4TH GCSTMR WORLD CONGRESS, 19 - 22 JANUARY, 2019, DHAKA, BANGLADESH

1ST INTERNATIONAL CONFERENCE ON SUSTAINABILITY IN THE NATURAL AND BUILT ENVIRONMENT

(ICSNBE-2019, DHAKA)

Proceedings of the

1st International Conference on Sustainability in the natural and built environment

(iCSNBE-2019, Dhaka)

19 - 22 January 2019

Dhaka, Bangladesh

EDITORS

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Proceedings Book of the 1st International Conference on Sustainability in the Natural and Built Environment (iCSNBE-2019), 19-22 January 2019, Dhaka, Bangladesh

Published by Science, Technology and Management Crest Australia (STAMCA)
in association with
Global Circle for Scientific, Technological and Management Research, Sydney, Australia

The Conference Supporters and Sponsors

Hosted by: North South University (NSU)

Supported by: Department of Environmental Science and Management (ESM), NSU

Event Partner: Noman Group

Media Sponsors: Prokriti O Jibon Foundation and Channel I

Editorial Team

Date published:
19 January 2019

Publisher:
Science, Technology and Management Crest
12 Boyer Pl, Minto, New South Wales 2565, Sydney, Australia

Paper Peer Review Process:

All full-length papers included in the Proceedings of the 1st International Conference on Sustainability in the Natural and Built Environment (iCSNBE-2019), 19-22 January 2019, Dhaka, Bangladesh have been independently peer reviewed by two reviewers. The submitted abstracts were reviewed by the Technical Committee, and if the abstract was accepted, the author was invited to submit the full papers. The full papers were then reviewed, and the review comments were sent to the authors to address the comments in updating his/her papers. The revised paper submitted by the authors was then checked by the Editors, and accepted once the paper satisfied the requirements of the Conference.

Welcome by the GCSTMR Chair

The International Conference on Sustainability in Natural and Built Environment (iCSNBE-2019), Dhaka, Bangladesh aims to provide an international platform for effective exchange of ideas, reaffirming the existing collegial contacts, provide opportunities for establishing new ones as well as providing a forum for academics and researchers to present and share the results and findings of their latest research and practice on a wide range of topics relevant to sustainability in both the natural and built environment. Sustainability is the core of today's research in many different fields of knowledge which endeavours to make our planet more liveable by numerous actions including proper utilisation of energy and natural resources.

As the Chair of Global Circle for Scientific, Technological and Management Research (GCSTMR), the Principal Supporting Organisation of the iCSNBE-2019, I would like to thank the Hon'ble Vice-Chancellor of North South University Prof. Dr. Atiqul Islam and the Pro-Vice Chancellor (Designate), Prof. Dr. Gias U. Ahsan for providing the venues of the conference and supporting all its activities. I would also like to extend my gratitude to North South University and Noman Group for sponsoring the event and Prokriti O Jibon Foundation, Channel I and North South University's Public Relations Office for the media coverage. Also, thanks to Mr. Sabur Khan, Chairman, Daffodil International University for sponsoring the Conference Dinner. Thank you to all other sponsors, Keynote Speakers, Invited Speakers, Authors, Secretaries, IT Team Members, Conference Advisory Committee Members, Organising Committee Members, Technical Committee Members, Reviewers and Volunteers for making this conference a reality.

Finally, I would like to convey my heartiest thanks to the iCSNBE-2019 Technical Committee (TC), especially TC Chairs Dr. Rafiqul Islam and Prof. Dr. Md Jakariya and the Conference Secretaries Engr. Shafi Noor and Raisa Bashar, for their hard work over day and night to make this conference highly successful.

Ataur Rahman

Prof. Dr. Ataur Rahman, PhD, FIE Aust., MASCE, MAGU, MIWA, MAWA
Professor (Water Engineering), Western Sydney University, Sydney, Australia
Chair, Global Circle for Scientific, Technological and Management Research (GCSTMR), Sydney, Australia

Welcome by Conference Chair

Sustainability is a growing global concern as the human lifestyle on the planet is rapidly changing with impacts on the climate, resource stress and global lifestyle gap. Global citizen needs to understand all the facets of concepts of sustainability. The 1st International Conference on Sustainability in the Natural and Build Environment provides such an international platform for effective collaboration of ideas and networking opportunity for academics, researchers, industry partners, government and politician then to enabling collective efforts to re-design the lifestyle that is going to be as comfortable as the planet can support for every global citizen as equal as possible.

This conference has attracted papers from wide disciplines of science and engineering, from academics and industry researchers making it the most diverse but effective forum for exchange of knowledge and actions. Areas covered are urban planning, transportation, waste management, construction, renewable energy technologies, climate impacts, agriculture and marine science. There were 83 abstracts submitted by total 159 authors from 8 nations across the globe. The highest numbers of authors (131) from Bangladesh and 2nd highest is from Australia (17). Out of those, total 46 full papers have been accepted after extensive reviews. As the first conference of this kind in Bangladesh, it is considered a great success and demonstrate the keenness of sustainability work globally, especially citizens of Bangladesh.

As the General Chair of this valued conference being held during 19-22 January 2019, in Dhaka, I would like to thank the Plenary Speakers, Keynote Speakers, Invited Speakers, Authors, Sponsors, Conference Advisory Committee Members, Organising Committee Members, Technical Committee Members, Reviewers, Volunteers and anyone who supported indirectly whose names could not be listed, for making this conference successful.

Rafiqul Islam (PhD)
Principal and Director, Solar E. Technology, Australia
Chair, 1st International Conference on Sustainability in the Natural and Build Environment

Welcome by Conference Co-Chair

The 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE) 2019 is a bold and timely initiative. As sustainability is a major global concern, this conference provides a platform for presenting papers on interesting topics that could help influence ideas for sustainable development.

I am excited for the papers that are to be presented at the conference. The program is enriched through the participation of a wide range of national and international academics from different disciplines coming together to tackle sustainability issues. iCSNBE can be an academic platform where, through generating new ideas it can help developers find solutions for a problem. The papers cover some new and different hypotheses and introduce policy directions and sustainable ideas that could help academics and also policy makers to attain certain SDG goals.

The successful organization of iCSNBE – 2019 would not have been possible without the tireless work and dedication of a few extremely hardworking people. I am extremely grateful to the General Chair of iCSNBE 2019, Dr. Rafiqul Islam and the Chair of GSTMR, Dr. Ataur Rahman, for their constant support. I am also thankful to Ms. Raisa Bashar and Ms. Haniyum Maria Khan and their diligent team of volunteers from Environmental Science and Management department of North South University for working tirelessly in making this event a success. My gratitude also goes out for all other editors, including Engr Caleb, Mr. Noor and Dr. Khandakar.

I would like to thank the Hon'ble Vice-Chancellor of North South University, Prof. Dr. Atiqul Islam and the Pro-Vice Chancellor (Designate), Prof. Dr. Gias U. Ahsan, for supporting iCSNBE's activities. I would also like to extend my gratitude to Mr. Abdullah M. Talha of Noman Group for sponsoring the event and Mr. Muqeed Majumdar Babu of Prokriti O Jibon Foundation and Channel I and North South University's Public Relations Office for the media coverage. Also, thanks to Mr. Sabur Khan, Chairman, Daffodil International University for sponsoring the Conference Dinner. As Co-Chair of the conference, I would like to thank the Plenary Speakers, Keynote Speakers, Invited Speakers, Authors, Sponsors, Conference Advisory Committee Members, Organising Committee Members, Technical Committee Members, Reviewers and anyone who supported indirectly whose names could not be listed, for making this conference successful.

Md. Jakariya, PhD
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Engr. Caleb Amos, Doctoral Scholar, Western Sydney University, Australia

PLENARY SPEAKER

Professor Vivian W. Y. Tam
Title: Construction Automation – A Concrete Perceptive

Dr. Tam is the Associate Dean (International) at School of Computing, Engineering and Mathematics, Western Sydney University, Australia and Honorary Professor at College of Civil Engineering, Shenzhen University, China. Her research interests are in the areas of environmental management in construction and sustainable development, focusing on life-cycle analyses, green building and recycled concrete.

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

CO_2 Concrete

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Abstract

This multi-disciplinary project aims to utilise waste material and greenhouse-gas-emission to create new high-grade material for structural applications: CO_2 Concrete (under a company trade name of 'Ecobond', http://www.ecobond.com.au). The new material is the first of its kind for recycled concrete research to: (i) fully realise the effectiveness of recycled concrete; (ii) raise the industry's awareness on the severe impact of greenhouse-gas emissions on the environment; and (iii) recognise the potential of CO_2 Concrete for high-grade structural applications. It is emphasised that recycled concrete has been used only for non-structural applications and its potential has been significantly suppressed mainly because thorough research has been insufficiently performed. Using our new techniques, the new CO_2 Concrete has improved its strength by 29% from which has matched the strength of virgin concrete. The new CO_2 Concrete also uses less cement than virgin concrete which makes CO_2 Concrete more environment-friendly.

1. BACKGROUND

This research focuses on converting greenhouse-gas-emission and demolished concrete waste, i.e. if not being used will mostly be dumped to landfills which undesirably consume precious land, into useful ingredients to create the new material. The new material, CO_2 Concrete, is created from this project which

is a useful addition to the construction industry. Up till now, the only recycled aggregate classification manual available in Australia (Ref: H155-2002) is only allowed for non-structural concrete applications (Cadwell 1951, Commonwealth Scientific and Industrial Research Organization 1998, Commonwealth Scientific and Industrial Research Organization 2002) because researchers have not yet discovered an innovative way to increase chemical bonding in recycled concrete. Companies have long pessimistically believed that recycled aggregate is inferior to the normal aggregate (Commonwealth Scientific and Industrial Research Organization 1998, Commonwealth Scientific and Industrial Research Organization 2002, Commonwealth Scientific and Industrial Research Organization 2006). This old belief blindly neglects the usefulness of recycled concrete created from carbon-conditioned recycled aggregate for high-grade applications even though high-grade recycled concrete has been pioneered from the works of Professor Vivian Tam with applications were successfully implemented in Hong Kong. In this research, it is the first time that CO_2 Concrete is specifically created for high-grade applications using software embedded in a new automation system running on a computer to identify optimal design criteria.

Greenhouse-gas-emission is one of the most impacting environmental issues in today's society. Greenhouse gases are known to absorb infrared radiation in the atmosphere. The most common greenhouse gases emitted by human activities are CO_2 of about 77% according to data from United States Environmental Protection Agency (2012). The rapidly-increasing trend in global CO_2 emissions (about 23.64% since 1990), particularly since the early nineties has led to the generation of about 50,000 metric tonnes of CO_2-equivalent in the whole world for 2010 as seen in Figure 1. Designing high-grade CO_2 Concrete with low life-cycle cost and greenhouse-gas-emission for buildings will solve one of the pressing issues in Australia and around the world in providing a single national reporting framework for energy and greenhouse-gas-emission (Australian Government 2016).

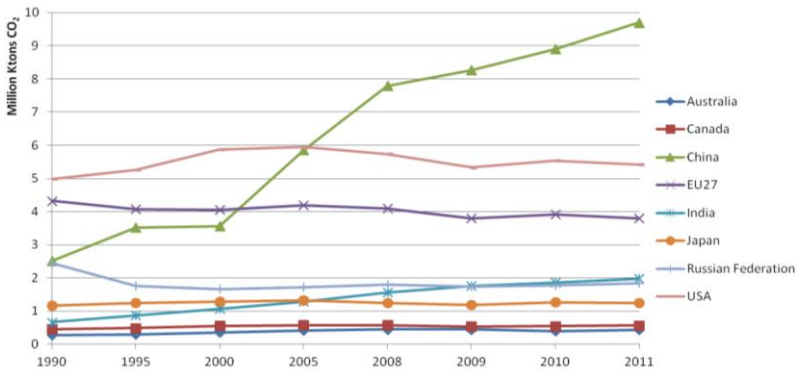

Figure 1: Total CO_2 emissions from various countries (Joint Research Centre 2015)

1.1 Carbon-Conditioning Process and Its Concrete Improvement

For CO_2 Aggregate, a carbonation chamber was designed and built, including a translucent polyvinyl chloride pressure pipe with a screw top lid connecting to a CO_2 tank, brandishing a regulator in controlling pressure. CO_2 was introduced to the chamber for the experimented pressure and duration. Figure 2 illustrates the carbonation chamber used.

Figure 2: Carbonation chamber

Experimental work has been conducted by varying recycled aggregate replacement percentages, chamber pressure and chamber duration. It has been found that the carbon-conditioning process for recycled aggregate improves CO_2 Concrete strength that matched the virgin concrete as seen in figure 3.

