 10 also shows that the site is located in vacant land, so, the proposed park can be the best use for that vacant land.

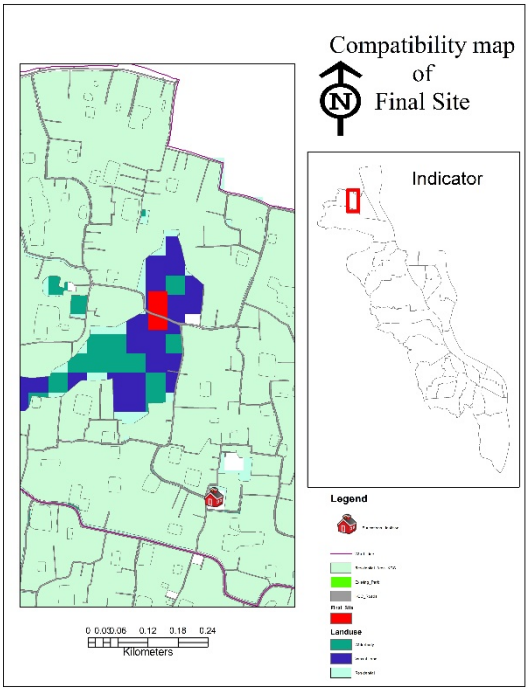


*Figure 10: Final site with its surrounding*

The site is surrounded by a large residential area just within a walking distance. No additional park, recreational space, or urban green space is located nearby.

The place is far from CBD but well connected to CBD by roads. Moreover, an educational institution is located nearby and well connected through road. So, it can be a perfect location for the proposed park.

KDA Master Plan Proposed 3 parks in the surrounding of that area but none of them are implemented yet. The red circle in fig. 11 shows the locations of proposed parks in KDA Master plan 2001-2020. So, this is also recognised by KDA Master Plan that Park is needed in that region. So, this location can be an ideal location for sitting of a park.

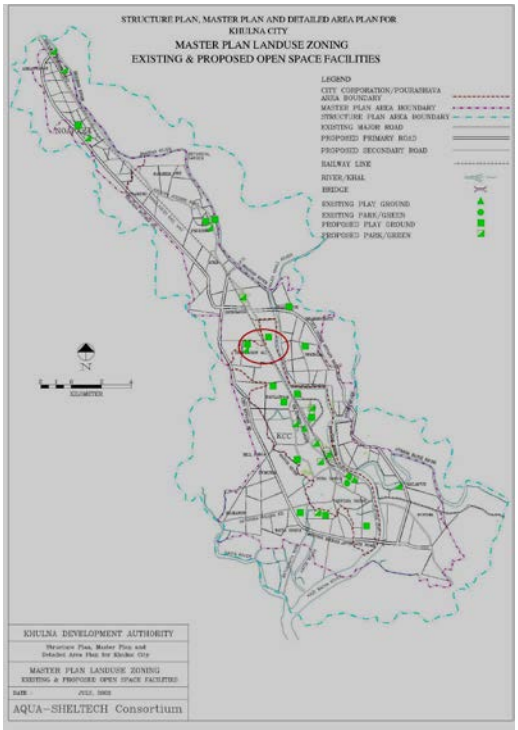


*Figure: 11 Proposed park locations of KDA Master plan*

## 4. CONCLUSIONS

The economy of Khulna city is booming since 90s' and the extent is expanding day by day. Still, people living there are not fulfilled with all necessary services they require. Park and open space is one of it. Still the people of Khulna city only have 54 acres of parks and open space which is nearly one forth of the minimum requirement of 210 acres. Though, there are several parks in Khulna city right now but most of them are located near or within CBD. Moreover, a few of them are located in planned residential areas like Nirala residential area, Mosguni residential area, Sonadanga residential area etc. but remote areas like wards # 1, 2, 3 are deprived of those facilities. In this study, the proposed site for the park is located in KCC ward # 1 and close to ward # 2 and 3 which may offer a good opportunity for the people living there to fulfil their demand.

## ACKNOWLEDGEMENTS

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# TRANSFORMING INTENDED OPEN SPACE INTO URBAN VOID:
## A CASE OF PLANNED RESIDENTIAL AREA IN KHULNA, BANGLADESH

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***Abstract:*** *Urban Voids are vital component in the context of the built environment that we think as leftover space has nothing to give surroundings as we experienced. Its number is enormous with hidden potentiality and the capacity of becoming the cornerstone for the city of tomorrow. But the existence of urban void in already planned development is alarming. Now a day city grows spontaneously in the developing context to meet the everyday need with acute shortage of amenities. All the development is not possible to be measured under top-down planning process. So, our planned development should be the best within our reach, but that is not the reality. There is many flaws exist in public space planning. Especially found in the planned residential area. Where these are given but not used properly. Such spaces could be unused not only because of their limited functionality but also because of the fact that the public eye does not perceive them at all. The aim of the research is to find the form of the transformation of open space into the urban void in a planned residential area of Khulna through addressing user preferred local Place making process. Based on case study, this study finds that how urban void could be addressed through the lens of place making through in-depth observation & place performance evolution. The upshot is made up of a comprehensive guideline for rethinking Urban Void as a catalyst for ensuring future urban development.*

***Keywords****: Public Open Space, Urban Void, Place making, Planned Residential Area, Khulna.*

## 1. INTRODUCTION

Future cities will have to confront limited urban spaces and resources, undertake the preservation or conservation of sense of place, and continuously expand the existing urban environment where land is a resource that will always be valuable but it must be managed carefully to support equity amongst generations. Cities of global south have reached unprecedented sizes in terms of urban population against the shortage of urban land over the last few decades (Hardoy et al., 2001).

The process of growth of cities for meeting demand involves layering over time, densification and this in turn gives way to demolition, erasure, cuts that open up new voids as a by-product, the neglected or either forgotten spaces of today's cities (Trancick, R. 1986) Such spaces could be unused not only because of their limited functionality but also because of the fact that the public eye does not perceive them at all. Today's functionalist development denies traditional qualities of urban space that have been lost where buildings are isolated object & space between them are vast and formless rather than evolving from historic streets & squares (Gehl, J. 2011). Montgomery believes that active and vibrant urban spaces are associated with the knowledge of how to manage, develop and design not only the cities but also each and every parcel of the city. In this regard, he used the term 'Urbanity', which consisting of a city filled with activity, street life and urban culture if they are absent then there is a certain delinquent exist. Behind attractive, cozy facades of today's planned development still fail to combat the pattern of sprawling, auto-centric urban development (Jacobs, J.1961). That is leading humanity most of the time towards a gridlocked condition where life, space and building all are becoming isolated from each to other. So, at the end a question has raised, that is the planning responsible for raising more useless or underutilized spaces in planned development because of two dimensional perspective of planning?

In the context of the limited supply of land for housing in Bangladesh, this is crucial that available lands should be utilized at their best to meet the demand of rapidly urbanizing population in cities of Bangladesh (Ali, S. et al. 2016). So we have to accommodate a giant number of people within a limited space with at least 30% of the total land area is dedicated to remaining open for public use in the master plan to maintain living standard what is strongly dependent on open space activity belongs to a particular area (Nilufar, F. 1999). The impact of this global urban problem of land scarcity and unprecedented urban population growth has experienced in Bangladesh. To challenge this problem our government takes initiative to provide a planned residential area for ensuring quality living in the era with inadequate land provision for public open space. But caution is raised when underutilized open spaces are found within the planned development in developing context. So this is very important to investigate the form of their underutilization.

We all know that the public open space distributed within a planned residential area should be planned in such a way that rising open space's users standard and quality of living by providing purposeful activity choice. But if they fail to do so they are transformed into a different form of user and activity. Not all of them are always good or bad can be ensured by studying their value as a place. That is the approach of this papers study. Identify the form of their underutilization, their classification and way to deal with them to make more efficient. It's an obligatory alarm because they have been existing within a planned area from the beginning.

## 2. FROM PUBLIC OPEN SPACE TO URBAN VOID

### *2.1. Define Open Space for Public Use*

Under section 2(b) of the Park, Wetland and Open Space Conservation Act 2002, defines open space as, Open space means, in master plan what has been marked as open space or what has been declared as open space. When an open space is properly utilized then it should be counted within the public realm and its basic unit is individual spaces what are used as public space themselves. As Carmona (2010) public space as a central component of the public realm is penetrating in social sciences and humanities fields. Public space relates to all those pieces of the built and natural environment where the public has free admission. The "public-private" places where public access is unrestricted during daylight hours at least. Cooper and Francis (1998) gave a definition drawn from the work of Lynch (1981) who argues that open space is clear when it is accessible; "urban open spaces are defined as publicly accessible open places designed and built for human action and enjoyment including parks and downtown shopping centers". Thompson (2002) orated that public place should be conceived of as an outdoor room within a neighbourhood, somewhere to relax, and enjoy the urban experience, a venue for a scope of different bodily processes, from outdoor eating to street entertainment; from sport and bet areas to a venue for civic or political roles; and most importantly of all a place for walking or sitting away. Public spaces work best when they constitute a direct kinship between the space and the multitude that inhabit and work around it (Carmona, 2010) defined it as Public space is an inbuilt piece of the public land with the physical public realm capitals the sequence of spaces and settings that facilitate public life with societal interaction in that public space. It is studied as sites or contexts of formal and informal public life that have 'physical' and 'social' dimensions. The actions and events arising persistently within urban places defined as open space can make it public realm to all. If it is failed to do so then these spaces could be unsuccessful. When they fail to become successful in terms of public use then they are just waste of public amenities.

### *2.2. Attributes of Successful Public Open Space: Place making*

According to Carr et al. (1992), and Carmona, (2010) open space should be meaningful, democratic and responsive. That allows people making strong linkage to open space, protecting the rights of user groups and addressing user's needs. By following (Copper and Francis, 1998) Successful open space depends on some factor. You have to feel safe their

particularly for women, children and elderly where public access is a critical factor to open space quality. Lynch (1981) defines accessibility in terms of open-space rights such as the right of presence, use and action. The environment of public open space should be comfortable there from rain, wind and sun with proper seating facilities (urban furniture) and urban services with economic impact and benefit inducing aesthetic value. Because how people perceive space may contribute to the space use or lack of use. If space bears any meaning or value to the users itself rising demand of it to users. The fact that space is considered as an important symbol or reference may be enough for people to attach meaning to the open space even though they are not using it. The amount of freedom and control of a space offers has been suggested as the basis for people's use and enjoyment of an open space (Lynch, 1981). All above mentioned is key indicator for space how can be a good destination for the public. When any space becomes a destination for the public would mean something greater than only space. But there is a growing awareness that the use of an open space may not in itself be enough to make a space successful. The larger meaning of an environment for people is an important dimension of urban quality what can be addressed as place making. By PPS (2004) place making initiatives create opportunities and spaces for gathering and socialization. The place making process also offers opportunities for neighbors to work together on a common project, creating new social connections and networks. For local communities, the place making process and the places that result can also work to bring diverse populations together, including people of different ages, ethnicities, backgrounds and cultures. In evaluating thousands of public spaces around the world, PPS has found that successful ones have four key qualities: they are accessible; people are engaged in activities there; the space is comfortable and has a good image; and finally, it is a sociable place: one where people meet each other and take people when they come to visit.

Each place has a "unique address"; without explaining how it becomes identifiable he argues that "physical setting", "activities" and "meanings" constitute the three basic elements of place (Relph, 1976). After then Canter (1977) began his theory by addressing these two questions, what are the main components which integrate to create places? What procedures are available for identifying places and their attributes? By answering them, introduced places as a function of "activities", "physical attributes" and "conceptions". But what will be happened if there is no intended function among the bustle of business?

### *2.3. Urban Void: Underutilized Open Space*

If there is raised some question about a space like, How does it relate to the city? Why is the space empty? What was lost in the space? Who can use the space? When will the space no longer be empty? Then the urban void has been referred to, among other things with these questions, as untitled space, marginalized space, interstitial space, residue, gaps, and terrain vague. Despite the broad range of terminology refers to the same general concept, each term, by design, evokes slightly different thoughts, emotions, and ideas. Designed on a simple two-dimensional plan, staged from below, these spaces have no consideration for the quality of public life and accommodate no real requirements for the users of the urban fabric. However, the users understand in a completely different way spaces, opposed to designers, who see their many hidden potentials, which can be unfolded and developed in such voids (Trancick, R.1986). By Sola-Morales (2002), "They are the edges lacking effective incorporation with the inner islands empty of activity, and the forgotten debris that remains out of the urban dynamics."

So it can say that Urban voids are these areas that for whatever reason have been waiting to be developed, or not. To create better spaces for living working with scale is the most difficult and most subtle concern in urban designing and planning discipline. If this is neglected or fails city will decline in its quality of life. The widespread practice of planning from above and outside of context is responsible for them. To avoid such a condition we have to consider first life, then space and then buildings in planning. Instead of reverse order in the planning process that prioritizes buildings then spaces and perhaps

a little life working with the human dimension requires life and space to be treated before buildings (Gehl, J. 2010). To compare that urban voids are undesirable urban anti-spaces that are in need of redesign for making positive contribution to the surroundings or users. Because they are ill-defined, without measurable boundaries and fail to connect elements in a coherent way (Trancik, 1986) in developing areas. Within residential area, this kind of space determines poor quality or threat for living.

## 3. APPROACHING TOWARDS THE STUDY AREA AND WAY OF INVESTIGATION

### *3.1. Data Collection Method*

How the public open spaces of the planned residential area become underutilized or differently utilized is investigated in this research. To get the answer of above mentioned question In-depth field observation and place performance evaluation result is compared. Observation is the active acquisition of information from a primary source we know that. In this research, observation plays a vital role. Canter (1977) believed that direct field observation provides researchers with direct experience and understanding of a space. Then to understand the way of place making Place Performance Evaluation (PPE) is used to determine their factor for initiating spontaneous place making for the non-place (PPS. 2005). In-depth observation and questionnaire for PPE are performed in this study to collect data that are examined in a residential area of Khulna named Nirala R/A.

### *3.2. Nirala Residential Area as a Case*

*Figure 1: Study area compared to Khulna city; Nirala R/A (Right one) (2017).*

Nirala is one of the oldest planned residential area developed (figure 1) by KDA (Khulna Development Authority) in Khulna (Chaudhury, 2010). The Project was included in the First National Five Year Plan of Bangladesh with the commitment of better living condition in planned residential neighborhood with proper distribution of open space for public use (Mashiur, 1996). To understand and analyze this phenomenon of mismatch between formal orthodox town planning by the concerned authorities and spontaneous development by the communities towards the open spaces dedicated to public use, this site is potential due to the presence of variation in open space and use among all available in Khulna. Nirala R/A is selected for the study which is developed in 1982. With the time running spontaneous changes addressed in its development that is over time effecting its socio-spatial dimension of open spaces also. The total areas of Nirala R/A is 67.31 acres. Nirala is designed of 63.08% residential plots, but at present 68.40% is covered and the rest of the plot is vacant, the remaining lands were used in different purposes.

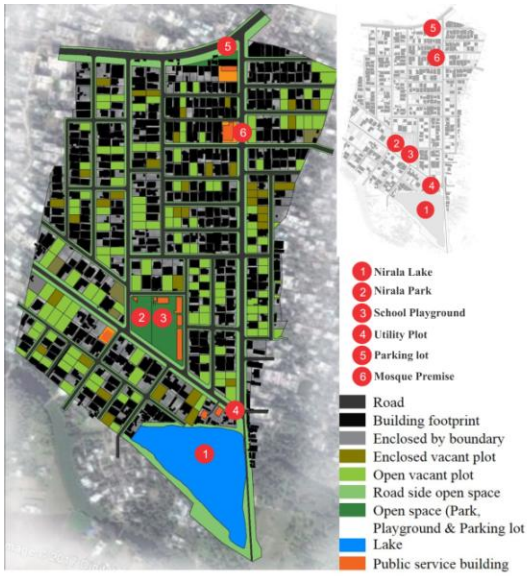



*Figure 2: Land use of Nirala R/A (Right one) (2017).*

The remaining 36.92% open spaces are for natural resources (Lake and park), social institutions (school playground and mosque), utility areas (parking, area for pump and community center) and for road network. The

usage of these varieties of open spaces for public use or not found in field survey, 2017 is perceived questioning against planning, what is the key reason to select it as study area.

So now, if we are looking towards the open spaces then we can categorize it in different segments. First of all, it's divided into two portions, Public and private. Public open spaces are park, lake, school playground, parking lot, mosque premise and reserved spaces for future extension of road. Private open spaces are setback spaces and open plots. Open spaces intended for public use is only examined in this research indicated in figure 2.

## 4. BUILT ENVIRONMENTAL CONDITION OF PUBLIC OPEN SPACES IN PLANNED RESIDENTIAL AREA

Under 4 key components of place making (1. Access & Linkages, 2. Comfort & Image, 3. Uses & Activities and 4. Sociability) public open spaces of the Nirala R/A (i.e. park, lake, service lot, parking lot, school playground, mosque premise) is observed and reported below.

***Access & Linkages:*** Accessibility defines how easily a place can be found and linkage defines its territory as a place. In the figure 2 shows all the study sites are located beside roads and parking lot, utility plot and the park situated very near to transit point.

*Figure 3: Utility plot block approach to lake.*

But in reality from the road detect the lake and school playground is very difficult. The Lake is surrounded by residential plots and access way is approximately hidden (Figure 3) by utility plot occupying local temporary shops.

*Figure 4: Obstructed Playground entry.*

School playground is surrounded by school building and solid wall with two entry points which remain close at the school periods. So, with proper signage if you want to play on the playground you have to wait till class ending (Figure 4). Due to the racial segregation parking area and mosque premise denied female access mostly. We should keep in mind that, a good place is always accessible to all.

***Comfort & Image:*** Safety, security and the condition of comfort ability is the key determinant of comfort and image of a place. Overall structural stability in walking and sitting condition, crime rate & environmental condition determine comfort ability for particular site. Considering these condition the park, school playground and mosque premise are comfortable most sites of the study area. Whether mosque premise trigger social and gender discrepancy. With vulnerable local structures parking lot and utility plot is also feeling comfortable to its users due to social surveillance over the day under the manner of safety and image. The safety measure of the lake is very loose because of contradictory location with less infrastructural support whether only social surveillance is working there. Water of the lake is contaminated because the adjacent buildings serviced water is opened to the lake and garbage is directly thrown to it, it's (Figure 5)

*Figure 5: Insanitary setting of lake.*

decreasing visitor count extremely. Due to unacceptable environmental condition and safety facts the lake is not comfortable for its users. We should keep in mind that, a good place always comfortable and safe to use.

***Uses & Activities:*** Diverse group of activity and user is the key determinant of place. Mix of service, economic vitality, frequency of events and overall busyness trigger users. Considering these condition parking lot and utility plot is very successful with local business ownership and retail facilities though all they are occupied illegally (Figure 3 & 6). These areas are inviting for a particular group of people because the space is mainly occupied by tea stall and food vendor providing cozy resting facilities.

*Figure 6: Running use of parking lot.*

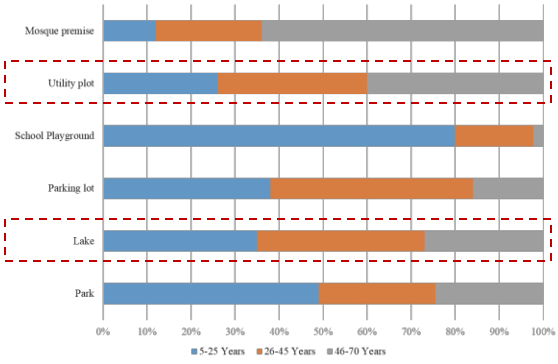
Without economic vitality and limited community events other sites work, but not like them. Even in the peak hour important open spaces found with less users like the park and lake

*Figure 7: User less park at peak hour.*

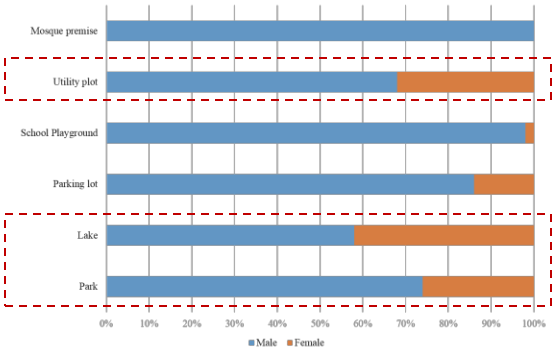
(Figure 7). This condition is very important to determine which spaces are turned into place with the local place making process.

***Sociability:*** Chance of active and passive contact is the key determinant of a sociable place. Mix of different types, ages and gender of users in different time of the day and seasons is the key determinant of place also, that also indicate the sociability of any particular site. But out of the site they have no impact on surroundings. As a successful public open space definitely this is the major shortcoming among all. For example plots surrounded the lake and the park did not show any impact towards them. Even there is some vacant plot found in them. Considering this mix of different age group of user is found at all the sites. Social and gender discrepancy works in the case of mosque premise and parking lot. For the lake, its main user is outsiders. Except this case rest of the sites are well composed with insider and outsider ratio.

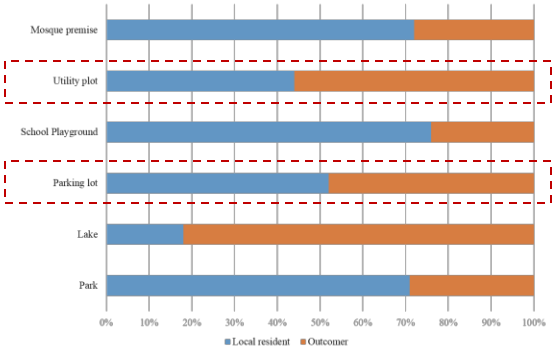
Here from above study the mix of user is presented in Bar Chart 1, 2 & 3.




*Bar Chart 1: Users age group ratio in different space use.*




*Bar Chart 2: Male-Female ration in different space use.*




*Bar Chart 3: Insider-outsider ration in different space use.*

The balance in ratio is indicated better place for public use. From the table parking lot and service plot becomes the most public area in the means of diversity, though park meet a bit against demand.

## 5. DEFINING UNDERUTILIZATION OF OPEN SPACE AND RECOMMENDATION

From the above study now it's easy to categorize these open spaces into different category about their physical usage. It's very important to categorize these open spaces to take further initiatives. It has seen in approved layout plan there is some open space with mentioned function and in reality there are some ancillary open spaces that are not mentioned before. Most of the spaces are denoted with a particular function. In this study, it's checked the condition of the open spaces reflected the form of relation between users and activity in figure 7 and 8 respectively.

From the result showing in the chart some phenomena like some public open spaces are not used as mentioned (Park, Lake), some of them are not used as mentioned, but used differently (Parking lot, service lot), some are underused and

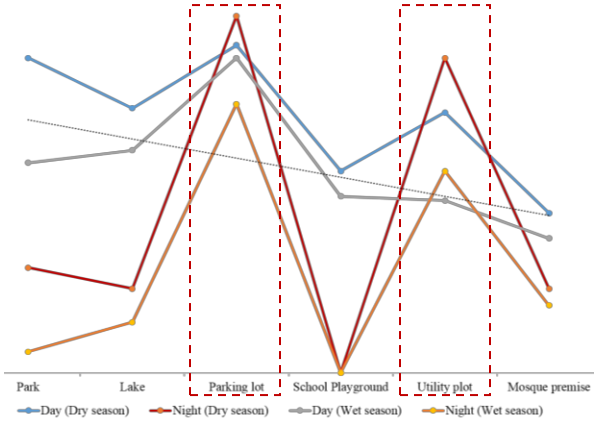



*Figure 7: Season wise open spaces demand compared in percentage (field survey, 2017)*

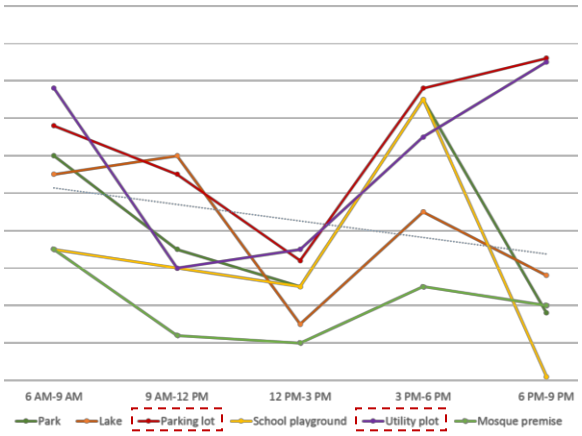



*Figure 8: Place-performance evolution chart from 6am-9pm; result in percentage (field survey, 2017)*

some are partially unused (Playground). So the missing link is the formalized acceptance of indigenous values of place making between the process of the local user to decision maker levels. So, it is important to Encouraging social interaction, community building, and civic engagement within a public open space—all central components of place making yields important physical and mental health benefits including a greater sense of belonging, increased physical activity, and reduced rates of depression

and psychological distress. All after that, the active use of a public space depends on its features, appearance, proximity, and accessibility. All that means to real understanding of human behaviour we have to reconsider in three dimensional relationship between building and space rather than considering only two dimensional land use plan for determining urban growth where the buildings are only sited in the landscape as a part of usual process of urban development but not a part of the integrated fabric of street, square and viable public open spaces. Ensuring that some guidelines for extracting overall development of open space in developing context are given below:

- Provision of community engagement to activate all these open spaces, to give structure, shape and form with maintaining context bound emotional well-being.
- Provision of more active facades in surroundings through spatial improvements is linked to the community's economic future through the development.
- Efficient use of resources by ensuring multiple uses of a single open space, if possible provide vertical mixes.
- Make gathering spaces of excellent quality: Ensuring universal accessibility, safety and security issues that welcome everybody.
- Improve the outer edge of open space with proper facilities to drag adjacent plots development oriented to open space.
- Provide combined planning, whether there is one more public open space are located together.

All these are justified by the reflection of users end.

## 6. CONCLUSION

Instead of seeing 'void' in the urban development as something to be fixed and filled, the evaluation regards it as a part of the urban matrix. Change and development should be economically and socio-culturally viable, a range of sites for urban transformation from the hub for criminal activities, ghost thoughts and urban legends could be transformed by community initiatives into urban sources of profit and inspiration for urban exploration as well as first steps towards gentrification. Actually, this research is to evaluate and address urban vacant leftovers through assessing place performance and then extract the operationalization mechanism of these spaces. Void could be regarded as a positive aspect of the city, which provides people with breathing spaces for squatted buildings and dense development through reducing urban density. Related to that, void also refers to economic decline and the lack of investment that to be avoided since it refers to danger and various forms of crime. In terms of transience, the same "urban void" can be used by different people in different shifts and for different purposes, while some sites can experience a permanent state of transiency. Some might open possibilities for experimental and alternative lifestyles and might act as breathing spaces, some might stay vacant as they are occupied by no one, which provide the city with an identity and stories to tell with possibility of best use. From this research one can find the way how spaces remain void in any development without addressing them under various scales. Compiling those all scales for different location would be a directory for the whole city indicated which spaces are left to use at tomorrow and how.

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# UNDERSTANDING RURALITY THROUGH A LENS OF CONSTRAINTS IN GREEN URBANISM

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***Abstract:*** *Integrating rurality has become a popular choice in today's green urbanism in Bangladesh, where the concept rural is with coincided with green. Architects, planners and urban designers are seen to advocate to use extensively in designing. This paper, however, argues that today, with the rise of technocratic urban development, these engagements in cities have reduced into mostly a visual and aesthetic backdrop for recreation, locating their perception merely as mimicry. The paper asserts that the rurality is central to the understanding of the socio-ecological structure of the green and waterbodies, which in the past was constructed by negotiating with the landscape 'constraints' and the activities in the surrounding, giving a unique vocabulary to the landscape. When the socio-ecological structure of the landscape had been altered having minimal or no functional dependency, these were reduced to the object of visual consumption. The paper also argues that to integrate rurality in urban landscape, it needs to be understood by looking how 'constraints' play an imposing role in the formation of the socio-ecological structure of the landscape.*

***Keywords****: Constraint, Rurality, Water, Green urbanism*

## 1. INTRODUCTION

Over the period between 2000 and 2010, Bangladesh experienced faster urbanisation than the overall urbanisation of South Asia. In 2010, 45.7 percent of people in Bangladesh's population are living in urban areas and which continue to increase 1.69% per year by rapidly transforming rural areas to meet the demand of urbanisation. However, World Bank suggests that the rate urbanisation is not enough, as it falls behind East Asia.

Akin to the World Bank, there is also debate going on among government, scholars and investors to bring all rural areas in Bangladesh under Compact Township or to turn all villages into towns. Such arguments gain currency as rural areas are commonly marked by the lack of infrastructural development, and poor economic growth and inaccessibility to modern technological advancement/benefits.

More importantly, compact or regular township concept stems from a growth centric economic model, arguing that agglomeration of basic services will promote faster economic growth for the country. While a faster economic growth rate is desired by all and thus the existing planning organisations should adopt those planning methods that can increase the rate of urbanisation and dissolve rural landscape, a critical evaluation/reflection in that trajectory is necessary before a substantial number of villages are transformed into urban areas.

Already, a number of scholarly concerns have put forwarded, in recent years, to question the method/mode of urbanisation. A recent article published by Khaled Ashraf criticises current urban development approach to be 'dry planning'. He explains that due to the emphasis of physical infrastructure, the waterscape of Bengal is ignored, transforming the cores into a collection of dry-core. His article renews the concerns how badly the urbanised landscape has ignored in the key components of or deltaic landscape. The deltaic landscape of Bengal evolved negotiating with the water. Water remains and used to be the core component in the traditional so called 'rural' landscape. The organisation of economic and social models was integrated with water. Our concern and reservation against current mode of urbanisation and technological development stem

from there. We review the transformation from rural to urban in one of the most important regions of Bangladesh, Khulna, to evaluate the trajectory of urbanisation before erasing the rurality by urban landscape.

As a city, Khulna occupies the third most important position in the county. It was the house of 1.6 million people in 2016.

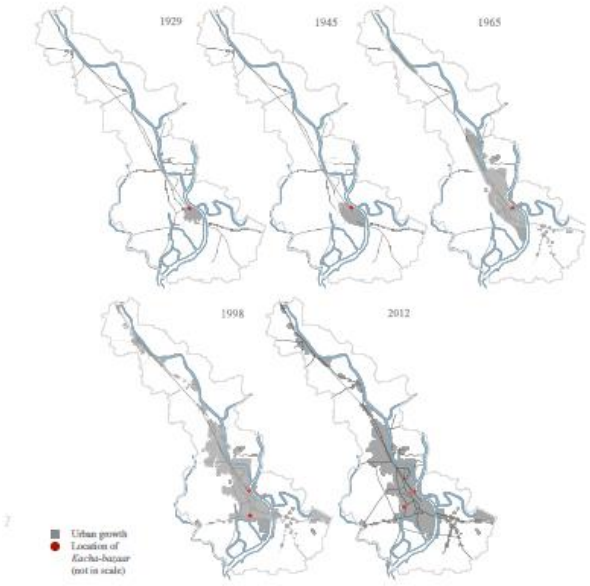


*Figure 1: Maps showing the spatial growth of Khulna city between 1926. Source: R.H Thomas, 'Map of Khulna in 1929, (Calcutta: India office, 1929); Khulna Development Authority Growth Maps and Google satellite images.*

Khulna holds a colonial history of more than a hundred year and occupies an important strategic position in the south. However, before going through the urban history to comprehend the rurality, a brief review of literature concerning rurality is as follows.

## 2. RURALITY

In literature, rurality carries a wide range of definitions. In the context of this paper, a few of the key variables and arguments are presented herewith.

In a significant volume of academic writing, rurality is defined by underdevelopment and progress (Scoones, 2009; Alemu, 2012). Rurality lacks the provisions of modern infrastructure and state of art technology. Rural is remote (Haynes and Bentham, 1982). The remoteness is caused by the lack of transport. Its remoteness and lack of development, confine rurality with the livelihood of agriculture. In most rural areas today, change in livelihood is unsubstantial, only a minority of the workforce is employed outside agriculture (Archbishops' Commission on Rural Areas, 1990).

Compared to urban areas, the rate of change in rural areas is perceived to be slow. Ward and Brown (2009:1239) identified rural as 'places of tradition' rather than 'modernity', of 'agriculture' rather than 'industry' and of 'nature' rather than 'culture'. In overall this stream explores rurality to be attuned with a negative dimension of 'slowness'.

On the other hand, political and policy issues have some positive, yet mostly negative take on rurality. When it comes to physical or spatial concepts of infrastructure, lower density issues and constraints, there are more negative reviews on rurality than positive perceptions. A majority literatures are progress centric, where physical aspects of rurality represent as the problematic aspects of rural areas. This situation is viewed more as a 'challenge' of living than as a positive condition or choice in the development process.

Despite these negative dimensions, there are now growing literature that reveals many important aspects of rural realities, without which the definition of rurality fails to capture a comprehensive characteristics (Rural) realities. Scholars from different disciplinary background have appreciated the tradition, heritage, and social values attached to rurality.

Chigbu (2013b) explored rurality within a lens of ecological and social relationship. Rurality, Chigbu explains, is an evolving character/place that responds to local ecology and social environment. Chigbu, (2013a) talked about people-to-people and people-to-place relationships, which gives an overview of socially rich landscape. His work argues rurality to be a combination of five aspects including social, cultural, ecological and place. While Chigbu's contribution is vital in both transcending and evoking a positive image of rurality, it lacks an observation on the

fundamental element responsible behind creating the people to place relationship.

We examined the mostly criticised aspect of rurality -- physical 'constraints'. We argue that 'constraint' is both a core component and strength of rurality and elaborate in the following discussion of urban history of Khulna how 'constraint' plays essential in building a meaningful relation between people-to-place.

## 3. LAND AS THE NEW VOCABULARY OF LANDSCAPE

By mid-May of 1781, Mr Tilman Henckell and his assistant arrived at the Jessore-Khulna region as Magistrate Soon after Henckell been posted, he realised that the forest land of the region could offer immense financial return for its fertility and naturally irrigated channels (He proposed the government to reclaim the forest land of Sundarbans and lease those to local land-lords for cultivation.

*Figure 2: Map (highlighted area) showing the district and Sundarbans forest, Lower Bengal in 1786. The location of Khulna is shown in red. Source: Major James Rennell, 'An Actual Survey of the Provinces of Bengal, Bahar, & c. ed. King of Great Britain former owner George III and King of Great Britain donor George IV( London: A. Dury, 1786)*

Between 1790 and 1846 the Colonial government undertook extensive mapping to lease the forest land to local landlords for cultivation. This instigated a long history of conflict.

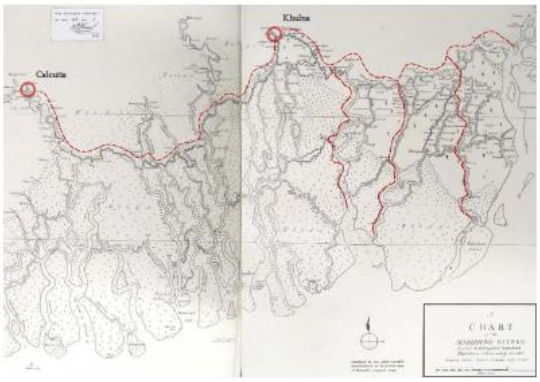


*Figure 3: Map showing the Sundarbans river route between Calcutta and Lower and Eastern Bengal via Khulna. Source: James Rennell, 'A Bengal Atlas: Containing Maps of the Theatre of war and Commerce on That Side of Hindoostan: Compiled from the Original Surveys: And Published by the Order of the Honourable the Court of Directors for the Affairs of the East India Company, (London: S.N., 1781)*

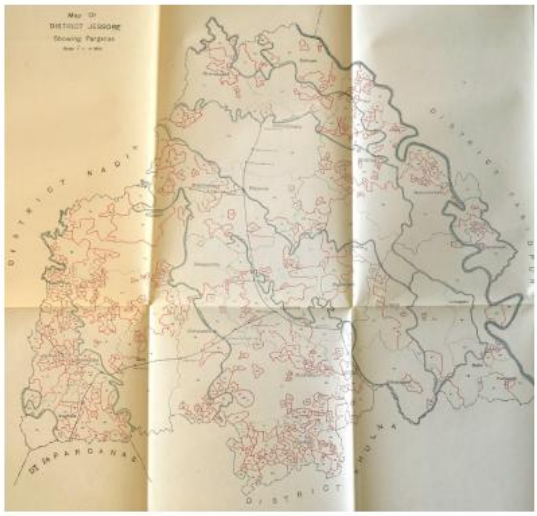

*Figure 4: map showing the estates in Jessore in 1925. The big estates were broken into smaller ones (red borders). Source: M. A. Momen, 'Final Report on the Survey and settlements operations in the District of Jessore, 1920-1924', (Calcutta: Bengal Secretariat Book 1925)*

Between the local and the colonial administration and to resolve those the latter

adopted a strong enforcement of legal boundary on forest land and transforming its elements into landed property.

A new vocabulary of landscape had been practised, where land became the key determining force in the transformation. In the extensive process of reclamation and development, the region underwent massive deforestation to convert it into agricultural land. In legal documentation, landscape had been identified as static and non-relational legal entity.

*Figure 5: Top map showing the Inland and the below showing the road networkings in Bengal in 1778. Source: F. C. Hirst, 'The Surveys of Bengal by Major James Rennell, F.R.S. 1764-1777'. (Calcutta: The Bengal secretariant book depot, 1917).*

In the latter half of nineteenth century, for the growth of agricultural land and agricultural production, Khulna emerged as the hinterland of the then colonial capital, Calcutta. The tropical weather, heavy rain and criss-crossed water channels made the soil soft and suitable for cultivation, but at the same time created constraints for the road transport. While it was important for the colonial government to transport the produce faster to Calcutta, which was located about 104 miles far, according to a colonial official, the disconnected rural roads of Khulna and interruption by water canals/rivers made it impossible to travel by land for more than two miles.

The rivers and canals reaching deep into the settlements could help in collecting goods to local markets, creating opportunities of exchange and building a stronger market community and settlements. Interlaced water networks created a sustained model of livelihood involving agriculture, fishing and trading through which transformed Khulna into a vital agricultural market in the region. Map shows that the water network, in fact, crafted the surrounding villages into a series of prosperous markets, increasing the trade opportunity and rapidly transformed the area into market centric settlements.


*Figure 6: Map showing the border of the Khulna District in 1887. A closer inspection of the map reveals numerous dotted marketplace in the District. The map also showing the relative location of Morrelganj. Source: Sheet no. 121 of the Atlas of India (Calcutta: India office, 1887).*

With the growth of trade, the colonial government upgraded Khulna to the status of town in 1884. The government recognised the financial potential and invested in the development of Khulna. To remove the

constraint of transporting agricultural produce and to make the good transport faster, the government established the railway network. In the following decades railway development helped Khulna to rapidly urbanise and grow. Khulna's share of the Jute trade (one of the cash crops) in Calcutta reached record high — 60% of total jute collection from Bengal.


*Figure 7: Map showing the railing line connecting Calcutta, Jessore and Khulna in 1898. Source: Map Room, Cambridge University Library.*

Railway removed the constraints but initiated a new mode of development, which had the capacity to defy the natural constraints. The speed of the railway was beyond the capacity of human to interact. The previous circulation routes that meshed with the intricate relationship between water and land provided constraints to move the goods, but at the same time fostered new opportunities for livelihood and socialisation. The relationship between people to place and people to people in rural landscape which were created through the constraints of transport had been replaced by the speed of technologically advance infrastructure.

After railway establishment, the colonial government built further infrastructure to administer the revenue collection of Sundarbans and facilitated the growth of market-town. 1929 map of Khulna shows that the town embraced dense urban development.

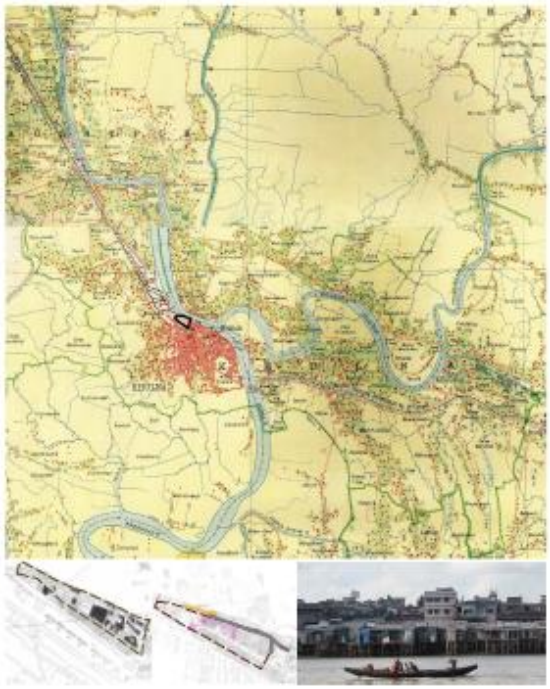

*Figure 8: Top map showing Khulna town (in red) and the location of Boro-bazar (previously known as Charlie's Haut, in black coloured outline) in 1929. Kacha-bazaar was part of Boro-bazaar. Top map source: R.H. Thomas, 'Map of Khulna in 1929'. (Calcutta: India office, 1929)*

The pattern of the development (in the map) shows a stark contrast between the rural and urban landscape. Whereas in rural context, the landscape appears to be the key initiator of settlement structure and growth maintaining water as the central feature, in the urban development infrastructure appears to be the one. Landscape appears to be internalised by the bold lines of the roads. These roads also cement the

edge of the landscape elements including water bodies and canals, making those ecologically handicapped urban objects.

The ecological relationship of the water with the surrounding landscape could not overtake or blur the legal boundary, rather those were characterised by lines of legal mapping and infrastructure. The 1929 map shows red dots, which denote the source of water bodies, to be scattered in a perforated manner in the landscape — a relationship that existed in the bigger scale of landscape, continued to diminish/elope in the urban landscape of Khulna.

1961 master plan of Khulna shows that the previous landscape lines were straightened to create efficiency in the circulation, making the circulations to ignore the lines of the landscape. This singled the complex and 'unnecessary things' out of the landscape that was amorphous and relational, controlling a land that was intrinsically in flux. The muddy landscape of the roads which created constraint in the speedy circulation, the new development made those grounds hardened, alienated and non-relational making an ordered vocabulary of development.

A system of organised approach in the name of providing utility became the attributes of the new vocabulary. It shattered the extra-ordinary depth of the ordinary rural elements – trees, plants, flower, stone, rock, clay, water and termites. These were removed to create a hierarchy of roads to manage the traffic flows and removing the scopes of negotiation of ordinary rural elements, let alone between the human and nature.

In the successive decades, with the growth of urban Khulna and the technological advancement, the mesh was broken into hierarchy of planning. Everything became constructed and the parts which were left marked as barbaric or unplanned. The constant urge to construct image of development and remove the constraint internalised the landscape and made the inhabitants of neighbourhood like isolated bubbles of a soap.

The infrastructure centric approach created identical change in the people -to-people and people -to-place relationship. To take an example of water, before 60's, one of the central neighbourhood in the city, used to be dependent on a pond, named Tarer-pukur, for drinking water. As much as the neighbourhood was named after the pond, the everyday act of brining water from Tarer-pukur made the place a platform of creating a mesh of intricate socio-spatial relationship.

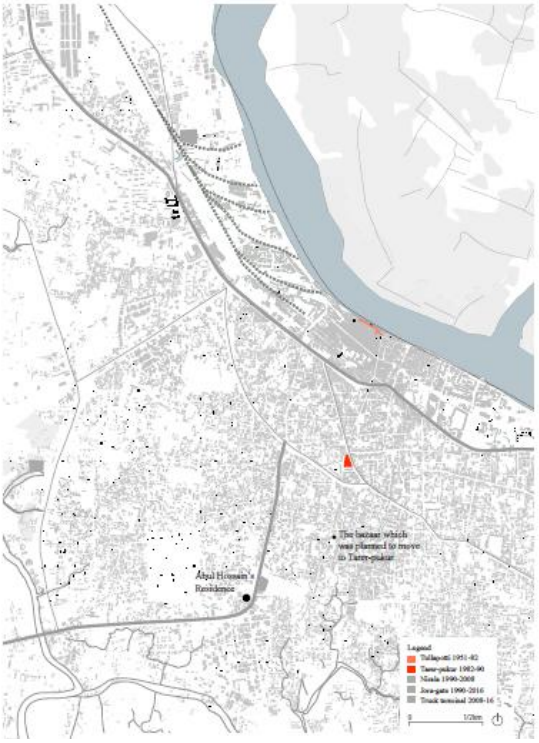


*Figure 9: Map showing the relocated Kacha-Bazaar in Tarer-pukur(red). In 1982, Vendors were evicted from Tulla-potti, Boro-bazaar (orange) to Tarer-pukur (light red).*

However, in the late 60's after the establishment of Government Water Agency, it and modernised water pipe system, the constraints to bring water from the pond has been removed. With the infrastructural development and provision of water supply at home, the neighbourhood no longer needed to come to the pond to collect water. The dependency on Tarer-pukur ended.

With no dependency on the pond, the government struggled to maintain the pond for few years. That objective could not be achieved for long and the water body later filled with land to create more landed property.

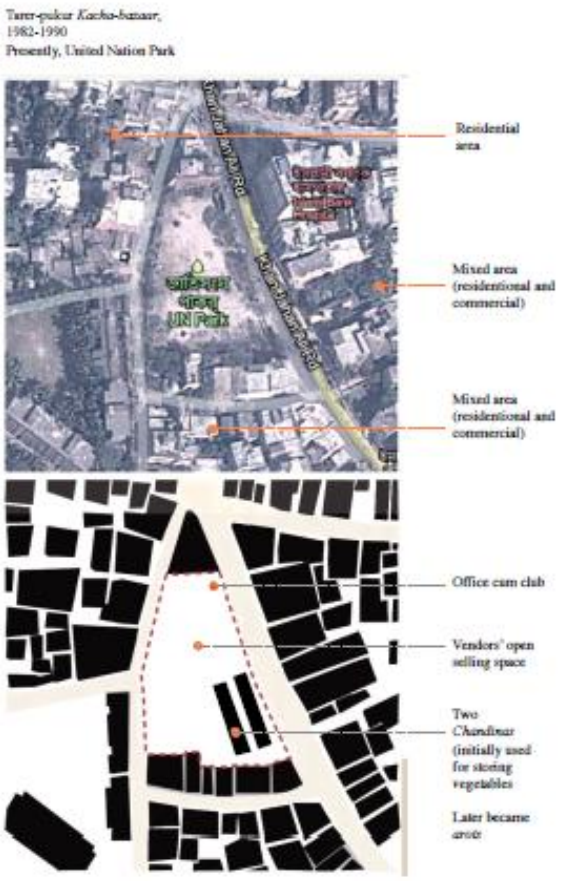


*Figure 10: Tarer-pukur Kacha-bazaar, 1982-1990.*

## 4. RURALITY AND CONSTRAINT

People and their surroundings are both the product and process of several Parallel histories. These histories are interconnected with each other in different layers. Each layer of those histories has different dimensions - time dimension, political dimension, and economical dimension, social and spatial dimensions. We tend to evaluate anything with its visible or most popular layer, without being critical with the inner or invisible layers, which created a huge gap with reality and narrations.

Another important critic is ignoring the other members of ecosystem besides Human. Scholars have prominently noted people centric histories in their elaboration of the concept of rurality. Which eventually isolated people from the landscape. Landscape, which is the fundamental initiator of any settlement, is hardly valued in the people centric view. In the history of Khulna, we see that the power play treated landscape as an instrument of financial return, rather than another member of that story, which have their own versatile characters and contributions. In reality, the landscape and its constraints in rurality is a co-living entity, which had been separated for higher economic return and development. These types of segregation create huge distance between people to people, people to place.

Talking about rurality, commonly two concepts are overwhelming. First one is a very utopian view consisting of fresh air, fresh food and all good soul people. And second one is the story of underdevelopment. Rurality is a major victim of these two persisting historical contents. History, because of these two given biases, a fabricated and top-viewed reality of rurality is presented in front of us. Isolated thought in either of the two streams lacks the zest of relationship that rurality can create.

Definition stems from the history, which is a collection of few relationships with respect to time. However, like the functioning of ecology, the constraints of rurality force people to build a changing relationship with the landscape. When we focus on the needs of the people and separate them by the development of infrastructure, we remove the relationship they have. For example, the water body of Tarer-pukur neighbourhood, where people needed to come to the pond for water embracing the constraints, a scenario also common in rural areas

Providing supply water was a highly demanding and 'practical' development strategy, however, ignored the relationship they have through the persistence of the constraint, which the agency removed in the name of development. The relation between water and neighbourhood written by the everyday inconvenience of bringing water home was written in a negative manner in the lens of development. We in our foam bubble (Peter Sloterdijk) like (co-) isolated living beings see these relationships as constraints. Where Place to place, people to place, people to people relationships are still present and practiced through 'constraints', we have considered them as 'Rural' and underdeveloped. This paper argues that it is necessary to think beyond the liner history in the

name of Development. Ignoring the fact, that mutual dependence is the ecosystem, we tend to remove the constraint and dependency, thereby directly interrupt the ecosystem, which results nothing good but creates a non-relational/cosmetic urban development.

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# SUSTAINABLE DEVELOPMENT IN RURAL AREAS CONSIDERING AGRICULTURE AND GROWTH CENTER INFLUENCED AREA ZONING THROUGH GIS ANALYSIS:

## A STUDY ON SHIBPUR UPAZILA

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***Abstract:*** *There has been worldwide concern for sustainable development especially after the 1992's Rio's UN Conference on Environment and Development. Rapid encroachment of urbanization on valuable agricultural land will have great influence on whether sustainable development can be achieved. Preservation of rural agricultural land is as important as sustainable development in rural area. A sustainable development in rural area can be achieved using GIS analysis in an attempt to confined future development within the growth centers influenced area preserving agricultural land. This research has demonstrated location of growth centers and other landuse in rural area through land suitability analysis so that development can be sustained in the future. Future development zone and non development zone is identified by using GIS dataset of inundation land type, agricultural cropping pattern and suitability analysis for the specific land zoning. Finally this research is an attempt to show how rural sustainability can be achieved through GIS analysis of agricultural land and growth centers influenced area.*

***Keywords:*** *Agriculture Zone, Rural Sustainability, Growth Center, Growth center influenced area, Zoning.*

## 1. INTRODUCTION

Sustainable development is both a global and local challenge to managing change. It requires integrating social, ecological and economic objectives and system requirements that are generally expressed in terms of maintaining some suitably defined aggregates of social, ecological and economic capital. The most accepted definition of sustainable development according to the Brundtland's report is, *"To meet the needs of present without compromising the ability of future generations to meet their own needs". It advocated the idea of "sustainable growth".* According to *The World Conservation Strategy* report (1980), by the International Union for the Conservation of Nature and Natural Resources (IUCN), for development to be sustainable it must *take into account the social and economic factors as well as the ecological ones*. Development of rural areas is directly depending on environmental resources, and that are characterized by a semi-natural to natural landscape which provides amenity and recreational values to the rural population. Yet, the threat to rural areas is that they are under pressure of urbanization. This goes along with landuse change and socio-cultural change, and thus with alterations of the regional ecological and social capital. The identification of the areas where the phenomenon is the most relevant is necessary to assess environmental planning adequately, being the agriculture the most threatened by the urbanization pressures (Allen, 2003). For this reason it appears necessary to build a classification of areas that accounts for the geographical, economic and social relationships between the areas and the urbanization centers. Such relationships appear substantially influenced by the urban morphologies which in turn shape the urban ecological systems (MacGregor-Fors, 2010). Like urban area, rural area does not have large number of facilities and amenities for the betterment of the people. Therefore, there is a need to identify existing rural growth centers in rural areas and accordingly propose new growth centers ensuring rural sustainability so that the rural areas become self-sufficient in its basic socio economic

facilities and amenities . Growth centre may be defined as service centre which has a potential for further development which provides goods and services to its own population as well as its surroundings population creating balanced socio-economic development of an area. The aim of this research is to demonstrate that Sustainable development in rural areas can be achieved through growth centers when thouse are established without damaging agricultural land. And all kind of rural facility will be agglomerated in the growth centers what will preserve the agriculture land and confined the all development along the growth centers influenced zone. For this GIS (Geographic Information System) is an attempt to identify suitable land for agriculture as well as other landuse.

## 2. THE CONCEPT OF GROWTH CENTER AND RURAL SUSTAINABILITY

The definition of growth center is different throughout the world. According to ESCAP (ESCAP 1979), Growth centers or rural centers are as centers that fulfill a criterion. According to this criterion, the centers that contribute directly to the basic needs of agricultural producers, both in respect of economic and social services are termed as growth centers. These services include the provision of the marketing of agricultural products and the arrangements for inputs that are fundamental for the production of agricultural commodities.

In the context of Bangladesh, growth centers are rural markets that have been identified by the Planning Commission on the basis of socio-economic and administrative criteria for making development investment (LGED, 1995).

Center for Sustainable Development defines Sustainable development for rural area as “Improving the quality of life for the rural poor by developing capacities that promote community participation, health and education, food security, environmental protection and sustainable economic growth, thereby enabling community members to leave the cycle of poverty and achieve their full potential”.

## 3. GIS SPATIAL ANALYSIS

A geographic information system (GIS) lets us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends. A geographic information system (GIS) is a computer based information system that has the capability of handling all kinds of spatial data for decision making. It enables the input, management, manipulation, analysis, modeling, output and dissemination of spatially referenced landrelative data (Scaria, 2012). GIS is becoming essential to understanding what is happening and what will happen in geographic space. Once we understand, we can prescribe action. This is a fundamental tool for multi criteria analysis. For Demographic & Socioeconomic Analysis, Landuse & Suitability Analysis, Future landuse zoning this software can give a fruitful conclusion with all the geographic data analysis.

## 4. LAND SUITABILITY ANALYSIS

Land Suitability Analysis (LSA) is one of the most useful analyses for setting up a proposal for an area. It is a GIS-based process applied to determine the suitability of a specific area for considered use, i. e. it reveals the suitability of an area regarding its intrinsic characteristics (suitable or unsuitable). This analysis generates the most suitable location for a proposal which is economically, environmentally and socially viable for setting up a proposal.

## 5. STUDY AREA SCENARIO

Shibpur Upazila comprising one Paurashava and nine unions with an area of 208.78 sq.km (51590.54 acre). The landuse of the area is predominantly agriculture even in paurashava area almost 60% lands is engaged in agriculture use. The upazila located in the influenced zone of the capital Dhaka and in serious risk of agriculture land conservation. Though our study area is one of the richest agriculture production area of the country but the industrialization threat is enormous here for the national highway passing through the rural area of Shibpur Upazila.

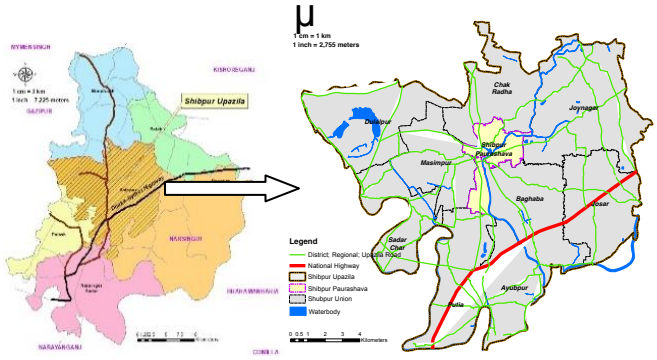


*Figure 1: Location Map of Shibpur Upazila*

## 6. OBJECTIVES AND METHODOLOGY

The main objectives of the study are:

1. Preservation of Agriculture land according to Inundation land type and cropping pattern to ensure rural sustainability.
2. Fixation of Rural Zoning Area into developed and no developed zone considering Rural Growth Centers and Agriculture Land.
3. Development of Rural Growth Center in more concentric way to establish sustainable development in rural area.

Arc GIS 10.3 developed by the ESRI is used for the analysis in this study. The hydrological analysis software hec-ras is used for inundation data of the area. Beside this, all the growth centers data and road and infrastructure data has been collected by primary physical feature survey by UDD. And all the thematic maps has been illustrated by the raster data set and shape files of GIS for this study.

## 7. AGRICULTURE ZONE PRESERVATION ACCORDING TO INUNDATION LAND TYPE AND CROPPING PATTERN

To preserve the agriculture land four type of dataset can be considered to demark the agricultural zone more precisely.

1. Inundation Map
2. Land Type according to Inundation
3. Cropping Pattern
4. Land Height or DEM

### *7.1. Inundation Map*

Flood and inundation are annual event, which is utilized for agriculture in flood plain land. Inundation area can be associated with agricultural land. As the flood is the regular phenomena in our country so the regular Inundation area should be preserved from any kind of development. By the last 30 years' inundation data the maximum depth in the study area in flood season has been identified. After getting the inundation scenario of the area, the inundated land is classified into five categories according to Master Planning Organization (MPO).

According to this classification the land with the maximum depth above 0.9 meter should be considered as occasionally sub flooded Zone. And the area above 1.8 and 3.6 meter (Excluding water way) should be considered as respectively occasionally sub flood flow zone and sub flood flow zone. As these areas are environmentally critical zone for the annual flood scenario. So these areas must be preserved from any kind of development to sustain an ecological balance. To demark the agriculture land in rural area this inundation depth is the tool what give a clear indication about the agriculture zone what must be preserved.

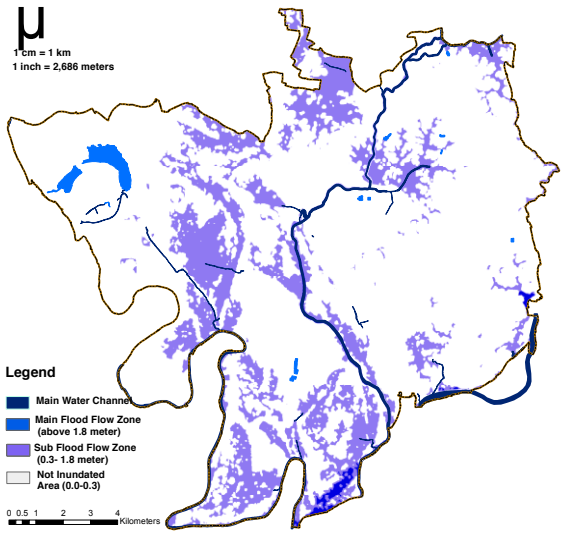


*Figure 2: Inundation scenario in Shibpur Upazila*

### *7.2. Land Type according to Inundation*

From the above Inundation map, according to inundated depth the land type has been identified here. In rural area The inundation land type can be fundamental tool to define the agriculture land.

The Master Planning Organization (MPO) was a strategic planning wing of the Government of the People's Republic of Bangladesh. was introduced considering inundation criteria of lands during monsoon. Details of MPO land type classification along with flood flow zone considerations are presented in the next table:

*Table 1: Inundation Land Type*

| MPO land types | | | Flood zones |
|---|---|---|---|
| **Land type** | **Description** | **Flood depth (m)** | **Based on MPO** |
| $F_0$ | High land | <0.30 | Flood free |
| $F_1$ | Medium high land | 0.30 – 0.90 | Occasionally flooded |
| $F_2$ | Medium low land | 0.90 – 1.80 | Occasionally Sub- flood flow zone |
| $F_3$ | Low land | 1.80 – 3.60 | Sub- flood flow zone |
| $F_4$ | Low to very low land | >3.60 (excluding waterway) | Main flood flow zone |

*Source: Master Planning Organization (MPO)*

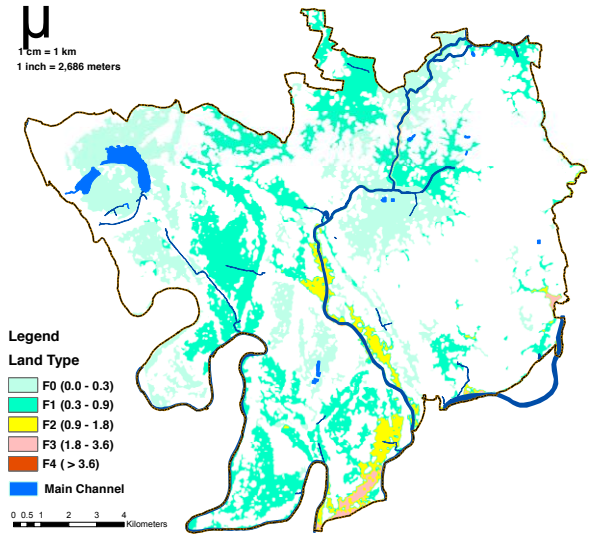


*Figure 3: Inundation Land Type in Shibpur Upazila*

According to this land type, $F_0$ is totally flood free land and this land is recommended for any kind of development. And $F_1$ is a occasionally flooded area what is recommended only for conditional use and can be used for agriculture purpose. On other hand, $F_2$, $F_3$ and $F_4$ land types are recommended only for agriculture purpose. No other use is granted in this land. So for a sustainable development is land type classification is an effective tool for future zoning and landuse regulation.

### *7.3. Cropping Pattern*

Cropping pattern is a very important aspect to define the high value agricultural Land. Tough in our study area more than 70% of the land are using for agriculture purpose. But all lands are not equally productive. For the land elevation, drainage congestion and inundation in rainy season almost 30% land are single crop land. But for the relatively high land condition, maximum land of our study area is double and triple crop land. As like other flood plain area the agricultural potentiality of our study area is very high and a big parcel of land are double, triple and multiple crop land are producing a large number of crops.

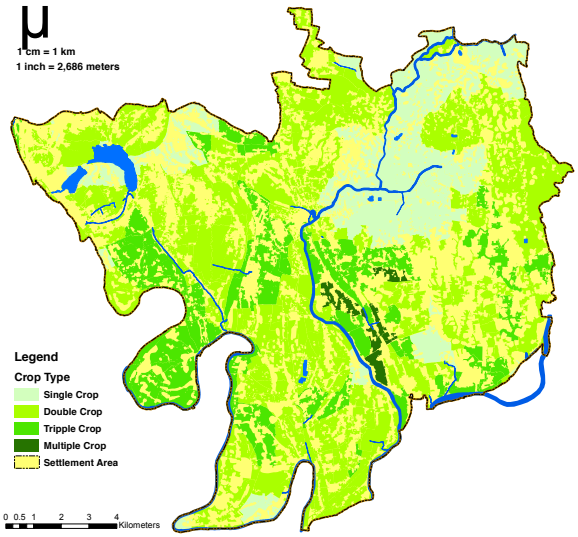


*Figure 4: Cropping Pattern in Shibpur Upazila*

So considering this high value of land agriculture chunk of land must be preserved for the ecological and economical sustainability in the rural area. And double and triple crop land must be preserved by use regulation from the industrial and settlement uses.

### *7.4. Land Height or DEM*

In agricultural practices, accurate representation of field topography is required to implement

precision agriculture management for more efficient agriculture zone demarcation. A DEM is a digital representation of land topography representing elevations on the earth's surface what gives an indication for landuse category what will be suitable for this land according to elevation. By this elevation model the hilly area, low land area and relatively high land area has been segregated here what is compulsory tool for broad landuse zoning.

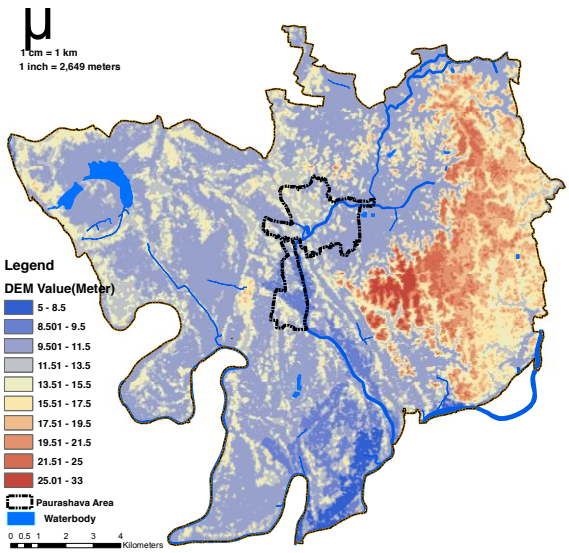


*Figure 5: Digital Elevation Model (DEM) in Shibpur Upazila*

## 8. ZONING FOR FUTURE DEVELOPMENT AND NO DEVELOPMENT

By the Zoning regulation and by fixation of the zone for future development and no development area the rural area sustainability can be gained. For fixation of the future development area the present infrastructure scenario, Road Network and location of Growth centers are having been analyzed.

### *8.1. Growth Centers influenced area and linkage*

The location of the growth centers and hut bazar can be considered as the growth pole of the rural area. The main agglomeration of the infrastructures and commercial activities are concentrated into the rural growth centers. By the physical feature survey of major hut bazars (46) of the study area, the major road network with the growth centers and the location of the Hut bazar and Growth centers is projected in the GIS map.

By the analysis of the landuse data, the particular landuse surrounding the growth centers has been identified. And development pattern and level of services among the growth centers and the road proximity analysis has developed a picture of influenced zone of the growth centers.

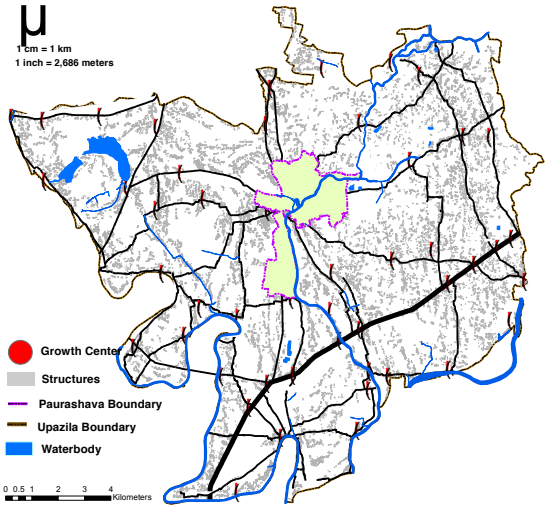


*Figure 6: Location of Growth Centers and Hut Bazar in Shibpur Upazila*

### *8.2. Agricultural Suitability*

To identify the best suitable area for agriculture and analysis has been conducted using water depth, slope and cropping intensity. These following factors has been incorporated in the following way.

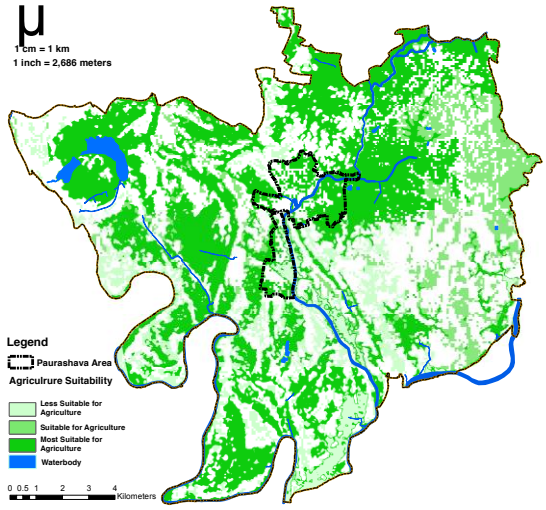


*Figure 7: Agriculture Suitable Area in Shibpur Upazila*

Cropping Intensity (CI) =CI positively influenced agricultural suitability from single to multiple crop land.

Water Depth = Water depth positively influenced the agricultural suitability by the raster calculation in GIS with relevant weightage the suitable area for agriculture land has been identified.

### *8.3. Zoning Area*

To identify the brought zoning of future development and no development zone, the influence area of growth centers and agriculture suitability maps are the two fundamental dataset. By the overlay of these two dataset this zoning map has been produced. Two important criteria growth center influenced area and road network has been considered here to identify the future development zone. And to identify the future no development zone or agriculture zone the agriculture suitability map was the major criteria. By overlapping this two maps the conflict area has been identified and the final zoning for or suitable area for agriculture and human settlement has been declared here.

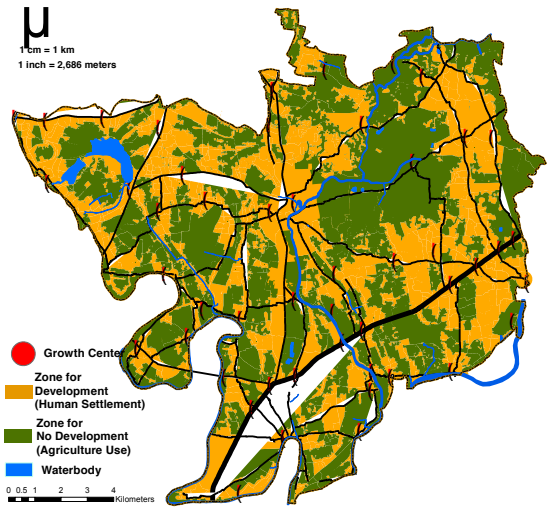


*Figure 8: Future Zoning Recommendation in Shibpur Upazila*

## 9. DEVELOPMENT OF RURAL GROWTH CENTER

Growth center may be defined as service center of rural area which has a potential for further development. Growth Center in the village can be compared with Central Business District (CBD) of the arena. The growth center performs as center of economic, social and cultural activities in the rural areas. In this point of view, the growth centers in the rural area should be developed in more compact pattern. And all the basic facilities and agglomeration of the services must be present in the growth centers. As the present characteristics of our maximum rural area, not having a high demand of facilities.

Provision in Growth center:

- Growth centers must be act as the focal point if the rural economy.
- Growth centers will be the main hub of the all level of service in rural area including education, Health facility, Government Services, Community facilities, Open spaces etc.


*Figure 9: Growth Center Model for Rural Area*

- It will develop as the market places of local agriculture product and indigenous goods of the rural area. So Enough infrastructure for this commercial support such as; cold storage, go down must be present here.
- Better circulation Network among the growth centers and better road infrastructure for the transport of the agro product must be developed.
- The major development zone of the rural area should be concentrated within the

influenced area of the growth center. Any kind of development such as small scale industries, multi storied building and other facilities can be provided within this influenced area.

- To ensure rural sustainability this area act as the sub urban area of the rural area and will be functional as the pull factor for the rural settlement and any other activities.

## 10. CONCLUSION

Sustainable development is a significant and challenging issue in rural area. But it is important to keep in mind that agriculture land preservation is as important as it. Besides this, growth centers also keep importance in rural life. So land suitability analysis using GIS dataset is an attempt to identify suitable land for growth center and other landuses. Agriculture land suitability analysis identifies which land needs to be preserved and also which land use for what purpose. To preserve the agriculture land four type of dataset like Inundation Map, Land Type according to Inundation, Cropping Pattern, and Land Height or DEM has been considered to demark the agricultural zone. Again to ensure rural sustainability zoning area for future development and no development area has been recognized considering growth center influenced area and agricultural suitable area. Finally a growth center model has been proposed that can help to ensure rural sustainability.

## ACKNOWLEDGEMENTS

We like to thank the Urban Development Directorate (UDD) what is working on the rural area development plan in Bangladesh and The honorable director of the UDD, one of the leading Urban planner of the country who incorporating the GIS analysis in every sector of planning. Beside this, I like to thank the project director of the “Fourteen Upazila Development Plan” for supporting us with all the database od Shibpur Upazila.

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# ANALYSIS OF ENVIRONMENTAL FACTORS FOR PLANNING OF GREENERY INTEGRATED BETTER PEDESTRIAN WAY IN DHAKA CITY

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***Abstract:*** *In Dhaka city, walking holds a major share of everyday total trips. For this reason, pedestrian way has been the major concern in transportation plan and pedestrians are considered as emancipated road users, with their special needs in comfort, time efficiency and attractive surroundings. We investigated the climate condition of pedestrian way in terms of the presence and absence of greenery. The objectives of the study were to find out environmental factors of greenery integrated walkway in Dhaka city pedestrian way and to find out their relationship with choice of walking and frequencies of walking in city streets. Five study areas were selected for the research. Two of them were greenery integrated pedestrian way and three were without greenery. All of five are mixed used areas. An observation survey, a questionnaire survey and a pedestrian volume survey were the tools to collect data from field. Several tools like SPSS, Microsoft Excel, and Arc GIS 9.2 were used to analyze the data collected from primary sources. The result shows that, pedestrians require quality walking space which should be environment friendly, comfortable and attractive so that pedestrians can be encouraged to walk within the walkway. Pedestrian way with greenery influence people to for walk, rather than travel, for a long time throughout the whole day. On the other hand, pedestrian way without thermal comfort and aesthetical pleasance discourages people to walking. Simple statistical procedures were used to analyze data. The study result also suggested that, street greenery contributes in improving environmental condition and also manipulate people for walking.*

***Keywords****: Air temperature, humidity, greenery, pedestrian comfort.*

## 1. INTRODUCTION

Pedestrian walkway is considered as an important ingredient of environment-human system in an urban setting [1]. So climate condition at street level is most important for pedestrians and is certainly critical when considering walking as an alternative means of commuting. A pleasant environment, with greenery, can make the pedestrian way more effective. According to PQN Final Report, November 2010, **"**people may walk, even considerably long distances, instead of driving in their air-conditioned petrol powered cars if outdoor conditions are comfortable enough for pedestrians.**"** A high quality green oriented environment for walking is in strong relation with aesthetic quality and design [2]. A study conducted on the greenery factors in Singapore stated that an environmentally comfortable walkway encourages the pedestrian to walk rather that driving [2]**.** It has also revealed that the temperature between shaded and non-shaded area by means of greenery is more than $3^0$C [2]**.** Such micro climate impacts on pedestrian way increases the volume of pedestrians in many times.

In Dhaka city, pedestrian services exist in a limited quantity and most of the cases designed without greenery. Comfort and attractiveness of walkway are mostly ignored in roadside walking environment at Dhaka city. One of the worst problems in the city is insufficient walkways with inadequate supply of utilities. Nevertheless, some problems of walkways in city area discourage people to walk. It seems to be a large number of pedestrians but a limited number of pedestrian

way users. It results in large portion of accidents every year [3]. In Dhaka City pedestrian accidents figure in almost half of the total accidents [3].

The Greenway is an excellent way to create more efficient mobility and manage the transportation demands of future population growth. Greenway can provide a safe transportation alternative to cars and other transport modes. In addition, green oriented walkway also brings health benefits to the pedestrians by giving a shaded, cool and comfortable place by mitigating heat island effect [4]. However, no systematic study has yet been conducted on the impact of greenery in pedestrian way of Dhaka city. Several researches have also proven that appropriate walkway design can increase both the quality and quantity of walking. If the issues related to pedestrianization are continuously overlooked, then the problems will grow to a proportion that would be hard to solve. In this research, an effort thus has been taken to provide optimal greenery integrated pedestrian walkways considering several relevant factors such as presence of greenery, pedestrian volume, design of walkways, and aesthetic condition.

## 2. METHODOLOGY

The research is based on a questionnaire survey and an observation survey that had been developed at the very earlier stage. Those were considered as the main data-gathering instrument for this study. The questionnaire is divided into two main sections: a profile of the respondents and the survey paper. The profile contained socio-demographic characteristics of the respondents such as age, gender, civil status, occupation etc. All of five study areas were selected based on different characteristics on their different level of pedestrian services as follows; 1) Jatrabari, Kakrail, Moghbazar areas contain pedestrian walkways without greenery integrated walkway and 2) Manik Miya Avenue and walkways around Ramna park fall under green oriented walkway but not optimized ones. A pedestrian volume survey was also done to analyze the difference of pedestrian usage of walkway because of presence or absence of greenery. Collected data were then summarized, tabulated and analyzed to fulfil the research goals.

The survey paper has explored the perceptions of respondents, particularly on the walkway environment at present. The question paper section also contained questions to choose a particular walkway and their highest duration of walking in presence and absence of greenery.

### *2.1. Data Collection and Processing*

This is a qualitative research starting from collecting secondary data i.e. Dhaka City road maps, relative literatures published in international journals, case studies and then conducting filed survey to analyze existing physical conditions and pedestrian volume at study areas by method of observation survey. After that, a questionnaire survey was conducted among pedestrians, both at greenery integrated and without greenery ways to understand people's perception about their preferences toward walkway. A pedestrian volume survey was also done in each of the study area to analyze the difference of pedestrian usage of walkway because of presence or absence of greenery. Collected data were then summarized, tabulated and analyzed to fulfil the research goals. A total number of 500 respondents were being surveyed from the five specific locations. Data on the following factors were collected through questionnaire survey and personal observation in the pedestrian walkways of the study areas: Presence of greenery, Climate condition, Aesthetic condition and Pedestrian volume. GIS-based analyses were performed to optimize greenery oriented pedestrian walkways by evaluating four considered factors.

## 3. EVALUATION OF WEATHER CONDITION

### *3.1 Temperature*

Street greenery has the ability to effectively reduce urban heat and improve thermal comfort on various scale levels. In streets with large tree crowns on both sides, as Manik Miya Avenue and Ramna Park area, the temperature had been captured $2^0$C lower than in streets without greenery as in Kakrail, Maghbazar and Jatrabari areas.

*Table 1: Average Temperature Captured in Manik Miya Avenue and Ramna Park area*

| Greenery Integrated Walkway | |
|---|---|
| **Time of the day** | **Temperature (average)** |
| **8:00 am-9:00 am** | 30.09° C |
| **9:00 am-10:00 am** | 30.88° C |
| **10:00 am- 11:00 am** | 31.34° C |
| **11:00 am-12:00 am** | 32.18° C |
| **12:00 pm-1:00 pm** | 32.27° C |
| **1:00 pm-2:00 pm** | 33.02° C |
| **2:00 pm-3:00 pm** | 33.15° C |
| **3:00 pm-4:00 pm** | 32.59° C |
| **4:00 pm-5:00 pm** | 31.26° C |
| **5:00 pm- 6:00 pm** | 30.48° C |

*Source: Field Survey'14*

The observation shows that, in the morning, the thermal condition remains cooler in both type of places. As the time goes away, the temperature also increases. At the mid day, temperature reaches at the highest point. But the shady areas hold lower temperature than the sunny areas throughout the day.

*Table 2: Average Temperature Captured in Kakrail, Magh Bazar and Jatrabari.*

| Walkway Without Greenery | |
|---|---|
| **Time of the day** | **Temperature (average)** |
| **8:00 am-9:00 am** | 30.89° C |
| **9:00 am-10:00 am** | 31.72° C |
| **10:00 am- 11:00 am** | 32.28° C |
| **11:00 am-12:00 am** | 33.59° C |
| **12:00 pm-1:00 pm** | 33.49° C |
| **1:00 pm-2:00 pm** | 34.74° C |
| **2:00 pm-3:00 pm** | 34.97° C |
| **3:00 pm-4:00 pm** | 33.96° C |
| **4:00 pm-5:00 pm** | 32.48° C |
| **5:00 pm- 6:00 pm** | 31.61° C |

*Source: Field Survey'14*

From the survey, it has been evident that, a walkway with large tree provides a shady, cooler and comfortable walkway to the pedestrians, which pedestrians desire most to walk for a long time. The temperature is almost $2^{0C}$ less in green areas than the opposite throughout the day.