The carbon-conditioning process has reduced porosity and water absorbency of recycled aggregate. In addition to improving recycled aggregate quality, pressurised CO_2 also helps fill openings in the concrete composition, generating sufficiently strong chemical bonding mixture between old aggregate and the old cement mortar defined as old interfacial transition zones. Recycled aggregate of various qualities is assessed based on the amount of attached old cement mortar. One of

the weakest parts of recycled aggregate is located on its surface area, consisting of porous old cement mortar and weak old interfacial transition zones. There are different approaches to improving recycled aggregate quality by either removing or improving the old cement mortar as seen in Figure 3. This proposes to improve the old cement mortar using the carbon-conditioning process.

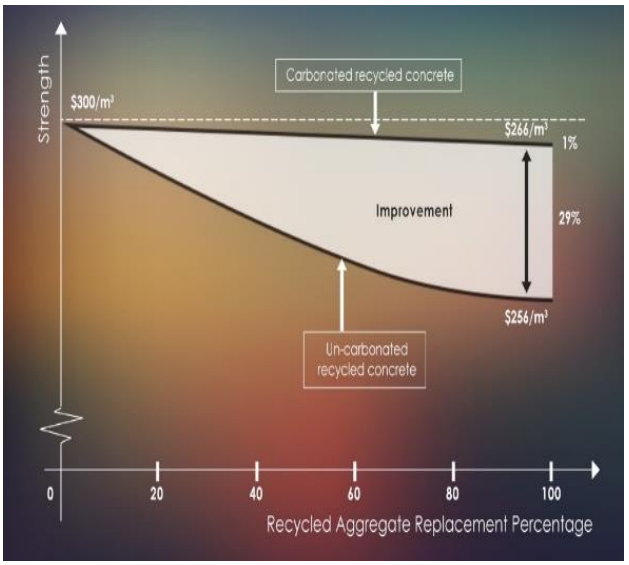

Figure 4: Strength improvement using the carbon-conditioning process

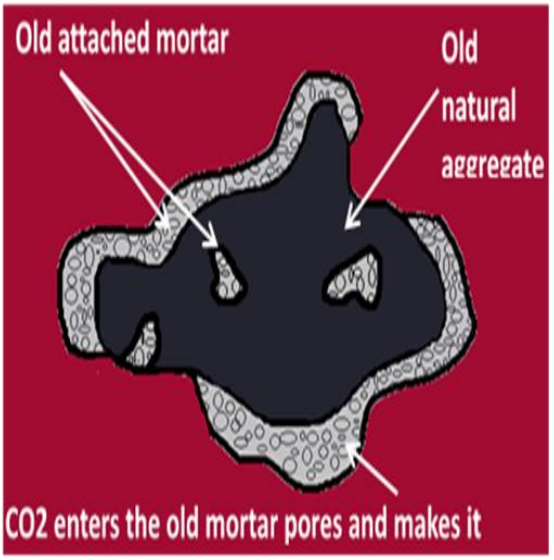

Figure 3: CO_2 Aggregate structure

1.2 Industry Partnership

This project's team has been selected in the Top-10 research team in Australia by Innovyz Institute Pty. Ltd., http://www.innovyz.com/waste-recycling-companies, for a 9-month Waste and Recycling Technologies Commercialization Program, http://www.greenindustries.sa.gov.au/waste-recycling-commercialisation-program, with a $1.5 million funding supported by Green Industries, Government of South Australia. The Program requires this research team to have weekly phone discussions, monthly face-to-face meetings for Project Leader Days and one week each term for Mentor Week (each term being 3 months: Term 1 is validating and expanding technologies; Term 2 is defining commercialization paths; and Term 3 is for investment strategies and capital raising activities) to ensure the success of the expected product and its delivery. The partnership between the research team can guarantee the success of this project.

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PLENARY SPEAKER

Klass Visser

Title: Bypassing the HFC Phasedown by Using Highly Efficient CO_2 and Hydro Carbon Refrigeration for the Cooling of Buildings in Bangladesh

Mr. Visser is a design engineer and the owner of the prestigious KAV Consulting Pty. Ltd. His research interests include sustainability, renewable energy technology, power generation, green building technologies and so on. He has extensive international experience in the design, building, and trouble shooting of medium to large ammonia systems with involvement in more than 800 NH3 projects over the past 45 years.

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Bypassing the HFC Phasedown by Using Highly Efficient CO_2 and Hydro Carbon Refrigeration for the Cooling of Buildings in Bangladesh

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Abstract

In many large office buildings, hospitals and hotels, mechanical cooling is affected by chilled water generated by a refrigerating plant which rejects its heat to the environment by means of cooling tower water or, increasingly so, by air-cooled condensers and adiabatically assisted air-cooled condensers. Hot water for space heating, air conditioning reheat and sanitary purposes are usually provided by a boiler.

Using several databases – Australia, EU and USA – on annual energy consumption per m^2 of building, it is shown that significant reductions in the electrical energy, natural gas and cooling water consumption may be achieved when using transcritical CO_2 refrigerating systems for building cooling, heating, and sanitary hot water, thus reducing gas or oil consumption and attendant emissions, and cooling water consumption.

It is shown that the specific energy consumption measured in kWh/m^2.year reduces about 30% when retrofitting trans-critical CO_2 systems to existing Australian buildings and about 55% in new buildings. These numbers range from about 10% to 50% in hospitals.

The natural refrigerant CO_2 is non-toxic, non-flammable, low cost and energy efficient. CO_2 also has superior heat transfer properties and its GWP (Global Warming Potential) value 1. As such CO_2 is a sustainable refrigerant and will future proof any system against the serious implications of the impending phasedown, and ultimate phase-out, of the high GWP HFC refrigerants by the amendment to the Montreal Protocol, known as the Kigali amendment, where it was agreed to by the 197 signatories to the Montreal Protocol on 15 October 2016.

Keywords: Transcritical CO_2 refrigerating systems, building energy and cooling water consumption, direct and indirect emissions, Montreal protocol, Kigali amendment.

1. INTRODUCTION

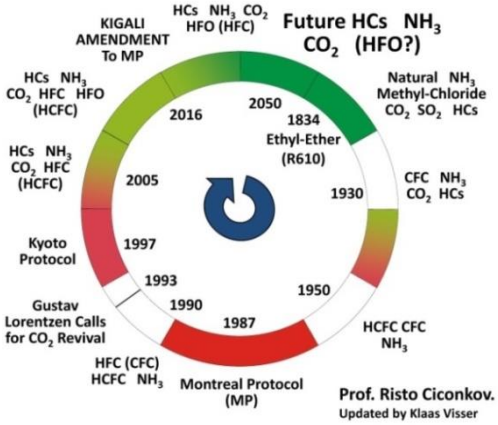


Figure 1. History of refrigerants

The late Prof. Gustav Lorentzen publicly called for the revival of CO_2 refrigeration in 1993, see Fig. 1. Since then air-cooled gas cooling – some with adiabatic assistance by spraying water onto the air inlet face of the finned coil gas cooler – has been applied almost universally. This has resulted in virtually all CO_2 refrigerating systems needing to run in transcritical mode some or all of the time because the cooling air temperature is close to or exceeds the CO_2 critical temperature of 31.1°C in many cases. This results in the compressors needing to operate at a discharge pressure of 8 MPa or higher to ensure a reasonable COP. The summer design COPs of transcritical CO_2 compressors are generally lower than those of air-cooled HFC or evaporatively cooled ammonia systems. Consequently, to date, most CO_2 refrigeration applications have been in the form of CO_2/HFC cascade systems with air-cooled HFC condensing. Larger industrial plants have employed CO_2/NH_3 cascades with evaporative condensers.

As observed by Pearson (2010) the obvious solution is to reduce the temperature of the condenser cooling medium to allow a complete subcritical CO_2 refrigeration cycle all or most of the time. This is easily accomplished with an evaporative condenser, where the effective cooling medium temperature is the ambient air wet bulb temperature rather than the ambient air-dry bulb temperature in the case of an air-cooled condenser or gas cooler. Furthermore, existing CO_2/HFC cascade systems may be converted to multifunction two stage transcritical CO_2 refrigerating systems in future when the Montreal Protocol (MP) has completed its new onerous task of reducing the levels of HFC production and consumption, as agreed to under the provisions of the Kigali Amendment to the Montreal Protocol on 15 October 2016.

1.1 Main advantages of CO_2

1. CO_2 is non-toxic, non-flammable, has a low Global Warming Potential of 1, is low cost and environmentally sustainable, and reduces cooling water and energy consumption.
2. CO_2 has better heat transfer properties than Ammonia and HFC refrigerants at all temperature levels.
3. CO_2 pressure vessel and suction piping diameters are about half the diameter of NH_3 vessels and piping.

1.2 Disadvantages of CO_2

1. CO_2 systems operate at higher pressures than NH3 and chemical refrigerants.

2. In confined spaces CO_2 can be fatal at concentrations exceeding 8% by weight. CO_2 detectors need to be installed in all refrigerated chambers close to floor level.
3. An Ammonia cooled CO_2 cascade condenser is an expensive piece of equipment. Should CO_2 leak into the Ammonia side of the heat exchanger, as reported recently, ammonium carbamate will be formed, which is a highly abrasive salt. It would quickly damage compressors significantly if not detected.

2. KIGALI AMENDMENT TO THE MONTREAL PROTOCOL

Table 1. Phase-down schedule for HFCs in Article 5 and non-Article 5 parties

	Non-A5 parties (developed countries)	**A5 parties (developing countries) -** *Group 1*	**A5 parties (developing countries) -** *Group 2*
Baseline formula	Average HFC consumption levels for 2011-2013 + 15% of HCFC baseline – see Figure 2.	Average HFC consumption levels for 2020-2022 + 65% of HCFC baseline – see Figure 3.	Average HFC consumption levels for 2024-2026 + 65% of HCFC baseline
Freeze	-	2024	2028
1st step	2019 – 10%	2029 – 10%	2032 – 10%
2nd step	2024 – 40%	2035 – 30%	2037 – 20%
3rd step	2029 – 70%	2040 – 50%	2042 – 30%
4th step	2034 – 80%		
Plateau	2036 – 85%	2045 – 80%	2047 – 85%

* For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan, 25% HCFC component of baseline and different initial two steps (1) 5% reduction in 2020 and (2) 35% reduction in 2025.

The Kigali Amendment to the Montreal Protocol was agreed to on 15 October 2016. The Agreement is summarized in Table 1. Figure 2 shows the rate and timeframe for the HFC reduction in the 50 developed countries – 45 countries starting in 2019 and 5 starting in 2020. Figure 3 shows the same for the 137 Group 1 developing countries and the 10 Group 2 developing countries, commencing respectively with a freeze in 2024 and 2028 with the first mandated reductions four years after the freeze starts.

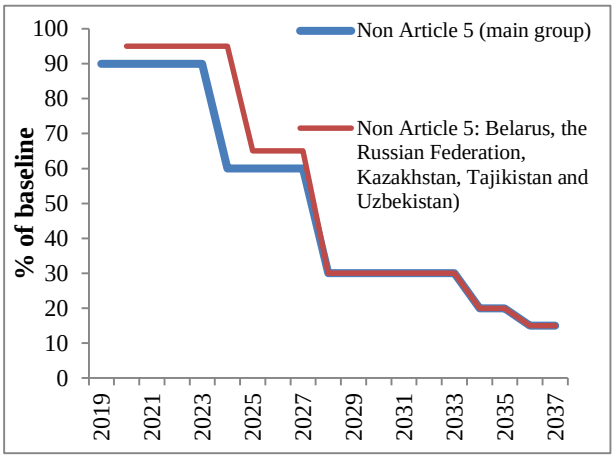


Figure 2. HFC phase down schedule for developed countries

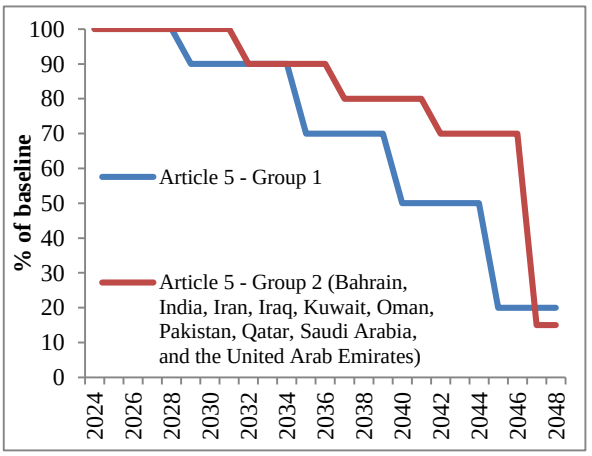


Figure 3. HFC phase down schedule for Groups 1 & 2 Article 5 developing

3. POTENTIAL IMPACT OF HCFC PHASE-OUT AND HFC PHASE DOWN ON BANGLADESH

3.1 HCFC and HFC phase out

R22 is an ozone depletion substance scheduled for complete phase-out by 2030 by limiting production. For instance, in Australia, the annual importation of R22 has been limited to 2,500 kg from 2015 until 2029 when no further R22 imports into Australia are permitted. R22 removed from systems is carefully stored with prices escalating rapidly. In many cases where R22 is phased out a suitable HFC drop in the refrigerant is charged into a system to continue operations. However, the HFC phase-down schedule starts in 2019 with a 10% reduction in production. It is clear from Table 1 and Figure 2 that an 85% HFC phase-down needs to be completed in developed countries by 2036. In Article 5 countries the phase-down needs to reach 80% and 85% by 2045 and 2047 respectively.