### *3.2. Humidity*

In the following diagram, the humidity level is shown for greenery integrated walkway which is relatively high and in comfortable level in morning and evening time for the pedestrians. From 8:00 am to 12:00 am humidity level remains 57%. In the mid of the day it decreases to 6% and then it rises from 51% to 54% in the evening.

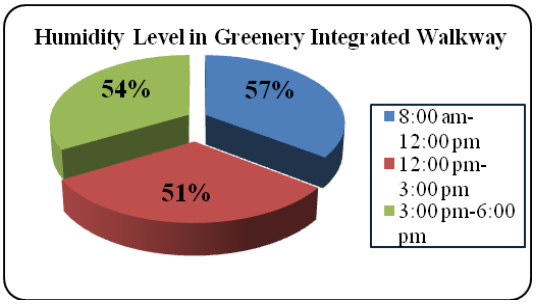


*Figure 1: Average Percentage of Humidity in Manik Miya Avenue and Ramna Park Area*

As the temperature increases, humidity level also decreases. In the evening, from 3:00 pm-5:00 pm, the average humidity level is 44%. At the mid of the day, the humidity level downs to the highest level, which is 38%. For that reason, these areas- Kakrail, Maghbazar and Jatrabari are much uncomfortable for the pedestrians.

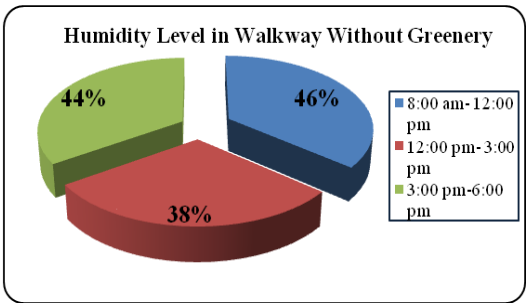


*Figure 2: Average Percentage of Humidity in Kakrail, Maghbazar and Jatrabari Area.*

### *3.3.Evaluation of Momentary Climate Condition*

Even though people evaluated momentary microclimates more comfortable in streets with greenery, they were hardly aware of the positive influence of street greenery on their thermal perception. This insight is based on the analyses of the mental maps, where 78% of the respondents in Manik Miya Avenue and 56% respondents in Ramna Park Area attributed their thermally

comfortable zones to the presence of green. At the same time, 47% of the respondents in Kakrail, 46% in Maghbazar and 43% in Jatrabari accounted their walkway as uncomfortable. In Manik Miya Avenue and Ramna Park area, no respondents accounted the both area as thermally uncomfortable. Moreover some people thought that Manik Miya Avenue is more suitable and comfortable to walk than any other areas in Dhaka.

*Table 3: Momentary microclimate conditions in study areas*

| Respondents Opinion | Percentage of Respondents | | | | |
|---|---|---|---|---|---|
| | Street with greenery | | Street without greenery | | |
| | Manik Miya Avenue | Ramna Park Area | Kakrail | Maghbazar | Jatrabari |
| **Very uncomfortable** | 0 | 0 | 19% | 17% | 39% |
| **Uncomfortable** | 0 | 0 | 47% | 46% | 43% |
| **Neutral** | 9% | 32% | 19% | 24% | 14% |
| **Comfortable** | 78% | 56% | 10% | 11% | 4% |
| **Very comfortable** | 13% | 12% | 5% | 2% | 0% |

*Source: Field Survey'14*

### *3.4. Evaluation of Green Street Design*

In Ramna Park area 69% respondents considers the walkway as pleasant and 11% of them told that the walkway is very pleasant especially in the evening. A few respondents pointed the road as unpleasant because of the illegal grabbers and street hawkers. In Maghbazar and Kakrail area respectively 48% and 42% respondent replied the walkway unpleasant. The worst condition among the five study areas is of Jatrabari. 57% of the pedestrian recognized it as unpleasant and 21% of the said it very unpleasant. Female and aged pedestrians of this area commented negatively. They said that at the mid of the day the area become totally unsuitable for walking. That's why at this time of the day the road has the long time traffic jam. But often people are seen to walk endangering their life to a great threat to fulfill their needs.

### *3.5. Walking Time in Greenery Integrated and Without Greenery Walkway*

#### *3.5.1. Walking Time for Abstract Destination*

The majority of the respondents were willing to walk in the sun for a maximum time of 5-15 minutes, which holds for 70% of all respondents in selected three areas: Jatrabari, Maghbazar and kakrail, while their willingness to walk in the shade varies between 15-30 minutes to 45-60 minutes. 70 % of all respondents were interested to walk for 30-45 minutes in a shady walkway and 17.20% of respondents were willing to walk for maximum 60 minutes in greenery integrated area. These percentages shows that a greenery integrated walkway can change the peoples' perception on walking.

*Table 4: Walking time for Abstract Destination*

| | Destination (Abstract) | | | |
|---|---|---|---|---|
| | Walking time (Sun) | | Walking time (Shade) | |
| | Count | % | Count | % |
| **5-15 min** | 81 | 16.20% | 0 | 0% |
| **15-30 min** | 389 | 77.80% | 63 | 12.60% |
| **30-45 min** | 23 | 4.60% | 351 | 70.20% |
| **45-60 min** | 7 | 1.40% | 86 | 17.20% |

*Source: Field Survey'14*

#### *3.5.2. Walking Time for Specified Destination*

86% respondents were ready to walk for 15-30 minutes in a walkway without greenery. On the other hand, 78% of respondents were highly interested to walk for 30-45 minutes in a shady walkway. Another 3.40% answered that they can walk for highest 60 minutes to go to work places or to school or colleges. Many respondents told that, if the walkway is provided with a healthy walking environment, they will manage to walk for long time, which will give them financial as well as health benefits. Only 2% people in study areas without greenery will to walk for 45 minutes. And respondents think it impossible to walk for 60 minutes in those areas without greenery. The percentage of respondents to walk

for 30-45 minutes is also significant, which is 31.80%. Only 39.40% respondents were eager to walk for 30 minutes in a sunny walkway.

*Table 5: Walking Time for Specific Destination (recreation, health or others)*

| Destination Type: Specific (Recreation/Health/Others) | | | | |
|---|---|---|---|---|
| | Walking time (Sun) | | Walking time (Shade) | |
| | Count | % | Count | % |
| **5-15 min** | 216 | 43.20% | 6 | 1.20% |
| **15-30 min** | 197 | 39.40% | 48 | 9.60% |
| **30-45 min** | 79 | 15.80% | 159 | 31.80% |
| **45-60 min** | 8 | 1.60% | 287 | 57.40% |

*Source: Field Survey'14*

*3.5.3. Walking Time in Respect of "Gender"*

The presence of greenery has a very slight impact on gender. In greenery integrated walkways, for abstract and specific destination, percentages of walking for 30 minutes for male and female are respectively 38.12% and 37.89%. This indicates that both male and female pedestrians like to walk in a shady and cool walkway.

*Table 6: Willingness to Walk in the Sun and Shade (as a function of Gender)*

| Walking Time (By Gender) | | | | |
|---|---|---|---|---|
| | Walking time (Sun) | | Walking time (Shade) | |
| | Male | Female | Male | Female |
| | % | % | % | % |
| **5-15 min** | 12.26% | 57.30% | 7.90% | 30.55% |
| **15-30 min** | 31.08% | 39.10% | 24.22% | 29.00% |
| **30-45 min** | 48.19% | 3.60% | 38.12% | 37.89% |
| **45-60 min** | 8.47% | 0.00% | 29.76% | 2.56% |

*Source: Field Survey'14*

## 4. FINDINGS & CONCLUSION

Interview and observation survey results indicated that people in general perceive thermal conditions in streets with greenery to be more comfortable than in streets without greenery, even though they were hardly aware of this positive influence of street greenery on their thermal comfort. Additionally, the study found that street greenery raises aesthetic appreciation of streetscape – independent from microclimatic aspects. Moreover, people significantly valued the presence of greenery in aesthetic terms as common people have limited knowledge on climate impact of greenery in pedestrian way. From the study it can be summarized that the pedestrians always require quality walking space which should be environment friendly, comfortable and attractive so that pedestrians are being encouraged to walk within the walkway. In addition, sidewalks designed in an integrated way with greenery can provide pedestrians to walk with a healthy feeling of fresh air which will in turn reduce the dependency on motor vehicles.

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# COMMUNITIES IN A GROWING MEGACITY:
## A PATHWAY TO URBAN SUSTAINABILITY FOR UTTARA, DHAKA

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***Abstract:*** *Dhaka is witnessing a process of urban expansion at sheer scale and speed. With the growing influx of population, the geographical boundary of Dhaka is also expanding. Satellite towns are planned at the fringe and outskirt of the city to meet the housing demand of increased population. Realizing that -in absence of efficient commuter facility this vision of decentralization of the city may be futile- a strategic transport plan (STP 2005) has been prepared recently proposing metro & bus rapid transit and construction of new link roads, circular roads and flyovers for connecting the satellite towns with the rest of Dhaka. If these towns are not (re)designed or (re)qualified to be transit oriented, the benefits of proposed transit system at community level cannot be ensured. The research finds neighbourhood TOD (transit oriented development) can be a planning approach to create more liveable neighbourhoods in suburbs of Dhaka city by reducing private car dependency while providing alternative public transport choices, safe and comfortable pedestrian pathways for fast and convenient access to transit stops and community facilities. Following that vision, this study attempts to rethink Uttara Model Township-a satellite town located at the northern end of Dhaka, with a goal to present a community vision that best utilizes the opportunity created by the proposed transit specifically, MRT, BRT, elevated express way and Western Bypass while creating new local transportation options, pedestrian-friendly environments and recreational opportunities.*

***Keywords:*** *Urban growth, Sustainability, Satellite town, Transit oriented development.*

## 1. INTRODUCTION

Dhaka, a growing megacity, is in a continuous process of urban expansion. The need to cater for high population growth and inward migration from rural areas theoretically reinforces governmental policy towards city expansion. In support of this policy, new urban developments are proposed on the fringe where suburban and agricultural land is being transformed and prepared for vast new towns. (Mahtab-uz-Zaman & Lau 2000). Historically, urban expansion tended to be to the north of the river Buriganga, and therefore, plans were formulated to promote northward expansion. In this process of planned expansion, Dhanmondi was the first to be developed as a residential area in 1950 to serve the ever increasing residential needs of the new capital. Since then Mirpur (1960), Mohammadpur (1960), Gulshan (1961), Banani (1964), Uttara(1965) and Baridhara(1972) model towns have been planned by public sector (currently RAJUK) following governmental policy towards outward expansion of the city at the cost of suburban and agricultural land.

In last 25 years, Dhaka has expanded almost 2.5 times of its size. The urban extent of Dhaka in 2014 was 36,541 hectares, increasing at an average annual rate of 3.3% since 1999. The urban extent in 1999 was 22,825 hectares, increasing at an average annual rate of 5% since 1989, when its urban extent was 13,878 hectares (Figure 1).This expansion plan for Dhaka city is often quoted as 'ambitious' by the scholars and urban critics since 'infrastructure provision is slow to cope with the pace of development' (Rodger 1991). For efficient functioning of these new residential communities, the need for large-scale infrastructure provision for utilities and transportation has never been met by either the public or private sectors (Mahtab-uz-Zaman & Lau 2000). Further it gave rise to urban sprawl as oppose to the compact character of inner urban core. In Dhaka Metropolitan Development Plan (DMDP)1995–2015, more roads and highways were recommended to link with the sprawling new developments (RAJUK 1997), leading to a vision of a low-rise, low-density city form, with long journeys-to-work. However, this planning proposal lacks comprehensive study of the reality of Dhaka's inner city, and fails to take account of the cost of

developing infrastructure on the fringe (Rodger 1991).

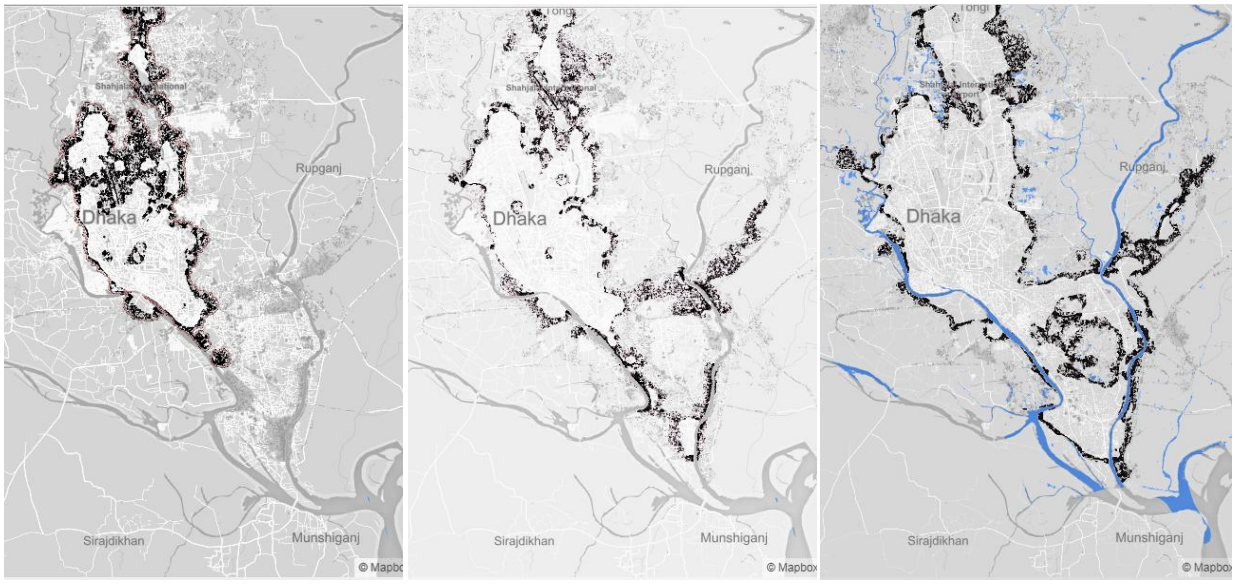
Furthermore, the existing overcrowded urban networks of Dhaka is suffering from undersize infrastructure, poor connectivity, lack of mass transit system and facilities including lack of choice in mode of transportation, insufficient stops, poor quality pedestrian networks etc. – resulting in a high level of operational disorder. This is, in turn, significantly diminishes the efficiency and effectiveness of the existing transport uses. The deteriorating traffic conditions are not only slowing down citizen's mobility but also worsening air pollution and seriously compromise the ability of the urban network to serve and sustain quality of urban life.

To improve the situation, there are a number of ongoing and proposed policy actions around transportation in Dhaka including construction of flyovers, metro lines, elevated expressways, water taxis, articulated buses, foot over bridges etc. This development trend is often criticized for its piecemeal approaches which lack common vision for the city and its region as a whole. Issues like sustainability and quality of urban life is rarely addressed. There is a need to design an efficient and comprehensive urban network that is well integrated with its urban system considering both in present and future context.

In the latest urban polices for Dhaka, priority has been given to Transport Oriented Development (TOD) as a strategic tool to enhance the linkage between landuse and transport network and to promote compact, mixed and walkable community development. As stated in the Dhaka Structure Plan 2016–2035, TOD based development close to mass transit (MRT/ BRT) stations can ensure effective and affordable mobility. Transport-oriented development and traffic-calming interventions involve systemic and managerial aspects ensuring convenience, efficiency, aesthetics and safety to mobility (RAJUK 2015). However, Mowla (2015) argued that TOD reduces the propensity to travel therefore is good as a concept but its application in an existing developed setting would require massive interventions and skill. Dhaka's institutional framework, technological capability, financial capability, geo-morphological context and social attitude are not ready for this intervention. Mowla (2015) warns, Dhaka is not a virgin land where fresh transport oriented developments (TOD) can be proposed without massive amputation.

## 2. OBJECTIVE AND METHODOLOGY

This paper examines urban growth of the outer city suburban community and argues against the urban expansion policy in absence of upgraded/appropriate transport infrastructure. Taking Uttara satellite town as a case study, it attempts to justify urban development that is conducive to transit riding, and supports the underlying principle of transit oriented development as a pathway to sustainable community development. The paper identifies key challenges and urban design options for sustainable urban growth of Uttara Model Town on




1989 1999 2014

*Figure 1: Urban Expansion of Dhaka (1989-2014) source :Atlas of urban expansion (2016)*

the basis of pre-structured fieldworks and design exercise undertaken by the fourth year students of Architecture at American International University-Bangladesh, under academic guidance of the authors. Filed works involves physical survey and mapping of morphological elements (landuse, plot configurations, open spaces, building height & density) and mobility networks (street pattern, accessibility and connectivity, traffic flow, mode of transport) of the exiting Uttara model township. Base map of Uttara model town and other historical spatial data are collected from RAJUK, google satellite imageries and other secondary sources including published literature, government records and archives.

## 3. SUSTAINABLE URBAN GROWTH AND TRANSIT ORIENTED DEVELOPMENT: GLOBAL PERSPECTIVE

Urban growth and urban expansion are sometimes use synonymously by the common people, although they are different. Urban growth is the sum of increase in developed land. One of its forms is expansion. According to Clark (1982), urban growth is spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy and society. Wilson et al. (2003) have identified three categories of urban growth: infill, expansion and outlying. An expansion growth is characterized by a non developed area being converted to develop and surrounded by no more than 40% of existing developed area. This conversion represents an expansion of existing urban patch (Wilson et al. 2003). Expansion type development has been called metropolitan fringe development or urban fringe development (Heimlich & Anderson 2001). It is important to understand not all urban growth is necessarily unhealthy. In fact some types of urban growth (e.g. infill growth) are generally considered as remedies to urban sprawl (Bhatta 2010). The relation (travel distance and travel mode) to existing developed areas is important while determining what kind of urban growth has occurred (Bhatta 2010). For instance, when new development is separated from the existing urban area by long distance communication line and characterized as low dense, less compact, scattered; surrounded by non developed areas and the land for the development is reclaimed from lowland, farmland or natural area- such growth is termed as urban sprawl. The negative consequences of such low-density, urban sprawls are at the heart of many serious critiques of automobile cities and the environmental impacts of cities (Kunstler 1993; Gillham 2002; Newman & Kenworthy 1999). The strong relationship revealed by many studies between more compact, mixed-use urban form and reduced use of cars is reflected in efforts around the world to reduce urban sprawl and create more transit-oriented communities (Bernick & Cervero, 1997; Calthorpe 1993, Beimborn & Rabinowitz 1991; Williams, Burton & Jenks 2000). These efforts to achieve more compact, people-scale, walkable development patterns are also associated with a need to build more effective communities in cities and to create a much higher quality urban public realm that has a real sense of place and meaning for people (Benfield, Terris &Vorsanger 2001; Calthorpe & Fulton 2001; Moe & Wilkie 1997).

As defined in literature, Transit Oriented Development (TOD) is a planned design process for a community which encourages compact, mixed use, pedestrian friendly environment where development consolidates around public transport station. The transit station may be a railway station, bus stop, metro station or a tram stop. The aim of designing a TOD around a public station is to reduce automobile dependency by encouraging public transports. TOD concept is widely used to resist urban sprawl by infill development in suburbs.

American architect and urbanist Peter Calthrope, who brought together the notion of the pedestrian pocket with the idea of planning development around transit stations, largely sparked the new interest in development around transit. As advocated by Calthrope (1993), the urban design principles associated with TOD are:

-Organize growth on a regional level to be compact and transit supportive;

-Place commercial, housing, jobs, parks and civic uses within walking distance of transit stops;

-Create pedestrian friendly street networks that directly connect local destinations;

-Provide a mix of housing types, densities and costs;

-Preserve sensitive habitat, riparian zones and high quality open spaces;

-Make public spaces the focus of building orientation and neighbourhood activity;
-Encourage infill and redevelopment along transit corridors within existing neighbourhood.

The TOD standard sums up the new priorities for contemporary urban development. They reflect a fundamental shift from the old, unsustainable paradigm of car-oriented urbanism toward a new paradigm where urban forms and land uses are closely integrated with efficient, low-impact, and people-oriented urban travel modes: walking, cycling, and transit.

In practice, TOD has been applied in many cities across the world, including developed and developing countries. There are good examples of TOD ranging from Curitiba in Brazil; Singapore and Hong Kong in Asia to Stockholm in Sweden and Washington DC in the USA; Toronto, Montreal in Canada (Curtis, Renne & Bertolini 2009 ). However, TOD efforts by cities in developing countries are fairly recent and still at experimental stage. Pojani and Stead(2015) suggested that given the great diversity of land use approaches, preferences, and constraints in developing cities, if an overall dense and compact development cannot be achieved or if densification is not desirable in a given context (i.e., already hyper-dense inner city areas), densification and intensification of land uses can be encouraged around transport nodes and along transport corridors (the transit-oriented development or TOD model at a regional scale) in order to increase access for larger portions of the population.

## 4. THE CASE OF UTTARA MODEL TOWN

Uttara Model Town is the earliest satellite township project ever initiated in Bangladesh (the then East Pakistan) where the process of urban expansion is still ongoing. The township was conceived to encourage the process of decentralization following the western model of suburban development. Hence, new residential area was planned along the Dhaka-Mymensingh highway away from the northern end of the then Dhaka with an intention to solve the housing need of the growing

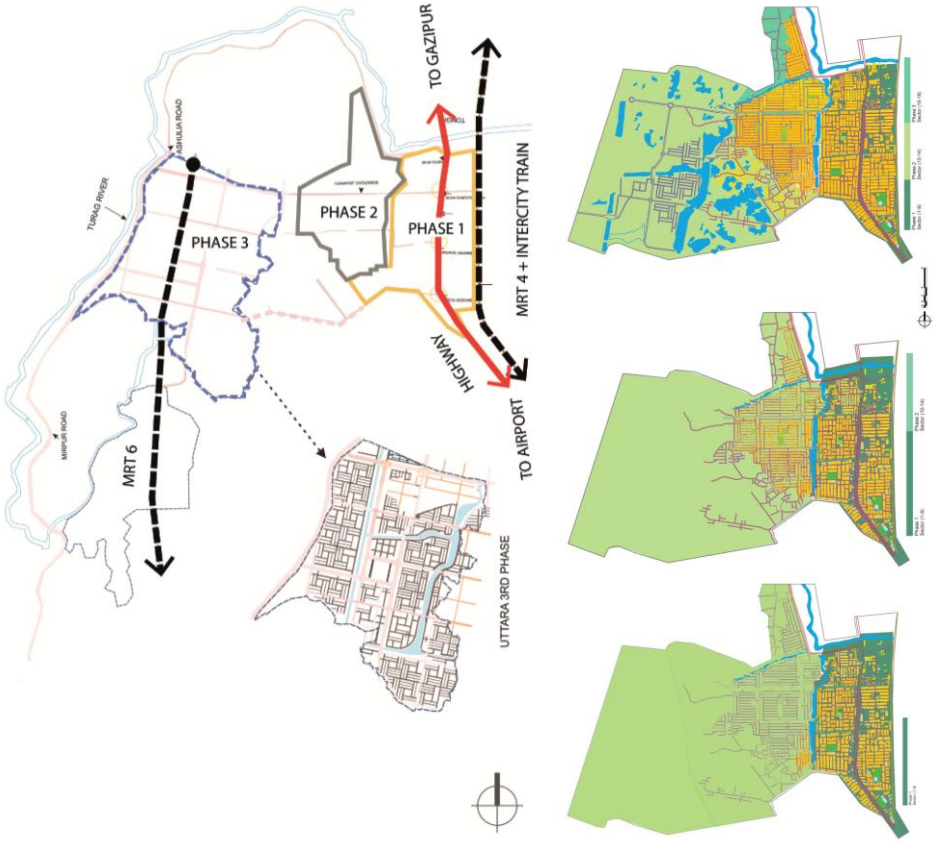



*Figure 2: Development phases – Uttara Model Town, Dhaka*


*Figure 3.1: Growth of built-up area Uttara Model Town; Map source: Author (adapted from Google historical satellite imagery)*


*Figure 3.2: Aerial view of the township showing urban growth from 2006 to 2015, source: Google image inventory*

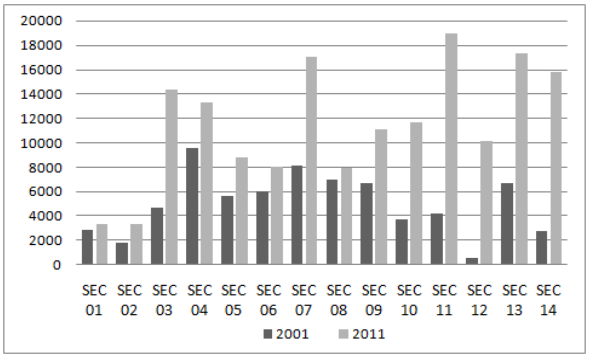
middle income class in early 70's. Initially, the project was called as Dhaka North Satellite Township, later it was changed to Uttara Residential Model Town (Rashid 2002).

The development of Uttara town are being made under three planning phases (Figure 2). The project has been planned by Capital Development Authority / RAJUK, previously known as Dhaka Improvement Trust (DIT). 1st phase was initiated in 1966 and it was completed in 1992. In the first phase RAJUK allotted 6,000 plots of different sizes on 950 acres of land. The work for Uttara extension under the second phase started in 1992 and it was completed in 1998. RAJUK acquired 438 acres of land for the second phase and allotted 5,315 plots (Alam 2009). The development work in 3rd phase is still ongoing. Under the project about 2008.08 acres of additional land were acquired. Total 8,295 residential plots, 21,125 apartments with all amenities and urban facilities are planned (RAJUK 2011).

### *4.1. Density*

Uttara was primarily planned as medium density, low height residential suburb for a total population of 1,24,000 with an average net density of 95 persons per acre (Rashid 2002). It is apparent that the planning authority eventually changed their approach and opted for more dense development in 2nd and 3rd phase. At present, it is the residing place for more than 1,79,907 inhabitants (BBS population census 2011) with a density of 130 persons per acre. In 3rd phase this project is planned with an estimated density of 240 people per acre, which is greater than the avg. density of Dhaka (150 persons per acre) but lower than the density of historic core (600 persons per acre).

*Table 1: Sector wise population, Uttara Model Town (source: BBS Population Census, 2001 & 2011)*




### *4.2. Growth*

The process of habitation was tremendously slow at the beginning due to long delay in infrastructure development. Rashid (2002) noted that, the roads, electrification works and water supply to all sectors was ensured in the 1984-85, that is 14 years after the initial completion of work. The problem of providing communication was solved in the late 80s. Again, the schools, colleges and commercial functions began to be built in the late 80s. According to the survey in 1984 only 25% of the allotted plots had built-up structures. Of these structures 57% were of single storied buildings, which reflected the low density of population of the township (Rashid 2002). Our study shows that in 2015, 82% of the allotted plots had built-up structures (Figure 3). Data shows that the number of population and corresponding built up areas have significantly increased in recent 15 years (Table 1and Figure3.1).

According to the early proposals, the model town was supposed to accommodate the community of all income groups. But this was never materialized fully by the Government. In practice, it deviated from initial concept in favor of providing subsidized housing opportunity exclusively for the upper income group (Shankland Cox and Partnership 1981). Since its inception, plot value has reached far beyond the capacity of middle income class. As reported by REHAB (2012), per *katha* (720 sqft) land price in Uttara was BDT 300,000 in 1990 and BDT 7,500,000 in 2010. Over the past two decades (1990-2010) the price of land per *katha* has increased almost 25 times. The scenario is more or less same in the case of apartment price. In 2010, avg. price of per sqft apartment was BDT 5300 which was BDT 2000 and BDT 1650 in 2000 and 1990 respectively. Between the years 1990 to 2010 per sqft apartment price has increased more than 3 times (REHAB 2012).

### *4.3. Layout*

Morphologically, Uttara illustrates a mix pattern of pinwheel and oblong grid structure. This difference in layout however corresponds with phasing of the development. For instance pinwheel pattern with a field/park and community facility at the center is evident in phase 1 (Sector 3, 7, 4, 6 except Sector 1), where as phase 2 (sector 5, 9, 10, 11, 13, 14) was laid out as oblong grid pattern in which fields/ parks are absent in most of the cases (except in sector 11, 12, 13). The ratio of plot area to

street area is comparatively higher in oblong pattern than pinwheel. It is clear that, to accommodate more people, the quantity and quality of community services and open spaces are severely compromised.

In 3rd phase, new sectors are planned on the west of existing development on the low-lying areas. This time the scale of urban expansion is larger than the previous development. There is already a growing concern about the environmental impact of this development on the local ecosystem. But the dominant challenge lies on the successful integration of this new development with the existing community and the city at large through sustainable transportation system.

## 5. CHALLENGES AND OPPORTUNITIES FOR SUSTAINABLE URBAN GROWTH IN UTTARA

It is evident that, Uttara Residential Area is undergoing a rigorous process of transformation. Traffic congestion, water logging, pollution, illegal establishment and social crime are growing local problems that are commonly reported. The township is also experiencing a rapid change in land use and built environment. Commercial and office functions are penetrating deep into the residential area. The walkup-houses are transforming into multistoried apartment blocks. Uttara also lacks urban amenities like library, cinema hall, sports complex etc. But above all, the community's liveability is under threat as its growth outstrips the rest of the city. Once quiet, green suburban Uttara in 50 some years has evolved into a bustling town with the increasing influx of people moving in from the city. The poorly envisioned transport infrastructure and associated built fabric of the township is crumbling to keep pace even with the current urban expansion and mobility demand. For re-qualifying Uttara community, the key challenges and opportunities relating to urban mobility and transportation are discussed below:

### *5.1. Connectivity*

Dhaka- Mymensingh Highway is the major road that connects the township with mainland Dhaka at present. It is one of the regional highways (N3) that connect Dhaka with the northern region of the country (Mymensingh, Bogra etc). This highway literally divides the township into two parts resulting complete segregation between east and west portion of the same development.

From the highway the west part of the community can be accessed via collector road through 3 avenues (Jasimuddin Avenue, Rabindra Sharani Avenue and Sonargaon Janapath) which forms the east west artery of the grid system. The north south linkage is however indirect and made by tertiary and secondary streets. Such layout makes it difficult for the traffic to move from north to south through the township. On top of that, Sonargaon Janapath being the only east west connecting road that links 3rd phase with the rest is under threats of traffic bottleneck in future.

Since the existing Dhaka-Mymensingh highway is the only current option to access the township, a multi-level transport infrastructure (overpass or under pass) could be an alternative for bypassing highway traffic. Infact there is a proposal for elevated expressway connecting regional highways that ends at Shahjalal International Airport, located half km away from the township. Expressway extension is already announced towards north up to Baipaile due to the fact that this may otherwise create a bottleneck situation at the approach road and therefore hinder smooth flow of community traffic. If implemented there will be an opportunity to reconnect the west and east part of the township at street level.

### *5.2. Mass transportation: Circular commuter service connecting west and east part of the township*

Exiting mass transport system is not adequate and doesn't offer any alternative or option to the commuters. Public bus is the only means of mass transit to and from Uttara. Although a good number of bus services are currently operating, yet none of the services offer fast, reliable and comfortable journey for the daily commuters. A large group of population is using private car or auto-rickshaw to avoid the peak hour transport crisis, resulting long queues of traffic in the highway. However the proposed plan to execute MRT 4 and MRT 6 and BRT line through the township (Figure 2) might improve the situation on the highway, but there is a strong possibility to shift the traffic congestion into the internal roads and crossings. Moreover proposed upgrade of Sonargaon Janapath as one of the main east west connection of the city in the Detail Area Plan (DAP) might aggravate the traffic situation of Uttara Model Township as a whole since

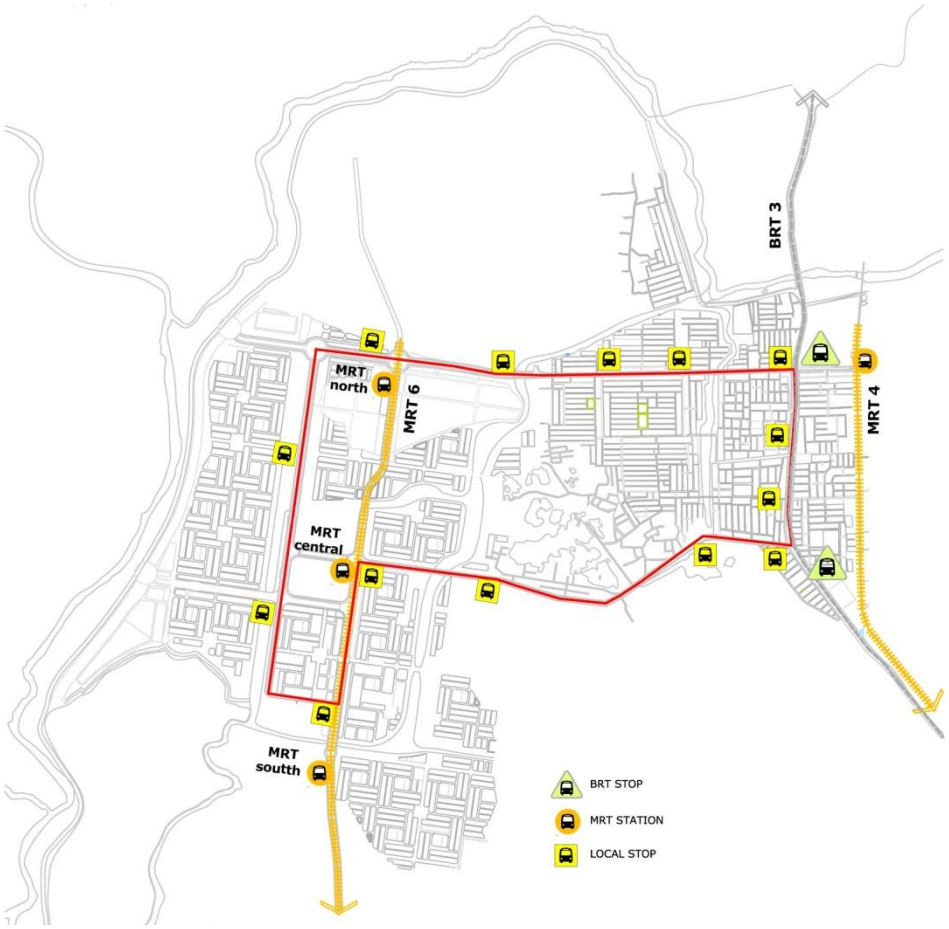



*Figure 4.1: Proposed route map for intra community circular commuter service ; Source: Author*

*Figure 4.2: Visualization of the integrated pedestrian-public transit network ; Source: Author*

this is the only primary road that connects the 3rd phase with the rest.

With the implantation of the 3rd phase there will be a need for quality mass transport for moving inside the community. A circular commuter service connecting all transit nodes including all 4 proposed MRT stations perhaps could be a feasible option (Figure 4.1).

### *5.3. Promoting mixed use development along the transport corridor*

Like many other planned residential community in Dhaka, the building usage in Uttara are transforming following privately regulated restructuring process. As community is growing, many residential buildings have been transformed to commercial facilities and services particularly along the major vehicular routes and nodes. Such transformation triggered by the local needs perhaps is changing the residential character of the township. However, there is also growing consensus that mixed use development can enhance liveability by creating active building frontage with vibrant street life (Davis 2012; Jacobs 1961). Consolidating the mixed use development along the proposed mass transit route may ensure mutual benefit for both community and businesses operators and thus maintain socio-economic vitality.

### *5.4. Improved pedestrian and NMT (Non Motorized Transport) facilities connecting the mass transit points and community services*

Community liveability is sensitive to the quality of the public realm, of which the street system is a major component (Appleyard 1981). This suggests that creating a more attractive, interactive, pedestrian-friendly streetscape, and other policies that encourage non-motorised transports, may be important for sustainable development (Burden, 1999).

Unfortunately pedestrian has been given the minimum priority in existing development. Not even the sidewalks are available in every road inside the township. The safe passage for pedestrian to cross the street is barely present. There are five footover bridges over the N3 highway for pedestrian crossing and 6 more over bridges and 8 underpasses are planned to be constructed in 3rd phase. No safe pedestrian crossing is available over the busy primary roads like Sonargoan Janapath. Existing footover bridges are poorly maintained, narrow and some of them are not strategically located and thus remain underused.

Designing safe and uninterrupted pedestrian link connecting the mass transit points, community services and amenities would reduce dependency on automobile, therefore maximize the use of public transport and could contribute to create quality public realm (Figure 5.1 and 5.2). However, it is not an easy task to change the existing rigid grid road system into a quality pedestrian path. The major challenge is to find alternative parking spaces for cars since these roads are designed to facilitate the cars by providing access to each plot adjacent to the roads. Among several conceptual strategies including shared parking space in adjacent/ back to back plots, our analysis reveals provision for community parking space as the most practical alternative considering its spatial planning and socio-economic feasibility. The design strategies for alternative community car parking are elaborated in the following section.

### *5.5. Injecting community parking in spaces of communal use*

The ground floor of almost every residential building is occupied with parking space. In Uttara, plot sizes are predominantly smaller in size (3 *katha*/ 2160 sqft), (77% of total plots). Since there is no binding in law to provide community space for buildings with less than 3000 sqft area, most of the buildings do not have any designated community space (MoHPW 2008).