The 20 or 50 chemical refrigerant manufacturers in the USA, Mexico, France, Japan, India, and China have been and are developing new chemical refrigerants called HFOs, which come in a bewildering variety at exceedingly high prices! The HFOs are drop-in replacements for HFCs. However, the German Motor Car Manufacturing Association (GMCMAs) led by Mercedes Benz, BMW, and Volkswagen, has decided not to use HFO refrigerants in their cars because of the highly poisonous gases produced by burning HFOs. The leading members of the GMCMA have opted for CO_2 refrigerant for the heating and cooling of their cars. Rumour has it that Toyota is also considering CO_2 for their car air conditioning. It is worthy of note that the author's dear late friend, teacher, and mentor, Prof. Dr. Gustav Lorentzen was granted a patent on a CO_2 car air conditioning system in 1993, which expired in 2009!

3.2 Current energy situation in Bangladesh

Bangladesh has a land area of 147,630 square kilometers which is 59.6% arable. This represents 540 m^2 of arable land per capita of a population of 165 million. Domestic energy for cooking in rural areas is mostly provided by wood, cow dung, agricultural residue, charcoal, leaves, rice husks, sawdust, combustible city garbage, and jute sticks etc. In some respects, this is environmentally sound, but it has several serious disadvantages. Firstly, the spread of smoke throughout the living areas is a danger to health. Secondly, the burning of wood leads to extreme environmental degradation and reduces the carbon sink. Other fuels are kerosene, bottled gas, biogas, PV Solar Home Systems (SHS) and, increasingly, electricity from the grid. The current plan is to have the entire nation connected to the grid and fully integrated with all generating systems feeding into the grid, including SHS, ideally with battery storage. Six million SHS units were operating at the end of 2018 and the roll-out of SHS is continuing at a high rate. This is to serve the rising living standards due to strong economic growth and increased urbanization with many of the rural population, comprising 60% of the nation's population. It is recognized by the Bangladesh authorities that the demand for electricity will increase due to an increasing use of comfort cooling. The important issue facing the Bangladesh authorities is whether to accept standard split AC units with HFC refrigerants or whether to insist on a Natural Refrigerant like Hydro Carbons (HCs). Fortunately, HC split units and water chillers are now available for cooling and heating, including heat recovery for domestic hot water.

4. AUSTRALIAN DATA USED IN ANALYSIS

In November 2012 the Council of Australian Government (COAG) published Part 1 of a Report as part of COAG's National Strategy on Energy Efficiency. The report deals with seven building types; offices, hotels, hospitals and supermarkets. The data on the former four building types have been used in this study to arrive at potential energy performance in those buildings should they be retrofitted with CO_2 refrigeration technology applied to both heating and cooling. In Figures 5 and 6, the cooling COP (coefficient of performance) s of a commercially available semi-hermetic CO_2 compressor with a swept volume of 27.2 m^3/hr are shown at varying suction and discharge conditions.

Figures 4 and 5 show the COPs at 7.5, 8, 9 and 10 MPa discharge pressures at CO_2 gas cooler exit temperatures ranging from 5 to 35°C and 5K Suction Super Heat (SSH) at +10 and +5°C SST respectively. It is clear from Figures 5 and 6 that CO_2 behaves much like any other refrigerant in that the lower the discharge pressure and the higher the suction pressure, the higher the COP will be and vice versa. It is also clear from Figures 5 and 6 that, provided the gas cooler CO_2 exit temperatures do not exceed 31°C, transcritical CO_2 COPs have quite acceptable values compared to those shown in Figure 6 for R717, R22, R507A and Propane at SCTs ranging from 16 to 45°C.

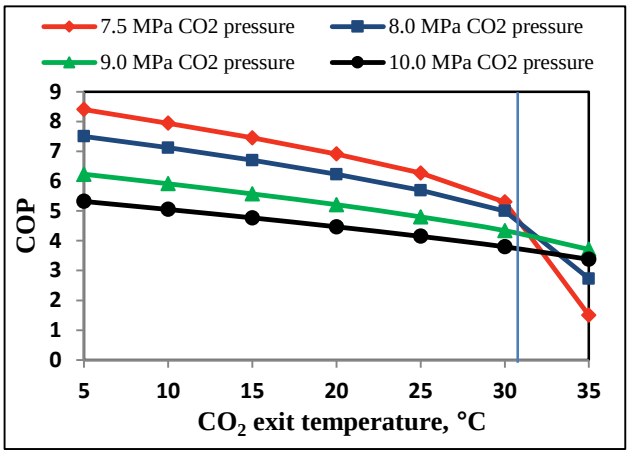


Figure 4. Compressor COP vs CO_2 exit temperature at 10°C SST and 5 K superheat

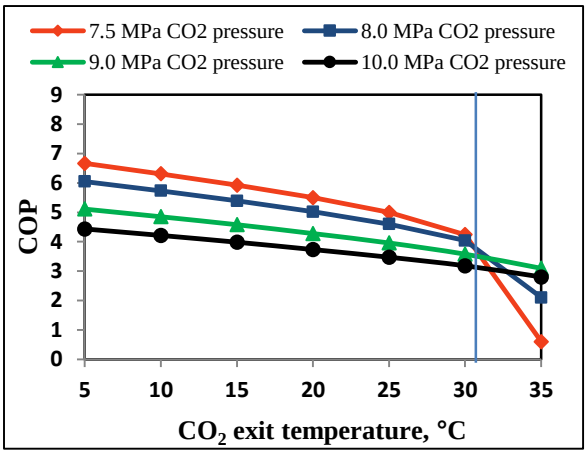


Figure 5. Compressor COP vs CO_2 exit temperature at 5°C SST and 5 K superheat

5. ANALYSIS BASED ON COAG REPORT

5.1 Existing situation

In Table 2 the specific energy consumption in MJ/m^2 is listed for Australia Stand Alone Office Buildings (SAOBs), Hotels (HTLs), Hospitals (HSPs) and Supermarkets (SASMs). Furthermore, the percentages of Electrical Energy (EE) and Fuel (FL) are listed and broken up in MJ/m^2. They are based on the projected building areas in m^2 and the total energy consumption PJ in 2015.

The total energy consumption is the sum of the fossil fuel – mostly natural gas – used in MJ plus the EE as electrical fuel in MJ obtained by multiplying kWh EE consumption by 3.6 as 1 kWh = 3.6 MJ. The analysis is carried out by defining the amount of EE and FL used and the percentage proportion of the use of these two fuels by of the total specific energy consumption per m^2 of building area.

Table 2. Specific energy consumption in MJ/m^2 for Australian SAOBs, HTLs, HSPs, SASMs

Parameter			Type of Building				
No	**Description**	**Unit**	**SAOBs**		**HTLs**	**HSPs**	**SASMs**
			T[1]	BB[2]			
1	Building area	m^{2}x10^3	40,911		11,424	13,747	5,926
2	Annual Energy Consumption (AEC) / Emissions (E)	PJ/a;MtCO$_2$e/a	35.6/9.2		17.7/3.5	22.2/3.7	20/5.7
3	Specific AEC	MJ/m^2.a (kWh/m^2.a)	870(241)		1,549(430)	1,615(449)	3,375(938)
4	Electrical Energy (EE)	PJ (%)	15.4(43.21)	16.7(47)	11.3(64)	10.9(49.1)	19.8(99)
5	Natural Gas	PJ (%)	3.4 (9.8)		6.3(36)	10.5(59.9)	0.2(1%)
6	LPG/Diesel	PJ (%)	0.1 (9.8)		0	0.710	0
7	EE End Use						
.1	HVAC	%	18	67	52.0	47	35
.2	MT Refrig.	%	-	-	-	-	25
.3	LT Refrig.	%	-	-	-	-	15
.4	Lighting	%	37	15	20.0	17	25
.5	Equipment	%	31	11	11.0	7	
.6	Domestic Hot Water	%	3	2	9.0	2	
.7	Pool Heating	%	-	-	6.0	-	
.8	Other	%	11	5	2.0	27	
8	Gas End Use						
.1	Space heating	%	-	49	26.0	32	100
.2	Domestic Hot Water	%	-	8	23.0	12	
.3	Pool Heating	%	-	-	6.0	3	
.4	Sterilisation	%	-	-	-	6	
.5	Laundry	%	-	-	13	-	
.6	Other	%	-	43	32	46	

[1] T = Tenant [2] BB = Base Building

EE is used for HVAC, lighting, equipment, domestic hot water, pool heating, and other undefined duties. In the case of the supermarkets, the MT (Medium Temperature) and LT (Low Temperature) refrigeration duties also consume EE. Natural gas is used for space heating, domestic hot water, pool heating, laundry, sterilization, and other undefined duties. In Table 3 we have summarised the specific HVAC EE consumption in kWh/m^2.year and Table 4 shows the total amount of heat required for space heating and hot water. In the case of hospitals, the 6% sterilization heat has not been added. In all cases "Other uses" have not been added as it is not known what those "Other uses" are.

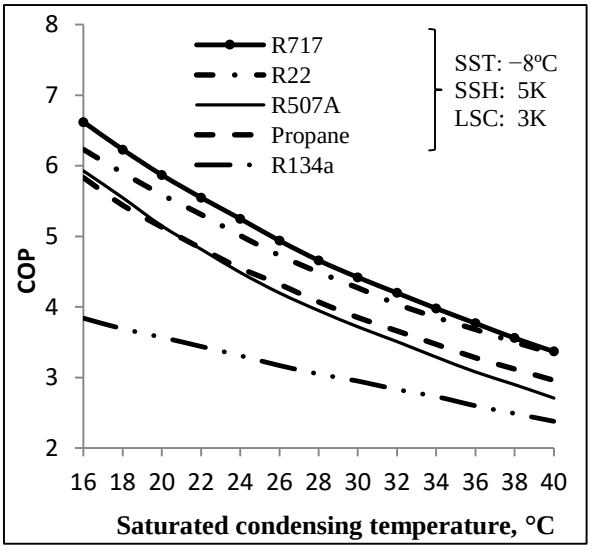


Figure 6. COP vs condensing temperature of a commercially available compressor with a swept volume of 637 m³/h

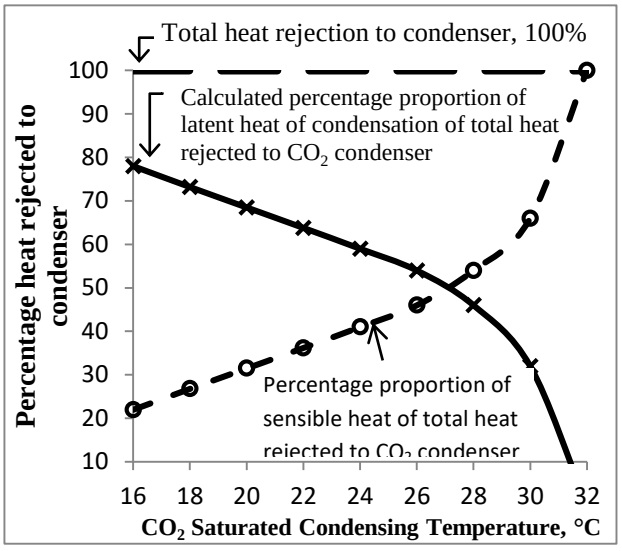


Figure 7. Heat rejection profile for a commercial compressor at 5°C satd. suction, 5 K useful suction superheat and 5°C CO_2 liquid temp.

5.2 Evaluation of energy consumption using transcritical CO_2 refrigeration systems in office buildings, hotels and hospitals.

Table 3. Definition of total space heating and domestic hot water heat required based on Table 2

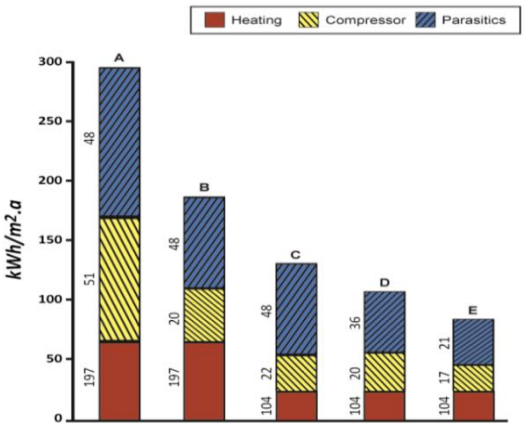
Parameter				SAOB		Hotels	Hosp.
No.		Description	Unit	T	BB		
1		Electrical Heating					
	.1	Total electrical	kWh/m².a	104	113	275	220
	.2	Heating Proportion	%	3	2	15	2
	.3	Total electrical space heat required, 1.1 x 1.2	kWh/m².a	3	2	41	4
2		Gas Heating					
	.1	Total gas	kWh/m².a		23	153	22.7
	.2	Water heating proportion, Items 8.1 to 8.5, minus 8.4	%		57	68	54
	.3	Total gas water heating, 2.1 x 2.2	kWh/m².a		13	104	123
	.4	Hot water boiler efficiency	%		80	80	80
	.5	Available heat in hot water	kWh/m².a	-	10	83	98
3		Total Heat Water Heating Load	kWh/m².a				
	.1	Item 1.3 above	kWh/m².a	3	2	41	4
	.2	Item 2.5 above	kWh/m².a	-	10	83	98
	.3	Total water heating required	kWh/m².a	3	12	124	102
	.4	Total water heating required, 3.3 x 3.6	MJ/m².a	11	43	446	367
	.5	Total space heating required, Item 1.3	MJ/m².a	11	7	148	14
	.6	Total heat required	MJ/m².a	22	50	594	381
4		Specific Global Warming Emissions (GWE)					
	.1	Electrical GWE @ 1.8kg/kWh/m².a	$kgCO_2.e/m^2.a$	104	113	275	220
	.2	Natural gas GWE @ 59.3 kg/GJ	$kgCO_2.e/m^2.a$	5		33	5
	.3	Total specific GWE	$kgCO_2.e/m^2.a$	222		308	225

All of these facilities require HVAC, perhaps a little space heating and domestic hot water (DHW), particularly hotels and hospitals. The low critical point of CO_2 is a distinct advantage when heating DHW from the mains temperature to a desirable level of 55 to 65°C. The advantage consists in the fact that in transcritical operations there is no condensing phase and therefore the HVAC CO_2 compressors Total Heat Rejection (THR) may be used to heat water. This is entirely different from the conventional refrigerants

(R717, R22, etc.) where up to 90% of the THR is rejected at a constant temperature during the condensing phase. In Australia, mains water temperatures rarely exceed 20°C enabling a gas cooler exit temperature of 23°C. As is clear from Figures 4 and 5 at these conditions the COPs of CO_2 compressors are high. Figure 5 is based on Direct Expansion (DX) CO_2 for AC cooling at an SST of 10°C, whilst Figure 4 is based on 5°C SST for chilled water. If higher hot water temperatures are required, the compressor discharge temperature may be increased by lifting the discharge pressure or increasing the amount of suction superheat or a combination of both.

5.3 Examination of additional possibilities

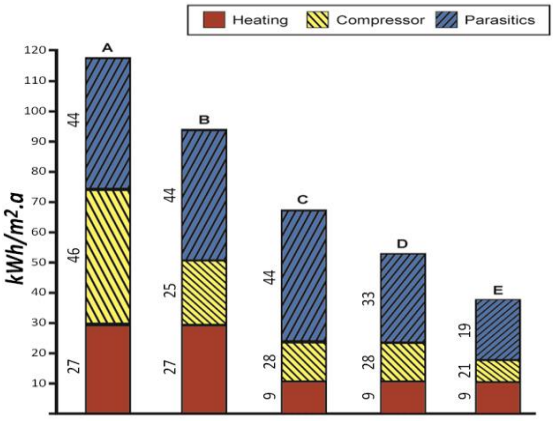
Figure 7 shows the proportion of latent and sensible heat to be disposed of in the CO_2 condenser/gas cooler. At 30°C Saturated Condensing Temperature (SCT) the amount of sensible heat to be removed from the compressor discharge is 68% of the total heat leaving only 32% of the heat to be removed as latent heat when condensing at 30°C. The advantage of this is that a considerable amount of heat may be removed by air-cooling thus saving water in evaporative condenser/gas coolers and cooling towers.



A = Existing situation in Hospitals in Melbourne
B = Retrofit CO_2 compressor
C = Retrofit CO_2 heat recovery
D = Slow down fans
E = New Building with pumped CO_2 and slow fans

Energy Consumer	A	B	C	D	E	Remarks
Parasitics	48	48	48	36	21	
Compressor	51	20	22	20	17	
Heating	197	197	104	104	104	Gas
Total	296	265	174	160	142	
Reduction kWh/m^2.a	-	31	122	136	154	
Reduction %	-	10.5	41.2	45.9	52.0	

Figure 9. Reduction in energy consumption when retrofitting CO_2 cooling and heating to existing & equipping new hospitals in Melbourne with transcritical CO_2 cooling and heating systems



Melbourne
B = Retrofit CO_2 compressor
C = Retrofit CO_2 heat recovery
D = Slow down fans
E = New Building with pumped CO_2 and slow fans

Energy Consumer	A	B	C	D	E	Remarks
Parasitics	44	44	44	33	19	
Compressor	46	25	28	25	21	
Heating	27	27	9	9	9	Gas
Total	117	96	81	67	49	
Reduction kWh/m^2.a	-	21	36	50	68	
Reduction %	-	17.9	30.8	42.7	58.1	

Figure 8. Reduction in energy consumption when retrofitting CO_2 cooling and heating to existing & equipping new buildings in Melbourne with transcritical CO_2 cooling and heating systems

A serious problem exists in AC systems where there is a strong emphasis on compressor COP. This invariably means that a high chiller Saturated Suction Temperature is chosen. This leads to relatively high water temperatures with low ranges requiring high pump energy. Adding to that the almost obsessive practice to design for maximum Nett Lettable Area in a building frequently reduces the space for ducting. This results in high air velocities in ducts requiring high fan EE consumption.

In Figure 8 and Figure 9, bars A show the existing situation in Melbourne office buildings and hospitals. Bars B shows the total energy consumption when replacing existing compressors with CO_2 compressors with far superior COPs, as shown in Figures 4, 5 and 6. A lot of the heat required in a building may be recovered from the CO_2 compressor discharge saving a lot of heating energy and cooling water as the amount of heat rejected to an evaporative condenser/gas cooler or cooling tower reduces. The energy reduction benefits are shown in bars C. Bars D show the benefit of reducing the air volume by slowing down the fans 25%. Bars E shows the results if we pump liquid CO_2 around the building to DX evaporators in the Air Handling Units in new buildings. Retrofitting CO_2 refrigeration with heat recovery would reduce the energy consumption by about 42% in existing buildings and 45% in hospitals in Melbourne.

6. COOLING WATER CONSUMPTION

Table 4. Variation in specific water consumption of nominal 630 kW pure and hybrid CO_2 evaporation. Condensers at a constant wet bulb temp. of 28°C and increasing dry bulb temp. from 30 to 40°C

Ambient dry bulb temp., °C	30	32	34	36	38	40
4.1 Standard evaporative condenser with 8 wet pass circuit						
Water consumption, l/h	791	858	925	992	1,056	1,119
Heat rejection, kW	635	633	632	631	629	627
Specific water consumption, l/kWh	1.25	1.36	1.46	1.57	1.68	1.78
4.2 Hybrid condenser/gas cooler - 6 dry passes plus 2 wet passes						
Water consumption, l/h	286	369	450	530	609	686
Heat rejection, kW	648	642	635	628	621	614
Specific water consumption, l/kWh	0.44	0.58	0.71	0.84	0.98	1.12
4.3 Summary of water saving benefits of a hybrid evaporative condenser for CO_2 gas cooling at 28°C						
Specific water consumption standard evap. Cond., l/kWh	1.25	1.36	1.46	1.57	1.68	1.78
Specific water consumption hybrid evap. cond., l/kWh	0.44	0.58	0.71	0.84	0.98	1.12
Reduction in specific water consumption, l/kWh	0.81	0.78	0.75	0.73	0.7	0.66
% reduction in water consumption	64.8	57.4	51.4	46.5	41.7	37.1

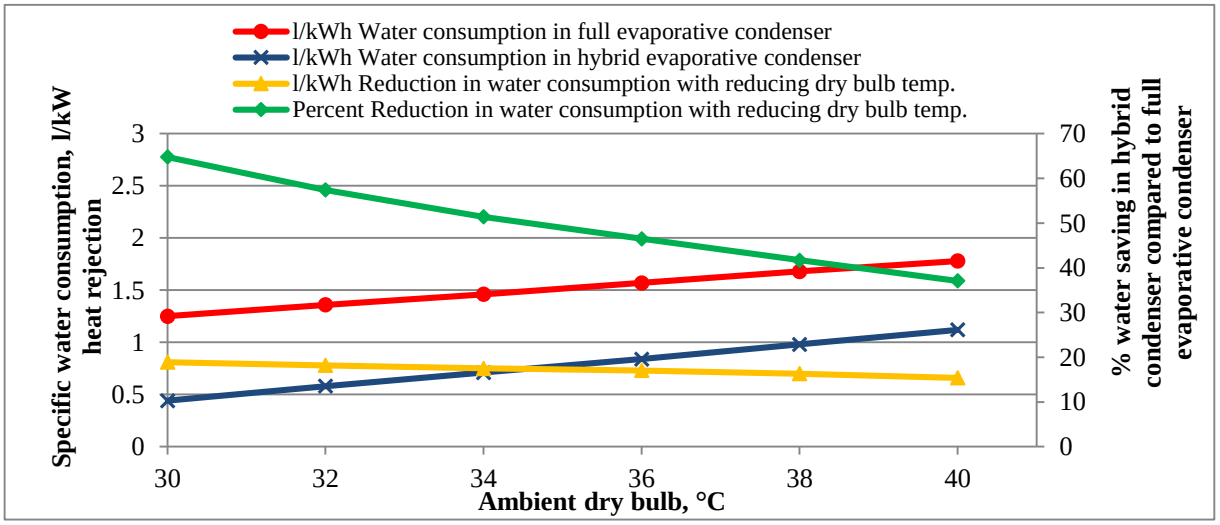


Figure 10. Comparison of water consumption by full and hybrid

Potable water is becoming an increasingly valuable commodity in Bangladesh. Nearly 90% of domestic potable water is groundwater, much of which has a high arsenic content which is seriously detrimental to human health. Cooling towers and evaporative condensers consume large quantities of scarce potable water.

A big advantage of water-cooled transcritical CO_2 is that it consumes less than about one-third of the cooling water consumed by conventional cooling towers and evaporative condensers. See Table 4 and Figure 10.

7. CONCLUSIONS

It is clear that retrofitting transcritical CO_2 refrigerating systems for cooling and heating into office buildings, hotels and hospitals have significant energy and cooling water consumption reduction benefits and attendant reductions in both indirect and direct Global Warming Emissions. Transcritical CO2 discharge vapor contains 100% sensible heat. Thus we estimate the reduction in cooling tower cooling water at 50% in the case of SAOBs, 80% for hotels and 65% for hospitals with the use of hybrid CO_2 evaporative condensers which remove up to 50% of the heat in the CO_2 compressor transcritical discharge vapour by air cooling with the balance of the heat being removed in the evaporative condenser suction. Equipping new facilities with water cooled CO_2 systems for cooling and heating future proofs such buildings against the potentially severe impact of the implementation of the Kigali Amendment by the MP.

Much greater energy savings would be possible in new buildings if the CO_2 were pumped around the buildings in a Liquid Recirculation fashion. This would permit lifting the evaporating temperature which would increase the compressor COP. But perhaps, more importantly, it would be possible to reduce airflow, which would drastically reduce the energy consumption of the supply and return fans and thus reduce the heat load on the AC compressors. The adoption of CO_2/HFC cascade systems by Australian supermarkets since 2003 was largely driven by the high cost of replacing CFC and HFC refrigerants with attendant GWEs.