Common parking provisions for the neighborhood in designated areas can alleviate the need to park the cars beneath every building. Infact, at the initial planning level, there was a proposal for community parking space for each sector which was never realized. However, finding areas large enough to inject the community parking facility in an existing planned neighborhood which is already saturated is challenging. Our investigation reveals that there are left over lands and underutilized facilities in almost every sector of the township. There are community mosques, planned and implemented by government, already placed strategically within 5 to 10 minutes walking distance of the community residents. Usually these mosques are located on a larger plot with typically two to three stories in height and

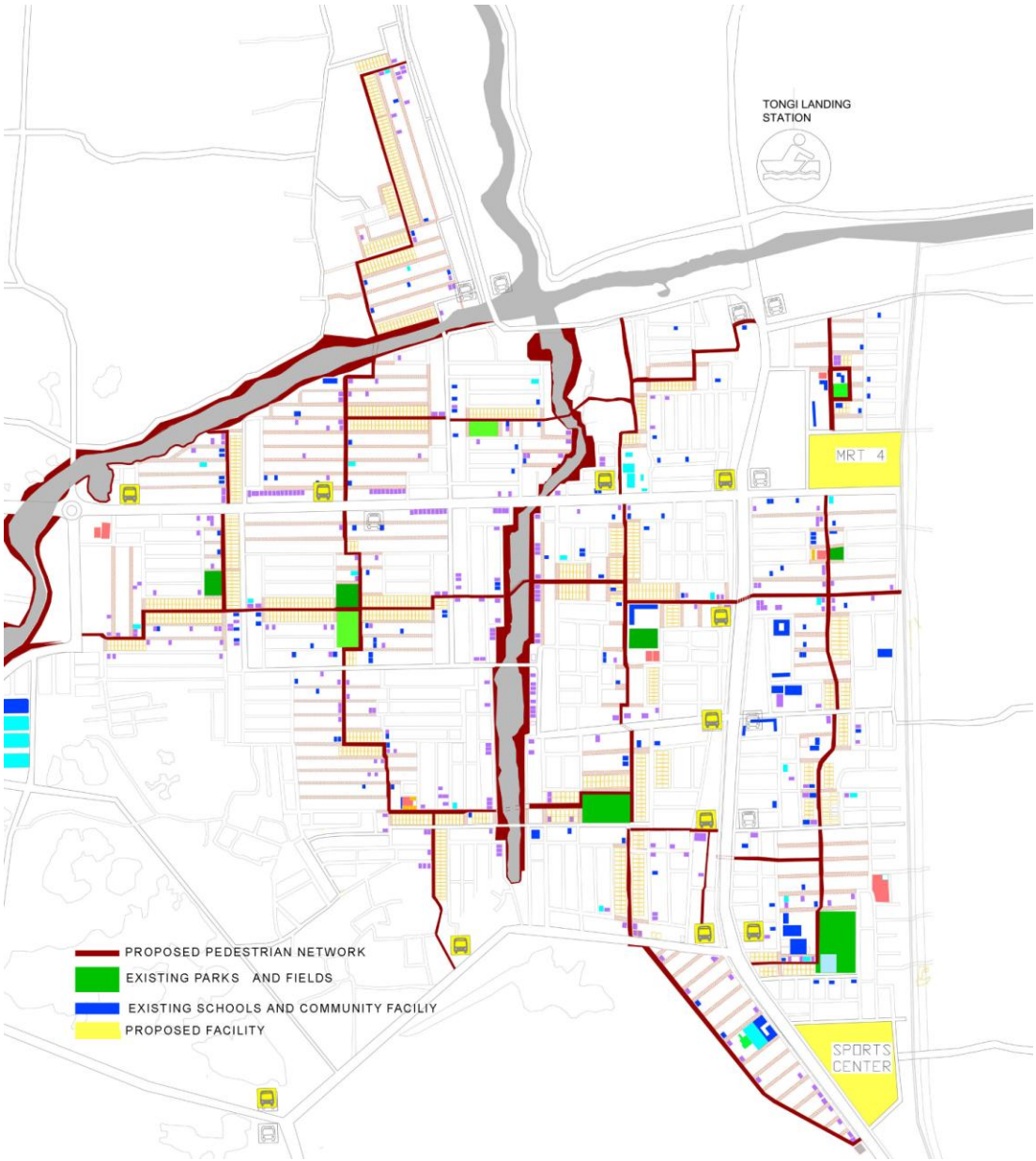
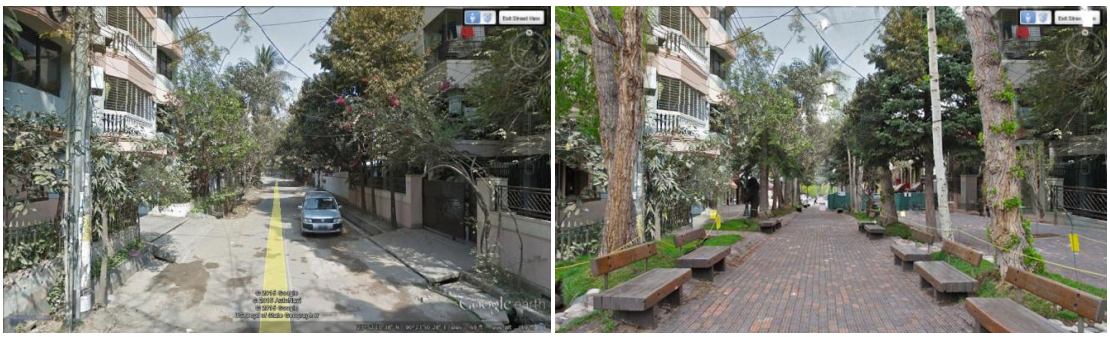



*Figure 5.1: Proposed pedestrian networks connecting transit stations; source: Author*



Existing Proposed

*Figure 5.2: Selected streets of Uttara are proposed to be re-qualified as dedicate pedestrian paths*

constructed phase by phase as per requirement and availability of fund over the years. These large spaces are very often left under-utilized for years because of slow and gradual expansion process of the mosques. These mosques usually depend heavily on community funding and donations for construction & maintenance. If the current mosque buildings are redesigned or retrofitted, with multi-storied buildings having community parking facilities at the basement & lower levels then there will be no need to occupy the ground floor spaces of the residential apartments for parking. Those liberated areas can then be easily used for community gathering, social activities & children's play as well. Since there would be no need for vehicular access to all the plots except for emergency vehicles, many of the current roads can be transformed as dedicated pedestrian paths.

Most of the community mosques that were constructed earlier were given a foundation of maximum 2 to 3 storey. Since the space capacity is unable to accommodate the current user number, many existing 2/3 storied mosques in planned residential areas are already in the process of redesigning, retrofitting or rebuilding. The maintenance & security expenses of community parking could be borne by the users. Depending on availability & user preferences, the vacant parking spaces during working hours might as well be rented on hourly basis for guest parking. This model can also be applied in municipal market buildings where available.

### *5.6. Activating water transport in the internal water-networks as an alternative system besides road*

After completion of 3rd phase, total length of water channel will be aprox. 13 km. Separated into 3 branches the water channels are running through the township along north south direction. Originally the water body was a part of Turag River system. Later it was channelized to create space for urbanization. At the north east corner the water body is still connected to Turag River and at the south west to a large water retention pond (almost 600 acres in size). This ensures year round availability of water.

As mentioned in DAP (2010), the main purpose of the water body is to allow natural drainage and therefore prevent flood. Existing water body and surrounding stripped greens are, however, serving as recreational places for the community people as well. There is a huge potential to use the water networks for local transportation purposes without hampering the aquatic life and resources. Integration of boat stations with the proposed local transit nodes would create a multi-modal transportation network that would easily accessible, comfortable and convenient.

## 6. CONCLUSION

The speed and sheer scale of the urban transformation of Dhaka presents formidable challenges. As cities get bigger, they clearly have to expand around their peripheries; since it is much more difficult to increase densities of the inner core. What alleviates the impact of this expansion is the better transportation from the core to the edge. Therefore, to achieve sustainable urban expansion, stronger metropolitan development management measures should be enforced to control local development on the city fringe and promote sustainable transportation. We should understand that urban transportation network has an impact in shaping the urban areas and dwellers' lifestyles. It is not merely an engineering or planning problem. Transportation is integral to every critical thing in the life of a city including housing, employment services, environment, infrastructure and economy. Hence an efficient and effective urban transportation system is a means to both promoting sustainable urban development by providing adequate access and mobility to the urban dwellers. Moreover, realizing transit oriented development requires coordinated efforts across different spatial scales (structural plan to detail design of urban area) and development phases, where attention to quality urban design is crucial. An urban design scheme for the TOD should be contextual and consider various dimensions including the integration with and access to the transit station, supporting a right mix of land uses and density, and the creation of a walkable, human scale environment around it. In addition, getting a TOD right is often about getting the details right – for example, reserving direct pedestrian links to the entrance/exit to stations and shaded, safe pedestrian walkways can be critical elements of a successful TOD experience. In conclusion, changing an urban development from its present form and pattern to achieve sustainability is a very challenging process. Not only the urban forms or transportation systems have to change, but also the social values and

underlying processes of urban governance and planning need to be reformed to reflect the sustainability agenda as a whole.

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# CONSERVING PLACE IDENTITY AND COLLECTIVE MEMORIES IN REGENERATION OF INFORMAL MARKET PLACES:

## THE CASE OF NILKHET BOOK MARKET, DHAKA

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***Abstract:*** *In spite of being one of the oldest and largest cultural icon of the city the Nilkhet book market is on the verge of experiencing its transformation which is seemingly contrasting to the existing setup. But existing redevelopment proposal ignores the long established horizontal growth and essence of the organic development of this existing market and the cultural values as well. This paper attempts to criticize the existing proposals towards the redevelopment of Nilkhet book market and examine the principles and criteria for cultural conservation and sustainable regeneration in order to investigate the scope of conserving its place identity and social reminiscences. After the field study and several focus group discussions on the market's present condition and analyzing the future impact on the surroundings; the concept of cultural conservation and sustainable regeneration has been reviewed and therefore an argument of safe guarding the existing experience against the process of internationalizing, industrializing and innovating approach has been brought under discussion and an alternative approach has been Proposed. In so doing, this paper contributes to wider understandings of cultural conservation and sustainable regeneration approaches by revealing the significance of place identity and social reminiscences of Nilkhet book market and discussing the 'Conservation Led Sustainable Regeneration' approach for such market places.*

***Keywords****: Cultural conservation, Informal market place, Place Identity, Sustainable regeneration,*

## 1. INTRODUCTION

In many developing countries physical transformation of urban areas consider the economic shift as a prior decision making force rather than taking into account the fact of displacing the place identity and destruction of the collective memories while making changes in these places. Moreover, the notion of place is not different one such as environmental psychology sector (Russell & Ward, 1982), human geography (Cloke, Philo, & Sadler, 1991), urban planning or Architecture. But in recent years this has been increasingly treated as a unifying concept among urban designers and architects. The urban landscape provides an appropriate milieu to chart the shifting sands of memory and its effects on place and people (Tou Chuang Chang & Huang, 2005).Markets and Bazaars are such places in which people experience social interactions, feel the space, and perceive the environment. The formation and retention of collective memories are the consequences of such activities and behaviors (Tavakolianferdosieh, Esmaeelpuor, & Noghsanmohammadi, 2016).In many developing countries these market places has grown informally over the time in the core of the city center creating strong place identity leaving the imprint of collective memories as the psychological manifestation of social, cultural, political and religious activities. Eventually such activities around those market places become the part of the urban tradition and cultural fabric of the city. According to the Nuryanti (1996), Heritage is a part of cultural tradition of any society and conservation of this is an important part of modern urban policies. But in most of the cases these market places are transforming in need of a physical reconstruction and economic regeneration without considering the need of conserving its place identity and cultural values. Sustainable regeneration of bazaar and market places in traditional cities of the countries like Bangladesh is in need of finding alternative approaches concerning the effects of city development on cultural heritage and urban element of the city.

Focusing on the context of Nilkhet, Dhaka, the book market has become the largest icon not only of the city but also of the country for selling and buying both old/Second hand and new books over the past four decades. For many students, teachers and enthusiast readers this place is not only just a book market but also a part of their memory lane. The organic arrangement and the verity of activities of the informal market place have given a unique identity to the market. But the proposed high-rise shopping complex replaces not only its physical existence but also rendered certain activities, people and place memories invisible. Without the establishment of a development proposal it is questionable yet that how far the current regeneration efforts in historic urban area discourse the community needs and assimilate the local desires, inclinations and socio-cultural values of cities dwellers.

The major objectives of this study is to find out the scope of conserving place identity and collective memories of the Nilkhet Book Market and criticize the existing development proposal by the so called "market owner's" association. Finally this paper suggests an alternative approach for the sustainable regeneration of this city icon. For doing so, the concept of collective memories, place identity and heritage has been reviewed along with the concept of conservation, regeneration and their interrelation.The Qualitative data has been collected in several ways such as in depth interview, observation, photographs and focus group discussion with both the shop owners and association members. On the other hand the existing study area has been brought under perspective through collecting quantitative data by questioner, spatial mapping and empirical examination and measurements.

In so doing, this paper contributes to wider understandings of conservation, regeneration and conservation-led sustainable regeneration approaches by revealing the significance of place identity and social reminiscences of Nilkhet book market.

## 2. PLACE IDENTITY, COLLECTIVE MEMORIES AND HERITAGE

The relationship between 'memory', 'identity' and 'nation' is often assumed to operate in a linear fashion. Popular thinking espouses that collective memory binds people together under a shared identity. The persistence of nation-states is explained by the transmission of such collective memories as 'heritage' from one generation to the next, uniting communities across historical eras. As Smith postulates, 'no memory, no identity; no identity, no nation' cited in (Bell, 2003). In reality, personal memories of events, people and places often differ markedly not only across individuals and groups but over time. Similarly, collective memories of events vary according to the political–economic needs of society and its changing values over time.(Tou Chuang Chang & Huang, 2005). Personal memories are the subjective remembrances of an individual that anchor his/her existence as a unique human being. Collective memories are shared experiences that bind people together, and which are usually kept alive through group interactions and acts of remembrance. Two qualifications must be made concerning collective/group memory. The first is that while such memories are collective, they need not be 'collected' in the form of historical documents and commemorative practices (Kong, 1999). However, it is not uncommon for selecting elite – leaders, officials and academics – to decide which of these narratives should be mapped onto a specific place and time. State-led memory formations often can and do run counter to the popular memories belonging to individuals and groups (Tou Chuang Chang & Huang, 2005). The reification of collective memory as heritage is fraught with selective remembering and institutional forgetfulness. If heritage refers to an inheritance from the past belonging to and valued by individuals and communities, we realize the impossibility of heritage to encompass the entire scope of history and all manners of personal and collective recollections. Heritage is confined to what a society deems useful for its survival. Selective recall and interpretation of history is thus essential. For this reason, institutional forgetfulness should not be seen as an innocent and inevitable slide into the past but an active process in which certain places, people and their pasts are rendered forgettable by a range of authorities (Bunnell & Nah, 2004). In as much as creative destruction may be seen as a premeditated act of 'remembering to forget' through the selective removal of the old, what may be termed destructive creativity also induces 'forgetting to remember' particularly when new landscapes – often having very little to do with the area's history – are created. Although we acknowledge Mitchell's (Mitchell, 1998) use of the term 'creative destruction' (Mitchell, Atkinson, & Clark, 2001), our utilization of the term varies from the original. Mitchell uses the concept to refer to urban changes arising from entrepreneurial investment and consumption, and the destruction of the rural idyll (Mitchell et al., 2001). The city offers a potent text to interpret the

exclusionary politics of place transformation. Significant not only for what it says but also for what it neglects to say about the past, the built environment – its buildings, architecture, monuments and also activities – serves as a textual corollary that mirrors the values of planning elites, businesses and inhabitants. A particular urban text explored in this paper is public art. The rhetoric of 'public-ness' and 'accessibility' so often espoused by urban art forms may also disguise its covert role of camouflaging societal conflicts (Deutsche, 1996).In many post-industrial cities, art offers a beguiling way to visualize urban histories in highly aesthetic yet narrowly conceived ways (Hayden, 1997). Nevertheless, because of their permanence and visibility, urban heritage in the form of public art, and also built environments and cultural activities, often claim privileged positions as 'memory sites'. But as we will demonstrate in the case of Nilkhet, the memories that are inscribed and the identities projected through this urban form is often called into question by the very public to which they are directed.

## 3. CONSERVATION AND REGENERATION; COMPLEMENTARY OR CONFLICTING

Conservation and regeneration have, in the last two decades, frequently come to be offered as largely corresponding courses. For instance, historic buildings have been supportive in many flagship property redevelopment projects through adding value and place individuality to outlines, features which have been of increasing significance during a period when 'culture-led regeneration' has become gradually more trendy. Conservation bodies, in turn, have usually comprised these comparatively new economic and social parts for the historic environment, which are quite diverse from the rather constricted cultural character conservation once presumed (Pendlebury, 2002). 'Modern' attitudes to conservation in the case of UK originate from the didactic and instructive 19$^{th}$ century literatures of John Ruskin and William Morris. Clear moralities of intrusion were developed, which remain conventional in architectural conservation. Strain is placed on the inviolability of reliable historic fabric and the custodianship of buildings for future ages. This established motion as a response to the revolution of British cities by modernist planning in the 1960s and inventors and development-minded local authorities were mostly regarded as the conservationists' adversary. In turn, old buildings were habitually regarded by local authorities as an impediment rather than a utility to regeneration. Furthermore, although key statute reformed little during the period of British Conservative Governments of 1979– 1997, a period commonly linked with a laissez-faire approach, this strengthening of the policy implication of conservation sustained (Pendlebury, 2000). So not only was conservation mainly relieved from deregulatory activities—in addition, national policy direction progressively highlighted its prominence. This was paralleled by the improvement of new roles for the historic environment. From the 1970s conservation pressure groups such as SAVE Britain's Heritage (1978) had been enunciating the economic case for conservation. The economic function of conservation became more unambiguous in the 1980s and part of government policy. One of the provocative government ingenuities in the initial days of the Thatcher Governments was an enlarged importance on making the management of historic properties held in care by the government more efficient (Wright, 1985). In government planning policy the economic role of conservation appeared in Circular 8/87 (Department of the Environment (DoE), 1987) which claimed that conservation and regeneration are basically corresponding. Planning Policy Guidance Note 15 (PPG15, DoE & Department of National Heritage, 1994), in turn, went further than former management on promoting a creative method to discover new practices for historic buildings. Historic buildings were often protuberant in property-led urban regeneration initiatives of the age, such as the restoration and reuse of the Albert Dock in Liverpool, a large complex of Grade 1 listed warehouses, which was the Merseyside Development Corporation's flagship scheme. Less-high-profile schemes such as the Civic Trust-assisted regeneration of the small town of Wirksworth in Derbyshire also thrived.But in cases like Nilkhet and related urban 'memory sites' of the third world cities where these places act as the active urban heritage as well as inhabits a major informal portion of the city, Regeneration schemes frequently overlook the imperceptible features of the collective memory and cultural values of these sites and concentrates on the so call aesthetics and economic return by following the endeavor to form a characteristic global city.

The case of Wedding card Street, Hong Kong is one of those regeneration projects. Lee Tung Street, known as the Wedding Card Street by locals, is located at Wan Chai, Hong Kong. A

project accomplished by the Urban Renewal Authority (URA), was uncertain down in December 2007. The destruction is perceived by many as well as irrevocable detriment to the cultural heritage of Hong Kong. In 2003, the Urban Renewal Authority proclaimed it would spend HK$3.58 billion to renovate Lee Tung Street and McGregor Street an area covering 8,900 square meters. Conferring to an authority spokesman, up to the end of June 2005, up to 85% of the 647 exaggerated homeowners on Lee Tung Street had approved to accept reimbursement offers of HK$4,079 per square foot. The purchase of the land was expected to be completed early 2006. The street was dully demolished starting from December 2007. The place consisted of four high-rise buildings and one underground car park, and new shops that organized make the appearance of the street as a "Wedding City". The old shops here, which are commonly small businesses and family traditional based; have to shift to somewhere else to make business, facing high rent and losing their old customers as well as the memories and the heritage. (Huang, S. M., 2009).

On the contrary in the case of Central Market Koudougou, Burkina Faso we see an opposite image of the previous case. It's an existing market place regenerated by traditional style, with the use of vernacular material and with the involvement of people. The market is now serving well and become more popular. The effect of Koudougou Central Market is double actually: at the urban level, it supports and increases the fabric of a mid-sized town, providing a monumental civic zone for commercial and social interchange. On the level of construction, it introduces simple and easily assimilated improvements to a traditional material – stabilized earth - which allow it to achieve its full aesthetic and environmental potential. By applying blocks of compacted earth, the market not only exhibits the greater climactic presentation of the local building material, but also shows how humble earth blocks can be used to generate a refined outline language of vaults, domes and arches. The market is the result of a truly participatory process that brought together and engaged the entire community in the site selection, design and construction of the market as well as in its use and maintenance. (Bolay, J. C., 2015)

## 4. THE STORY OF NILKHET BOOK MARKET

The name Nilkhet derives from the Bengali word "Nil". During the English colonial era Nil was cultivated here so the area was entitled Nilkhet (Nil + Field). Nonetheless, in current Dhaka Nilkhet is eminent as a book and printing market. It is the biggest second hand book market of Dhaka City. It initiated instantly after Independence when four young booksellers started selling second-hand books and magazines on the roadway outside the Balaka cinema hall. This market was formed in 1979 and shortly it had become a widespread market of books for the great demand of adjacent educational institutes. The market land is possessed by the Land Ministry since 1980 (Shahjahan, 2009). Currently the present market has over 2500 shops comprising a Kacha Bazar and a 315 years old mosque. The mosque is a three dome mosque made in the Mughal period. Along with local and international books and publications Nilkhet is well-known for low priced printing, photocopying, stationery and educational resources.

### *4.1. The Informal Identity and the Unwritten Memories*

The one place in Dhaka where students can discover every type of books and stationary they need is Nilkhet. The Nilkhet book market area is sited very adjacent to three important universities in Bangladesh namely Dhaka University, Bangladesh University of Engineering Technology and Dhaka medical college.


*Figure 1: Major places near the Nilkhet book market (Google maps, 2013)*

The study area also thoroughly linked with the Dhaka College, Dhaka City College, Eden Mohila College and thirty numbers of private universities. Every day about 15-20 thousand students visit here to accomplish their needs. This market is allocated into two parts; the book

section and the print section. Print section's weekly holiday is on Friday and the book section's holiday is on Tuesday. This is one of the leading places for book printing and binding within the city. The market lies between two major nodes and three central key roads of south Dhaka among which two roads openly links the southern part of the Dhaka with the northern part. The node between the Nilkhet book market and new market is one of the major 22 nodes of Dhaka city. Thus its Nilkhet book market one of the most cherished land with in the capital. According to the Dhaka, DAP 2010, within the range of 1.25-2.15 kilometer 2% land is being occupied for commercial purpose of which the total focus is around the study area. 26% land is being used for education and research persistence which validate students as one of the major target group of the market determining the business type of the market. The rest 10% of the site is now being used as mixed use and 30% land is being used as residential purpose (**figure 02**). The custom of selling and buying second hand books is one of the exclusive issues of this markets which designates that the mainstream of the sellers are small and medium entrepreneurs proposing books to their target customers within a very economical range of money.

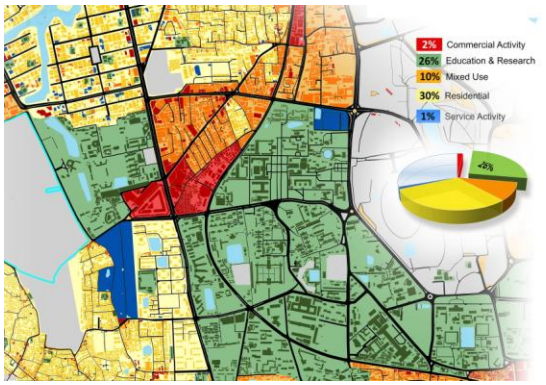


*Figure 2: Adjacent land use map (1.25km-2.15km radius) of Nilkhet-New market area. (DAP: 2010)*

This is one of many reasons that the market still conflicting with its comparable competitors and stood over time. The narrow passage with vague pathway, semi-permanent constructions with tin shaded roof, the overhead lighting from the gap of the two contiguous roofs, the asymmetrical arrangement, and the compact size of the shops and heavy blast of the customers inside the book market generates a distinctive environment inside the book market. The junction points of the narrow pathways inside the market form small but very active nodes and free space and let some food vendors pursue their business on that space. The 315 years old mosque may seem blunt within this overcrowded market place and over shaded by the vivacious activity of the market but its impact on the market can certainly be experienced each day five times and on the weekly prayer hour when even the narrow corridors of the market act as the impermanent public prayer space. Majority of the street vendors have robust association with the book shops inside the market and they sell a decent portion of their books in the street. This informal living nature of the market has been developed over years and ultimately formed a uniqueness of the market. In **figure 03** the current arrangement along with the zoning of diverse program of the market has been shown.

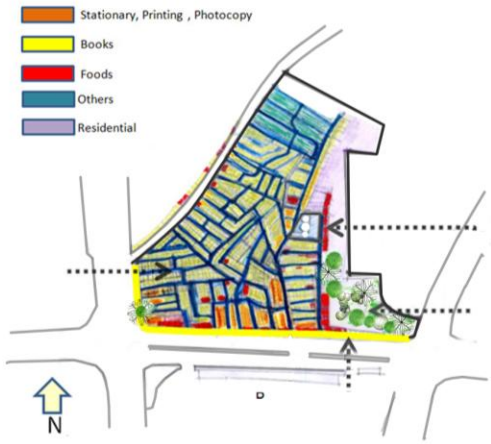


*Figure 3: Existing arrangement of Nilkhet book market (Author, 2017)*

The main respondent of this study was the students who defined this place as their first inclination while buying their related books within the city. Every year particularly in the opening of the semester students from all over the city derive here to full fill their need of books and other educational equipment. The graduate students shared their experience of this market regarding printing, plotting presentation sheets, binding their thesis dissertation, other reports and even shared their onsite experience of working on their final presentation inside this market. While sharing their experience they define that inside this informal market remarkably all the shops are systematized in the market's own unique manner where shops are characterized according to the study subject and book types which may appear confusing to anyone who comes here for the very

first time but for the insiders and the regular consumers this obscurity is never a matter of disturbance rather it aids to find exact shops within the market in a very proficient style.

### *4.2. Towards Declination and the Emergence of Regeneration*

Undoubtedly the market is serving up a part of total population in Dhaka but also creating a man-made catastrophe at the major traffic node of Dhaka City. A lot of shops take places on the adjacent footpath and even on the major vehicular roads aside, which have been marked out as a cause of vehicular jam on this vital traffic node of Dhaka city. The adjacent street trading is causing inconvenience to the pedestrians and vehicle due to their haphazard arrangement. The main problem resulting from increasing street vending within the market periphery is the overcrowding and it leads to encroachment of the public places and roads. Congestion and pollution of city environment in terms of garbage are also linked with this, showed in **figure 04**.


*Figure 4: Impact of the book market to its adjacent roads. (Author, 2017)*

The 4 to 8 feet width corridors inside the market are not efficient to serve the huge number of users. The 5.7 Acre existing market has over 1300 shops connected with the narrow dark pathway causing violent activities sometimes.

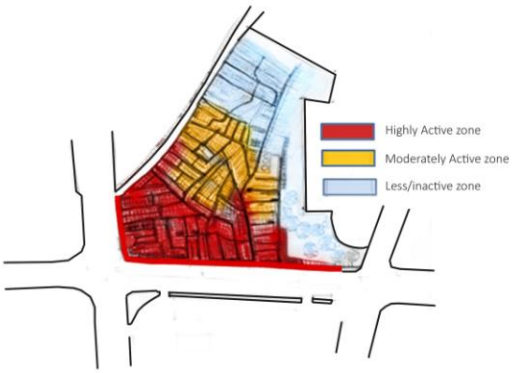


*Figure 5: Activity mapping inside the market place. (Author, 2017)*

The ambiguous circulation of the market place is its identity but at the same time for the lack of proper maintenance and accessibility so many shops are not even working properly in the middle portion showed in **figure 05**.

During the rainy season, rain penetrates through the gaps between the roofs and thus creates an inhospitable condition inside the market. The market over the time faced several difficult times and according to the second major respondent group (shop keepers/owners) of the study area, fire hazard is one of the most sever hazards which occurred in the market place couple of time and as they described this is the consequences of local and political clashes which had hidden intention to evict the book market from this land.

The life cycle does not depend on physical qualities of the market only; a new born shopping mall may end up with dead, like an example of New South China Mall -the world's largest mall and largest dead mall- which was opened in 2005 with empty retail spaces since then. But places like Nilkhet book market are not the result of a sudden birth. These kinds of market places grow over decades. As Lowry (1997, p.78) states, market places have a life cycle: birth, growth, maturity, and decline; even rebirth. The life cycle concept identifies changes over time in the characteristics of this phenomenon; and as a result, developers and retailers would have opportunity to plan their strategies in modifying to the shifting circumstances of the retail industry (Lowry, 1997). So, in order to keep Nilkhet alive, it is vital to follow-up the lives conditions and bring in the accurate type of regeneration for this book market. Physical regeneration strategies are only one aspect of the subject. And in cases like Nilkhet, social and cultural aspects need to consider while initiating a holistic physical regeneration approach integrating with the cities prevailing urban fabric.

*Figure 6: Inside Nilkhet Book market (Author, 2017)*

### *4.3. Recreating Place, Replacing Memories: The Re-Development Proposal of Owners Association*

The location of this market is one of the highest commercial places of Bangladesh and thus the maximum valuable land. The market owner's association has decided to build here a multistoried building for maximum commercial benefit but the long established horizontal growth and the beauty of organic arrangement of the existing market conflicts with their proposal of totally vertical approach. Once the land was under Government ownership, later the land has leased for 99 years under various privet ownership. 3.6 Acers have already been leased and rest of the 1.1 acre is steel under the process. The whole market is now operated by several owners' associations namely Hajrat Bakusha Somity, Islamia Somity, Sath Vai Somity and one of the front portion is owned by Dhaka South City Corporation.

*Figure 7: Eviction of tenants of Bakushah Market at Dhaka's Nilkhet for the construction of a high-rise building market* (News Bangladesh, 2016)

According to the statement of Bakushah Hawkers' Market Cooperative Society's president, the market consists of 1,200 shops most of which are rented out. He stated that the Cooperatives signed an agreement four years ago with the AG Green Property Ltd (for the construction of high-rise building) and the company has already paid the signing amount to the market owners (News Bangladesh, 2016). But while having the focus group discussion with the association's governing body they stated that there are 2200 members of the association and each of them will get a space in the newly built high rise. The rest will be owned by the developer company, AG Green Property Ltd. Clearly a large number of these shareholders are not the actual shop owners. As a result, these small entrepreneurs had to leave the place and look for an alternative place. According to the statement of the tenants of the book shops, they will never effort to rent a shop in the proposed multistoried market. Consequently, the adjacent powerful commercial forces like New Market and Gausia Market will occupy the market place and the age old book market will be no more there. A 33 multistoried high rise building may seem economically beneficial for this site but the amount of traffic it will generate in a place like this which is already overcrowded is still questionable. It will change not only the use type of the market but the user group as well which will led the Place to lose its identity as a book market.

## 5. CONSERVATION LED REGENERATION AS A SUSTAINABLE APPROACH

Today, urban fabric and market place integration is one of the most important issues in the field of urban design. But at the same time question arises regarding this rapid transformation of cities and urban places. Such as Singapore has transformed, over the course of 50 years, from 'third world to first' (Lee, 2000) and, within the past decade, has emerged as a global city. This has spurred local scholars to question the significance of globalization for Singapore's urban landscape (see KIANG and CHAN (2000); Soh and Yuen (2011). Such studies argue that, in the process of internationalizing, industrializing and innovating, much of the intangible 'heartware' embedded in local places and practices are being replaced by modern hardware capable of usurping place identities and social memories (Su-Jan, 2012). However, in cases like Nilkhet book market technical solutions are not enough to achieve sustainable urban regeneration. This aim urges incorporating together a diversity of conflicting agendas at diverse levels and need to across sectors achieving coherence and long-standing clarifications. To this end, urban governance arrangements, including cross-sector co-operation and citizen participation channels, need to be up-to-date with the new reality of social innovation and co-production of the built environment.

The enlargement of the conservation approach to encompass also the existing social-life system, permits us to state that conservation is now associated with the maintenance of the historical integrity of cultures within a given urban structure (Zancheti & Jokilehto, 1997). It is clear that the subject of the conservation process is city life as a whole, in both its material and symbolic (immaterial) configuration, with its elements of state and process. Conservation thus seeks to maintain the urban environment together

with the cultural practice of its use. With this type of approach, urban conservation can be differentiated and liberated, as a field of theoretical and practical reasoning, from the traditional theories of restoration of works of art and architecture (Zancheti & Jokilehto, 1997). It is also viewed as a process founded in the local culture, in an equitable distribution of urban services, the use of democratic principles of management, and the maintenance and regeneration of traditional social values and practices (Zancheti & Jokilehto, 1997).

As a product of humanity, a city is an artifact composed of several historically recognizable parts or strata. There may be no historic center as such, nor specified historic areas, but rather an historic urban structure that regenerates itself through the use of characteristic elements and processes (Zancheti & Jokilehto, 1997). The policy of implementing sustainable approach has led to an immediate thought: conservation is a process that involves the entire city. This approach is quite different from the traditional of restoration and rehabilitation activities which were based on the identification of especially valuable elements, such as, monuments, sites or historic centers. Following from the sustainable approach, the city is understood as a unique ensemble that needs to be conserved in its historical integrity. This means understanding the city as a dynamic process, a structure in continuous change. Similar to other structures, it has both states and processes; these elements and their unity characterize the city. Conservation of a city should not aim at halting the process of change, or prohibiting the introduction of novelties in the city life, as has been commonly propagated by some critics of conservation (particularly those still embedded in the ideology of modernism). On the contrary, it can well be a way to perpetuate a process of generation of novelty that can be appreciated on a more collective base (social, cultural, economic as well as technical) (Zancheti & Jokilehto, 1997).

## 6. CONCLUSION

This study urges to establish sustainable approach to conservation led regeneration in the context of diversity and specificity of cultural and socio-economic development. But still the globalization of world economy and the development of the post-industrial society are restricted and restrained to specific regions of the world and as well as it is embracing only some features of urban life. This paper revealed that there are diverse approaches of renovation under way that retains varied modes for the identification of morals but each case should be assumed in its specificity, and should be confronted following a scheme that aims at the execution of proper conservation, regeneration or both procedures at the same phase.

This paper tries to conclude that, there is a requirement to stress that every form of sustainable method in renovating an urban area should be accustomed by a solemn exploration of current values and the practices of their development or regeneration. But at the same time, values in the form of place identity and collective memories have seemed in the urban regeneration procedure only in an obscure method, more or less unnoticeable to an inexpert eye. Typically, when these values are considered and at that moment the objectives of the conservation led regeneration process are being deliberated. Even in this study area, ethics are not certainly professed following unblemished categories nor as ultimate concerns to the decision making process. This paper discovers that, there is a prerequisite to boost the discussion about place identity and collective memories as the central concerns of the regeneration procedure and to assure sustainable approach under the thinking process in the context of urban development.

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# UNDERSTANDING PARTICIPATORY PLANNING:
## CITYWIDE COMMUNITY UPGRADING PROCESS, JHENAIDAH

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***Abstract:*** *Unplanned urbanization in Bangladesh has resulted in acute shortage of housing and infrastructure. Most urban poor live precarious lives in settlements devoid of proper municipality service. Recent urban development policies in Bangladesh mandates people's participation in public projects. People-centered planning is also an important feature of the recently adopted Sustainable Development Goals. However, the participatory tools and methods in most public projects in Bangladesh remain ritualistic. With a case from Jhenaidah, Bangladesh, we try to define the steps of participatory planning and the crucial factors resulting in the major outcomes. We also try to examine how sustainable this process is. Through Jhenaidah Citywide Community Upgrading Process (JCCUP), poor communities of Jhenaidah city came together to build a network, community based savings and develope housing and infrastructure for their communities. Flexible financial- institutional framework is one of the vital factors which has brought positive changes in socio-relational power dynamics among actors of their process. The overarching objective of this process is to empower communities in a way so that along the process the communities gradually learn to use their own socio-capital resources in bringing physical and social change in the community, voice their opinions and ask for active support from city authority- with minimal support from external experts. Looking at the many positive social and physical impacts the process has brought to the communities, it can be said that JCCUP is a beginning to successful people-centred planning. The communities still have to go a long way in terms of capacity building and unless the local government gets more involved with the process, it will remain vulnerable to collapse without active involvement of external experts.*

***Keywords****: Community development, Community based saving, Participatory planning, Low-income housing.*

**List of Acronyms**
ACHR: Asian Coalition for Housing Rights
ACCA: Asian Coalition for Community Action
NGO: Non-Governmental Organization
JCCUP: Jhenaidah Citywide Community Upgrading Process
POCAA: Platform of Community Action and Architecture
UPPR: Urban Partnership for Poverty Reduction
SAFE: Simple Action for the Environment

## 1. INTRODUCTION

Since 1980s Bangladesh has experienced a rapid growth of urbanization, the rate increasing from 1.82 during 1990-1995 to 2.36 during 2010-2015 (United Nations, 2014a). This had resulted in an acute shortage of housing and infrastructure (LGED, 2015). Housing is predominantly developed by the private market in Bangladeshi cities and the market is usually very much driven by profit. A large portion of the population cannot avail even the worst quality housing available in the market; that is when the illegal settlements or slums come in the picture. There are around 50,000 illegal and low income settlements in Bangladesh's 29 largest municipalities (NHA, 2014). Poor housing materials, limited access to public services, densely crowded and unsanitary living conditions, lack of tenure security etc. are some characteristic problems of these settlements. Regarding slum development projects, in most cases solutions offered by implementation agencies in do not address the real problems on the ground because there is an overall lack of dialogue between the people and the organizations. "Participation" remains limited to periodic meetings and public announcement in most planning projects that mandate public participation. As opposed to this kind of supply driven planning methods, demand- driven

planning would mean involving beneficiary communities in every level of decision making with a goal of empowering them along the process. "Real" participation of people brings out the best solution possible and gives people a sense of ownership of the development efforts. This process provides a perfect balance between what the people want and what can be done for the people, therefore ensuring sustainability.

The 17 Sustainable development goals adopted in the 2015 UN summit features social inclusivity and people-centred planning as a vital way to attain different development goals to address poverty. According to Oxford Institution of Sustainable Development, social sustainability is defined as : "Concerning how individuals, communities and societies live with each other and set out to achieve the objectives of development models which they have chosen for themselves... In this sense, social sustainability blends traditional social policy areas and principles, such as equity and health, with emerging issues concerning participation, needs, social capital, the economy, the environment, and more recently, with the notions of happiness, wellbeing and quality of life." (The Young Foundation, 2018)

In this research, through a case study in Jhenaidah, Bangladesh, we have tried to define the steps of participatory planning, find out whether we can call the process sustainable or not and address crucial factors which influence major outcomes.

### *1.1. Methods*

This is a qualitative research. The main insights of the study is drawn from the authors' professional experiences and involvement with POCAA. Facilitating and participating in workshops, community visits, interviewing locals, architects and NGO representatives etc. helped us in building an empirical understanding of the process. The NGO Alive gave us access to documents regarding demographics of disadvantaged communities, survey results of household profiles, occupation, capacity and willingness of families to participate in the project. A number of published write-ups by architect Farzana and graphical documents from Co.Creation.Architects served as secondary sources for our analysis of the case.

## 2. BACKGROUND OF THE PROCESS

The Jhenaidah citywide community upgrading process (JCCUP) was initiated by a small group of architects (Co.Creation.Architects and POCAA) and a local NGO (Alive) in the beginning of 2014. Through this process, nine disadvantaged communities of Jhenaidah city have formed a network, started community-based savings and have built around 45 houses for themselves till date. Housing and infrastructure development is the main goal of this process but the overarching idea is to empower the make communities empowered so that they can continue to make their lives better by using their social capital resources.

## 3. SELECTION OF COMMUNITIES

The support team (POCAA and Alive) visited potential disadvantaged slum communities in the city to discuss about savings and the housing prospects of the project. It was a challenging process as many communities do not trust development organizations easily. Eventually, after several trial and error steps, and consultation with the local government and within the support group, five communities were selected for the project. (Farzana, 2016b) Currently, six communities are involved in this process: Mohishakundu Shordarpara, Vennatola, Arappur Dashpara, Shatbaria Modhhopara, Shatbaria Uttorpara and Shatbaria Purbopara.

## 4. COMMUNITY-BASED SAVINGS AND FUNDING MECHANISM

Saving is an important tool in this process. This is the first step towards participatory action, the community takes responsibility to manage their saving and create a central fund which can will use to realize different development projects.