Bangladesh is on the verge of an increase of small to large air conditioning and refrigeration systems. If the decision is made to use Hydro Carbons for small to medium size systems and CO_2 for large AC and refrigeration systems Bangladesh has bypassed the HFC phase-down phase and the subsequent phase in of expensive, inefficient HFO refrigerant is avoided and the systems are future proofed.

Retrofitting transcritical CO_2 cooling to the air conditioning in hospitals, hotels and office buildings will have immediate large benefits and future proofs the system.

NOMENCLATURE

a	annum (year)	AC	Air Conditioning
HVAC	Heating, Ventilating, Air Conditioning	K	degree Kelvin
AEC	Annual Energy Consumption	kWh	kilowatt hour
AWBDT	Ambient Wet Bulb Design Temperature	kWP	Compressor EE consumption
BB	Base Building	kWR	Refrigeration capacity
CFC	Chloro Fluoro Carbon	LPG	Liquid Petroleum Gas
CO_2	Carbon Dioxide	LTR	Low Temperature Refrigeration
CO_2-e	Carbon Dioxide equivalent	m^2	Square Metres
COP	Coefficient of Performance	m^3/h	Cubic Metres per Hour
°C	Degrees Celsius	MJ	Mega joule – 10^6 Joules
DHW	Domestic Hot Water	MTR	Medium Temperature Refrigeration
DX	Direct Expansion	NH_3	Ammonia
EE	Electrical Energy	PJ	Peta joule - 10^{15} Joules
EEC	Electrical Energy Consumption	SCT	Saturated Condensing Temperature
GC	Gas Cooler	SSH	Suction Super Heat
GJ	Gigajoule - 10^{12} Joules	SST	Saturated Suction Temperature
GWE	Global Warming Emissions	THR	Total Heat Rejection
HFC	Hydro Fluoro Carbon	T	Tenant

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PLENARY SPEAKER

Rafiqul Islam (PhD)

Title: Educating Engineers with Personality as World Citizen Leading to Sustainable Development

Rafiqul Islam is a mechanical engineer specializing in renewable energy technology with a Doctorate of Engineering degree in solar energy from AIT, Thailand. Dr. Islam has 10 years of tertiary engineering teaching followed by 22 years of industry. He is sole inventor of 6 registered patents Dr. Islam is also principal consultant and director of the Solar E. Technology International which successfully installed nearly 300kW of solar PV system in Australia. He is an active director of Islamic Cooperative Finance Australia for 10 years who developed a real market model of equitable partnership real-estate financing method.

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN:978-0-6482681-4-7

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Extended Abstract

The UN Agenda 2030 has set some 17 sustainable development goals (SDG) and 169 targets to be achieved by 2030. With the current world population of 7.7b, rising to an estimated 8.6b by 2030, and with rising globalization of technology and resources, every world citizen is under stress of a kind, to tackle either a basic survival or a lifestyle race. To reduce inequalities (SDG10) but achieving or sustaining reasonable gross domestic product (GDP) level inevery nation, in 21st Century and beyond, will require the world citizen to work smarter, intellectually, physically, ethically and emotionally. This article provides an overview of how personality, society,and sustainability are connected then indicates how to design education system for developing engineers as world citizen. In the context of a fast-developing nation, like Bangladesh, this is even a vital challenge for the nation to build its citizen for the best fit for the 21st Century and beyond. Lessons learned from this short paper can be a trigger point to start that journey building a new curriculum structure supporting development of such citizens of the future.

The sustainability race:

It is not quite certain,how theachievements of the sustainable targets are responsibly measured, but sure, the cycle of an impact,if the targets are 100% achieved, will be realized in a very long term. The impacts will be visible in real-world climate phenomena, the human lifestyle balance and so on, in many decades from now. Further time expansion, such as Agenda 2050 and Agenda 22C (22nd Century) for similar goalsto be set soon.

Good thing is that most corporate businesses, most government bodies, non-government organizations, numerous philanthropes are putting sustainability as one of their activity agenda. The many decades of work since it was firstrealized that human activities on this planet is responsible for the climate-related impact to the life on the earth, the world citizen is now moving forward to recover.

However, the balance between the sustainability and the prosperity is still a dilemma in many nations, especially the fast-developing nations and the developed ones. The concept of sustainability needs to enter the root of all the activities on the planet by every single citizen. To enable this, sustainability education must spread rapidly in all levels of education, from primary through tertiary and any continuing education programs worldwide. The fundamental of the sustainability education isgiving the understanding of how everything we do (ouractions) is connected to the planet and our lifestyle and then inquire into how we also design our work to create a sustainable lifestyle on a sustained planet which has natural limits of resources and climate.

Engineering personality and societal connection in the current world order:

In the current world order, the engineering has become the sector which is the most foundation building block of all living functions on the earth, be it food, clothing, housing, infrastructure, aviation, transport, medical, communication, security, agriculture, mining, energy, data and the growing list as far as space exploration and so on. There is a strong correlation established between GDP growth (an indicator of prosperity) and number of engineering graduates in the most fast-developing countries. Therefore, engineering education remains one of the most fundamental need of this century in addition to the basic education listed in the SDG4.

The economic development requires continuous improvement of engineering concepts and material transformation through creative and innovative exploration of science and techniques. The innovative products or services to support the consumers including those with a certain social, cultural and personal needs. Therefore, it is the need, the personality,and the science all three blend together in a lifestyle design, where engineers have a strong role to play and take that as opportunity. In the 21st Century, the engineers will need to develop strong self-esteem and establish personal strengths to take the challenge of one's own choice, thus be able to deliver sustainable lifestyle for the future citizens, without being a passive citizen who considers employability as the prime purpose of becoming an engineer.

Traditionally, the material outcome of an engineering graduate lies in their technical success after the graduation. An engineer, as develops the career as a person and as a professional, can and do influence the people and social culture and lifestyle in addition to the technical success. In this challenging time of 21st Century, the engineering education will need to prepare engineers capable of working locally while learning as well as delivering creative, innovative but socially sensible sustainable engineering solutions as a world citizen. A world citizen is a personality which takes ownership of the progress and concerns of the human society and the earth as single entity and respects other's presence equally on this planet.

To work as world citizen, engineers also need to develop personality traits that help both, the prosperity and sustainability, globally. Engineers will need to develop strong ethical and moral sense which cross national borders. The global connectivity in the recent world order has already demonstrated how cultural and social practices are migrating fast through communication and cross-national people movement. Engineers are no different. Engineers thus need to develop tolerance and be respectful to multi-cultural differences worldwide.

In coming decades, the engineers will need to have strong language adaption and communication skills that fits in multi-cultural environments. They will need strong background of social history of their target choice of nations to serve. They will learn the problems and needs of other societies and prepare them to fit for others as well as for their own nation. Engineers will need to design systems with a mindset that the local climate impact and actions (SDG13) have global outcomes.

To balance the prosperity and sustainability, engineers must have a good sense of entrepreneur attitude, delivering project outputs in a team environment collaborating with cross-functional personalities in workplace as well as co-

sharing the concepts of sustainability. It is believed that engineers are not good leaders. To deliver the sustainability globally, this will need to change from being a doer to a leader-doer.

The engineering education:

In order to develop an engineer becoming fit for the challenges of sustainable world, the education system will need to cover technological, spatial and temporal scale of knowledge. The globally diversified educational institutions will take the benefit of global connectivity to really help achieve the sustainable goals on worldwide scale. Every course must contain element of sustainability of relevance to the course. The subject delivery must emphasize a connection between the content and the concepts of sustainability, where it exists. Courses to have open choices of subjects fostering a student-centric development rather a degree-oriented development. Student-centric development means that student can chose whatever subjects fit in their personality and their choice of the society to serve.

Asimple example of how to achieve SDG10 (inequality) is by outsourcing engineering skillsbeyond national boundaries. This will also close knowledge gap amongst the geographical space as well as improve cross-national economic remittance benefits.Particularly, nations which has high population vs useful natural resource ratio, who cannot feed on the local natural resources, the opportunity to outsourcing will dramatically give them opportunity to earn thus to reduce poverty (SDG1) and hunger (SDG2). To make cross-national outsourcing successful, the world needs global engineering education curriculum standardization and recognition.

Educational institutes will need internationally collaborative quality control in curriculum outcomes through of teaching and research. Engineering education will need active training on creativity development opportunity by inquiring into deep learning and challenging with real-world complex problems that the world faces every day. However, it is not that every student will take the same challenge and become equal engineers. It will thus again, derive how a person can become emotionally connected and passionate about making a change in the world.The education system may also impose a professor to havereal-world engineering outputs for a progressive percentage of time, such as 25% or so, enabling them to develop engineers with real-world challenges.

The engineering personality development should be an active education program instead of students learning through passive interaction with other model personalities. Language, communication, cultural and social history learning opportunity will make engineers more productive in delivering the social change that is required for the future sustainable world. Leadership training also should become a curriculum choice for engineers.

The model that is explained above will also help balance the GDP growth globally, assist technology migration complementing people migration, and to improve the urban settlement (SDG11), industrialization (SDG9) and employability (SDG8) and positively impact all other sustainable development goals.

Conclusion and Lesson for Bangladesh:

From the above discussion on the topic of educating engineers for the future, the key focus for a fast developing nation like Bangladesh is that, while the economic development of the nation is vital to catch up to the level of so-called developed nations, the journey must be well planned and our citizens are well prepared to tackle the future challenges without compromising the values as person, peace and sustainability as a whole. The development of economic structure with social and cultural integrity as well as diminishing the living environment is unsustainable in the long run. For Bangladesh, the value creation through the Engineering Education lies in the curriculum development offering student-centric but with global fitness then these graduates will be able to offer global engineering solutions even more than now at the same time serve the nation.

Quality of private and public both sectors of Engineering Education must be maintained without compromise to jump ahead such that the graduates are fit for the future challenges right now. The long-term success of the digital age will be dependentupon these citizens.

Keywords: Engineering Education, Society, Sustainability in global scale, World citizenship, Sustainable Development Goals, Engineering personality, Innovation, Global connectivity.

PLENARY SPEAKER

Professor Md. Jakariya, PhD

Title: Groundwater Arsenic Contamination in Bangladesh: Challenges and Way Forward to Ensure Sustainable Safe Water Coverage

Prof. Jakariya specializes in Human Geography, Environmental Risk Assessment, Climate Change Adaptation, Migration and GIS. He has wide range of experience in project development and management related issues. He received an MPhil degree in Environment and Development from Cambridge University, UK, in 2000, and PhD from KTH, Sweden in 2007.

Abstract

Groundwater arsenic contamination in Bangladesh was first detected in 1993. In order to eradicate diarrheal diseases caused by drinking microbial contaminated surface water, UNICEF promoted the concept of installation of hand tube wells all across Bangladesh. The hand pumped tube wells were installed mostly between 20-30 meters deep. According to the data provided by UNICEF in 2008, there are approximately 8.6 million tube-wells in Bangladesh. Of these, 4.75 million tube wells (55%) have been tested for arsenic among which 1.4 million (16%) were marked red indicating that they are unsafe to use as sources of drinking water due to the high arsenic level. Different studies have demonstrated that the concentration of arsenic in groundwater may vary over time and there is no fixed trend of this change. Therefore, it is important to check tube well water for arsenic over a certain period.

In the absence of any proper medicine, drinking arsenic safe water is considered as one of the most important mitigation measures to halt further exposure of the disease. Until now, it was not possible to find out better options in terms of community acceptability, technically and financially viable options, compared to that of the tube wells. That is why, the investment that was made until now to distribute different alternative safe water options were rejected by the arsenic affected communities. At this juncture, local masons identified a new technique of installing tube wells looking at sediment colour. According to local masons, light brown or brownish oxidized sediments are free from arsenic contamination. A Sida funded project, called SASMIT (Sustainable arsenic mitigation), validated the local masons' initiative by comparing it with the scientific Munsell colour chart. To develop this method further, the whole colour concept has been digitalized to strengthen this research work and provides real time assistance to local drillers and researchers during new tube well exploration. However, still there are some areas where the colour concept method will not work as because of the unavailability of coloured sediments. Small community based safe water distribution option might give safe water access to that exposed population. It is expected that a combination of both approaches, mentioned above, might give easy and sustainable access to safe water for the millions of exposed population who are still drinking contaminated water.

KEYNOTE SPEAKERS

Professor Mizan R Khan **Topic: Economy, Ecology and Society**

Dr. Khan is a Professor at the Environmental Science and Management department of North South University. He received his higher degrees in Economics from Russia and the USA. He is also one of the foremost experts of climate change and finance in Bangladesh and has several publications to his name, including books published by MIT Press and Routledge.

Dr. Nurul Quadir **Topic: Government and Sustainability in Bangladesh**

Dr. Quadir is an Additional Secretary at the Ministry of Environment, Forest and Climate Change of the Government of Bangladesh. He has a PhD in Agriculture and Environmental Sustainability from the UK and is a regular attendee/speaker at UNFCCC conferences and meetings like COP.

Professor K. M. U. Ahmed **Topic: Aspects of Groundwater Development**

Dr. Ahmed is the pioneer of Arsenic research, SAR Systems and Groundwater Development in Bangladesh. He obtained his PhD in Hydrogeology from the UK and currently holds the position of Professor and Chair of the Department of Geology of Dhaka University. He has a vast research and project implementation experience with several private and public entities.

Abdullah M. Talha **Topic: Sustainability in the RMG Sector**

Mr. Talha is a national multi award-winning entrepreneur specializing in supply chain, marketing, branding and technology. He is currently the Deputy Manager Director of Noman Group and has vast knowledge of the textile industry of the country. He has a BBA from North South University and is enthusiastic about several societal causes.

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Paper 1

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

A Study about the Traffic Congestion at Gumti Bridge on Dhaka –Chittagong Highway

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Abstract

To cope up with the ever-increasing traffic demand of Bangladesh, Dhaka-Chittagong highway (N1) has been converted to four lanes from two. However, this attempt didn't lead to utmost success due to congestion at some critical points of delay. Long queues of vehicles with tailbacks at N1 highway near Daudkandi Toll Plaza has been observed and recorded over the last two years on regular intervals. The vehicles coming through the four lanes get stuck at the starting point of Gumti (Daudkandi) Bridge, that has only two lanes. The traffic congestion begins when vehicles from a four-lane try to get on a two-lane bridge. This narrowing or bottleneck is the main cause of the delay in N1 highway. Besides, slow collection of tolls at the toll plaza also adds to the suffering. This study investigates the present condition of the Gumti Bridge on Dhaka-Chittagong highway and shows fundamental relations of traffic flow along with the probable causes of traffic congestion. The main bridge lane is 1410 m along with approach road of length 1010 m. For this comparison, readings were taken at the four-lane highway and near the two-lane bridge, on three significant days of the week (weekend, week starting day, regular week day). Video cameras were used to count traffic manually on the Highway at peak hours and off-peak hours separately. Velocities were taken by speed guns. It was found that traffic volume is higher at Chittagong to Dhaka highway than Dhaka to Chittagong highway. The velocity decreased by 45.67% and volume decreased by 45.92% approximately for a peak hour on Sunday. At off-peak hour the velocity decreased by 52.83% and volume decreased by 56.42% on Sunday. From the result it is found that the flow, density and velocity decreased significantly at the two lane (obstructed flow) than at the four (free flow) lane. The result indicates that traffic volume is fair in terms of highway capacity but congestions are created due to bottlenecks near the two-lane bridge. An effective project management that would inaugurate four lanes and second Gumti Bridge simultaneously, could ensure a full functional traffic flow across the national highway.

Keywords: Congestion, Bottleneck, Toll Plaza, Gumti Bridge, Four lanes.

1. INTRODUCTION

The national highway N1 or Dhaka Chittagong highway is a vital road network that connects the capital of Bangladesh, Dhaka and the port city Chittagong. The Kanchpur, Meghna and Gumti bridges (KMG) project on the Dhaka-Chittagong highway created a short-cut route from Dhaka to Chittagong. The bridge over the Gumti River was built with the financial help from the Government of Japan and was opened to public on the 1990s. At first, its official name was Bangladesh Japan Friendship Bridge 2 but lately it gained popularity as Gumti Bridge.

Nowadays, the movement on the vital road is hampered due to traffic congestion at bottlenecks. Traffic congestion is one of the worldwide urban problems, which can lengthen journey time, increase energy consumption, aggravate environmental pollution and result in traffic accident. There are many reasons of

traffic congestion at Gumti Bridge such as encroaching of roads(bottlenecks), illegal loading and unloading, two lane bridge for four lane highway, absence of electronic toll collection system, absence of additional lay by for heavy traffic, heterogeneous traffic speed and increasing traffic demand due to economic development, etc. At the very beginning, the bridge was built with two lanes. There was no extreme requirement for four-lane bridges at that time. But Bangladesh is getting economically developed gradually. The economic development of Bangladesh upholds the GDP growth and it expanded 7.65% in 2017-18 from the previous year (Byron, 2018). The National Highway (N1) contributes approximately one third of this national GDP. Such trend in economic development of Bangladesh has direct impacts on the strong growth in both the number of passengers and freight traffic.

Initially the 2 lane bridge was sufficient for the moving vehicles. But with the increasing traffic generation, it has become impossible to afford numerous vehicles simultaneously on the bridge. While the N1 highway was upgraded to four lanes, the two key bridges named Meghna and Gumti (just 13km apart) still remained at two lanes, leading to obvious bottlenecks near both of them (Tanjil, 2017). After approval of 4 lane highway in 2005, the highway was supposed to be completed by June 2012. However, the authorities extended the deadline five times that increased the estimated cost of the project. The highway was finally declared ready for public use in July 2016 when the aggregate cost stood at $36 billion, much higher than the initially estimated $21 billion. According to the WB report, the estimated cost of construction per kilometer of the Dhaka-Chittagong highway is $2.5 million while a four-lane highway costs $1.1 million to $1.3 million per kilometer in India and $1.3 million to $ 1.6 million in China (Ashraf, 2018). But even after this huge expense, the traffic congestion due to bottlenecks, is hindering the smooth traffic movement across the highways.

The National Highway No.1 (N1) is the busiest road in the country and a top development priority. Besides, except truck and bus (12.68%), the remaining vehicular class consist of small vehicles, which makes N1 very accident prone and congested highway. Though individual year varies significantly, the average growth factor of Truck and Bus is found 6.68% and 4.07% per annum respectively (Ullah et al., 2017). As there is no addition lay by for heavy vehicles, this situation is not getting solved. A few days ago for a vehicle accident, a long tailback was created which was approximately 110km long. Bottlenecks due to a stretch of narrow road near Kanchpur Bridge and poor parking were largely responsible for the situation (Star Online, 2018). A traffic stream having vehicles of varying range of speed, creates great hazard that may lead to heavy traffic congestion. The slow-moving vehicle will block the way of the fast moving vehicles, thereby creating traffic congestion (Manzur, 1986).

Toll plazas usually appear to be a bottleneck for highway traffic flow. They cause traffic congestion in the highways which in turn causes loss of time and money. It is evident that toll plazas are usually the bottlenecks for highway traffic flows. But due to delay in collection system, the users of this road normally have to face long queue. All the parties concerned are being negatively impacted by this delay. Thus modern highways follow the electronic toll collection system.

2. METHODOLOGY

Gumti Bridge is 40 kilometers (24.85 mi), southeast of Dhaka across the Gumti River which is one of the major rivers in the country. The bridge is located along the Dhaka–Chittagong Highway (National Highway N-1). The geographic coordinate of the Gumti Bridge is 23°31'49.8"N and 90°42'07.1"E.

Preliminary investigation was carried out along the case study road to determine the best approach to be used in dealing with the research (Rahim et al., 2015). Noticeable congestions were observed within the exit points of the bridge near the toll collection system.

Figure 1: Layout of the study area

For this study Traffic volumes were counted by viewing videotapes recorded with a camera at a collection site by sample survey method. Video is captured for one hour and data is collected later by rewinding (Botswanq Guideline 9, 2004). PCU factors are adopted from the manual book of Geometric Design Standards for Roads & Highways Department (RHD Manual Book, 2000). The following PCU values are used.

Table 1: Passenger Car Unit (PCU) for different vehicles

Type of Vehicle	PCU
Private car	1
Micro	1.5
Bus	3
Truck	3
Pickup	1.5
Motorcycle	0.5
Cover van	3
Lorry	3

For the study purpose, we divided the heterogeneous vehicle into eight categories such as motorized two wheelers, motorized three wheelers, car, light commercial vehicles (LCV), bus, truck, lorry and non-motorized vehicle (NMV).

Readings were taken at the four-lane highway (free flow) and near the two-lane bridge (obstructed flow) at three significant days of the week (weekend Friday, week starting day Sunday, regular week day Tuesday). Video camera was used to count traffic manually on the Highway at peak hours (10-11 am) and off-peak hours (3-4 PM) separately. Velocities were taken by speed guns.

The following data were generated:

Traffic density: This is the number of vehicle in a given length of road at an instantaneous time. It is measured in vehicles per kilometer.

Traffic flow: This is the quantity of vehicles in space measured in an interval of time. It is measured in vehicle per hour.

Speed: This is the distance travelled by vehicle during a unit time. i.e. rate of movement of traffic. It is measured in kilometer per hour or mile per hour (Rahim et al., 2015). Speed was determined by sampling a set of vehicles, noting their travel time (with the use of stop watch) on a predetermined length of road along the case road. The space mean speed can be determined by,

$$v_i = \frac{\sum_{i=1}^{n} q_i}{\sum_{i=1}^{n} \frac{q_i}{v_i}}$$

Where q_i vehicle will have, v_i speed and n_i is the number of such observations.

The fundamental equation of traffic flow is

$q = k \times v$

Where q indicates the traffic flow, k indicates traffic density and v is space mean speed.

3. RESULTS AND DISCUSSIONS

The results show a significant change in the velocity and flow of the traffic at free flow (4-lanes) and obstructed flow (2-lanes) condition. As we see in figure 2(a), the value of total PCU is greater for free flow for each kind of vehicles than that of the obstructed flow during peak flow. However, it is noteworthy that, the number of bus and pickup is more than that of the other vehicles. This indicates that, the number of heavy vehicles is more than that of the light vehicles like private cars or micro bus at the highway. As we look into figure 2(c), we see that, the value of total PCU is changed to some extent at off peak hour than that of the peak flow. Interestingly, the change is not uniform for all the vehicles. In contrast to the increase of private vehicles, the number of heavy vehicles has decreased at off peak hour. However, the number of pickup and utility vans is more in obstructed flow as they cannot move quickly in limited space or park at the truck lay by.

From figure 1b, change in velocity is observed. Here also, the vehicles are operated at more velocity during free flow than the obstructed one. The values show that, most of the velocities are lessened by 40% as the vehicles enter the obstructed flow. Thus, a significant amount of clogging is created at the vicinity of the bridges: where the 4-lanes start to shrink at 2-lanes. It is also observed that, the velocity at off peak hour increases to some extent for light vehicles at the off peak hour (comparing figure 2d with figure 2b). Lesser share of heavy vehicles at off peak hours contributed to the increase the overall velocity.

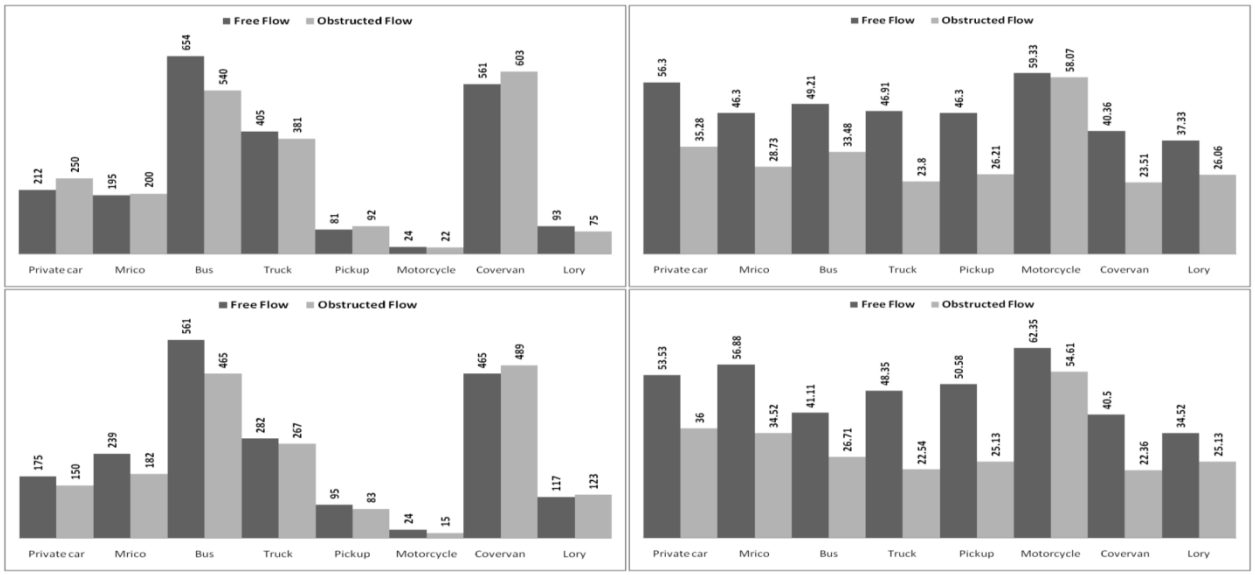

Figure 2: Variation of free and obstructed flow for a) Total PCU on Friday at Peak hour b) Velocity on Tuesday at Peak hour c) Total PCU on Friday at Off Peak hour b) Velocity on Tuesday at Off Peak hour

Comparing figure 3 (a, b, c and d), it can be stated that at obstructed condition flow is decreased about 51.78% than the free flow for Chittagong to Dhaka highway and about 52.94% for Dhaka to Chittagong highway.