The fund to build houses came from ACCA (Asian Coalition for Housing Rights). ACCA usually gives two kinds of fund for city-wide development; fund for big projects for building

houses or infrastructure and small projects for community savings account. Each of the participant households can receive loans from the small fund(s) to invest in a business or repair/ extend their house. In this funding mechanism, the money comes to each community as grant, but reaches each household in the form of loan. This means, every household who receives a loan will have to return it to its own community savings committee with a certain percentage of interest. This gives the communities the freedom to decide loan repayment conditions as per their capacity. According to women in Arappur Daspara, because this community based saving is controlled by the community itself, it is seldom the case that the borrower uses up the money without being able to repay for it. (Shyamoli, 2016) .

The communities continue to build their own communal savings in the meantime, so at any point, when a community feels that it has enough savings of own, they can combine it with the small project fund and use it for a communal project. They can also use their fund to give small business loans to its committee members. This fund helps them to improve their settlement without much of external aid. According to Farzana, "Saving is becoming community's strength. In her words, Many communities expressed the feeling that they never had this amount of money what they have today together! It was possible because of group savings." (Farzana, 2016b)

When the seed fund comes back to a committee in the form of loan repayment, they can start to give loans to the next members of their own community or to another community of the city-wide network. In this way, the fund revolves within the city. Furthermore, in the ACCA mechanism, the whole network can have a common fund called CDF (Community Development Fund) and through this they access private, national or international funds for development projects. This fund has not been built in Jhenaidah yet.

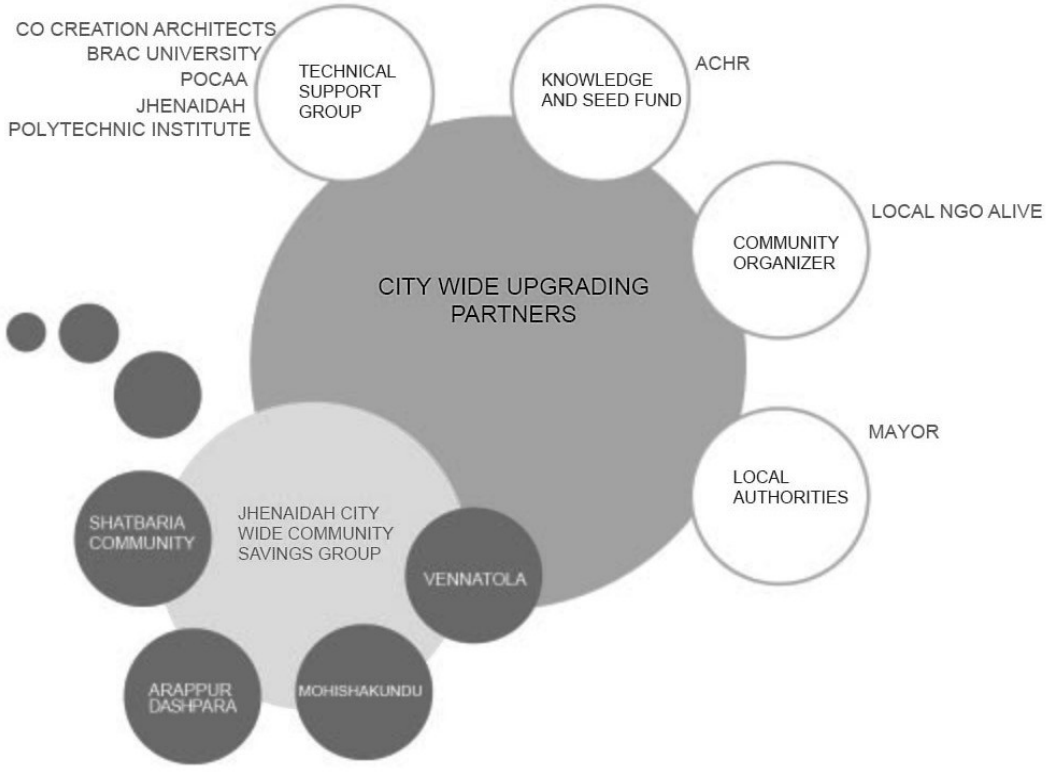


*Figure 1: Diagram of actors' relation in JCCUP*

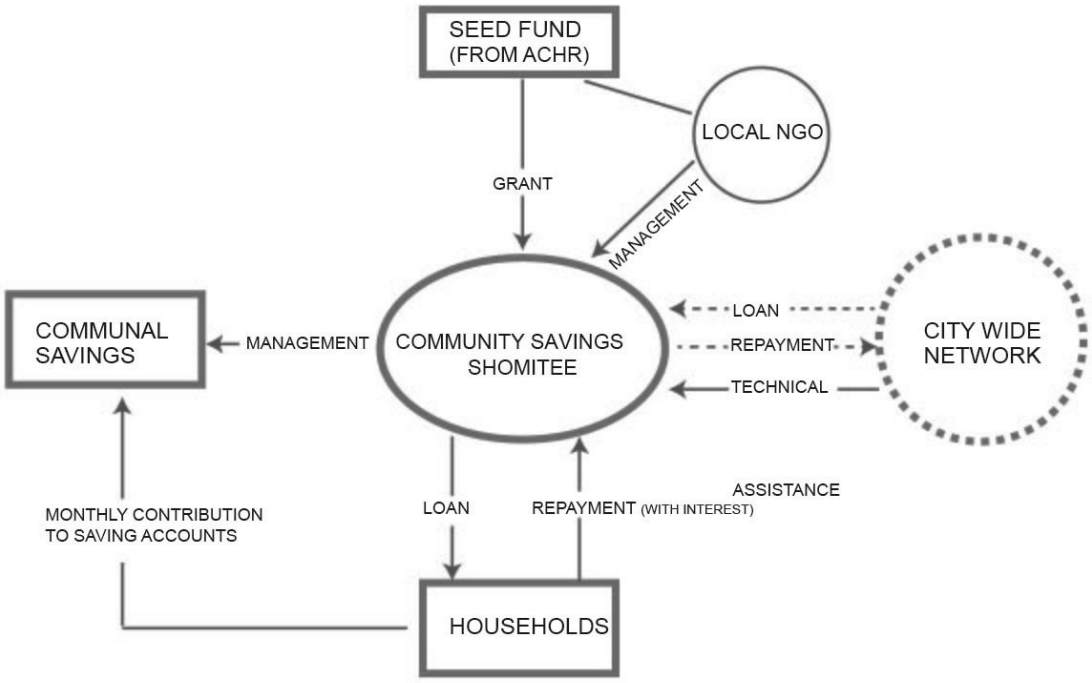


**Figure 2:** *Diagram of financial scheme of JCCUP*

## 5. PARTICIPATORY MAPPING AND DESIGN

The community in Mohishakundu Shordarpara designed and built 20 houses in the first year with big project grant and one house in the next year with repaid loan. Vennatola community has built 18 houses so far. The first step to build the houses was to make community maps. With help of the architects, the community gradually measured and mapped the relative positions of the built structures, the ownerships of plots and houses, secondary structures such as kitchens, toilets, communal toilets, materials and permanence of structures, communal structures such as the temples, shops etc., and infrastructure such as roads, drains, water taps etc. They also produced measured drawings of the site and plots.

Mapping is a tool through which the people of the community(ies) visualize resources, problems, opportunities and solutions. The mapmaking process works as the first step to translate each participating households' intangible ideas about housing into something tangible. Gradually, by adding layers of information and understanding, the community collectively creates a representation of their current situation and their future aspiration. After mapping, community women made preliminary designs of the houses through a 'dream house' workshop, with the help of scaled models. Through these models, they communicated their needs and aspirations for their houses to the architects.

*Figure 3: Women in Mohishakundu making a map of their settlement*

*Figure 4: Dream House workshop at Mohishakundu Community*

Based on these discussions, the architects designed two prototype houses and through repetitive consultations with the community, the final designs for houses were drafted according to the needs of each participating family. During a discussion, women at Mohishakundu Shordarpara have expressed how the process of mapping and building has changed the perception of their own capacities, one woman said: "We feel like now we can make our houses ourselves. The other day we were discussing about the budget to build the first story of our house and my daughter suggested that she can make it with half the money! The way apa (Architect Farzana) has worked with us, we feel like we are architects now!" (Mina, 2016).

With the help of the NGO, a building construction committee was built which was responsible for purchasing building materials and for carefully controlling through regular account keeping that the fund and resources at hand are used efficiently. Each family provided some labour to minimize the cost. The houses cost around 1,00,000 BDT (~2000 USD). With support from architects, the owners incorporated several building features to lower the cost of construction. Some of these are:

- stair steps made with pre-cast concrete slab
- linear window openings in order to avoid using lintels and metal grills
- simple pivotal window and doors without casing to save cost on timber
- rooms with minimum height requirement to save cost on brick
- filler floor slabs to save cost on concrete

*Figure 5: A two storied house in Vennatola (Co.Creation.Architects, 2018)*

## 6. NETWORKING AMONG COMMUNITIES

Moulaert, Martinelli and Gonzalez points out in a transversal analysis of socially innovative projects that local initiatives have "a symbolic, demonstrative effect on the broader urban scene, showing that change is possible… often the beginning of an interactive social learning process, blurring institutional and scalar boundaries" (Moulaert, Martinelli, & Gonzalez, 2010). This effect is visible in the case of JCCUP.

The project has started with a network of six communities. Although they live in different part of the city, they share a sense of connectedness which is fostered through community saving activities, community mapping etc.

Mohishakundu Shardarpara, the first community to collectively design and build houses, has assisted other communities in community mapping. They joined the support group in meetings in other communities and took lead in explaining how to produce and use a community map. Together with women of Mohishakundu, women in Vennatola produced their first community map. The women of Mohishakundu helped audit other communities' savings accounts and book keeping. Neighboring communities have also started savings program with the help from Mohishakundu community. This way, the network started to grow.

## 7. CHANGING SOCIO-POLITICAL DYNAMICS

A project/program that is designed to be people-centered can collapse even though participatory techniques are used. This happens

when the notion of participatory design is ritualistic, serving only a face-value, people's participation is a just a box to tick in. Involving people in every step of decision making process means when needed, there should be the flexibility to change the institutional framework or financial mechanism of the project to address the beneficiary community's life realities, and if needed the political hegemony of the context should also be questioned.

In a scenario of any development initiative, just as a sense of powerlessness is common in among slum communities, a given sense of power is common among professionals or 'experts'. According to Farzana (2016b) the conducts with community was a transformative process for the support group. Within the support group, professionals helped each other to bypass their professional boundaries to gain the trust of community people. How the NGO officials and architects talked to community people also made a difference; it was about carefully deciding to let go of the sense of power or pride that one gains from becoming a professional or expert. Even something simple like conducting meetings in a local veranda sitting together with local people on a bamboo mat instead of at the NGO office in a formal manner mattered in this process (Farzana, 2016b). Understanding how life is perceived by the community means acting in a flexible manner, where the experts accept the "politics of difference- as opposed to a politics of othering" (Saunders, 2002). Active presence, patience, participation and trust in people-led process were important factors in the process.

The effect of this project on local governance has been spreading in a slow but sure fashion. After the construction of 20 houses in Mohishakundu Shordarpara, the local government has offered increased assistance to the project. The Mayor, along with the architects from POCAA, presented these achievements in German Habitat Forum held in Berlin. Following this, the Mayor has assured the assistance to form a CDF (City Development Fund) for disadvantaged communities in Jhenaidah. He has also offered the architects with additional technical support from the engineers of the city corporation. If seen under the light of Albrechts' (2003) understanding of power, this is a critical transformation from a scenario where power-ambivalent citizens groups are not convinced of the power of informal structures and frameworks in shaping the flow of events in planning field, to a scenario where dominant relations (socio-political system or market favoring only the privileged) are changed by collective efforts supported by empowerment.

## 8. HORIZONTAL SHARING

Sharing knowledge with other communities, other cities, other countries, with the local GOs, local NGOs, and with educational institutions has been an important step in this process. With financial support from ACCA, two community leaders visited Sri Lanka to learn community saving mechanisms from the Women's Development Bank. According to Masud (2016), this visit was a practical learning opportunity for both the support group and the community. During the construction phase, the support group and some participants from the community visited SAFE, an NGO in Dinajpur to learn about cost-effective bamboo treatment. The connectivity with institutions have continued to grow with the support group's attempt of involving more local academia and professionals in the process such as the students and teachers from the Polytechnic Institute of Jhenaidah. The support group also arranged an academic design studio for housing project with BRAC University with one of the disadvantaged communities in Jhenaidah. To involve students and young graduates is also a way to create interests for local development within academia and eventually in practice. According to Alam, university students and professionals involving with these communities can be considered as increasing knowledge value within the communities (Alam, 2016b).

## 9. POWER DISPUTES AND GENDER ISSUES

In JCCUP, several instances of power inequalities should be analysed carefully in order to fully understand the drawbacks of development context at present time in Bangladesh. There had been instances where the community people were

easily demoralized, or even dishonest. Very often in such projects, community leaders feel uncomfortable in transferring leadership, as if that would mean letting go of their sense of control or belonging in the community. When the male leader of Mohishakundu was asked to transfer leadership after an instance of mishandling community savings account, he was openly skeptical about leaving responsibility to women, suggesting that women alone are not capable in managing leadership responsibilities (Masud, 2016).

The women of the communities are instrumental in the housing development process. They have demonstrated excellent capability in physical and social mapping, facilitating design and construction of houses, and managing saving accounts. Although the project is attempting to empower women through participation, women emancipation faces hindrance inside the community because of impacts from other spheres of their lives: personal and social. The women have sometimes perceived themselves as less capable than men because they remain victims of cultural construction of oppressing ideas against women, and more than often, the women themselves mobilize such values and norms of patriarchy.

However, to see events in a positive light, the process has been a successful tool in breaking the stubborn barrier of gender inequality, even if in a slow pace and at a small scale.

## 10. CONCLUSION

Even after a long process of mobilizing and building (housing or infrastructure) with a community, it may fall victim of self-sabotaging patterns, sometimes fail to see the bigger picture or become too cautious out of self-interests and lose faith in cohesiveness. This not only induces frustration among involved experts, having them to deem their efforts as futile, but also makes it difficult for them to establish ideas of alternative development in the discourse of mainstream planning practices. Boonyabacha from ACHR says in this regard: “There is a notion going around that the poor are helpless, lazy, ignorant, and untrustworthy that they do not have resources or ideas, and that they cannot think for themselves or manage money. So it follows that they need to be helped, trained, organized, spoken for and made aware. This assumption infects the policies of a great deal of the world’s development agencies and of housing-activism, shelter-delivery, and poverty-reduction programs, where solutions are conceived and carried out on the poor’s behalf by professionals, bureaucrats, activists and social organizers." (Boonyabancha, 2017)

Ideally leaders from the first few communities take forward the process while the support team gradually steps back and lets community leaders take lead in mobilizing more communities, managing funds, initiating tasks etc. This has not fully happened yet in Jhenaidah. Presence of an external support group has been always needed for the communities in staying focused on collective development efforts. This issue calls for another necessary step to take-setting up a separate community fund and creating a program for capacity building. Boonyabacha warns in this regard that, “If a community cannot manage money, it is doomed forever to having its development process determined by someone else” (Boonyabancha, cited Skinner, 2014).

In the case of Jhenaidah, the Mayor has always been supporting citizens and local organizations with logistic and legal help in their efforts in city-wide upgrading of disadvantaged communities. But what the upgrading process in Jhenaidah lacks is technical support from within the municipality. The slum development programs launched by the municipality must coincide the city-wide upgrading process.The dimension of support that Jhenaidah mayor has offered to the upgrading process does not necessarily reflect the status of other municipalities in Bangladesh. The readiness of local government to support disadvantaged communities is a crucial issue but if local government itself is not empowered enough through decentralization, devolution etc., it cannot do much to help the urban poor in the right scale.

More than concrete visible results such as housing or infrastructure, this process has tapped into the potential of communities to establish institutional associations and to utilize those to

bring positive changes in their lives. Despite manifold concerns felt by relevant professionals related to this process, City-wide Community Upgrading process in Jhenaidah is a successful beginning to *people-centred planning/ community-driven development*. Once the people fully realise the potential and benefits of this process, they will begin to invest more to the process, not only financially, but also their time and agency. Through more decentralized proposals from the grassroot levels, the communities can push for participatory budgeting and come out of established institutional frameworks for a better, sustainable future.

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# LIVING IN BETWEEN:
## RETHINKING PAVEMENT DWELLING THROUGH THE LENS OF COEXISTENCE; A CASE OF PANTHAPATH, DHAKA

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***Abstract:*** *Homelessness is an acute and common phenomenon in most of the developing countries of the world. Bangladesh has a large number of homeless people in urban areas. It is possibly the synthesized outcome of poverty and failing of state provision, which is manifested through the number of pavement dwellers (14,999 according to the BBS) currently living in Dhaka city. The declination of walkable pavement and the detachment of public spaces are the common scenario created by the living of pavement dwellers. So to revive the walkable pavement ultimate result is the exclusion of pavement dwellers which declines their pavement based economy. At a time some public services provided by the dwellers are gone with the eviction. This research aims to identify the existing typologies and situation of the pavement dwellers through a case of Sonargaon road, Panthapath, Dhaka. To explore the factors of the public interactive pavement and economic up-gradation of pavement dwellers. It is also envisioned to reveal the design guideline for pavement dwellers to upgrade their existing economic condition along with the usage of public pavement in the term of coexistence. In regard to the problem and aim this study tends to review the existing typology and mode of economy concerning the homeless people living on pavement including the related literature. A fruitful physical survey on surrounding aspects and the pavement dwellers of the selected area (of Sonargaon road, Panthapath, Dhaka) has been counted. Then a critical analysis of possible design solutions, supporting all the strength and weakness collected in participatory approach, have been provided. The expected outcome of this study is to introduce some design guidelines for the coexistence of public pavement and the economic up gradation of pavement dwellers which will someday be able to act as the medium of better living for pavement dwellers and the city will be for all indeed.*

***Keywords****: Coexistence, Economic upgradation, Homelessness, Pavement dwellers, Public interactive pavement*

## 1. INTRODUCTION

According to one estimate, approximately 320,000 migrants enter Dhaka annually. The number of pavement dwellers in Dhaka City is estimated at more than 215,000. People living in streets or other public spaces (which essentially designed for public service providing purposes) without a permanent shelter of their own often referred as ‘pavement dwellers’ or ‘street dwellers’ or ‘destitute’ (Ghafur 2006, p.46). Pavement dwelling is a part of floating homeless. Floating homelessness is the most visible type and is based on the physical criterion. (Ghafur 2004). Economic poverty is the main and sometimes the only cause which lead people in most of the developing countries to migrate to the street and to build temporary settlement on pavement. The pavement dwellers are so because of having lacking in their basic needs which is derived from the absence of economic opportunities. So it is assumed that by improving economic condition of pavement dwellers can be a remedy of their current vulnerable condition. Creating new accommodation can diminish this situation but it will not ensure their further sound livelihood. In some cases around the world some initiatives have been taken to accommodate the pavement dwellers. Their solutions were to relocate the

dwellers in some night shelters or permanent structures without considering their economy. The study is envisioned to reveal the opportunities of pavement dwellers for upgrading their existing economic condition along with the usage of public pathways. An in-depth and better understanding of the true scenario will enable practical design development in the future and that is the purpose of this thesis.

## 2. LITERATURE AND THEORY

This section will provide a brief summary of literature review as a prelude for developing a research gap for this research. Pavement dwelling is in the category of floating homeless which refers to people living in the streets without permanent shelters of their own. Floating homeless people are often pavement dwellers, street dwellers or destitute (Ghafur 2004, p. 271).

### *2.1 Pavement dwelling in our context:*

In our context pavement dwellers are basically people who live on the street without any permanent structure and the number of them especially in Dhaka is huge. But unfortunately a very few study have been conducted directly about the pavement dwelling. In some research the cause and category of the pavement dwelling has been clarified under homelessness. From there it has been come to light that the root cause of homelessness is poverty or economic distress. Poverty is a major cause contributing directly or indirectly to homelessness in Bangladesh. (Ghafur 2002, p. 33). Again from another study it has been clarified that the context of pavement dwelling varies from one site to another. So site specific study of pavement dwellers is very essential to understand their condition. (Nusrat 2010). So in a sense to upgrade the condition of the pavement dwellers, upgrading their economy is essential.

### *2.2. Initiatives towards Pavement dwelling:*

As stated above, a very few study has been conducted specifically about pavement dwelling, initiatives taken toward pavement dwellers have hardly fruitful results. So when in the past Govt. wanted to reduce homelessness, they tried to manage housing for the homeless people as a solution but failed in the end. Because economy is the factor which make people becoming homeless. As a result people remained in the former situation where they could run their economy. But recently an international organization named Concern World Wide has been working directly with the crisis of pavement dwelling through a project 'Amrao Manush Project'. Here the focus is not only to provide night shelter but also to assist their livelihood with some services. According to their annual report 2015, the purpose and the results seem working. But again as an over populated developing country like us it is tough to manage lands to provide permanent shelters to accommodate the pavement dwellers. As a result most of them remained uncounted. Again from physical survey of the beneficiaries it has been come to light that shifting them and their economy their income decreased. Though the idea of focusing on their economy is to the point but many of them ended up on the street again.

### *2.3. Emergency of Coexistence:*

So from the review of the literatures it is clear that by upgrading their economy can make their condition better and permanent. But as the location where the pavement dwellers choose to make their dwelling is closely connected to their economy, so shifting them to other place hampers their daily income and declines some services the pavement dwellers used to provide to the community. So here comes the need of coexistence so that the economic upgradation of the pavement dwellers, without shifting them from the specific location, can be integrated with the community which can offer them a dignified living.

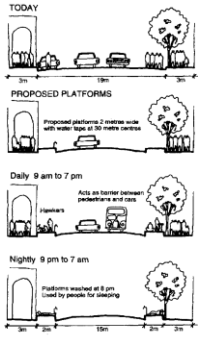


*Figure 1: Sections of a pavement of Bombay Street*

An example from the work of Charles Correa can be brought as the site specific approach of upgrading the economy of pavement dwellers in Bombay, India. (1968). He there tried to accommodate the economy use of pavement dwellers and the public pavement at the same and let them use city pavements for sleeping. This allows them to economise on their living expenses.

Theoretical framework :

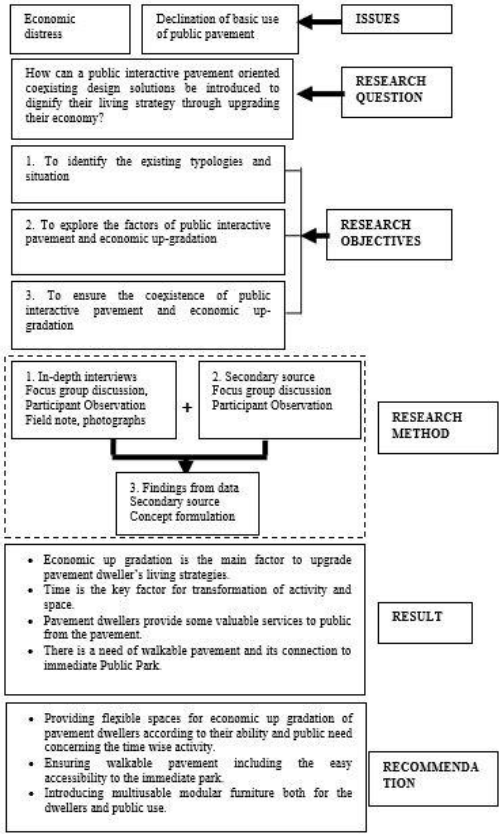


*Figure 2: Theoretical framework*

## 3. METHODOLOGY

The case study area is sonargaon road, pantha path in Dhaka, Bangladesh. Though pavement dwellers are not limited only in this area, rather scattered all over the city. It is observed that a stable form of pavement dwelling exists in *sonargaon road* for long time which is convenient and feasible for doing research with such vulnerable groups.

*Figure 3: Site perspective of the study area*

*Figure 4: Panoramic view of sonargaon road, panthapath, Dhaka*

As *panthapath* is one of the busiest and diversified mix used area (commercial, residential, educational and business), it was expected that a diverse characteristics of pavement dwelling will be revealed. *The pavement* is attached to a renowned public park 'panthakunja' under *Dhaka city Corporation* and the pavement is occupied by the dwellers whole day-night, so the connectivity of park is declined there. Moreover this area could be potential for further continuation/ extension of this research as pavement dwellers here are quite settled and be likely to make their livelihood on the pavement.

This research is exploratory in nature as it intends to look into the context of pavement dwellers, with reference to explore their way of living within the basic use of pavement based on the scope of government. To perform this exploratory research a number of instruments are applied for greater validity including in-depth interviews/ thematic semi-structured interviews,

focus group discussion (FGD, participant observation, field notes, photographs, especially videos as supporting documents and secondary source from documents (reports/ publications etc.).

## 4. RESULTS AND DISCUSSION

### *4.1. Findings from Research Objective 1: Existing Typologies and Situation of the Pavement Dwellers*

#### *4.1.1. Site and Context Analysis*

From the very deep observation and interviews, the existing typologies and the situations of the pavement dwellers of sonargaon road (beside panthakunja park), panthapath, Dhaka, have been brought to light. From the analysis it is clear that the dwellers occupy the whole pavement for their economic and living purpose.


*Figure 5: Living strategy of pavement dwellers*

The passers-by can't use the pavement for walking, as a result they choose the street as walking zone which is not safe and desired. Again the connectivity to the alongside *Panthakunja* Park has been declined; as a result the boundary fence of the park has given birth to a waste dump zone inside the park. Social surveillance of the street and the park both has become a major issue there. Many social nuisance is being committed at night in the park due to absence of the connectivity with the pavement. Here some illustrations have been added to express the condition both at night and day.

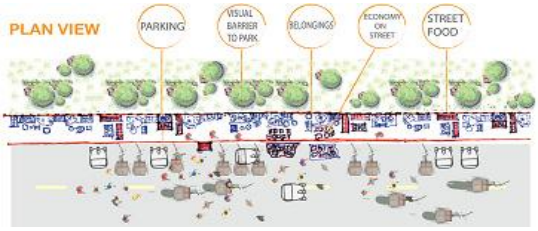


*Figure 6: Plan view of the study area*

The pavement dwellers have some distinct strategies to live on the pavement according to the vulnerabilities they face every day. That linear space of pavement becomes the space for different activities. They create a territory for each family according to their need. Food preparation and storage, belongings and economy all event have been occurred here.

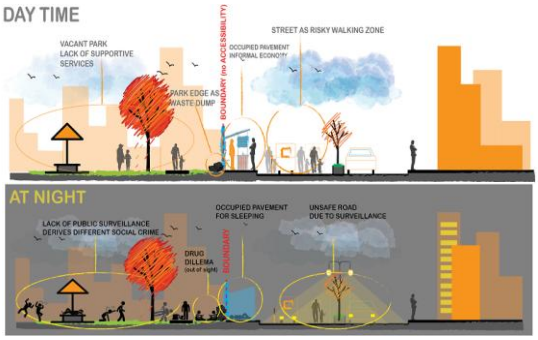


*Figure 7: Section at both day and night time*

Their main purpose is to run their economy and rest at night. So they try to use the space and tools in multiple ways. Obviously they transform the use of space according to time and activity. As a result their mode of economy is in some pattern.

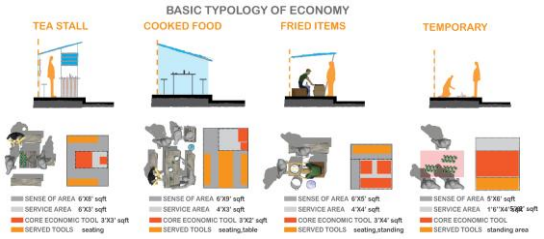


*Figure 8: Economic land use*

There are three types of mode of their economy according to stability including: temporary, semi-permanent, and permanent. As the dwellers live on the pavement whole day and night, they have to take rest in their ways. They

use some rope, brick and tarp to create a shade to get rid of the rain and other calamities.

The materials they use to create their structures are tarp, wood, rope, bamboo, brick etc.

### *4.2. Findings from Research Objective 2: Economic Up-Gradation of the Dwellers and Public Interactive Pavement*

#### *4.2.1. Analysis for Economic Up gradation*

Pavement dwellers own various means for leading their livelihood and street vendor occupied a major portion of their daily economic activities.

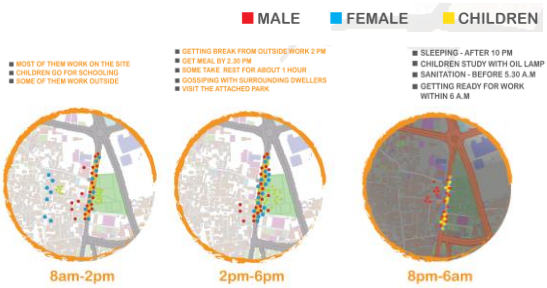


*Figure 9: Time wise activity of the dwellers*

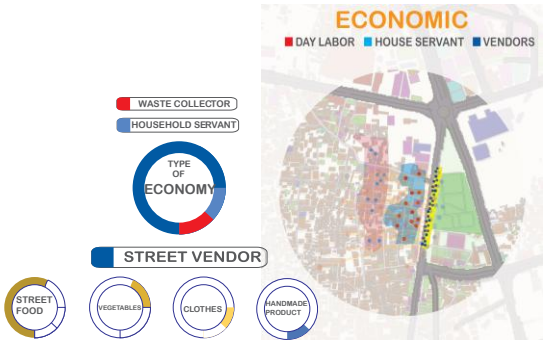


*Figure 10: Economic footprint and typology*

Other typologies of their economy are covered by waste collector, household servant etc. In the figure of economic footprint, it is clear that they pass most of the time on the site for economic purpose. As economic upgradation is an integrated process related to their daily activity, so time wise activity mapping has been done to understand their situations clearly.

Then according to their economic variations the land use of their economic zone has been given. Here it's been shown that how the dwellers run their economy at the minimum spaces on pavement.

#### *4.2.2. Co-Creation (Demand and Scope Analysis):*

- No walkable pavement area left
- Visual disturbance through the existing park(pantha kunja)
- Unhygienic situation to rest or pass
- The dweller itself providing security at night
- Need of a public toilet
- Street food providing by them is helpful to the surrounding community

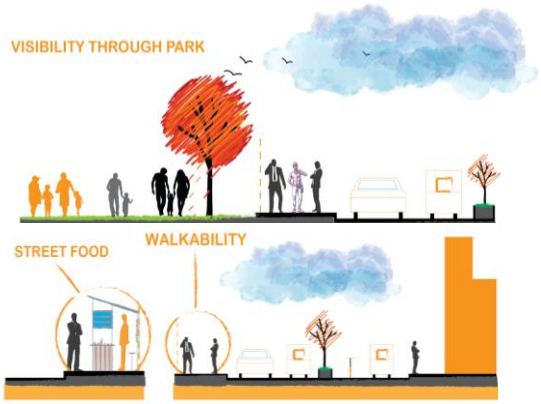


*Figure 11: Sections addressing community demand*

### *4.3. Findings from Research Objective 3: Coexistence of Public Interactive Pavement and Economic Up-Gradation*

#### *4.3.1. Design Concept Formulation:*

From the analysis of the outcome of first two objectives some key issues have been identified to focus on. The economic up-gradation of the dwellers, the public interactive pavement, accessibility to park.

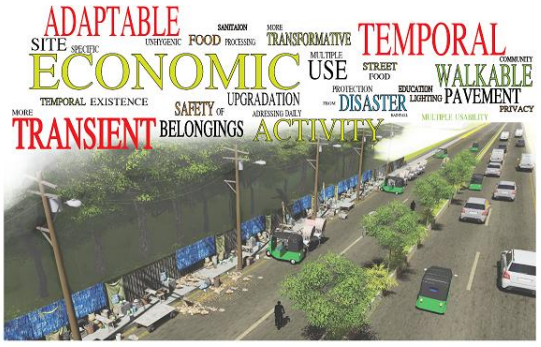


*Figure 12: Word clouds of design considerations*

As all the issues should exist at the same time, so a concept of coexistence has been formulized where the economic up-gradation and public interactive pavement can coexist.


*Figure 13: Design idea and concept formulation*

For that concept the boundary fence is the issue to rethink. As pavement and park both are the public spaces, so the boundary as a physical barrier between these two domains should not be like in conventional way.

## 5. DESIGN GUIDELINES (FUTURE WORK)

To fulfil the objectives some initiatives can be the design guidelines for the architects and urban planner. They are

1. Pavement oriented design solutions can be proposed
2. Rethinking the boundary between the pavement and park
3. Transforming the boundary into a public gathering zone including some economic activities run by the pavement dwellers

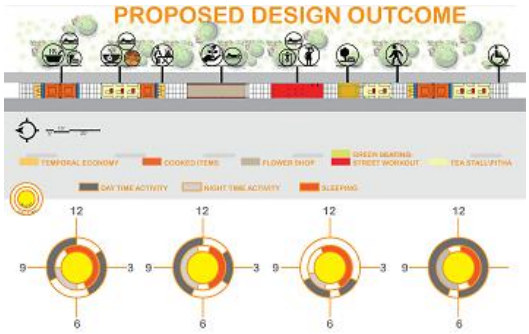


*Figure 14: Function and time wise zoning*

4. Providing spaces for informal economy while planning a pavement to make it public interactive
5. Designing the public spaces considering the time wise multiusability, such as public gathering, income generation, shelter at night for homeless

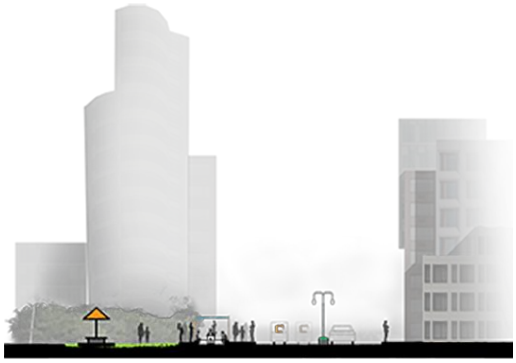

*Figure 15: Section through proposed income generating zone*

6. Introducing public toilet with some services considering the specific user of it (contextualization), such as space for temporary shelter and school of homeless children.

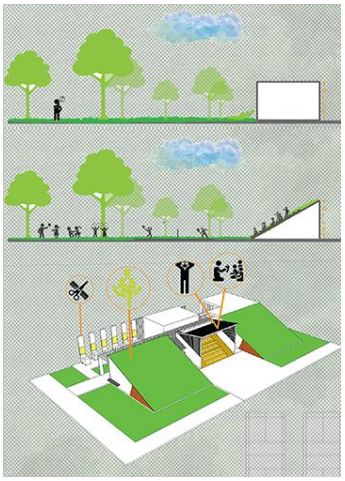

*Figure 16: Design consideration for public toilet*

### *5.1. Comparison of Existing Problem and Proposed Design Solution*

As time is a vital aspect for the dwellers to transform the space according to their economic varieties and public need. So flexible spaces have been proposed to be transformed with time. The same space can be used as vegetable selling in the early morning and as tea stall later. Again street workout zone has been proposed where the workout activities ends up between 6 to 8 am and then the space can be used for temporary informal economy. Thus the design is considered to be the medium of the coexistence of public interactive pavement and economic upgradation of the pavement dwellers for better living.


*Figure 17: Existing problem mapping*


*Figure 18: Proposed solution mapping*

From the figures above the comparison between the existing situation and the proposed situation have been illustrated. The existing problem mapping describes how the pavement is occupied by the economic activities and living of the dwellers. As a result the connectivity to park has been declined. So concerning all these issues the proposed design has been introduced to revive the public pavement for walking without disturbing the economic activity of the dwellers. This design is considered to upgrade the economy of the dwellers while making the environment more public interactive.

*Figure 19: Proposed activity in the morning*

*Figure 20: Proposed activity in the early morning*

*Figure 21: Workout activity till 8 am*

*Figure 22: Informal economy after 8 am at workout zone*

## 6. CONCLUSION

Up-gradation in the livelihood pattern of the pavement dwellers can contribute a lot to bring major changes in urbanization process which is essentially designed to accommodate everyone in a city and perform the relevant activities to benefit all class citizens. Exploring the pavement dwellers in depth in their homeless situation in different location may reveal different findings which must characterize their living thus survival strategies respective to different location. So potential scope for future research about pavement dwelling is being revealed which can introduce cities for all indeed.

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# INTEGRATED WATERSCAPE:
## DESIGN AND INTERVENTION GUIDELINES FOR URBAN WATER RESOURCES IN CASE OF BENAPOLE MUNICIPALITY, JESSORE, BANGLADESH

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***Abstract:*** *Urban planning and design related challenges of deltaic region are different from other parts of the world because of its dynamics, fluidity and non-permanent characteristics. Water here is the main determinant of the settlements and the settlers. Urban planning, design or architectural interventions here require different and more thoughtful attention to its water based landscape. However, urban transformation in Bangladesh so far does not purposefully address the 'wet' or 'watery' characteristics of this landscape. The outcome of this ignorance is rudely visible in Dhaka city by its countless water related issues in every monsoon as well as all round the year. The intermediate cities and small towns are also following those trend and outcome tends to be the same. Being the most vital gateway between Bangladesh and India, Benapole municipality is currently going through massive growth of build-up areas without any proper control or vision. As a result the resourceful productive green landscape, which is composed by plentiful play of blue ribbons and dots, is under threat of being replaced by concrete jungles. From 'waterscape', a perspective from political-ecology paradigm, this study aims to reveal the challenges and prospects of water resources of Benapole. By analysing strengths, weaknesses, opportunities and threats of Benapole waterscape it tries to develop a scheme of urban design and intervention guidelines with a vision to integrate Benapole waterscape with the society, their economy, everyday lifecycle and their civic identity. The idea of this study is expected to be applicable for same type of deltaic agrarian countries like Bangladesh.*

***Keywords****: Waterscape, Urbanization, Deltaic Urbanism, Urban Design Strategies*

## 1. INTRODUCTION

'Waterscape' is a perspective from political ecology paradigm which powerfully believes that water and society are inseparably correlated with each other (Karpouzoglou, T. and Vij, S., 2017). If we explore the relation between Urbanity and hydrology it becomes obvious that water has always played the most important role for the creation of cities and spreading urbanity throughout the world (Asad, R. and Ahsan, R., 2012). From this perspective urban design or planning in the context of Bangladesh is hardly considers the water-human relationship. The result is becoming visible especially in Dhaka by occurrence of water logging, sudden floods, rising of average temperature of the city and so on. Other medium and small size cities and towns are also following same path.

Benapole is fast growing border town of Bangladesh. The town has transformed from a rural area to a class-A municipality within a very short time, which represents the fast transformation. However, landscape of Benapole contains large number of water resources such as many small ponds, *haors*, *baors*, *Dighees* and *Hakor* River. This enormous waterscape is under pressure of extinction because of the fast un-controlled and thoughtless urbanization.

From waterscape perspective, this study tries to address the potentiality and prospects of Benapole landscape. To develop an integrated waterscape a combined initiative is needed from both top down approach by the government and its organizational levels and also from bottom up approach by the end users and dwellers of the city.

Mainly the study is composed based on four major objectives:

a. To find out the potentiality and importance of waterscape perspective in urban design in this deltaic region.

b. To explore the waterscape situation of Benapole Municipality.

c. To analyse the strengths, weaknesses, opportunities and threats of waterscape of Benapole municipality.

d. To provide urban design guidelines for Benapole Waterscape.

As an outcome, this study proposes a strategic framework for the spatio-physical intervention in Benapole waterscape. The guidelines have tried to maximize the relation between the peoples and the water resources of the municipality. Integration of the waterscape with the society is recommended by its societal uses as well as economic purposes.