Figure 3 (e, f, g, and h) depicts that, velocity changes abruptly from free flow to obstructed flow in both directions. It decreases about 48.76% for Chittagong to Dhaka highway and 47.47% for Dhaka to Chittagong highway.

In figure 3(i, j, k and l) indicates that at obstructed flow velocity only decrease 16.67% for Chittagong to

Dhaka highway any 16.67% for Dhaka to Chittagong highway.

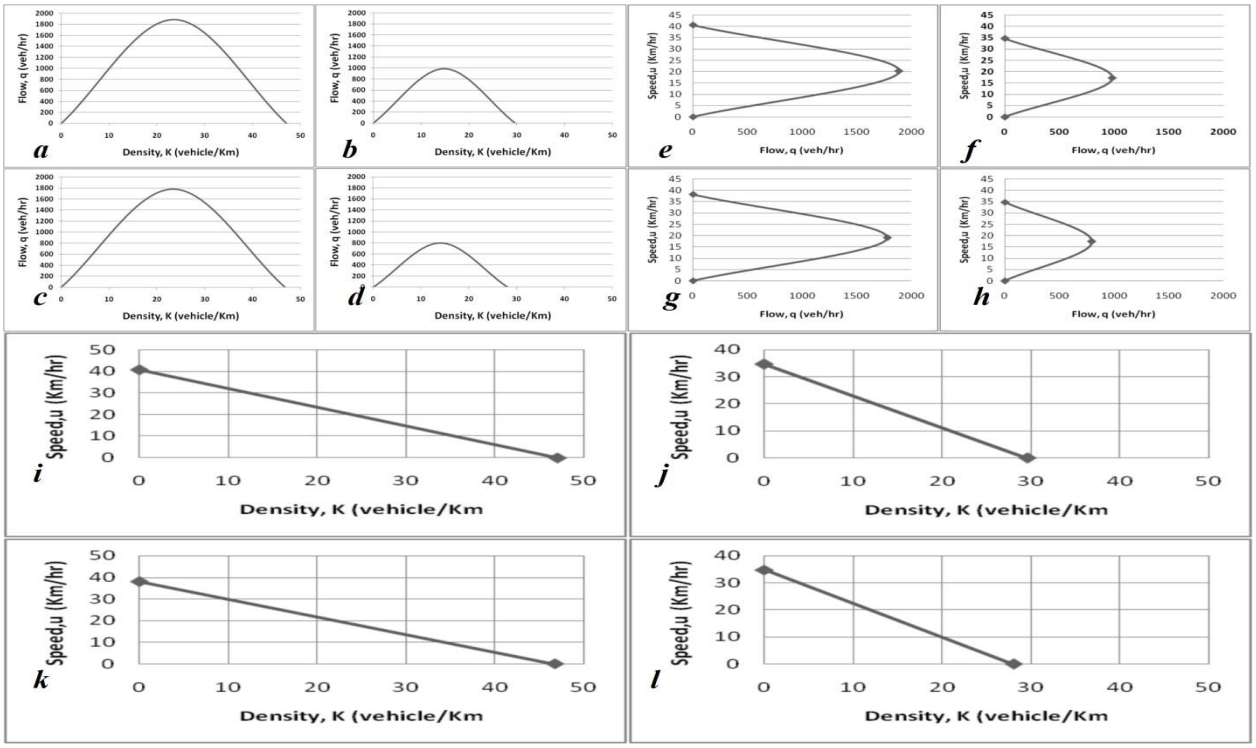

Figure 3: Fundamental Traffic Properties at Chittagong to Dhaka free flow (a, e, i); Chittagong to Dhaka obstructed flow (b, f, j); Dhaka to Chittagong free flow (c, g, k); Dhaka to Chittagong obstructed flow (d, h, l)

4. CONCLUSIONS

Traffic congestion has become a major problem for highways recently. Here, we focused on the fundamental relationship of traffic at peak hour and off peak hour along with the reasons for creating the traffic congestion at Gumti Bridge. From the results it is found that the flow, density, velocity has decreased significantly at obstructed flow than the free flow. The density of car is greater on Sunday and Tuesday than Friday. Besides, travel from Dhaka to Chittagong is more convenient than Chittagong to Dhaka. The presence of toll plaza in direction of Dhaka from Chittagong could be a cause here. The result indicates that, highway capacity is sufficient for generated traffic flow. However, the congestions due to bottlenecks near the two-lane bridges, illegal loading, unloading, 2 lane bridge for 4 lane highway, absence of additional lane for toll plaza, absence of additional lay by for heavy traffic, heterogeneous traffic velocity etc. are creating traffic congestion at the vicinity of the bridges. We can solve this problem by increasing number of lane at bridge, create additional lane for toll collection system, different lay bay for heavy traffic, clearing road side shops and hawkers etc. Most importantly strict rules and regulation should be imposed for motorized and non-motorized vehicles. Only after that we can minimize the traffic congestion at Gumti Bridge. Although the 2nd bridge is under construction, a full functional traffic flow could be obtained if the 4-lane highway and 4-lane bridge were unveiled simultaneously. Since this KMG second bridge project has been proved to not serve its purpose due to failure in project management, similar kind of projects involving the expansion of highway should be dealt with care so that no such bottleneck occurs at critical development spots like bridges.

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Paper 2

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Characterization of Available Sedimentary Clay of Hobiganj District

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Abstract

Finding the proper ceramic raw materials locally is important for sustainable development of Bangladesh, due to the fact that importation of raw clay from overseas or finished tiles cost the planet resource of transportation and subsequent climate impact. The conventional white-ware and tiles manufacturing industries use clay as the major raw material which is generally imported from foreign country. However, due to geological position of our country we have some sedimentary clay deposits. In this study, a local clay was studied to analyze its chemical, mineralogical composition, morphological, and thermal properties for plausible diversified applications. X-ray Fluorescence (XRF) analysis of clay showed 67.45% SiO_2 and 16.85 % Al_2O_3 as major ingredients with Fe_2O_3 and TiO_2, CaO, MgO, Na_2O and K_2O as minor impurities. X-ray Diffraction (XRD) analysis of clay revealed mineralogical composition as illite, kaolinite, quartz, and rutile. Scanning Electron Microscopy exhibited clay has tiny pyramid-like shape and pseudo-hexagonal structure of kaolinite in sample. Differential Scanning Calorimetry (DSC) showed different phase transitions such as metakaolinite phase formation occurred at 456^0C and α-β quartz transformation at 573^0C. From the thermal behavior of this clay, it was evident that Hobiganj clay resembles ball clay type.

Keywords: Clay Materials, XRF, XRD, SEM-EDX, and DSC-TG.

INTRODUCTION

Clay minerals are a group of hydrous aluminum silicates with a layered structure and very small (less than 0.005 mm) particle size. They are usually produced by weathering of rocks and occur widely in river sediments and soils. Different geologic environments produce different clay minerals from the same parent rock. Clay minerals form under a limited range of geological conditions. Most clay minerals form where rocks are in contact with water, air. Generally, the properties are almost common in all clay minerals. The basic structural feature of phyllosilicates is the combination of layers of pseudo-hexagonal network of SiO_2 tetrahedral (silica tetrahedral layer shown in Figure 1 (a) and layers of cations in octahedral coordination (octahedral layer) (Brindley and Brown, 1982; Klein and Hurlbut, 1993). Composite arrangement of each of the Al octahedral and Si tetrahedral layers result in a 1:1 structure as in kaolinite (a two-layer structure) or an octahedral layer sandwiched by two tetrahedral layers resulting in a 2:1 structure (as three-layer structure) shown in Figure 1 (b), as in montmorillonite and illite. The overall schematic representation of the common clay minerals is given in figure 1. The phyllosilicate types are divided into groups based on charge on the layers and on the nature of octahedral-tetrahedral layers (Ngun et al., 2012; Lee and Yeh, 2008).

Clay minerals are very important in process industries, engineering, construction, geology, environmental, and for other miscellaneous applications. They have been widely used as the main raw materials in fabrication of diversified ceramic products for construction materials such as bricks and tiles due to many

of their specific properties before and after firing. The chemical and mineral been reported to influence their ceramic properties. The main function of clay is to increase the plasticity and drying strength. Clay acts as a flux at high temperatures, its aids vitrification (Bender and Handle, 1982). Depending on composition and various other technical characteristics, clay can be processed into different shapes where plasticity, strength, and others parameter are varied (Namara and Dulberg, 1958). There has been an increasing interest in utilizing clay minerals such as bentonite, kaolinite, diatomite and fullers earth for their capacity to absorb not only inorganic but also organic molecules shown in Figure 1 (a). These raw materials are mainly made from silica and alumina with some impurity. In the firing process when free silica is present in high amount it causes crack within the ceramic body due to the quartz phase transformation. At the same time, high amount of alumina presence increase the refractory property of brick, tiles and other clay related ceramic body.

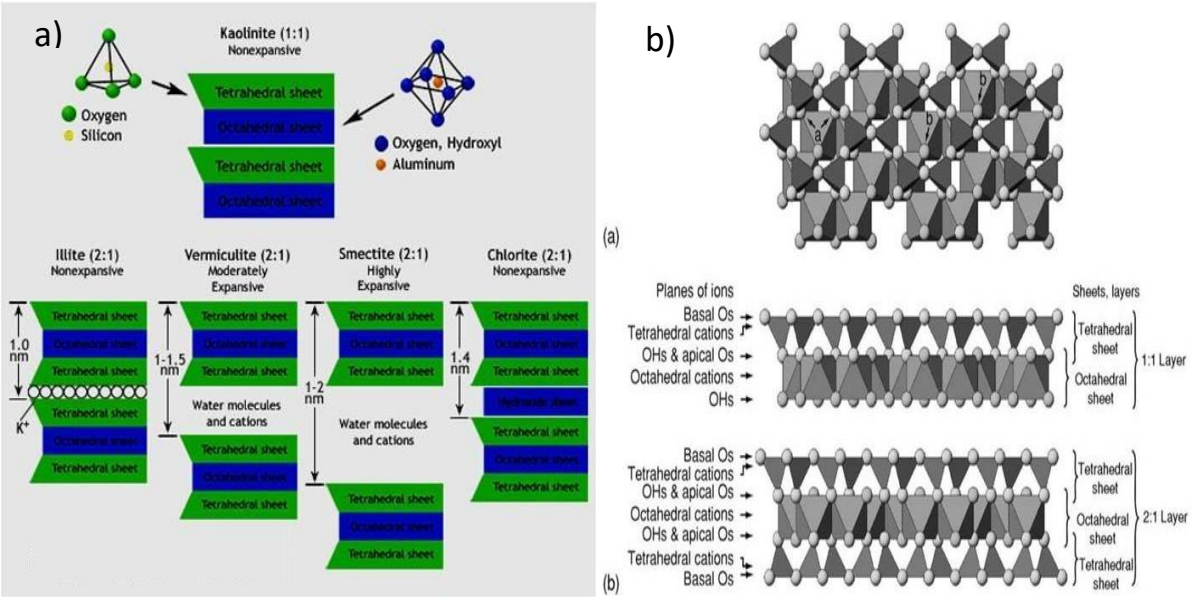

Figure 1. Structure of different clay minerals

MATERIALS AND METHOD

Geological studies reveal clay to be of two different types based on the way they were deposited. The types of clays which are found to be at the place of their origin are called residual Clay. Typically, these types of clays are deposited along the igneous rocks from which they were formed and are obtained in relatively pure state. Based on their in-situ nature, they are found to have coarse particle size with a wide particle size distribution. Due to this, these clays show lower plasticity. China clay is an example of residual clay, which is highly pure, has larger particle size and lower plasticity. The other type is sedimentary clays which are deposited by transportation from their origin by natural agencies like water, wind etc. Sedimentary clays are seldom obtained in pure state, due to impurities that are picked up during transportation and are retained in the deposits. The grinding action of clay particles in water and wind results in very fine particle sizes, giving the sedimentary clay very high plasticity. Ball clay is an example of sedimentary clay, which is not highly pure but has a finer particle size and very good plastic property.