## 2. METHODOLOGY

Approaches and methods used in this study are mainly qualitative, as it is based more on understanding the ecological issues specific to the case of Benapole using qualitative tools and relevant theoretical materials, and propose eco-spatial guidelines and solutions based on architectural means chiefly. It is an approach that is not concerned with numerical representations but with being more focused on understanding of the information (Gerhardt and Silveira, 2009). The study focuses mainly on surface water related issues which are occurring on specific case of Benapole Municipality of Bangladesh. As a result this can be categorised as case study research.

First objective is achieved by the study of secondary sources, the contemporary urban design practice approaches especially in the regions which are challenged and resourced by water. From this study this becomes clear that though regions like Netherlands, China, Thailand and some other countries are facing this same challenge of water urbanism and responding to it. Bangladesh is also trying to respond but lagging behind. Bangladesh Delta Plan- 2100 is a visionary evidence which is yet to go a far way.

Second objective is based on collection and analysis of data from the case of Benapole. Mainly water resources are studied by photographic analysis, mapping of different type of water resources and problem mapping of those water resources. These are mostly based on qualitative interpretation of case situations. To collect data from case spots, interpretation of citizens were also asked in a story telling approach. Some data were collected from focused group discussions. An interview (key person interview) with city corporation mayor was arranged to understand the future thoughts of the political bodies about the water resources.

Finally all the data was used to understand the strengths weakness, opportunities and threats of the Benapole waterscape. According to the situation urban intervention guidelines were provided to uphold the waterscape of Benapole.

## 3. WATERSCAPE: A SOCIO-ECOLOGICAL PERSPECTIVE AS URBAN DESIGN APPROACH

"Waterscape" is a perspective which mainly originated from political ecology domain. Main idea of this perspective come from the belief that water and society cannot stay separated (Karpouzoglou, T. and Vij, S., 2017). Theoretical position of the political ecology domain is based on the strong evidential belief that nature and society is highly integrated with each other and one shapes another. From that point of view some researchers of that paradigm give more focus on the inseparable relationship between water and society.

For example In Swyngedouw's seminal paper on the water history of Spain, the waterscape is considered as a perspective for understanding that water and society is deeply intertwined (Swyngedouw, E., 1999). According to his study, Spanish waterscape reflects the intricate ways in which nature and society are 'fused together in a way that renders them inseparable,' producing water as a 'restless hybrid' (Swyngedouw, E., 1999). Table 01 shows the use of 'waterscape' idea from different perspectives focusing on

different issues in varied scales and geographical areas.

*Table 01: Use of Waterscape concept by different authors in different contexts, scales and focuses*

| Concept | Authors | Location and scale of study | Focus of study |
|---|---|---|---|
| Waterscape | Karpouzoglou and Vij (2017) | Review of global literature on waterscape (no regional boundary) | Understanding contested geography of water |
| | Swyngedouw (1999) | Spain (National scale) | Water modernization |
| | Sultana (2013) | Bengal Delta (Regional scale) | Drinkable waterscape; technonature, political ecology, technology, development, tubewell, arsenic |
| | Clarke (2012) | City scale | 21st century an living waterscape |
| | Asad, R. and Ahsan, R., 2012 | Kamrangir char of Dhaka (Island scale) | Urbanization, Design strategies |
| | Sultana (2011) | Bangladesh (National scale) | Groundwater contamination |
| | Thaitakoo and McGrath (2010) | Bangkok (City scale) | Water urbanism and climate change adaptation |
| | Baviskar (2007) | Delhi (City scale) | Cultural politics of natural resources |
| | Kooy (2014) | Jakarta (City scale) | Informality of urban water supply |
| | Mehta and Karpouzoglou (2015) | Ghaziabad (Periurban area) | Water services fragmentation |
| | Zi-feng, D.I.N.G. (2009) | North China (Residential area scale) | Urban design scopes and prospects |

*Source: Authors*

From table (table 01) it is understood that waterscape idea is becoming considered recently in the field of urban design, planning and architecture. In some south Asian regions like Bangkok, China, Delhi etc. this idea has been started to be researched. However, practical implementation or application guidelines are not yet formulated. Integration of this idea with urban design theories is highly potential for the regions challenged by water. Though the idea is originated from political ecology perspective, the architecture and settlement of the deltaic region is highly dependent on and shaped by the waterscape. That is why this approach is needed to be addressed by planners, urban designers, architects as well as social organizations and politicians as well to make it work inclusively.

These days, the cities are growing so fast that the delicate equilibrium relation between urbanization and water system is under pressure (Asad, R. and Ahsan, R., 2012). In this era of hazards, that primitive relationship is attracting again the concerns of the researchers. The metabolism of the city depends on the incessant flow of water through its veins (Swyngedouw, 1996). To overcome the upcoming challenges of the planet, which are mostly by water, waterscape approach must be taken under thoughtful consideration.

## 4. WATERSCAPE OF THE BENGAL DELTA

Deltaic regions are by born a non-permanent form of nature. Here, silt is stored and reasserted by rivers at their own free will (Lahiri-Dutt, K., 2014). The rivers of Bengal delta aalso never flows in a same fixed direction. Here the rivers are seasonal. Which means, during the monsoon months they are in a heavily devastating appearance, unleashing a brutality in destructive powers through their floods (Lahiri-Dutt, K., 2014). Rural settlements of Bengal delta are built on raised plinths so that it can protect itself from getting washed away by floods. On the other hand the crops (especially rice, the main food source of delta) need those devastating floods to grow better. That is why the cropping period here has been formulated based on the flooding and changes of seasons (Brammer, 1990; Hofer and Messerli, 1997). This indicate that the water in delta is at the same time most terrifying enemy and on the other hand long cherished blessing.

Along with the rivers, the numerous *Haors*, *Baors*, *Dighees*, ponds, *Beels*, *Jheels*, canals and from small to large ponds, all together form the landscape of Bengal delta. There are about five hundred or so *Haors* located in the northeastern corner of the Bengal basin, in Sylhet, just to the south of the Meghalaya hills of the Eastern Himalayas, which receive on an average over 12,000 millimeters of rainfall annually (Lahiri-Dutt, K., 2014). The settlements can be imagined as floating piece of islands.

The waterscape of Bengal delta is energetic, dynamic and most importantly very much fluid. The character of this waterscape gives shape to the society and their lifestyle. To sustain in this challenging context, its urban planning, design and architecture must deeply understand, respect and consider the deltaic waterscape.

## 5. FINDINGS FROM BENAPOLE MUNICIPALITY WATERSCAPE

The waterscape, hence the totality of water resources in Benapole are main uniqueness of the regional landscape. Benapole waterscape consists of the *Hakor* River, *Pachuar Baor*, many *Dighees and* outstanding number of small ponds. All these resources together has shaped the ecological setup of Benapole.

Table-2 shows that rivers contain maximum portion of surface water in Benapole-Sharsha region. Rivers and *Baors* together contain 47% of total surface water. On the other hand small ponds being numerous in quantity contains second highest amount of water which is around 30%.

*Table 02: Statics of Water Bodies in Benapole-Sharsha Region*

| Water Body | Number | Area (SqKm) | % Area |
|---|---|---|---|
| *Baor / Haor* | 6.00 | 308.46 | 13.59 |
| Ditch | 359.00 | 82.77 | 3.65 |
| *Gher* (Fish Cultivation Only) | 414.00 | 264.33 | 11.64 |
| Irrigation Canal | 0.00 | 0.00 | 0.00 |
| *Khal* | 10.00 | 55.67 | 2.45 |
| Lake | 17.00 | 45.79 | 2.02 |
| Marsh Land | 18.00 | 35.44 | 1.56 |
| Pond | 2,489.00 | 698.26 | 30.76 |
| River | 2.00 | 779.55 | 34.34 |
| Total | 3,315.00 | 2,270.28 | 100 |

*Source: Bala, K.S., (2017) Water report for "Preparation of Development Plan for Benapole-Jessore Highway Corridor Project"*

### *5.1. Hakor River: possibilities till after encroachment:*

From morphology of *Hakor* two significant potential points are revealed. First, though maximum portions of the river is encroached (Figure 01), rather filling it up by build forms or industries like the cases of *Buriganga* and *Turag* in Dhaka, people are more interested in using the *Hakor* for fishing purposes (Figure 03) which is more ecology friendly than the trends of Dhaka.

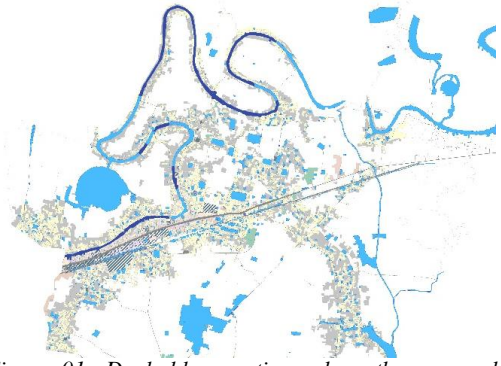

*Figure 01: Dark blue portions show the encroached areas Hakor River for fish farming purposes (Map source: Authors)*

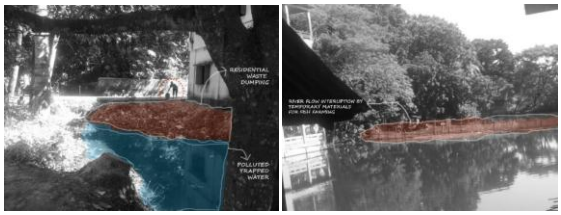

*Figure 02 (left) and 03 (right): River side is used for waste dumping as urban backside (left) and temporary partitions given for fish farming are blocking the river flow (right)*

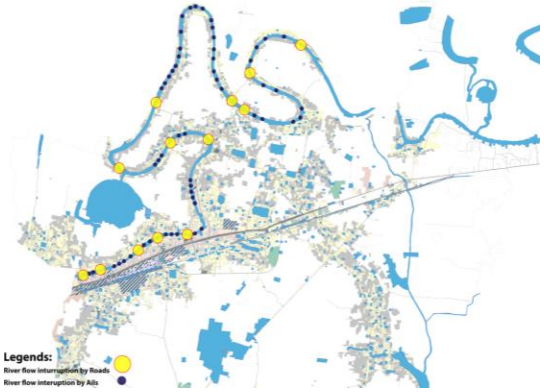


*Figure 03: River flow interruption by permanent roads (yellow dots) and semi-permanent aisles (dark blue dots) (Map source: Authors)*

Second is that, though the discontinuity of the river from its source flow from Indian side has eventually forced it to become a dead river, the connectivity with *Pachuar Baor* has been a highly influential reason of survival of the river till now. Those encroachments and temporary interruptions by soil aisles are just consequence of losing the flow. People's dependency on water as livelihood source has been another reason for the existence of *Hakor*.

### *5.2. Pachuar Baor as Ecological landmark:*

*Pachuar Baor*, situated on the southern part of the Benapole municipality including *Namaj Gram* and *Sadipur* ward, is one of the most extraordinary of ecological resources in the entire region. Spread over an area of 33 acre this semi-circular water body is connected with *Hakor River*, serving as the latter's life source. There are a number of *baors* reserving 13.95% of total surface water of *Benapole-Jhikorgachha* region (Table: 01, Report by water management expert) and *Pachuar Baor* is one of them positioned in *Benapole*.

*Figure 04: Orange portion shows the area of Pachuar Baor covering 33 acres of land (Map source: Authors)*

The place around the *Baor* is currently low density rural area but has a very high potential for future urban investments due to its scenic beauty and landscape characters. Benapole Municipality also has shown its intention to set up a municipal-park here by the side of the *Baor* while land acquisition is going on currently. Although some agricultural lands around the *Baor* are now being converted into fishing ponds in a speculative manner, the conversion rate is still low as maximum land around the *Baor* area is agricultural, specially used for rice cultivation, and produces two crops per year. These are potential lands for governments to claim and conserve.

### *5.3.Community Dighees creating neighbourhood identity:*

Water resources of Benapole includes numerous *Dighees*, most of which are more than 4 acres in size (Figure 05). These *Dighees* are significant for creating sense of identity among the communities also. Some areas are named after a particular *Dighee*, for example - the *Digheer Par* ward giving these water bodies a landmark value among the urban fabric of Benapole.

As these *Dighees* are, after the river and the *Baor*, the largest sources of surface water reserve, while they also bear massive ecological as well as socio-cultural significance. Though presently these *Dighees* are primarily used for fisheries and everyday purposes, rapid urbanization is also causing many of these to get landfilled, and encroached. Figure 06 shows a Dighee side built form in *Digheer Par* ward which indicates that previously the Dighee was even larger before being filled up for construction of the building.

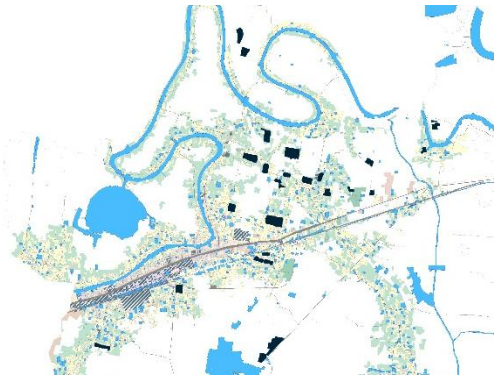

*Figure 05: Dark black portion shows the Dighees which are above 4 acres in size (Map source: Authors)*


*Figure 06: Dighee side built form in Digheer Par ward indicates threat of getting filled up (Photography: Authors)*

### *5.4. Marshy lands as source of ground water recharge:*

There is a large area of marshy land on the northern part of the municipality. This land stays under water most of the time of the year. These

marshes are located away from the settlement and here land elevation is lower than the other areas. These areas produce lots of fishes and in some cases water-borne edible vegetables like Lily (*Shapla*), *Kolmir Shak* etc. near these low lands there are some ponds and *ghers* (Excavated ponds for fish farming) .

In the rainy season the storm water drain out to these low lands from their surrounding elevated areas. As these low-lying areas are relatively less accessed by humans, these are potential areas for other water based habitats like different types of flora and fauna.

On the other hand, during the dry times some portions of these areas are used for agriculture, especially for wet rice cultivation. The potentials of this landscape is its multiple usability, seasonal productivity and lack of human accessibility. Though economic return from these lands are not satisfactory compared with the comparatively elevated lands, the area is significant for keeping equilibrium of the ecological system, as well as for natural water management system.

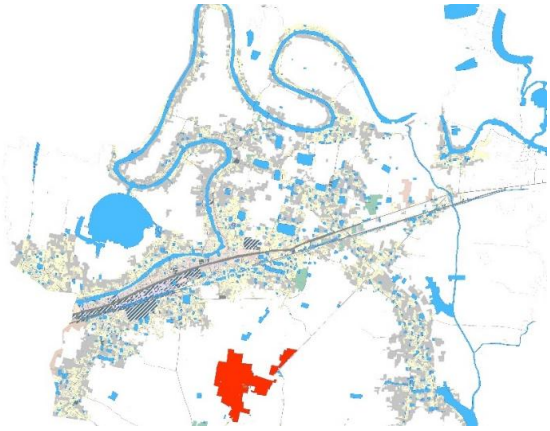

*Figure 07: Orange area indicates the marshy land which stays under water during most of the time of a year and serves as source of water for agricultural works. Also used for fish farming purposes (Map by: Authors)*

### *5.5. Private ponds:*

The overall landscape of Benapole region is a mosaic of numerous blue dots on the canvas of green. Settlements are mostly covered by those greeneries. However though small in size, these very high number of small size private ponds play an enormous role to recharge the ground water. Besides, in rainy seasons they play the role of water reservoir for excess water and protect surrounding areas from water logging. In rural hinterlands of Benapole, they serve as sources of water for drinking and everyday use during the dry season, when most of the existing tube wells fail.

However, the numbers of these ponds are decreasing day by day with the expansion of urban areas. They are getting filled up for construction of buildings and infrastructure in majority of the cases.

This situation of getting these ponds filled up is till now in a low pace. But if no steps are taken this will soon become a contagious trend, which will change the whole fabric of the landscape. As a result the balance of the ecosystem will be hampered hugely. Moreover the future uncontrolled urban areas will face problems like water logging and scarcity of drinking water as the ground water table will fall deep down.

So quick and long-term measures are needed to be taken to conserve the private ponds from getting filled up. Multiple usability, and economic vitality of those ponds should be focused.

### *5.6. S.W.O.T. Analysis of Benapole Waterscape:*

*5.6.1. Strengths:*

- *Pachuar Baor*: largest water reservoir of the municipality.
- Highest amount of agricultural land use in *Jessore-Benapole-Jhikorgachha* region.
- Availability of strong water resources (*Hakor* River, *Pachuar Baor* and lots of large *dighee*).
- Maximum regional landscape is still out of urban intervention.
- *Dighee* and water bodies already act as community identity and landmark. (e.g. some areas are named over the name of Dighee, for example *Digheer par* word)

*5.6.2. Weaknesses:*

- Local residents' lack of awareness about landscape and waterscape of the area.
- Gradual consumption of swamp land.
- *Hakor* River is disconnected from its main source flow.

- Areas on the both side of *Hakor* river is encroached in some urban portions
- Local people use the *Hakor* River for fishing purposes by adding aisles through the river. As a result the river is interrupted in many points.
- Gradual transformation of agricultural lands.
- River side is used as waste dumping zone in some points.

*5.6.3. Opportunities:*

- The existing agricultural land area of *Benapole* that can become a 'Grain Hub' for the region.
- Numerous quantity of small private ponds.
- Agro-economy can be enhanced to contribute to national GDP.
- Existence of different agro-aquaculture based cultural activities (e.g. *Nobanno* festival, fishing festival)

*5.6.4. Threats:*

- Fast growing uncontrolled urban areas
- Gradual transformation of low agricultural lands surrounding *Pachuar Baor* into residential land use
- Gradual transformation of marshy lands
- Fast transformation of agricultural low lands

## 6. RECOMMENDATIONS FOR INTEGRATING BENAPOLE WATERSCAPE:

By understanding the context of Benapole, recommendation has been formulated. These recommendations provide an inclusive vision of integrated waterscape. Main idea was to conserve the resourceful and under considered water sources by using them as community prides. In some cases isolation is also required. But most of the recommendations try to grow a system by which community and the agriculture based population can utilize the water resources as their earning sources as well as community strengthening spaces.

### *6.1. Hakor River related guidelines:*

- Reconnecting the segregated portions of *Hakor* River at *Kagoj Pukuria* and *Panthapara* periphery.
- Connecting *Hakor* River with *Betna* River at *Kupala* and *Sharsha* Region.
- 80' area on both side of river should be conserved as ecological corridor.
- Construction of new privately owned built forms on the river shore should not be permitted.
- Private land owners can be allowed to use river shore lands for productive landscape and agricultural purposes.
- Removal of soil made aisles from the river bed - currently used for fish farming.
- Construction of new private built forms on the river shore conserved land should not be permitted.
- Private land owners can use river shore lands for productive landscape and agricultural purposes.
- Promoting public access and activities to the river corridor
- Removing built forms which are situated on the river.
- Re-designing the roads that have interrupted the river flow.
- Promote public access and activities along the river corridor

### *6.2. Pachuar Baor related guidelines*

- Bring the entire *Pachuar Baor* area under conservation.
- Uphold the present agricultural activity around the *Pachuar Baor* area.
- Promote Agricultural Eco park as a municipal recreational facility near *Baor* area
- Proceed for public private partnership with the agricultural land owners at *Pachuar Baor* area to save land acquisition costs and avoid resettlement issues.
- Agricultural activity and land should be the prioritized element of the Eco Park.

- Intervention to agricultural land should be minimal at *Pachuar Baor* area.
- Promote agro sensitive eco resort near the *Pachuar Baor* area.
- Bring the entire *Pachuar Baor* area under conservation.
- Proceed for public private partnership with the agricultural land owners at *Pachuar Baor* area to save land acquisition costs and avoid resettlement issues.
- Promote agro sensitive eco resort near the *Pachuar Baor* area.

### *6.3. Guidelines related to Swamp Lands:*

- Not to provide direct accessibility to the swamp land.
- Keep swamplands seasonally used for agricultural purposes.
- Restrict non-agricultural activity in swamp lands.
- New fish farming ponds can be provided

### *6.4. Guidelines related to large ponds and Dighees:*

- The significant *Dighees* should be brought under conservation.
- The privately owned significant *Dighees* should be brought under public private partnership to encourage owners to conserve those community resources.
- Upgrading the shore areas of the *Dighees* by designing walkways and *Ghats*.
- Provide community playgrounds and afforestation areas attached with *Dighees* and large ponds where possible.
- Restrict *Dighee* side communities from encroaching them.

### *6.5. Guidelines related to small ponds:*

- Arrange seminars and workshops in all wards to increase awareness, including Mayor, ward commissioner, water management experts and people of the community.
- Enhance awareness among Benapole inhabitants to conserve private ponds by incorporating civic societies, NGOs, Imams of mosques, schools and colleges.
- Providing short term training facility to develop productive aquaculture using the private ponds.

## 7. CONCLUSION:

Bangladesh is the largest delta on the planet being borne and grown up with the chemistry of water and land. Water here plays the role of main controller of landscape and thus defines character of the deltaic settlements and their settlers. Traditionally the settlement here has been developed in a distinctive way which is quite contrasting with other parts of the world especially very different from the western world. Today's approaches to urban design of city making in this landscape of Bangladesh is highly conflicting with the chemistry of this landscape. Limited initiatives are available where waterscape of a region is dedicatedly integrated in urban design or planning of cities. As a result waterlogging, flash flooding are quite common in many cities and towns. Other ecological and environmental aspects such as ground water recharging ability, extinction of water dependent flora and fauna, rise of average temperature of urban area, etc. are far beyond consideration.

The case of Benapole is chosen for study because of its noticeable speedy transformation from a rural port area to class-A category municipality which indicates rapid growth of urban activities, needs and consumptions. Findings of this study have explored its highly productive waterscape resources which are still un-touched but under enormous threat of extinction. Mainly the *Hakor* River, Pachuar Baor, many large *dighees* and numerous small ponds have formed the agriculture based landscape like a painting on green canvas. It is high time to protect the canvas from being washed away by un-controlled and un-productive urban growth. In recommendation part, this study tries to suggest urban design and intervention

guidelines being focused on the water resources of Benapole landscape.

In recommendation water sources have been tried to conserve by utilizing them as community prides, rather than segregating them from public reach. However, highly inclusive initiatives integrating the urban designers, political bodies of the municipality, many civil organizations and most importantly the citizens are needed to turn the vision of this study into reality.

## 8. LIMITATIONS:

Being mostly based on qualitative approach this study lacks in quantitative logics and supports. Mostly this study tries to through an idea to envision urban transform with an ecology sensitive approach. The idea of this study has been formed based on previous literatures, research gaps, global goals for sustainable development and national visions especially stated on Bangladesh Delta Plan- 2100. Being originated from a deltaic region this study gives more focus on waterscape and landscape. This study needs more case driven experiences from different regions of various countries to enrich itself. Main limitation of this study is that in Bangladesh we do not have any discipline or institute focused and specialized on landscape design and management. On the other hand very limited number of architects and urban planners deal with regional or municipal scale of urban design in practical field. The recommendations of this study are both visionary and doable. This study needs review of landscape design experts and researchers who are specially dealing with water urbanism arena.

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# HOUSING THE URBAN POOR:
## IDENTIFICATION OF POSITIVE FORCES AND OPPORTUNITIES FOR LOW INCOME HOUSING SETTLEMENTS IN DHAKA FROM THE STUDY OF DWELLERS' RESPONSES

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***Abstract:*** *Too many residents in Dhaka, including some 3.5 million people living in slums and informal settlements, often lack access to basic services, infrastructure, and amenities. 0.5 million people migrate to Dhaka every year, resulting in more people dwelling in slums, squatters and streets. Housing solutions have failed to address the needs of the urban poor and the slum problem itself, mostly because of "upper income proliferation" and this paper discusses probable solutions en route to better living conditions in the city by means of providing adequate housing for the urban poor. Methodology includes multiple case studies via literature review, informal discussions and discourses. Transformations in informal settlements in Dhaka increase house space, improve accommodations for main households and accommodate more people without extending the city. These transformations can be encouraged in future masterplans. Getting rid of social myths, a better development strategy for Dhaka City, Mofosshol development for reducing migration to Dhaka, self-help housing with secured tenure and creating a sense of belongingness through innovative design solutions can be better principles for future designs. Land banking, spare-plot mechanism and cross-subsidies are encouraged in future policies. These measures are essential prerequisites to a better city environment in Dhaka.*

***Keywords:*** *Informal Sector Housing, Slum, Transformations, Urban Poor, Urban Design.*

## 1. INTRODUCTION

According to UNDP's estimation, more than half of the world's population now live in urban areas and by 2050, that figure will have risen to 6.5 billion people – two-thirds of all humanity. SDG 11: Sustainable Cities and Communities acknowledges that sustainable development cannot be achieved without significantly transforming the way we build and manage our urban spaces. The rapid growth of cities in the developing world, coupled with increasing rural to urban migration, has led to a boom in mega-cities. In 1990, there were ten mega-cities with 10 million inhabitants or more. In 2014, there are 28 mega-cities, home to a total 453 million people. Extreme poverty is often concentrated in urban spaces, and national and city governments struggle to accommodate the rising population in these areas. Making cities safe and sustainable means ensuring access to safe and affordable housing, and upgrading slum settlements. The first target of SDG 11 reads: "By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums" and the indicator for this target is the proportion of urban population living in slums, informal settlements or inadequate housing. Dhaka, the capital of Bangladesh, located in South-East Asia, is one of the fastest growing mega-cities in the world, with slum populations seemingly outpacing the growth of other urban areas. In the city corporation areas, a study estimates that 35% of the population live in slums, 43% of urban households live in poverty and 23% are considered to be extremely poor. Notwithstanding, the urban poor have been and continue to be largely excluded from national policies and urban planning processes and development plans. Housing solutions have failed to address the needs of the urban poor and the slum problem itself, mostly because of "upper income proliferation" and this paper discusses

probable solutions or measures that can be undertaken to aid informal settlements and help the urban poor.

## 2. AIM AND OBJECTIVES

The aim of this paper is to find probable solutions en route to better living conditions in the city by means of providing adequate housing for the urban poor. The objectives are –

1. To analyze dwellers' responses from previous housing solutions provided for slum dwellers.
2. To understand the positive forces from those responses.
3. To discuss a few relevant cases and their implications with qualitative assessment.
4. To apprehend solution criteria and suggest probable measures that can contribute in the solution to slums in Dhaka City.

## 3. METHODOLOGY

The methodology consists of multiple case studies and qualitative assessment of probable solutions. Discussions in postgraduate classroom exercises, taking place during May to August 2017, aided this process. Facts and arguments have also been obtained from the study of relevant photographs and articles from national and international dailies and their websites. As a local case study, the largest slum rehabilitation in the history of Bangladesh was selected, and the focus was on local dwellers' responses. Two foreign case studies, one from the subcontinent (Sri Lanka) and the other from Africa (Egypt) were selected considering their noted success with both closely related to the context and slum dwellers' behaviour in Dhaka.

## 4. LITERATURE REVIEW

It is almost impossible to discourage people from moving into slums, and formal housing solutions have failed to address this issue. [8] Rather, focus must be on the design and development of informal settlements considering the fact that these settlements cannot be treated differently to the rest of the city. [8] Previous researches have been conducted on slum dwellers' behaviour [2] [6] and sustainable slum development [4], but there is urgent need of research regarding better solutions involving design and policy issues, especially in the context of Dhaka. Facts such as 'how slum populations are going to grow can be accurately predicted' trigger the need for updates in this particular area [8] in the contemporary world architecture scenario.

## 5. CASE STUDIES AND ANALYSIS

Dwellers' responses have been studied in the case of "Bastuhara Housing" in Mirpur, Dhaka, Bangladesh and strategies of implementation have been studied in two successful housing programs in Sri Lanka and Egypt. Later, key information from these studies will help build suggestions.

### *5.1. Case Study, Bangladesh*

Built in the early 1970s to house displaced squatters and refugees from Pakistan, each of the 4,304 semi-detached dwellings, measuring 9'2"x 15'10" and arranged in closely spaced grids, has a single room and veranda. Missing Infrastructure: No toilets or water taps were fitted. Since their first occupation in the mid-70s, most of these houses have been extended, and by 1999, covered most of the plots that were demarcated around them. Although all the main households are still tenants of the Housing and Settlement Directorate, there are plans to sell the land and houses to the occupants if the properties remain as built, except for some allowance for depreciation.

- 3,160 units were ill-handled due to "Bureaucratic Entanglement". These houses could be bought by paying "hush-money" of around Taka 2,500 in 1974 rising upto Taka 1,20,000 in 1988.
- 1,124 units were combined to transform them 562 new houses for government employees.
- 93 units were extended, 62 by one room and 32 by more than one room. In many cases, the habitable space were more than doubled and the number of rooms were increased five-fold. However, they also managed to dig in some small canals and build a few latrines in the area to add to this transformation.
- Non-transformers tend to have smaller households, fewer adults, and marginally fewer children than transformers, indicating fewer points of housing stress. One of the main factors contributing to transformation is probably the shortage of accommodation, with the main need

appearing to be for larger dwellings, especially for more rooms.

- Interestingly, the extension is intended not necessarily for getting adequate space for all occupants of the household, but mainly as an investment to generate income by renting the extended part. The effectiveness of transformation in providing more space is quite impressive.
- There is a two-stage process of capturing extra habitable space. First, the original space is redivided into more rooms (albeit some are very small, e.g., original verandas). Second, new rooms are added, generally smaller than the originals.
- A summary of the dwellers' responses[2] :

1. Transformations increase house space, improve accommodations for main households and accommodate more people without extending the city.

2. Levels of investment can be quite high compared to the household's annual income.

3. High quality construction can be expected.

4. The change to ownership is a likely signal for transformation.

*Figure 1: The picture shows a Transformed House in Mirpur, Bangladesh: This house was bought in 1980 for Tk. 5,500 and it was extended in 1988 at a cost of Tk. 60,000 (eight months' income). There were four households and 18 occupants in 1999. (Source: Tipple, A. Graham 1999)*

### *5.2. Case Study, Sri Lanka*

One Million House Program of Sri-Lanka (1984-89), winner of World Habitat Award, was initiated and implemented by the national government and the local communities. A radical rethinking of Sri Lankan government policy resulted in it no longer seeing itself as a direct provider of housing, but rather as an enabler, helping and supporting poor people to provide their own housing through financial incentives and packages, as well as technical support. It recognized the latent skills and capacities of people and decentralized planning programming and implementation to the village level. As a result of this rethinking, the Million House Program was established to provide affordable loans to low-income households in both urban and rural areas to help them build or improve their own homes. To minimize construction costs, the houses are built using traditional technologies and local building materials, including sun dried bricks, mud mortar for walls and foundations and jungle poles for roof timber. [14]

Strong networking + Communication among all level of implementing bodies + Maximum involvement of user/families = A successfully achieved, affordable housing program.

Focus was on :

(a) very small loans, the average loan is $ 178 per family

(b) a large participation by the households, in the form of work or money, this participation represents 60-90% of the total value of the accommodation built

(c) and absence of strict technical standards

(d) technical assistance from the administration and a control of how the loans are used

(e) a wide range of loans for improvement, building of new accommodation, sites and services, water supply, sewage and drainage, etc.

(f) a policy for improving slums in Colombo and in other towns

(g) a land policy to facilitate land access in urban areas, beneficiaries occupying public land acquire ownership without land expenses

(h) a subsidy policy, interest rates are below those of the market, infrastructures are financed without repayment, administrative costs are not taken into consideration in the cost of the loan.

### *5.3. Case Study, Egypt*

Egypt's housing problem began to assume drastic proportions in the early 1960s. This phenomenon coincides with several others of the same period; the private sector increasingly tended to refrain from investing in housing; the population rose by high rates; the government's inability to meet popular demand for housing became

noticeable. Egypt's housing crisis can be attributed to a combination of factors, which may be summarized accordingly:

• The returns to investment in housing are lower than those pertaining to other economic sectors.
• The housing laws, being grounded in the political concerns of the 1960s, brought about a noticeable decrease in construction activity, particularly in housing for the middle-income groups.
• Egypt's inhabited area consists of only 4% of the country's area. This, coupled with the high rates of population increase, led to the increase in the prices of real estate and induced people to illegally build on agricultural land. This latter phenomenon involved approximately 60,000 faddans per.
• The costs, and therefore the prices, of housing units have progressively risen, putting these beyond the reach of the majority of citizens who basically belong to the lower/middle socio-economic classes.

"Mubarak Youth Housing Project" had been started in 1996. Its aim was to provide 70,000 affordable dwelling units, in a healthy and productive residential environment. The beneficiaries were the Youth who belong to the disadvantaged/low-income groups. The project was completed in December 2000, and its units were distributed in 15 new cities. The project was formulated to offer a wide range of floor spaces (100-70-63 sq. m.) in order to satisfy the needs of different household sizes. The designs of both dwellings and layouts had been chosen through national architectural competitions. The chosen designs fulfill the targeted requirements of gross residential density (120 persons/acre) and a maximum height (5 floors) to allow for ample green areas, parking spaces, and various social services. The project cost was about L.E. 2.75 billion. Of this amount, the state cross-subsidized nearly 40% from the sales of high-income residential areas and dwellings in both new cities and resorts. This is in exclusion of price of serviced land, which is, also, financed from these revenues. In addition, the State offered L.E. 1 billion in subsidized credit in the form of soft loans of L.E. 15000 per unit, payable over 40 years at 5% interest rate. The dwelling units were allocated according to objective criteria, which had been investigated to ensure the legibility of beneficiaries. [16]

## 6. SUGGESTED MEASURES

The most important progress towards solving slum problems is the awareness and good will of the government and concerned authorities and careful implementation of proper initiatives. The probable measures to solve slum problems in Dhaka, as observed and assessed in above case studies are presented below.

### *6.1. Getting Rid Of Myths*

In their article "Seventeen reasons why the squatter problem can't be solved" Schlomo Angel and Stan Benjamin held the following factors culpable for the failure of low-cost housing. [1]

1. Myth of Highrise
2. Myth of the Advantage in Large Projects
3. Low-cost Housing is not Necessarily Low-income Housing
4. Myth of Social Surveys
5. Myth of Completeness
6. Myth of Professionalism
7. Squatter Clearance
8. Land Shortage
9. No Housing Finance
10. Myth of the Nice Environment
11. Myth of Charity
12. Myth of the Principle of Paternalism
13. Upholding the Law
14. Private Property
15. Principle of "Knowing Your Limits"
16. Principle of "Somebody Else's Problem"
17. Myth of the Double Bind

In the design, implementation and delivery of informal settlement housing projects, the knowledge of these 17 reasons is vital for designers and policy makers, who must take into account the chances of failure these myths create. As importantly as designers and policy makers, the society and the administration must get rid of these myths too. In the words of Laurie Baker, "Should we not destroy our slum, but recycle them? Absolutely yes. Recycling our slums should be given far greater priority than more and more highrise flats. Dare we tell the haves to take a back seat for a while?"

### *6.2. Dhaka City Development Plan*

The UN's Habitat data, collected from national

census offices, gives the number one spot to Dhaka, with a density of 44,500 people per sq km. [21] Dhaka is a dynamic and vibrant city with a rich cultural heritage to be proud of. It is also rapidly growing. The city's astonishing population growth from 3 million in 1980 to over 18 million today represents the promise and dreams of a better life that the city holds for millions of residents. Too many residents today, including some 3.5 million people living in slums and informal settlements, often lack access to basic services, infrastructure, and amenities. This makes tapping into quality education, health, and jobs much more difficult, and are major obstacles to realizing the city's potential. Dhaka's population is likely to double to more than 35 million people by 2035. 0.5 million [21] people migrate every year, resulting in more people dwelling in slums, squatters and streets.

Dhaka's urban growth has mainly taken place in the northern part and expanded westward after the flood of 1988, when the government built the western embankment for flood protection. The embankment has greatly increased investment in those areas but the lack of planning has also created congestion and livability problems. The expansion of Dhaka City has been messy and uneven. Unplanned and uncontrolled growth has created extraordinary congestion. In the last 10 years, the average driving speed has dropped from 21 kilometers per hour to 6 kilometers an hour. If business as usual continues, it risks to drop to 4 kilometers per hour by 2035, slower than the average walking speed. Congestion in Dhaka wastes 3.2 million working hours per day. This costs the economy billions of dollars every year.

Without a fundamental re-think that will require substantial planning, coordination, investments, and actions, Dhaka will not reach its full potential. Dhaka is at a crossroad in shaping its future. East Dhaka still remains largely rural. If properly managed, the development potential of East Dhaka is massive. It is just across the Progoti Soroni and close to Gulshan. East Dhaka's development could help relieve congestion and stimulate opportunities. However, if not managed properly, the rapid and unplanned urbanization of East Dhaka can make congestion and livability worse, while increasing risks to floods and earthquakes. For Bangladesh to become an upper-middle income country by its 50th birthday, much depends on the success of Dhaka's urban expansion. For Dhaka to play this critical role, East Dhaka needs to be designed and built sustainably. This will require careful planning, proper implementation, and close coordination. It will require government ministries and agencies, private sector, citizens and the most brilliant and creative minds from Bangladesh and abroad to work together. [17]

### *6.3. Mofosshol Development*

More efforts are being put into the development of Dhaka, whereas the development is slow in other parts of the country. This is the principal reason why thousands of people migrate to Dhaka every year. According to reports in Daily New Age, food and job crisis has forced people to move from a flash-flood hit Sunamganj to urban areas, mostly to Dhaka. Decentralization and development of cities other than Dhaka is crucial in stopping migration and combatting the housing challenge.

### *6.4. Self-help Housing*

Self help housing is the initiative taken by the dweller of a particular settlement to improve the housing environment by adding dwelling units, necessary basic facilities, infrastructures etc. This concept works when initiatives are taken by the government to resettle a slum or squatter by providing the basic infrastructure and security of the tenure.


When communities of the urban poor do not have ownership rights to their settlement, the impulse toward improvement is decreased because there is no incentive to invest in something that they will eventually have no ownership right. Secure tenure to slum dwellers transforms their homes into a tangible asset. They can leverage their house to finance their work; they can rent out rooms for income support. Although securing tenure is not without its complexities, investment in community improvements and urban infrastructure build value into this tangible asset while improving

the productivity of home-based enterprises.

The Grameen Bank is a co-operative non-governmental association that first began a loan program for the rural poor to help them initiate income generating schemes. Then, with the success of the program, they decided to extend the bank's credit support to house-building in 1984, to build flood and water resistant modest houses. The Grameen Bank low-cost loan housing program, provides each borrower loans of approximately US$ 350 at 5% interest for basic housing scheme. Besides the money as loan, the borrower receives four concrete columns, a prefabricated sanitary slab and 26 corrugated iron roofing sheets at a much lower price. The structural system is based on a standard module, the pre-cast building materials are mass-produced off site, and the families construct the houses themselves. This housing scheme has been proven very successful in rural areas, the program is continuing with building over 30,000 new homes each year. The Grameen Bank Housing Project, winner of 'World Habitat Award' in 1998, has no scheme for the urban poor. [4]

It should be noted here that Grameen Bank is world famous mostly because of the percentage of loan money it retrieves, whereas other banks in Bangladesh incur a combined loss of billions of dollars every year [5] from their loan programs. Arguably, the banks should consider providing loans to the urban poor with better confidence.

### *6.5. Creating a Sense of Belongingness*

As discussed earlier about social myths, in most of the efforts taken to improve conditions of urban squatter settlements by architects and designers, there has been the eviction of squatters, and re-settling them in vertical, high-rise buildings. In most of the designing of these buildings as replacement for squatters, their usual living pattern had been ignored- no open space for social activities and children had been provided. Moreover, dwellers were not involved to the process of the development. As a result, no 'sense of belonging' worked for those urban squatters on those settlements. Every slum in Dhaka has a niche; small shrine or temple, mosque or church, based on their common faith, where they meet and have social gatherings. For most of these informal activities of social interacting; children playing, shopping, chatting etc they use from the most minimal space for social interaction at the door step, the circulation and open spaces, to the optimum community spaces for various social and cultural activities. These elements are as much essential as basic infrastructure services for creating a "sense of belongingness" and for the sustainability of informal settlements. [4]

### *6.6. Improving Living Condition in Slums*

Architect Laurie Baker was renowned for his initiatives in cost-effective energy-efficient architecture. In his book "Are Slums Inevitable", he said in answer to "What can we do with a slum?", "A great deal. We can "recycle" it; that is to say, we can build at the same site low-cost structures that accommodate an equal number of persons, and provide plenty of open space and other facilities." He suggested simple-structured housing units in stepped tiers, up to four storey, incorporated with open spaces for recreational activities and Gardens at different levels. About the challenge facing the idea about open spaces, the architect says, "The mentioned open land is for the benefit of all – and not for the wealthy to build even greater honor than those pulled down – merely to make themselves more wealthy." [13]

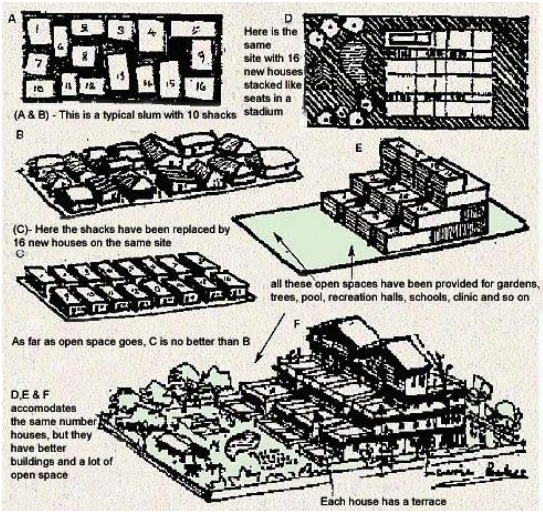


*Figure 2: Laurie Baker's idea about slums (Source: Costford)*

### *6.7. Design as Slum?*

A final year undergraduate thesis completed in

2016 by Saad Yousuf Andalib at Bangladesh University of Engineering and Technology was based on the fact that any initiative taken to house the poor results in "Gentrification". Computer Generated Approach can give an architectural and energy efficient solution to dense but healthy slum planning with considerations for infrastructure, civic facilities and sanitation. This approach is encouraged because the urban poor eventually come back to slums due to upper-income proliferation, so why not a designed "slum"? The design also considered sustainability, air movement, ventilation and sunlight penetration. This studio exercise invents and argues that with proper design solution, high-density, yet livable slums can be made possible.

*Figure 3: Saad Yousuf Andalib's idea about "designed slum" (Source: Saad Yousuf Andalib)*

### *6.8. Land Banking*

Land banks are governmental entities or nonprofit corporations that are focused on the conversion of vacant, abandoned, and tax delinquent properties into productive use. [18] These properties are often grouped together as "problem properties" because they destabilize neighborhoods, create fire and safety hazards, drive down property values, and drain local tax dollars. In some sense, these are properties the private market has altogether rejected. Visionary land banking system by the government can help Dhaka's urban poor fulfil their rights to land and housing without the interference of bureaucrats. Besides land banking, cross-subsidy and spare-plot mechanism have also been identified as important measures from case studies and previous initiatives undertaken in Dhaka, for example a working cross-subsidy system in Panthapath. [3] [4] [12]


*Figure 4: Land Bank Benefits [18]*

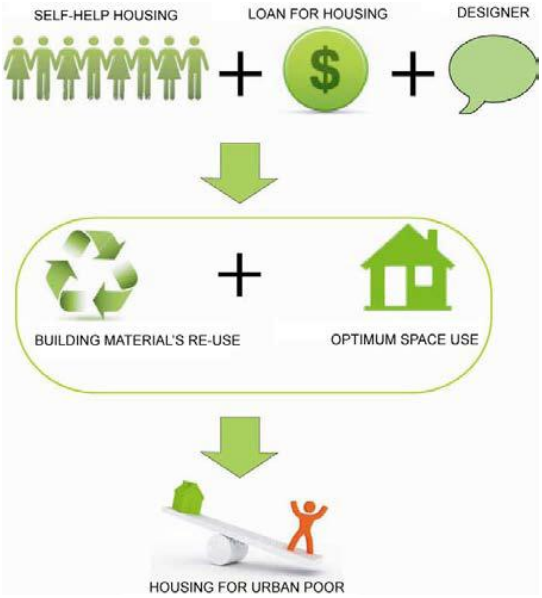


*Figure 5: Sustainable solution for transforming slums and squatter settlements [4]*

### *6.9. Spare Plot Mechanism*

This is a government initiated land subsidy system by which percentages from any portion of urban land (not affordable for the poor) are spared for housing the urban poor. In countries like Sweden or Israel, which have welfare democracy, and elsewhere, the commune and kibbutz systems have worked excellently where groups of people get together to solve their housing needs. In Malaysia and Columbia, Valorisation has been used where the government provides serviced land

to cooperatives and developers conditionally so that a fixed proportion of flats are sold at cost-price. Land Repooling or Reconstitution technique has given good result in all over SE and East Asia. Although one such attempt in Dhaka failed due to an absence of motivated workforce to convince the landowners of the benefits, spare plot mechanism remains a vital weapon to secure land for low-income housing. Land Sharing is working in Bangkok, Mumbai or Manila. Spare plot mechanism has also been applied in Mexico. Thus there is no shortage of good practice; only lessons have to be learnt and adopted to local context. [3]

### *6.10. Cross-subsidy*

In strong housing markets, nonprofit or mission-driven for-profit developers who build affordable homes can use profits from the sale or rental of market-rate homes to subsidize the costs of affordable homes. To use cross-subsidies successfully in an all-rental context outside of very high rent areas, communities may need to combine cross-subsidies with other approaches, such as making publicly owned land available for little or no cost, or increasing the allowable density of a development to provide greater opportunities for profits that can help offset the costs of affordable homes. Summary in below diagram. [19]

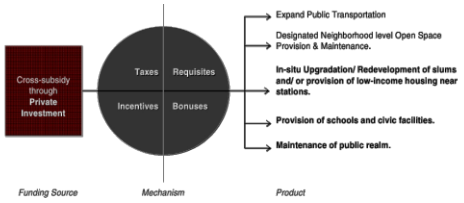


*Figure 6: Cross-subsidies, mechanism, product.*

### *6.11. Provision of Transformation in Masterplan*

Chilean architect Alejandro Aravena, Pritzker Prize winner, released a number of his residential designs as an open-source resource to help tackle the global affordable housing crisis. Aravena's firm, Elemental, has posted drawings for four of its low-cost "incremental" housing projects on its website for free download. The aim is to provide the material to government agencies and developers who might think it's "too expensive" to invest in well-designed social housing. The need for social housing is becoming more pressing and hence the initiative, according to Aravena. [20]

*Figure 7: Elemental's "Half-housing", Chile. [20]*

With the awareness of positive forces of transformation in informal settlements, any masterplan of affordable housing in Dhaka must have provisions for transformation and extension, for helping the urban poor in a better way.

## 7. CONCLUSION

One key issue about probable solutions for housing the urban poor, found in this analysis, is that the challenge is more about solving socio-economic problems rather than designing in a better way. For a better future, we must acquaint ourselves with these solution procedures which are equally important to one another. As much as we need to get rid of our social myths, transform Dhaka in a better way and reduce migration, we must design self-help community housing with security of tenure, create sense of belongingness and keep provisions for transformations in the masterplan; and include spare plot mechanism, land banking and cross-subsidy mechanism as part of our policies. These findings will enable urban designers and policy makers to think about the city in a far better way with better

considerations for the urban poor, who are an inseparable and important part of the urban population.

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# BIOMASS TO ORGANIC FERTILIZER :
## A CASE STUDY IN KUSHTIA, BANGLADESH

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***Abstract:*** *Chemical fertilizer industries are highly energy intensive and have fundamental dependence on natural gas supply. According to Petrobangla, in 2014, fertilizer factories of Bangladesh used 2.3 billion cubic feet per day which is 7% of the total natural gas production of the country. Due to interrupted gas supply, urea productions have declined from 1.4 million metric tons to under 1.0 million metric tons per year. At present Bangladesh needs approximately 3 million metric tons of chemical fertilizer whereas it produces around 2 million metric tons per year. To fill the gap the country annually imports 1.45 million tons urea fertilizer and spends around $1.7 billion. As natural gas reserves have diminishing characteristics Bangladesh should look for alternative source of energy and fertilizer for its food and agricultural sustainability. This research focuses on producing nutrient rich organic fertilizer from biomass. Here, we constructed an experimental setup in Doulatpur, Kushtia targeting 10 tons output per month. We collected Cow dung from the neighboring dairy farms and followed vermi-composting method. We conducted experiments for three cycles i.e. 120 days per cycle-360 days in total and counted the vermi population for each consecutive cycle. We tested the output fertilizer in laboratory and found the component ratios suitable for agricultural lands. This fertilizer can also be used as a remedy for the barren lands. This report provides cost benefit analysis of this type of setups and shows an alternate way of green farming in Bangladesh.*

***Keywords****: Green Farming, Vermicomposting, Waste management, Organic Waste, Compost Fertilizer*

## 1. INTRODUCTION

Traditionally,Biomass provides 73% of the total energy supply in Bangladesh and it is a potential source of organic fertilizer. The common biomass resources available here are agricultural crop residues, wood residues, animal waste and municipal solid waste. (A.S.N Huda,2014) Agricultural residues supply 66.64% of the total recoverable bio-mass, which is followed by 17.53% from animal wastes and poultry droppings, 7.64% from municipal solid waste and 8.19% from forest residues. Animal wastes are a mixture of organic material, moisture and ash. The manure can be decomposed both in aerobic and anaerobic conditions. Under aerobic condition, carbon dioxide and stabilized organic materials are formed. On the other hand, at anaerobic condition, methane, carbon dioxide gas and stabilized organic materials are created. Thus bad odors of manure and annoyance gas emissions from the application of raw manure are reduced. (Abbasi T, Tauseef SM,2012) Biogas including methane produced from manure can also meet the cooking fuel demand. The quantity of manure production from the animals depends on age, breed and feeding habits. Also, the amount of dung yield varies with the seasons. For example, the dung yields are generated more in the rainy season than that of summer, since grasses grow more during raining. (Ramchandra,2004) And farmers cannot store dung due to the rains. The resources can be utilized on a larger scale for organic fertilizer production. There were lots of work done in a minor scale but the uniqueness of this research is to implement in larger scale, production will be in tons which can refer to the feasibility of commercial level production.

*Figure-1: Organic fertilizer plant in Daulotpur, Kushtia*

### *A. Chemical vs. Organic fertilizer*

Bangladesh has a large agrarian base with 76% of total population living in the rural areas and 90% of the rural people are directly related with agriculture. Fertilizer is considered to be one of the main inputs for increasing crop yields and farm profit. Conventional system uses chemical fertilizers mainly urea, superphosphate and potash. However, the continuous use of chemical fertilization leads to deterioration of soil characteristics and fertility, and may lead to the accumulation of heavy metals in plant tissues which compromises fruit nutrition value and edible quality. (Shimbo, S., 2001) Chemical fertilizer also reduces the protein content of crops, and the carbohydrate quality of such crops also gets degraded. (Marzouk, H.A 2011) Excess potassium content on chemically over fertilized soil decreases Vitamin C, carotene content and antioxidant compounds in vegetables. (Toor, R.K., Savage, G.P. & Heeb, A. 2006) Vegetables and fruits grown on chemically over fertilized soils are also more prone to attacks by insects and disease. (Karungi, S.2006) Although chemical fertilizers have been claimed as the most important contributor to the increase in world agricultural productivity over the past decades (Smil, V. (2001), the negative effects of chemical fertilizer on soil and environment limit its usage in sustainable agricultural systems. (Peyvast, Gh., Sedghi Moghaddam, M. & Olfati, J.A.2007) Weakening soil quality requires increasing inputs to maintain high yields. This, in turn, threatens future food security and raises production costs for often already poor farmers.

Research comparing soils of organically and chemically managed farming systems has recognized the higher soil organic matter and total nitrogen (N) with the use of organic agriculture Soil pH becomes higher, (Reganold, J.P. 1988) plant-available nutrient concentrations may be higher, and the total microbial population increases under organic management. (Clark, M.S., Horwath, W.R., Shennan, C. & Scow, K.M. 1998) Organic fertilizers, which mainly come from agricultural waste residues such as cow manure and spent mushroom compost or municipal solid waste compost (MSWC), are often identified as suitable local organic fertilizers. These contain high levels of nutrients, e.g. N and P and high amounts of organic matter. (Olfati, J.A., Peyvast, Gh., Nosrati-Rad, Z., Saliqedar, F. & Rezaie, F. 2009) According to these studies, the usage of MSWC can be an effective alternative to chemical fertilizers. However, the apparent deficiency of an adequate supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with organic fertilizer lower than in those treated with chemical fertilizers. (Blatt, C.R. 1991) Organic fertilizers should be used in appropriate amounts to achieve suitable yield and quality. It improves soil by providing slow-release plant nutrients, retaining moisture in soil, preventing plant disease, increasing nutritional content in plants, and producing tastier fruits and vegetables.

### *B. Vermicomposting:*

Vermicomposting is as a bio-oxidative process in which earthworms interact intensively with microorganisms and other fauna within the decomposer community, accelerating the stabilization of organic matter and modifying its physical and biochemical properties. The action of the earthworms in this process is physical or mechanical. Physical participation in degrading organic substrates results in fragmentation, thereby increasing the surface area of action, turnover and aeration. On the other hand, biochemical changes in the degradation of organic matter are carried out by microorganisms through enzymatic digestion, enrichment by nitrogen excrement and transport of inorganic and organic materials. (Yadav, 2013)

*Figure-2: Earth worms*

The benefits of vermicomposting in recycling of organic wastes, animal wastes, crop residues, industrial waste etc. are reported at laboratory scale, but there is paucity of data on the applicability of vermicomposting technology under natural environmental conditions. In this study we particularly focus on vermicomposting of Cow dung and crop residues under field conditions.

## 2. METHODOLOGY

Vermicomposting have no dependency on electricity or enzymes like Thermophilic composting. It reduces operational cost and has no depreciation of electric machineries. Besides there are several indicators for performance evaluation of vermicomposting process; like worm survival and biomass growth and worm population growth. The population of earthworm is self-controlled and limited by available food, space and environmental conditions. Under perfect conditions worm populations can be expected to double every after 60 to 90 days. (Glenn Munroe,2007) A mature breeder has high reproduction rate and produces a cocoon every after 7 to 10 days. It is possible to hatch a large quantity of earthworms out of an initial small setup. Comparing these net advantages, we choose vermicomposting method to process animal waste.

### *A. Experimental Setup*

We built a small vermicompost plant in vallage: Mohishkundi, Thana: Doulatpur, District: Kushtia. We designed appropriate size of beds for composting, beds for storing raw materials, beds for drying final output, area for storage, packing, material handling , etc. The plant had 16 beds to process around 10 MT of cow dung and crop residue like stalks and stubble (stems), leaves, and seed pods etc. The entire structure and beds were surrounded by boundary walls to protect the facilities from birds, and other predator insects & animals.

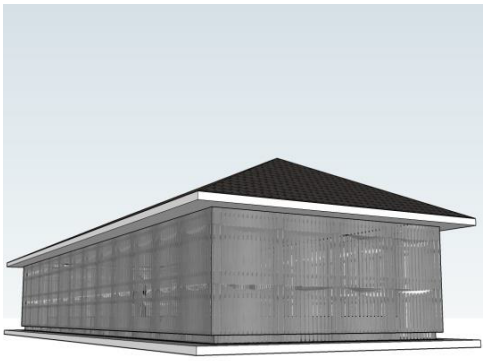

*Figure-3: 3D view of the compost plant*

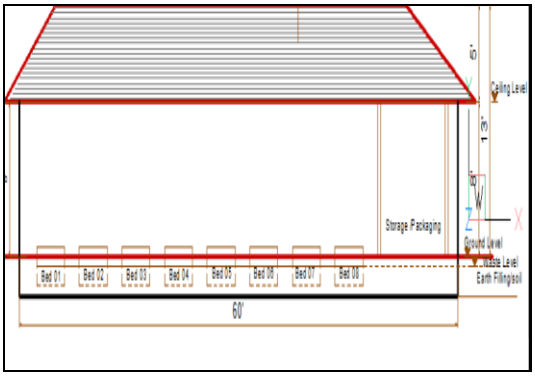


*Figure-4: Elevation of the compost plant*

### *B. Temperature control:*

The ideal temperature range for vermicomposting is 15ºC to 25ºC. If worm bed temperature drops below 15ºC, the worms will start to eat and reproduce less. If the temperature continues to drop they will go into survival mode. If the worm bed temperature drops below 5ºC, the worms will start to die off. On the other hand, if the worm bed temperature rises over 25ºC, the worms will start to eat and reproduce less. If the temperature gets over 35ºC, the worms will either die off or will leave in a mass exit which is every worm composter's worst nightmares. (Roohalah Rostami,2011)

In Kushtia, the average annual temperature is 26°C. May is the warmest month of the year and the temperature in May averages 30°C. January has the lowest average temperature of the year. It

is 18.5°C. (Climate-Data.org, 2016) For that, we made tin shaded structured and constructed the beds 1.5 feet beneath the surface to use the ground temperature. The beds were 5 feet in length, 2 feet in height, and 3 feet in width (with R.C.C slab) where each bed can process approximately 500 kg of wet cow dung and produce 150-200 kg of output fertilizer per month. Too much dung in a worm bed becomes a hot compost pile by generating internal heat and can kill the worms. So we kept the feeding layer less than 1 foot.

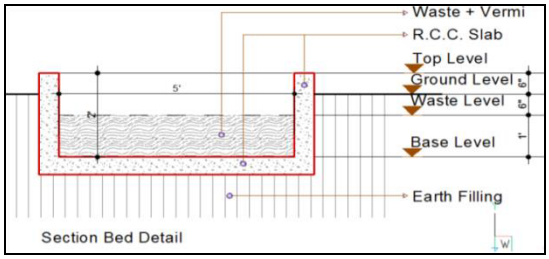


*Figure-4: Cross sectional view of worm beds*

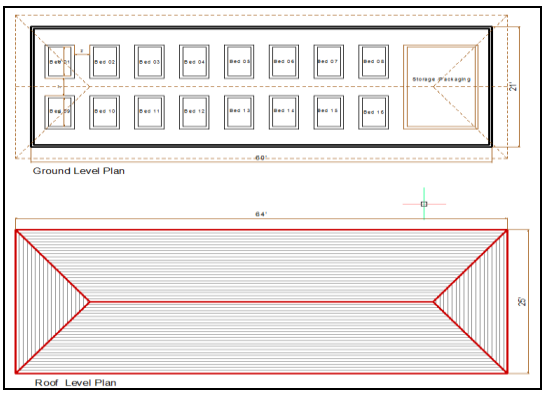


*Figure-5: Plan of the compost plant*

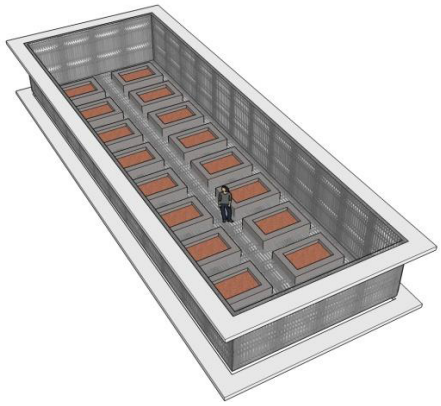

*Figure-6: Top View (3D) of the compost plant*

### *A. Raw material collection*

Available sources and continuous supply of raw materials are very critical for any vermicomposting plant. Under ideal condition earth worm doubles in their number in every two months. But if the supply of the raw materials is interrupted the geometric growth rate of worm population cannot be achieved. To ensure enough feed supply the project team announced among the villagers to store up cow dung to sell in the compost plant. About 40 local households and 5 dairy farms participated in the initiative and sold their animal waste and crop residue on an average price of 1 BDT/kg. Total raw material collection cost was around 1.5 BDT/kg where additional 0.5 BDT/kg is spent on packaging and transportation.

### *B. Moisture control*

Bedding is any material that provides the worms a relatively stable habitat. Worms breathe through their skins and if their skin dries out, they die. The bedding should absorb and retain water fairly enough for the worms to thrive. The ideal moisture-content range for beddings is 45-60%. (Rink, Robert,1992) We used moisture meter to determine the condition of the beds. We tried to maintain the necessary moisture by spraying water into the beds. Vermiwash is a liquid bio-fertilizer collected after the passage of water through a column of worms. It is a good foliar spray that acts as a plant tonic and helps to reduce plant diseases. [19] We made adequate drainage facilities and collection points for taking vermi-wash. (Zambare V. P., Padul M. V., Yadav A. A. and Shete T. B, 1990)

### *C. Ph Control*

Worms don't like too much acidic or alkaline food. They like food that has a pH value of 6.5-7.5 which is neither acidic nor alkaline in nature. If the feed is fresh vegetable or fruit waste then the pH value will be in the range of 3.2-3.5. Powdered limestone ($CaCO_3$) can be used to

improve pH level as $H^+$ ion acts as the acidity source. In chemical reactions $Ca^{2+}$ ion replaces $2H^+$ ions and produces water in combine with $OH^-$ (hydroxyl). As the acidity source is reduced by producing water the pH value is increased significantly. (Dr. John E. Sawyer, 2002)

$$CaCO_3 + 2H^+ = Ca^{2+} + CO2 \uparrow + H_2O$$

If the dry limestone powder touches the worms they will writhe around in pain and eventually will die off. So, dry limestone should not be applied on the top of the bedding. It should be soaked into water before mixing with the feed.

Beside we can control acid by turning the beddings weekly where the aeration process decreases the acid and improves pH. As cow dung has an average pH range of 7.5-8.3 (springer-link,2016) we did not use any limestone. We used 15% mix of the dry stalks and stems to improve the feed quality.

### *D. Stocking Earth worms*

Among thousands of species of earthworms, only a few were used on a wide scale and researched adequately for use in organic waste processing. The species used most commonly include Eisenia foetida (Red wiggler), Lumbricus rubellus (Red worm), Eisenia Andrei (Red tiger), Perionyx excavatus (Blue worm), Eudrilus eugeniae (African night crawler), Enchytraeids (White worm), Dendrobaena veneta and Perionyx hawayana. (Julie Orr, 2011)

We used Eisenia foetida (Red wiggler) worms as their growth and reproduction rate are high, their breeding cycle is approximately 30 days from mating to laying eggs and the worm population can be double after every 60 days. Red Wigglers are tough and hardy and they are very tolerant of variations in growing conditions. Each day they can consume organic materials equivalent to their body weight to produce nitrogen, phosphorous and potassium rich castings equal to 75% of their body weight. (Worm Farm Facts,2012)

We collected 0.1 million Red worms (1.5 BDT/worm) from another worm farm and stocked them in Doulatpur compost plant for waste processing and hatching.

### *E. Process Monitoring*

Simple smell test is enough for monitoring the process. If the feed smells rotten and wet it's probably turning anaerobic and that's bad. Some call it protein poisoning. (Worm Man's Worm and Crickets Farm 2018) This is when worms start to crawl on the surface, writhe in pain, deform and eventually die. If we see the worms are trying to escape even if they have plenty of food and clean beddings then we have to turn the beddings to get air into the feed. Bad bacteria do not like fresh air but the worms love it. We can use dry paper wastes and newspapers into the feed. We can also change the feed completely and treat it with powdered limestone.

*Figure-7: work in the compost plant*

## 3. HATCHING and PRODUCTION

We used 10 dedicated beds for hatching the earth worms and filled each bed with 500 kg of cow dung. The cow dung used is not fresh and used after 3 weeks from the collection time. It helped to reduce the moisture content of the wet dung. We put approximately 10,000 numbers of worms in each bed and monitored the worm growth rate and fertilizer production. We used natural condition and native technology and did not use any cooling fan or air conditioner to maintain the indoor environment.

### *A. Theoretical calculation*

Each worm weights aroung 0.5 mg and can eat 75% of their body weight/day and can produce 50% stool (compost fertilizer). (Red Worm Composting,2017)

In First cycle, each bed carries 10,000 worms that weight around $\frac{0.5\ mg*10,000}{1000}$= 5 kg

Everyday the worm can eat or process =5 kg*0.75= 3.75 kg waste/bed

From 10 beds the plant can daily process=3.75*10=37.5 kg waste.

For processing 500 kg waste each bed requires $\frac{500}{3.75}$=133.33=134 days (approx). For experimental suitability we consided 120 days for each cycle.

Everyday from each bed, 5kh*0.50= 2.5 kg fertilizer is produced. The plant can daily produce =2.5*10=25 kg organic fertilizer.

After first cycyle, plant production would be theoritically, 25*120 = 3000kg = 3 MT

As worm populacition can be double after 60 days, for 120 days the worm population becomes 20,000/bed, 0.2 million (approx) for the plant. With the increased worm population we can do similar calculation for the consecutive cycles.

### *B. Practical Results*

We started the hatching process on June 2013 and continued it for one full year. We completed three consecutive cycles of 120 days each. We counted output quantity and worm population. We used net (filters) to segregate worms from the output and used them for the next cycle of production and hatching.

As the experiment was conducted in natural environmental the practical data did not match the theoretical one. For example, after first cycle we got 0.15 million worms in place of 0.2 million. After second cycle we got 0.25 million in place of 0.4 million. Finally, after third cycle we got worm population 0.4 million in place of 0.8 million.

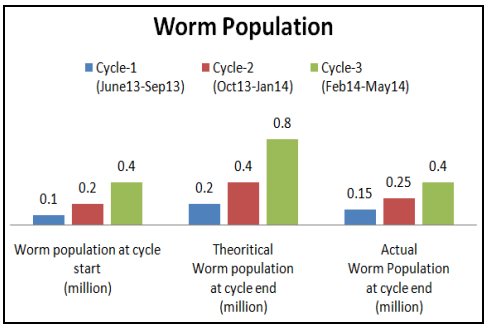


*Figure-8: Worm population in three cycles (One year)*

After first cycle the plant production was supposed to be 3 MT whereas we got 2MT output fertilizer. After secong cycle the plant output was supposed to be 6 MT whereas we got 4 MT output fertilizer. Finally at third cycle we got 10 MT output fertilizer. At this time the factory achieved 3MT/month fertilizer production capacity.

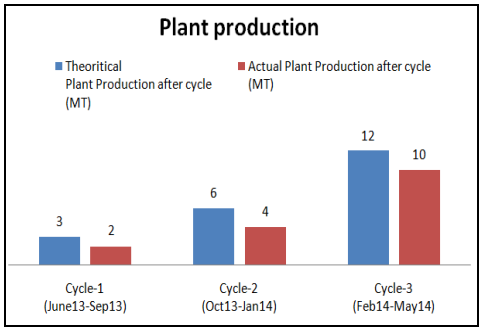


*Figure-9: Plant production in three cycles (One year)*

We Sent the output fertilizer sample in Mymensigh Agriculture university for Nutrient composition testing in the lab.

*Figure-10: Output fertilizer*

The test report says, the output fertilizer has a pH level 7.69 and have following nutrient content ratio:

| SL | Content | Nutrient in Output (%) |
|---|---|---|
| 1 | N (Nitrogen) | 1.792 |
| 2 | P (Phosphorous) | 0.5217 |
| 3 | K (Potassium) | 1.514 |
| 4 | S (Sulphur) | 0.135 |
| 5 | Na (Sodium) | 3.5642 |
| 6 | Zinc (Zn) | 0.0147 |
| 7 | Fe (Iron) | 0.33092 |
| 8 | Mn (Manganize) | 0.00933 |
| 9 | B (Boron) | 0.00688 |
| 10 | Mg (magnesium) | 0.48 |
| 11 | Ca (Calcium) | 5.5 |
| 12 | Cu (Cupper) | 0.00307 |

Table-1: Nutrient content in output fertilizer sample

From the above table we got a pie chart as follows:

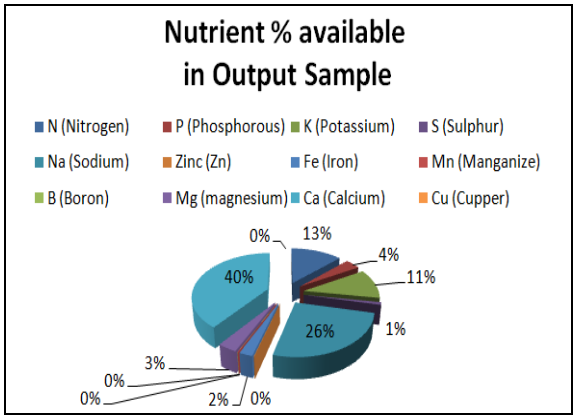


Figure-10: Nutrient content in output fertilizer sample

From Table-2 we get reference value of nutrient content and we compare it with the test results of Table-1. We found Nitrogen content 1.792% is slightly above the ususal range of 9.8-13.4%. The phosporus content 0.5217% is within the reference range of 0.19-1.02%. The Sodium content 3.5642% is higher than the average range of 0.058-0.158%. In this way we compared the other elements of the fertilizer and found that the output fertilizer is great to use for agricultural, horticultural, and ornamental and vegetables at any stage of the crop.

| Nutrient Element | Vermicompost (%) | Garden Compost (%) |
|---|---|---|
| Organic carbon | 9.8-13.4 | 12.2 |
| Nitrogen | 0.51-1.61 | 0.8 |
| Phosphorus | 0.19-1.02 | 0.35 |
| Potassium | 0.15-0.73 | 0.48 |
| Calcium | 1.18-7.61 | 2.27 |
| Magnesium | 0.093-0.568 | 0.57 |
| Sodium | 0.058-0.158 | <0.01 |
| Zinc | 0.0042-0.110 | 0.0012 |
| Copper | 0.0026-0.0048 | 0.0017 |
| Iron | 0.2050-1.3313 | 1.169 |
| Manganese | 0.0105-0.2038 | 0.0414 |

Table-2: Reference Nutrient element ratio ( Nagavaleemma,2004) for vermicompost fertilizer

### *A. Cost Benefit analysis*

A vermicompost plant which can produces 3MT-5MT output fertilizer per month and feed 1 million earth worms requires a minimum land area of 15,000 to 18000 suarefeet. It costs around 1.5 Lac BDT in rural areas. The plant contruction requires around 1.5 Lac BDT. If the plant starts with 0.1 million worm the cost will be 1.5 Lac BDT (considering 1.5 BDT/worm). In that case total capital investment would be: Land cost + Plant set up cost + Worm Procurement cost = 1.5+1.5+1.5 = 4.5 Lac BDT

Plant Operation costs include Raw material procurement cost (1 BDT/Kg) , labor cost (0.5 BDT/Kg) and packaging marketing cost (0.5 BDT/Kg). In total the production cost is 2 BDT/kg

At present Vermicompost fertilizer is sold in the market at a wholesale price of 12 BDT/Kg and a retail price 15 BDT/kg.

Considering the retail price there is a profit margin of 12-2 =10 BDT/kg

If the factory can produce a sustainable output of 3 MT per month the simple pay back period would be $\frac{4.5\ Lac\ BDT}{3000kg*10\ BDT/kg}$ = 15 months.

If proper effort is there, withing 2-3 years the factory can successfully payoff to its investors.

However continuous supply of raw material (any biomass or animal waste) is very critical for the sustainability of the plant. Enterpreneurs should give extra focus on this matter prior to the establishment.

## 4. DISCUSSION

Though vermicompost fertilizer have several economic and environmental advantages,Times of India(Farmers-go-for-chemicals-instead-of-vermicompost,2013) reported that the demand for vermicomposting has decreased over the years as only rich farmers, who export the farm production, are interested in buying the compost while no small farmers want to invest in it. They prefer chemical fertilizers over vermicomposting. Though, the price of vermicomposting is low and it gives quality agricultural products, the quantity of production is very low in compared to the chemical fertilizer production.

In this project we used practical design which refers to maintain ambient temperature system rather than controlled system to reduce the project cost and less technical environment to produce the vermi-compost which is more feasible.

Another criticism is that organic fertilizer works slowly on soil and its productive efficiency is lower than chemical fertilizer, (practicalaction.org,2015) which is costly. Very few companies produce organic fertilizer and some of its quality is questionable. The government provides a higher subsidy for chemical fertilizer that makes more vested interests so that disparity exists regarding the political economy of fertilizer policy and promotion. Entrepreneurs and investors lack knowledge and understanding about the market promotion and assessment of market demands, and policy barriers.

## 5. CONCLUSION

We think, Chemical fertilizer has detrimental effect on human health and environment. Though chemical fertilizer offers instantaneous results and higher yield but in the long run it causes soil infertility for many crop years and has domino effect in increasing cancer patients in the hospitals.

As Bangladesh is facing acute energy and fertilizer crisis too much dependency on chemical fertilizer is bad for future food and agricultural sustainability. Bangladesh should focus on alternative fertilizer production systems that require strict policy, short and midterm projects and visionary programs to minimize import dependency of chemical fertilizers. We believe, this type of compost plant can contribute largely in the agricultural economy and generate significant employment opportunities in the rural areas of Bangladesh.

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# ECOLOGICAL DESIGN AND PLANNING PROCESS USING GEOGRAPHIC INFORMATION SYSTEM:
## CASE STUDY, UPSHUR COUNTY YOUTH CAMP PROJECT

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***Abstract:*** *Now-a -days, Geographic information systems (GIS) is a common tool for any type of design decision and planning process for any profession. Before the invention of GIS software, people use difference types of survey tools for site analysis and made graphical representation manually with the acquired data. GIS makes these works more reliable and comfortable doing analysis to generate graphical representation with a variety of shapes and layer those shapes. This paper will show the process of using Geographic information systems mapping as a tool to do ecological design and planning for a landscape project. Through Arch map software, GIS was used here to analyse a site as well as to build a program for that site for further design decision. To do this, "Spatial Analyst Tools" in Arch Map was used to make an inventory site analysis. Then composite analysis was made taking various aspects from GIS map. Last of all, a layout of program was generated to go further to make a design decision. To implement this process, a site which was told to be designed as a youth camp was taken as a case study.*

***Keywords****: Geographic information systems (GIS), Ecological design, Planning, Landscape design.*

## 1. INTRODUCTION

In architecture or landscape architecture, it is a widespread practice to show diverse types of map and sometimes overlay those maps. Ian McHarg (1920 -2001) is credited as the father of map overlays, which is the basis of Geographical Information Systems. In GIS, limitless combination of different attributes is allowed. The attributes can be weighted arbitrarily and combined electronically to create one map. GIS can combine raster and vector data with computing technology. Data can be acquired from sophisticated digital imagery, GPS, satellite image, etc. Geography, mathematics, Databases, programming, computer mapping, mathematics, remote sensing, computer aided design, and computer science are the basis of GIS.

According to the perspective of ecological design, any form of design should minimize environmental damage which is came through human activities. GIS helps to analysis the elements of surrounding environmental. So, it helps to integrate with living process which is the base of ecological design.

The case study is situated in Upshur County, which is the northeastern county of West Virginia (WV), established in 1851 and named in honor of jurist and statesman Abel Parker Upshur. Upshur is primarily rural. The Upshur county has a total area of 355 square miles (920 km2), of which 355 square miles (920 km2) is land and 0.1 square miles (0.26 km2) (0.03%) is water [1]. This county has five parks and recreation places. James W. Curry Park, Pringle Tree Park, Historic Fidler's Mill, Upshur County Youth Camp, Upshur County Recreational Park.

The Upshur County Youth Camp is situated in Selbyville city. Selbyville is a city for Upshur County in the state of West Virginia. The youth camp has cabins, group camping areas, hiking trails, swimming pool. It has a tar pit portion. Historically, the site was primarily undeveloped land until the Buckhannon Chemical Company developed a facility on the site in 1908 to manufacture charcoal, wood alcohol (methanol), and calcium acetate. The tarpit portion of the site was used to dispose of wastes from the production of these three hazardous substances. Operations

and disposal of hazardous substances was continued until around 1933 when the facility was closed, abandoned, and salvaged.

In 1942, the Upshur County Farm Bureau bought the property and began to use it for the Upshur County Youth Camp. From 1942 to the present day, the property has been consistently used for hosting recreational activities under the Upshur County Youth camp program.

This paper will show the process of redesigning this area as a youth camp using GIS as a tool to take design decision and site analysis.

## 2. SITE DESCRIPTION

The larger Youth Camp Property is still in used today. The Tarpit Site has been unused since 1988. The 0.5-acre tarpit site was sealed by the US Environmental Protection Agency (USEPA) and included a reinforcing cover, a 6-8" soil cap over the cover, and an 8-foot chain link fence surrounding the perimeter to mitigate direct human contact to the tarpit contaminants [2]. Due to the age of the cap, ground cover and trees have penetrated the cap in several locations. However, the fencing around the perimeter of the tarpit is intact.

The Upshur County Commission and the Youth Camp's vision for the property is to expand recreational opportunities to its youth and broader community through cleanup of the Tarpit Site. The Commission plans for the site to be used as open space (Fig.1). So, some planning process is needed for the youth camp project. It is not only to propose a program but also to design the whole area through ecological design and planning process.

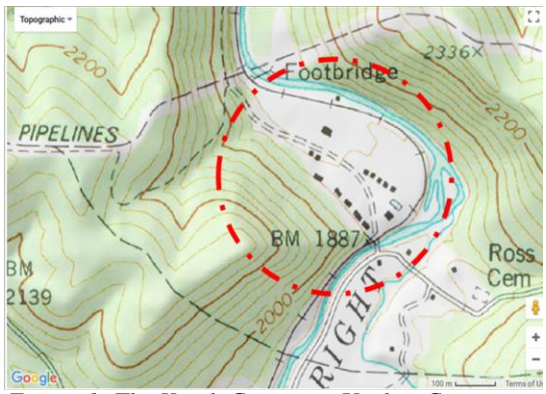


*Figure 1: The Youth Campsite, Upshur County, West Virginia (WV) (source: google map)*

## 3. LITERATURE REVIEW

"Ecology" means the relation of organisms to their environment in terms of welfare of that organisms [3]. Benton MacKaye explicitly linked regional planning to ecology. He defined regional planning as a comprehensive ordering or visualization of the possible or potential movement, activity or flow (from sources onward) of water, commodities or population, within a defined area or sphere, for laying therein the physical basis for the 'good life' or optimum human living. So, this ecological planning will be for a region that means it will be a regional planning. Ecological planning process can bring biodiversity and can balance between commercial needs and ecological needs.

It is the ethical obligation for a human being to establish an ecological balance. Leopold saw the need to protect the integrity of the ecosystem as a whole [4].

The sustainable planning solution for Upshur County Youth Camp Project should includes major duties to protect the natural environment. Ethical land-use policy acknowledges both the instrumental values served by and the inherent worth of the natural environment [4]. Decisions regarding this project require a basic respect for all forms of life, and a concerted and considerable effort to minimize the impacts of human actions on the other members of the biotic community. While some degree of human intrusion on the natural environment is inevitable, there is an ethical obligation to ensure that the human footprint is a small one [4].

Natural process is the best theory for any sustainable design. Ecological design is a way of strengthening the weave that links nature and culture. Just as architecture has traditionally concerned itself with problems of structure, form, and aesthetics, or as engineering has with safety and efficiency, to consciously cultivate an ecologically sound form of design that is consonant with the long-term survival of all species [5].

## 4. DESIGN STAGES

Ecological design explicitly addresses the design dimension of the environmental crisis. It is a form of engagement and partnership with nature. Ecological design offers three critical strategies for addressing this loss: conservation, regeneration,

and stewardship [5]. Ecological design works for regenerating the renewal tissues for a system. Conservation reduces the degradation of any system. Stewardship is a quality of care in relations with other living creatures and with the landscape [5]. Developing solution for this project should embrace these things. Ecological design can reduce the energy consumption so that people can engage with nature again.

In this project, at first, land pattern is important as it is related to nature and green space. It is helpful to make decision about spatial pattern of requirements, preferences, or predictions of some activities. Then, comes program. When the problem has been set and analyzed, then a detailed program can be made out [6]. Once the program has been done, then schematic plan. At the end of this phase, designer will develop one or more schematic plan showing building form and location, outdoor activity, surface circulation, ground form, and general landscaping. After that, detailed plan and contract documents is needed. Once the detail plan is approved, then it is time to go for supervision and implementation.

To summarize, there are eight stages in the typical site planning cycle in which the designer is properly involved [6].

- Defining the problem;
- Programming and the analysis of site and user;
- Schematic design and the preliminary cost estimate;
- Developed design and detailed costing;
- Contract documents;
- Bidding and contracting;
- Construction; and
- Occupation and management

## 5. INVENTORY ANALYSIS

Through the process of site inventory analysis, elements and conditions that will impact the ultimate use and design of landscape can be determined. Design, when based on thoughtful inventory analysis, can improve the environment, by creating new features based on the users' needs and keeping those features which are deemed useful and desirable.

### *5.1. Slope Analysis*

This map (Fig.2), shows the slope condition of this area. Slope is an important characteristic for building any structure. Digital elevation model data is used to create this map.

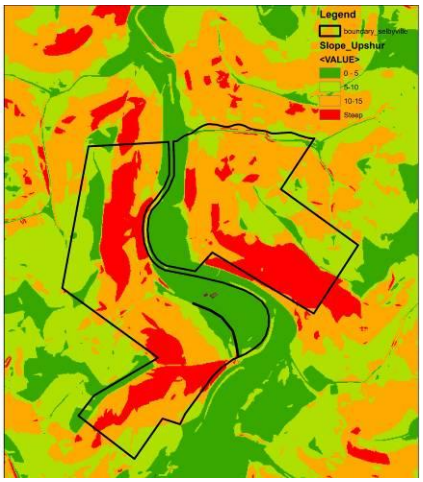


*Figure 2: Slope analysis for Upshur County*

The map shows that, there are hilly portion in both east and west side. Mainly the adjacent area of river Buckhannon has flat area.

Then Extract by Mask tool was used to show the condition only Selbyville area (Fig.3). It gives little different scenario. It shows that most of the portion of Selbyville has steep slope. But the western portion of the site has hilly area.

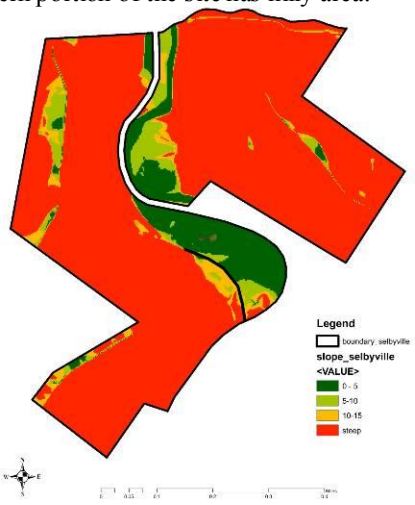


*Figure 3: Slope analysis for Selbyville area*

### *5.2. Aspect Analysis*

From the aspect analysis, it can be decided that, which portion has maximum sun disposure. Most of the portion of our project site is situated in North and Northeast facing Zone (Fig.4). North facing zone is good for ski runs.

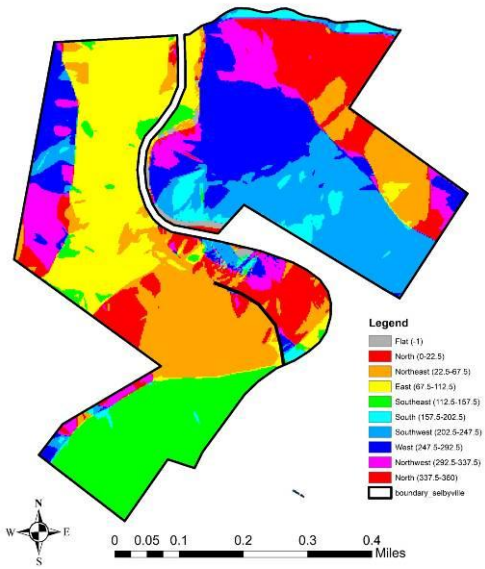


*Figure 4: Aspect of Selbyville area*

The portion of south facing slope is small. The snow will melt first at this portion. It is near the tarpit area. This south facing zone is good for placing any structure.

### *5.3. Physiographic Features Analysis*

Physiographic analysis of the site was carried out through GIS (Fig.5). Youth camp area generally has two types of physiological condition. One is moist flat and other is side slope.

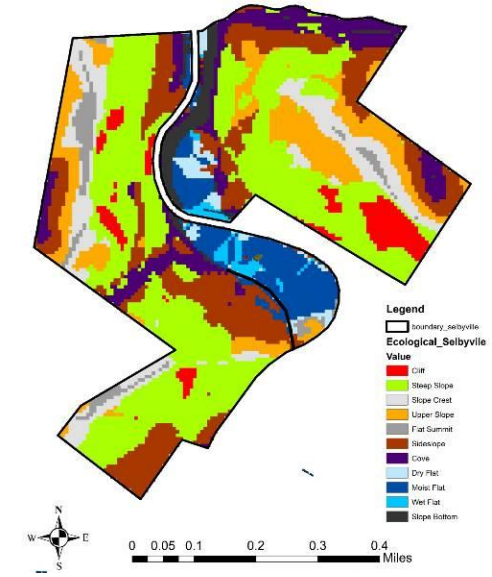


*Figure 5: Physiographic Features of Selbyville area*

There is also little cove area. Some portion is wet flat. Mainly wet flat portion has some water discharge problem, which makes this portion remained wet most of the time during rain.

### *5.4. Habitat Analysis*

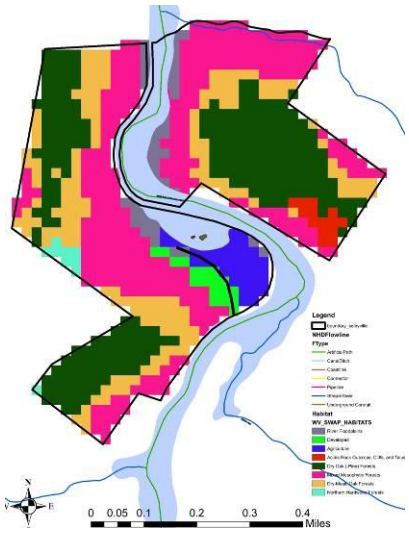


*Figure 6: National Hydrology flow line with Habitat*

This data set represents terrestrial habitats (Fig.6). Terrestrial habitats are broad classes based on natural and semi-natural vegetation, but map classes are also included of agriculture, developed areas, and open water. The maximum site area is good for agriculture. This map also shows the national hydrographic flow line, which means it shows the area of flood zone.

### *5.5. Soil Analysis*

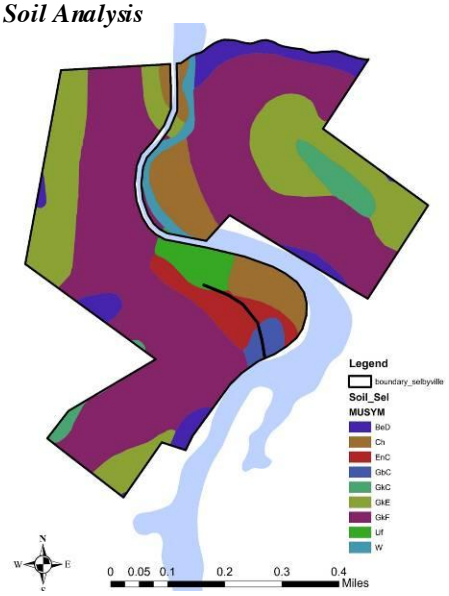


*Figure 7: Soil Analysis of Selbyville area*

The four hydrologic soil groups are:

**Group A.** Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

**Group B.** Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

**Group C.** Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

**Group D.** Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high-water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas (fig.7).

## 6. ECO-PLANNING

Generally, today's big city planning breaks the natural cycles. It is necessary to provide that connection through our project. By designing Upshur County Camp as a part of nature, resiliency is important. A well-structured approach will be needed to formulate propositions for designing a resilient locality. The lynch diagram (Fig.8) is showing the existing planning condition. Knowing existing condition and finishing site analysis, concept was evolved to maintain the ecology. Site inventory analysis gave a quite good reference for placing any activity in the site. Such as; flood zone should be avoided for building any structure. Physiographic features show the character of land. Soil analysis helps to understand the growing facility for plants and the stability for making structure.

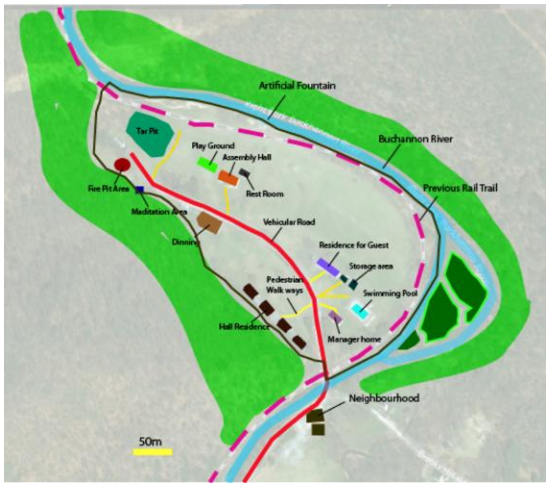


*Figure 8: Lynch Diagram of Selbyville area*

The harmonious balance between nature and built environment should be an inherent property of Upshur County Camp, not just mere a superficial one. The site should follow the core concept of ecological design that everything is connected to everything. Humans possess an innate tendency to seek connections with nature and other forms of life. Emphasis should be given on designing the area as a life sustaining and life enhancing habitat, not only for human but also for different living beings. Due to long contamination from the chemical waste, the natural environment has suffered severely. By restoring the natural order, a sustainable biophilia is generated.

*Figure 9: Conceptual design strategy for the area*

Designers should keep in mind that ecosystems are dynamic and interconnected. Conceptual design strategy (Fig.9) shows the design character and master plan for the area. Proposed structure locations followed the slope, aspect and soil analysis result. The plants' kingdom

is selected according to the soil types.

The aim should be to restore or repair a damaged ecosystem to return it to a former, healthy condition. Single-purpose solutions to narrowly-defined problems can cause unanticipated consequences. For this reason, the camp site should be emphasized as a whole, where preservation, conservation, restoration, reconstruction, and renewal of resources are prioritized to manage city ecosystem.

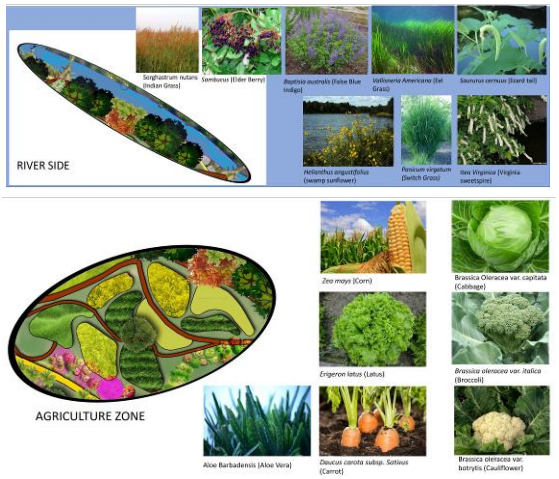


*Figure 10: Plantation Design according to soil type*

Natural features (Fig.10) play key role in enhancing the identity, legibility, coherence, and immediacy of urban form. The importance of natural elements should be emphasized in the design solution. Deep structure remains crucial to the history and future of the site– why it was settled, its initial location, its transportation routes, its economic development and population distribution, the character of its buildings, streets, and parks, and the health and safety of its residents. While designing the site, historical background of the site and relate that history with the present context is important. The reasons for embracing and promoting ecological design approach are compelling. This will have an essential role, not merely in producing safer and healthier urban habitats, but in making legible and tangible the systems that support life, and in changing the perception of what is possible. GIS helps to take several decisions for making location, transport routes, aesthetic appeal, future development area and so on.

It is necessary to provide a resilient design for any project. Resilience design can ensure the equilibrium state, after disturbance and GIS helps to do that through doing analysis with data and showing that in graphical representation. It helps to make the understanding more visible and reliable.

## 7. CONCLUSION

This paper shows basically the design procedure for a landscape project where GIS is used strongly as a decision-making tool through site analysis. Getting a clear perspective about the strength, weakness and opportunity of a location, is not only good for the designers but also for the users to understand about their needs and the reality. GIS helps to visualize the perspective of any situation through mapping and analysing the information, which is very helpful for any local and regional level landscape project to know the highest-level impact.

## ACKNOWLEDGEMENTS

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# IDENTIFYING LOW LYING CATCHMENT AREA FOR ENSUING SUSTAINABLE DISASTER MANAGEMENT:
## A CASE STUDY ON HAOR FLASH FLOOD AREA DETECTION

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***Abstract:*** *Haor basin covered a large amount of areas in Sylhet district which have been flooded during monsoon season. So, the early hitting of flash flood in haor basin created problems like death of livestock, destruction of crop production etc. People wouldn't get any warning before hitting as well as two or three upazila was being affected one at a time. Authority didn't get any notice or available data on the numbers of how many upazila going to hit and who need assistant to evacuate from home or property. After flood event, only way to assess the vulnerable areas is to identify the most affected areas and ensure sustainability of any development regarding land use and disaster management. This is quite impossible to identify the affected area through elevation.*

*In this context, catchment area detection and classify them as three different areas will help to get general idea about which district need more assistant than others. The main objective of this study is thus to detect the low-lying catchment area and reclassify those catchment areas into the high, moderate and low risk affected areas by using Hydrology tools in Arc-GIS software for haor basin and find out the low elevated high-risk areas. So, if there is predictable path of flood water moving and low land catchment areas, it will be very easy to identify the affected areas and save loss of property and human life. To sustain the disaster risk reduction (DRR) strategies by achieving Sustainable Development Goals(SDGs), this research could gain high amount of weightage in the path of these achievement.*

***Keywords****: Arc GIS, Low lying Catchment, Sustainability, Sylhet, Watershed*

## 1. INTRODUCTION

Bangladesh suffers from various natural disasters like cyclone, flood, storm surge, river bank erosion, drought, etc. with significant losses of lives and substantial costs to the economy. Low lying bowl-shaped haor basin which is covering around 6,000 sq. km in Sylhet Division. Haor flash flood is one of such kind of event. Flash flood in this region is stroked every year but the only problem these year the flood was came early. The early event caused loss of production. Loss of production was not that major concern in previous years. In 2017, these creates lots of issues. "Around 300,000 ha of boro field has destroyed in the haor due to the flash flood which counts around 12 lakh tons of rice" (Mostafiz, 2017). So, the problem is huge and it can be continued for next couple of years. In 2017, Haor flash flood is being most disastrous event which faced by Bangladeshi people. From March 17 when flash flood was entered into Sylhet division but in 2016, it was at April 19. So, the early striking of flash flood water into land made people faced like hugged death of livestock, destruction of crop plantation process etc. Bangladesh don't have any flood warning system or identification of affected area which might need assistant during flood or need special care in national disaster management policy. The authors of Dewan et al. (2007) upgraded flood hazard maps on the basis of Dhaka river basin of Bangladesh, by processing data of the historical major flood event of 1998 and considering the effects of land cover, elevation and geomorphological events. Larger city like Dhaka was worked by private organizations voluntarily but for haor flash flood, only BRAC seems have showing interest, not enough to build database or flood hazard map. After March 17, 2017 when flood water enters into Bangladesh crossing Indian border, people

wouldn't get any warning. There had been evidences that two or three upazila was inundated one at a time but the time for moving safe place wasn't available there. No specification of flood affected land area raised the causality of human and economic sector. The predictable path of flood water moving and also identify the low land can eliminate the risk of hazards turn into disaster.

Sylhet division, north-eastern part of Bangladesh especially is located in the low-lying area of the country. Most of the rivers like Meghna, Jumuna, Karnofully etc. in Bangladesh are originated from nearby hilly area of neighbouring country India. As a result of excess amount of rainfall, rivers are becoming extremely flashy which is characterized by sudden and wide variation in flow. If India faced extreme rainfall for 2-3 days then it was obvious that Bangladesh is also faced flood. For peoples living in north-eastern part of Bangladesh faces this common incident every year. Sylhet division is being affected every year. Near the foot of the abrupt Meghalaya Plateau at Sunamganj 5530 mm rainfall recorded and average 4180 mm in Sylhet. The highest rainfall in Bangladesh is 6400 mm in Lalakhal (Banglapedia). So, there is huge need to identify those area which may affect soon after flood water entered into Bangladesh from India. Excessive rainfall in Indian hilly region which encourage the natural system to make water moves quickly towards the Haor area of Bangladesh through rivers and canals. The Meghna basin is based on haor region of north-eastern part Bangladesh. For excessive rainfall, haor region was flooded these year. It is common in these regions but major problem is loss of production at high level. Crops, fish, ducks were begun to turned death after sudden flash flood. These create huge amount of production loss and created market panic as well as crisis. In the north-east region recent haor flash flood 2017, was triggered by heavy rainfall has reached the breaking point of embankments and resulted in inundation of haor areas in large scale. Haor flash flood has damaged seasonal boro crop which grown annually and also has adverse impact on livelihoods of haor dwellers. In natural hazards, economic loss considered as most concerning issue which imposed by flash flood and also hydrological, climate or natural hazard etc. are concerning matter day by day for their frequency, amount of affected people on a global and local scale (Marchi et al., 2010). In Sylhet division, it can be possible to predict the future affected zone through concerning socio-economic events as well as other matters.

Early 1990s, many watershed GIS applications have been developed for advancement of GIS capabilities, programming languages, and data availability. To identify those affected area, Watershed catchment area of Sylhet division will be identified and then Ranking between those area which may affected soon than other areas. There are several different indicators, that influence the vulnerability of a given terrain to the flash floods, such as: climate, topography, geomorphology, drainage capabilities and man-made structures (Youssef et al., 2011). Watershed delineation analysis determine the catchment area of any location with applying with its consecutive other tools. There have been many different approaches throughout the years to capture and describe the drainage possibilities, and through it, the susceptibility to exposure to the effects of heavy, rapid rains. Geomorphological information for flash flood has been already used by GIS tools in many similar studies. By using in hydrological modelling, it converts Digital Elevation Model (DEM) to delineate watersheds. (Maidment, 2002). The main aim is thus to identify the riskiest affected area of haor flash flood in Sylhet Division. The main objective of the study is specified below.

- To detect the primary areas where flood water reaches first in Sylhet Division
- Developed rank-based area classification on the base of low lying risky catchment area.

*Table 1: District–wise no's of haor and their area in Sylhet Division*

| District | Total area in ha | Haor area in ha | No. of Haor |
|---|---|---|---|
| **Sylhet** | 349,000 | 189,909 | 105 |
| **Sunamganj** | 367,000 | 268,531 | 95 |
| **Habiganj** | 263,700 | 109,514 | 14 |
| **Maulvibazar** | 279,900 | 47,602 | 3 |

*Source: Haor Master Plan, 2012*

## 2. STUDY AREA

Recent hoar flash flood affected on six districts. The whole study was focus on specific Sylhet division which contain four districts (Figure 1). There is a chance to study further on other two districts. In north east region Sylhet division which is situated at the foothills of Meghalaya and Assam states in India. This division has four districts Sylhet, Moulavibazar, Sunamganj, Habiganj. These districts have around 615,556 ha land under Haor region which contain 217 Haor.

"Haor" or wetland is Known by people of Bangladesh and this region is generally inundated every year in mid-May and for six months stays in underwater. Haor region in Sylhet division has hydrological characteristics. The region receives water from the catchment slopes of the Shillong Plateau which is across the Indian borders to the north and the Tripura Hills in south-east India. (Haor Master Plan, 2012).

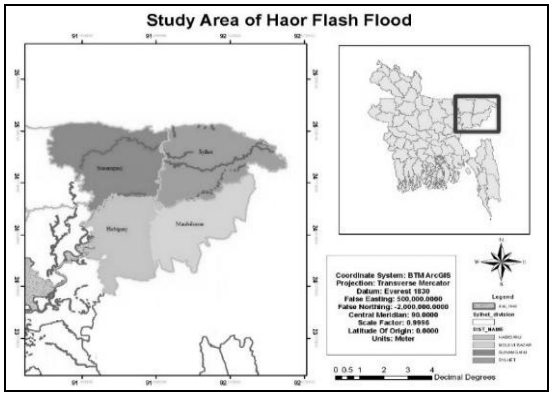


*Figure 1: Study Area*

## 3. METHODOLODY

The research method is developed based on developing conceptual framework and provide description of it. The study was conducted by software-based analysis.

### *3.1. Conceptual Framework*

The whole study was conducted on the basis of several following steps consecutively. Figure 2 shows these steps. The conceptual framework is given below with specific guideline of how objectives can be achieved.

There are two objectives have been selected to detect the low-lying catchment area and reclassify them and distribute them to 3 different part of risky zone.

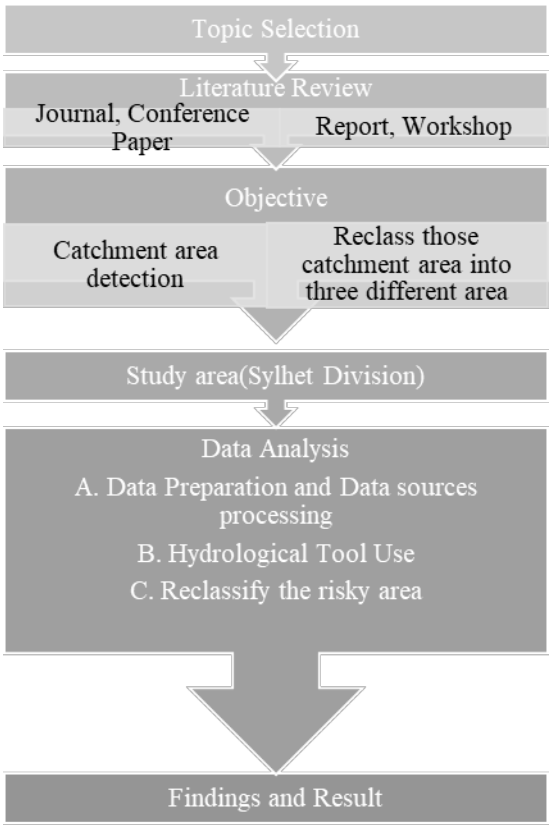


*Figure 2: Flow chart of Conceptual framework working in study as well as GIS*

### *3.2. Data Analysis*

Data analysis is divided into three parts. A. Data preparation and data source processing, B. Hydrological tool use in ARC GIS 10 software and C. Reclassify the risky area in ARC GIS 10 software.

### *3.3. Data Preparation and Processing*

The data source for this study, DEM is built up on the basis of available terrain data from "ZONUM SOLUTION" free software tools. It captured from 23°58' to 25°12' latitude and 90°50' to 92°30' from Longitude which covers the following study area. In the software around 4000 terrain point captured (Figure 3) and each row and column are having 100 and 40 points in uniform grid. All the data are collected in .txt file format and then imported to Arc GIS 10.0 software as row data for Digital Elevation Model. In Spatial

Analyst tool which is mainly converting vector feature into a raster grid and multiplying the original DEM with the raster grid, a new DEM is generated.

The coordinate system was converted from geographic systems to a projected geographic system, by using Arc Tool box (data Management, projections and transformations, raster, project raster) in Arc-Map.

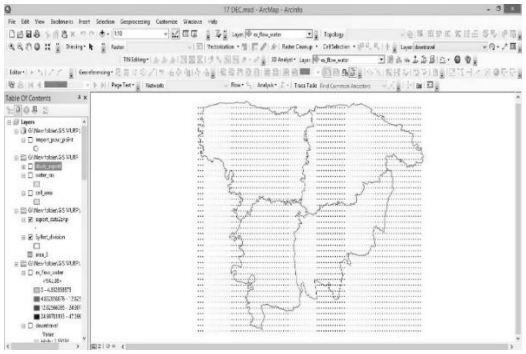

*Figure 3: 4000 Terrain Data*

Bangladesh Transverse Mercator (BTM) was selected because it is a coordinate system that is more adaptable to the study area.

After processing data from terrain to digital elevation model (DEM), there is several tools have been used to get results. The tools were running consecutively Fill, Flow Direction, Flow Accumulation, Pour Point Selection and Watershed delineation.

In Arc GIS, reclassify tool have been used to class them. With equal distribution of Catchment area in three specific zones have been added below.

- High Risk Catchment Area
- Moderate Risk Catchment Area
- Less Risk Catchment Area

Study finding have been determined on the basis of ultimate result from conducting reclassify tool and get results of risky area.

## 4. RESULTS AND DISCUSSION

The whole data processing is divided into two parts according to study objectives. (1) Detection Low Lying Catchment Area in Sylhet Division and (2) Rank Based Area Classification on Risky Catchment Area.

### *4.1. Detection of Low Lying Catchment Area*

This fulfilment of this objective will help to identify the low-lying catchment area in Sylhet Division. The catchment area detection was conducted on the basis of Hydrology GIS tool with help of Arc GIS 10.5. The tool was being used in the system are Flow direction, Fill, Flow Accumulation, Topo to Raster, Pour point, Watershed. This determine the path of flood water moving and the identify which catchment area receive the maximum water during next flood.

#### *4.1.1. Terrain data processing*

A terrain data processing has been started with the identification of drainage and catchment patterns through DEM which was mainly used to prepare the spatial information of the Haor beel area specifically for Sylhet Division. The Digital Elevation Model was processed using Hydrology Tools in Arc-Map, because the application of this tool allowed generation of information of fil, flow direction, flow accumulation, drainage lines, and watershed delineation for the Haor beel (US Army Corps of Engineers [USACE]., 2010). This information will help to accumulate the data regarding to our study objectives.

Once the area was specified, DEM reconditioning is necessary to consider unclear flow direction which occurred by any surface flooding. This technique allowed the adjustment of the surface of elevation of the DEM to be consistent with vector coverage. Therefore, it helped to find cells in a DEM with low elevation enclosed by other cells with high elevation. These low cells, so called “sinks”, may be formed by the landscape features or errors during the DEM generation as well as by the limited resolution of the Digital Elevation Model. The sink is filled until it will drain the water to the next lowest point by using “fill” tool in Arc Map interface.

#### *4.1.2. Flow direction and flow accumulation*

After DEM analysis, several tools had been used consecutively. After using Fill tool, Flow direction and Flow accumulation tool, there have some results which may presents some finding about the direction of water flow (Figure 5). Flow direction determines the direction of a site drains and determine the direction of flow for each cell in

the site.

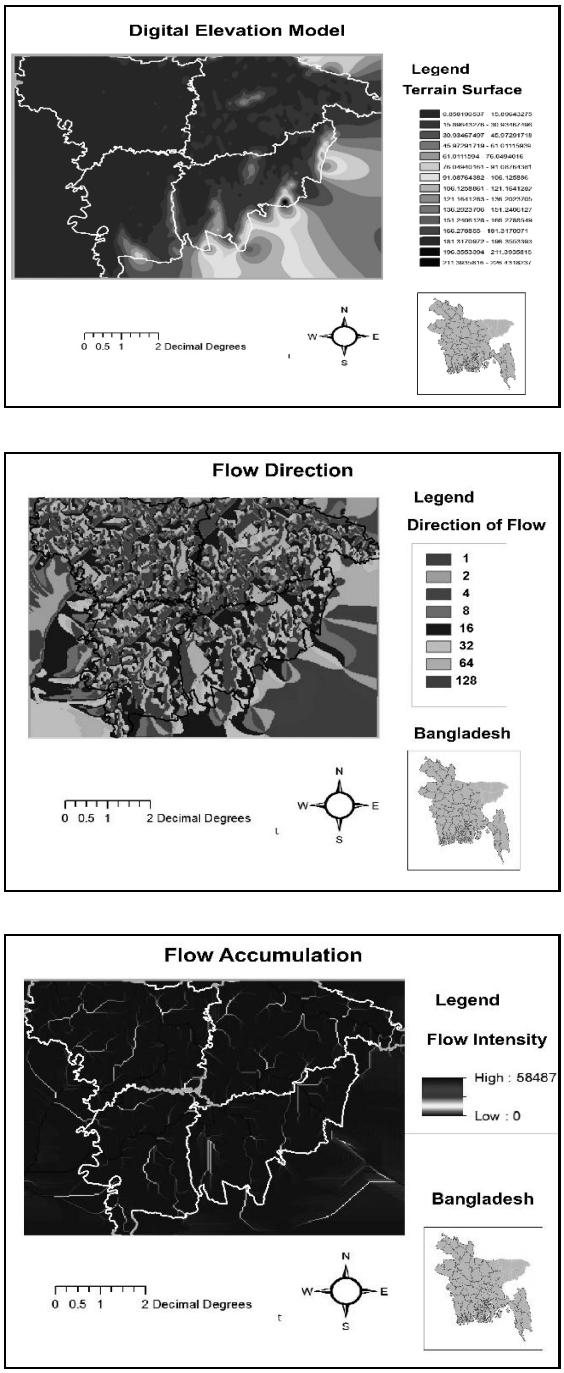


*Figure 4: (a) DEM, (b) Flow direction, and (c) Flow Accumulation map*

The flow direction for the Sylhet division was determined for the filled DEM, which is one of the most important for generating the hydrologic characteristics. In Arc Map, the flow direction tool finds out the steepest ancestry direction from each cell in the grid. There are eight output directions in which the flow of a cell can move in the basin. It mainly calculated the direction of the flow to

The flow accumulation for the Sylhet Division was calculated taking as base the flow direction. Its procedure consisted of calculating the accumulated

flow for each cell as the weight of each of them which flows through down slope. Therefore, the output of the flow accumulation represents the amount of water which would flow through each cell and it is also used as a base to create the drainage lines.

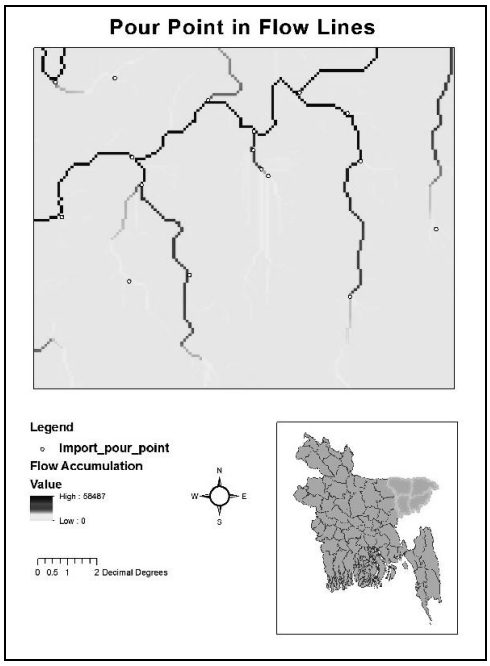


*Figure 5: Pour Point on Flow Accumulation Path*

*4.1.3. Pour Point detection*

After flow accumulation with other tools, to conducting delineation of watersheds, is to select pour points which typically points at the edge of the grid, or just downstream of major confluences. There around 62 pour point identified and input it with editor tool. Flow Accumulation measure distance of stream gage from an area of high accumulation grid. An area shaded blue is indicating high flow accumulation which is on top of or near the stream gage. The nearest high value flow accumulation cell represents the distance between stream gage point and the centre point of cell. The distance is about 25 meters to each of the nearest cells and it is on blue colour cell. Firstly,

outlet point was created on the flow accumulation path where the flow leaves the Haor Beel for this end. Mainly the drainage lines, accumulated flow, flow lines have delineated the watershed.

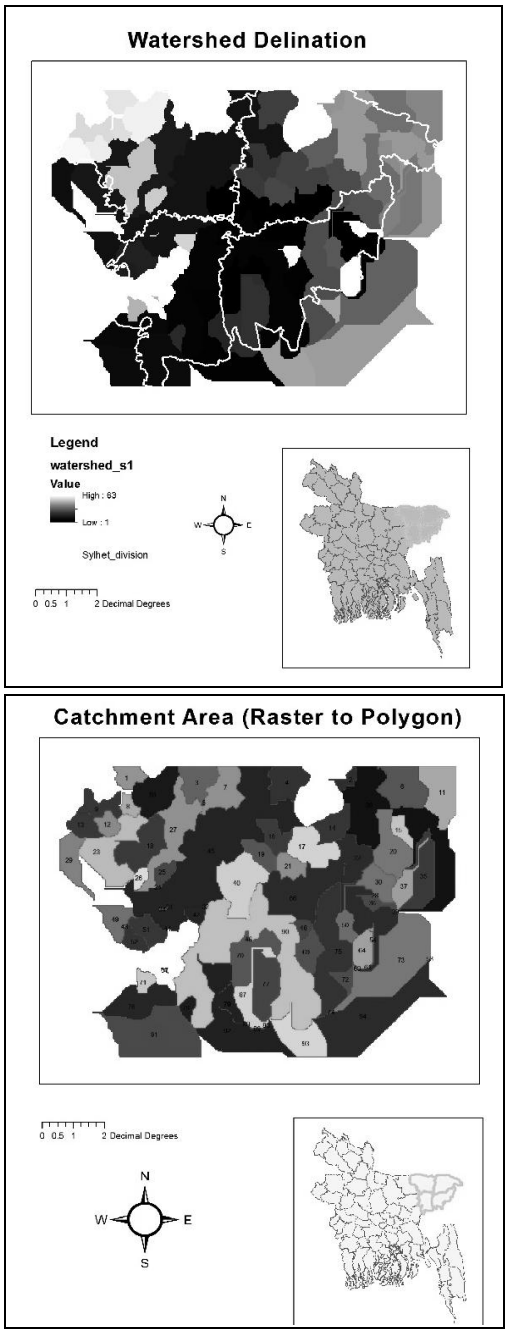


*Figure 6: (a) Black Polygon Represents the Catchment area with high possible of water logged area, less blackish polygon represents the moderate possible water-logged area. White polygon for Less possible water-logged area, (b) Catchment area (Raster to Polygon).*

*4.1.4. Watershed processing and catchment area detection*

In watershed processing delineation of the watershed as well as determination of the flow path in the river basin have been done. Arc Map was used to carry out this process. In this part, a bath point was created in the outlet of the basin in order to delineate it. There are 63 catchment areas detected by Watershed tool in Arc GIS. Watershed raster data need to convert into polygon which was done by Raster to Polygon tool in Arc Map. This process produces 94 catchment areas (Figure 6).

### *4.2. Rank Based Area Classification on Risky Catchment Area*

Using Reclassify tool in Arc Map, the area has been divided into 3 parts which are defined the high, moderate and low risky catchment area as shown in Table 2. Reclassify was done taking as base the Watershed. According to prediction on the flash flood water entrance in haor area, the high-risk area will be the first to face the flash flooding and afterwards, moderate and low risky catchment area showing further flash flooding.

*Table 2: Reclassify the Catchment area*

| Watershed Catchment | Reclassify the Catchment Area |
|---|---|
| **1-21** | High Risk Catchment area |
| **22-42** | Moderate Risk Catchment |
| **43-63** | Low Risk Catchment |

## 5. FINDINGS

Following results from analysis, come with set of ideas that Sylhet division have around 63 catchment area which may fill first when flash flood water enters to Bangladesh.

In this process there are three category (Figure 7) which also showed that which catchment area might be fill up first. 21 High risk catchments could need much more attention to detect future flow direction of water as well as low catchment area. Then the second priority will the 22-42 no. catchment area, which will be affective just after the high-risk catchment area.

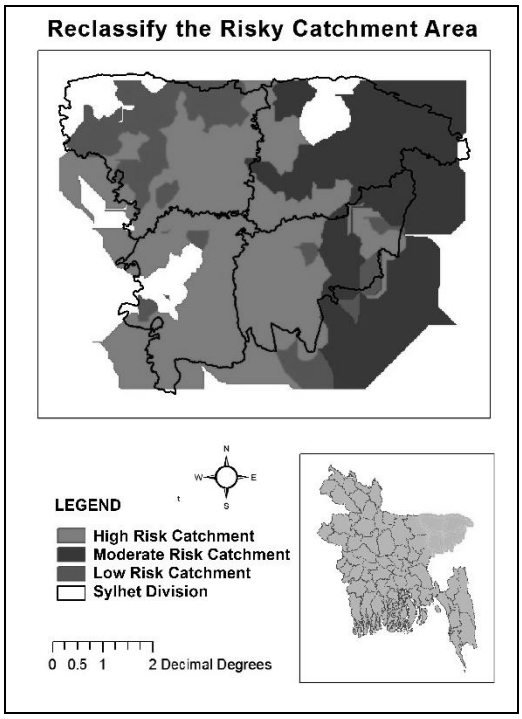


*Figure 7: Reclassify of water catchment area.*

## 6. CONCLUSIONS

Sustainable action plan is required immediately for those affected areas which are under high risk. Habiganj, Moulovibazar, Sunamganj are found to consume dramatically high amount of risk area. On the other hands Sylhet is safe from inundation of flood water. These districts also have considerable number of rivers so these could be justifying the low-lying catchment in these areas. The action has to be taken fast to control the situation as well as the life of haor people. As large portion of GDP coming from Haor area every year through fish and rice cultivation so after this event the vulnerability tried to turn into disaster and directly affected disaster economic loss in relation to global GDP. At some point, to achieve SDGs 11 may successfully achieve in Bangladesh after government interventions. But these event of Haor flash flood in 2017, can be a great imbalanced for the next year or more after another one will come across. So, the analysis and detection of catchment area could verify the vulnerable area which may save the most affective zone after the haor water entrance. So, it could save millions worth of property otherwise production being inundated.

There is a scope to prepare an emergency evacuation plan for these 4 districts as well as other two districts which are also victims of seasonal flash flood. The districts are Netrokona and Kishorgonj. But for short time shortage, it may not possible to conduct study on those two districts.

Another scope of this study, it is now quite easy to identify vulnerable areas of Sylhet division so that it can be added advantages towards sustainable development process in Sylhet Division and this will save millions worth of money and property.

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