Geological surveys indicated that Bangladesh has deposits of both some residual and sedimentary types of clays. Several places across the country have been identified as the sources of various types of clay. Notable locations are Bijoypur in Mymensingh, Barapukuria, and Maddhyapara in Dinajpur etc (Mahmoudi et al., 2008). Besides this location, there are also some locations in Hobiganj district where huge amount of clay deposit were found. The clays that are available in these sources are mainly Red Clay, Black Clay, Brick Clay etc. In this work, local Hobiganj clay is used as principal research materials. Hobiganj clay occurs abundantly in some localities of the district of Hobiganj in Bangladesh. The predominant color of Hobiganj clay formation is reddish yellow. Generally, the clay is light grayish white to bluish white with light yellow and slightly soap to feel, massive and soft to medium hard shown in

Figure 2. The natural clay was mixed as powder materials which were subsequently pressed to form cylindrical tablet sample of 15 mm in diameter, as well as 2 mm in thickness by uniaxial, die pressing.

A study was made on the natural clay of three different deposits of Hobiganj district. The aim of the present research is the study on physical, chemical properties of natural Hobiganj clay and their firing behavior. Within this research the methods used for the identification and quantification of natural clay for structural materials. X-ray fluorescence analysis may give detail about chemical composition of raw materials. After study the chemical composition of natural clay, necessary oxides are added for structural materials composition if modification needed. X-ray diffraction leads to an understanding of the structural characteristics of the clay mineral. Chemical compositions of Hobiganj clay collected from different area of Hobiganj district were investigated using X-ray Fluorescence Spectrometer. The different phases of Hobiganj clay were identified by using PAN-Analytical X-ray Diffractometer. Different phase % were identified by High Score plus Software. FE-SEM sample was taken as powder form for morphological information. Thermal behavior and weight loss of clay sample were studied by (DSC-TG) apparatus.

RESULTS AND DISCUSSION

X-ray fluorescence characterization

X-ray fluorescence (XRF) is the emission of characteristic "secondary" (or fluorescent) x-rays from a material that has been excited by bombarding with high-energy x-rays or gamma rays. The phenomenon is widely used for elemental analysis and chemical analysis of clays (Mahmoudi et al., 2008). Figure 2 shows the general appearance of Hobiganj clay when it was collected from Hobiganj district of Bahubal Thana. Basically, this Hobiganj clay looks like blackish type.

Figure 2. Graphical image of Hobigonaj clay

Table 1 shows that the clay contains a small amount of CaO, MgO, Na_2O, and K_2O which acts as fluxes. The presence of Fe_2O_3 and TiO_2 bearing materials impair the effectiveness of industrial raw materials, affect their utility for various applications. Traditionally, iron is removed by physical separation techniques, but hydrometallurgical treatment such as acid washing is the more effective and widely employed process. Sometimes iron oxide is also having helpfulness in brick and tiles for absorbing infrared radiation from sunlight. For making good quality of brick and tiles, it is very important to make sure the proper composition of clay raw materials.

Table 1. Chemical composition of Hobiganj natural clay raw material

Component ID	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	TiO_2 %	CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %	ZrO_2 %	Cr_2O_3 %
HOBI-11	67.45	16.85	7.52	2.02	0.03	0.98	4.53	0.33	0.06	0.02	0.07

XRD characterization

Figure 3 shows XRD pattern of Hobiganj natural clay sample. In this sample different phases are present. The clay sample looks like the ball clay type. In this clay sample, the intensity of silica or quartz is the highest it means high amount of silica is present within this sample. The kaolinite mineral has alumina (Adnan et al., 2011; Alim and Shahin, 1964). The Hobiganj clay sample has Al_2O_3 which is around 16.45 % of its weight. In this sample, iron oxide content is 7.52 %. In this clay, the main phases found are illite, kaolinite, quartz, and rutile (Titanium oxide-TiO_2).

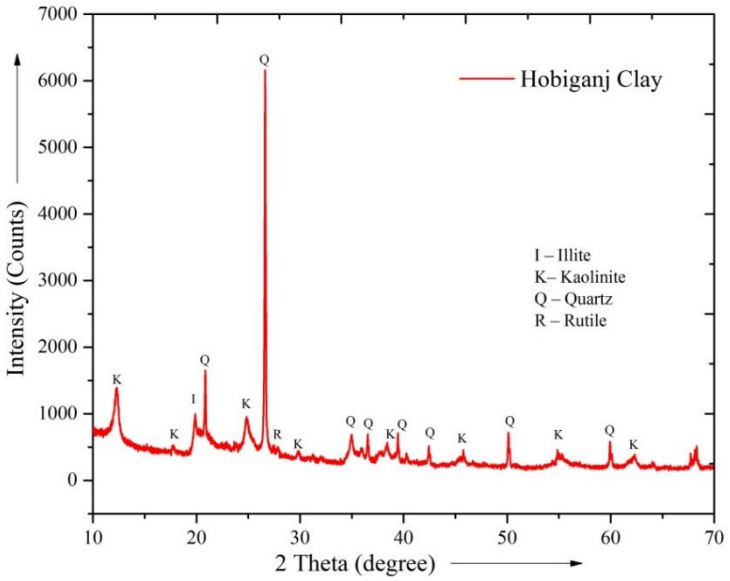

Figure 3. XRD Analysis of Hobiganj Clay

SEM-EDX Characterization

The Scanning Electron Microscopy (SEM) provides detailed images of individual grains of clay minerals and EDX provides detection of major and minor elements at points on grain surfaces, allowing highly reliable identification from crystal form and composition, as well as direct observation of particle packing and size (Klug and Alexander, 1972). Morphologies observed by SEM can also be useful in identification of clay minerals. Clay materials show a variety of morphologies, including platy, pseudo-hexagonal particles, booklets, and vermicular stacks. Hobi-11 is look like ball clay. The figure shown below is Hobiganj clay. At first, we investigated the natural clay sample for morphological view.

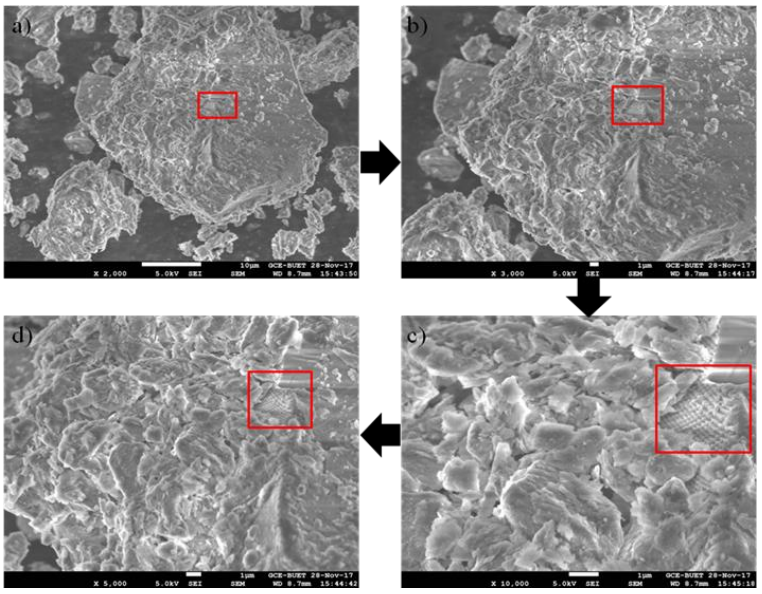

Figure 4. FESEM micrograph of Hobiganj clay

From FESEM micrographs (Figures 4 and 5), clearly, give information that the Hobiganj clay has tiny pyramid-like shape and pseudo-hexagonal structure. This pyramid-like shape may be the tetragonal or octahedral sheet structure. Morphological investigation of this clay sample revealed also huge illites like particles.

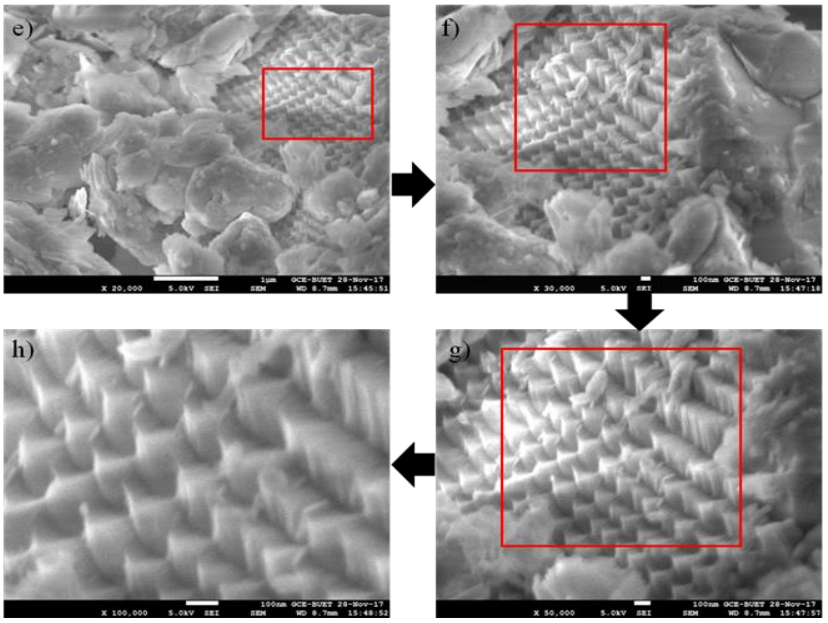

Figure 5. High magnification of FESEM micrograph of Hobiganj clay

Furthermore, EDX is used for *qualitative* (the type of elements) as well as *quantitative* (the percentage of the concentration of each element of the sample) analysis. Most SEM-EDX has dedicated software enabling auto-identification of the peaks and calculation of the atomic percentage of each element. One more advantage of the EDX technique is that it is a non-destructive characterization technique, which requires little or no sample preparation (Juhasz and Wojnarovits, 1984).

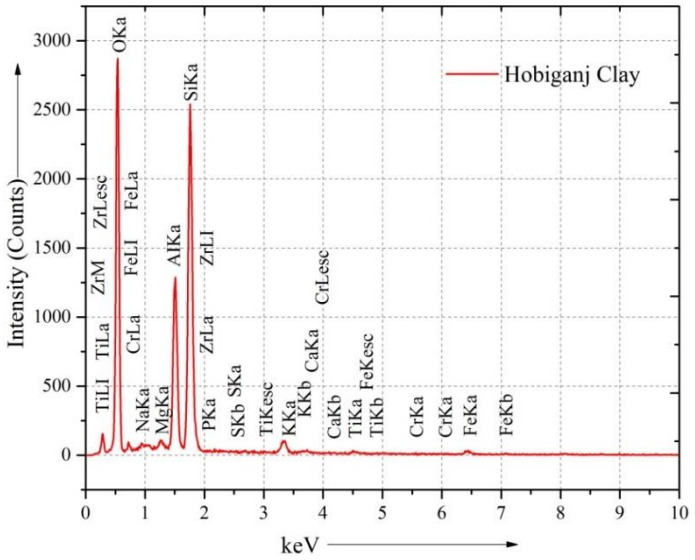

Figure 6. SEM-EDX spectra of Hobiganj clay

The Figure 6 shows the EDX curve with atomic % and mass % of different elements into Hobiganj clay materials. In this analysis result, Al and Si content is high like other clay minerals shown in Table 2. In Hobiganj clay the ratio of Al and Si is lower around half value. Table 2 shows that Ti, Ca, Fe, K, Fe and Zr are present in this clay sample.

Table 2: EDX-Analysis result of Hobiganj Clay

Element	(keV)	Hobiganj Clay	
		Element in Mass%	Element in Atom%
O(K)	0.525	37.77	52.31
Na(K)	1.041	0.30	0.29
Mg(K)	1.253	0.69	0.63
Al(K)	1.486	16.09	13.21
Si(K)	1.739	38.31	30.22
Ti(K)	4.508	0.81	0.37
K(K)	3.312	2.78	1.58
Ca(K)	3.690	0.52	0.29
S(K)	2.307	0.10	0.07
Fe(K)	6.398	2.55	1.00
P(K)	2.013	0.04	0.07
Zr(L)	1.480	0.07	0.02
Total		100.00	100.00

DSC-TG Characterization

DSC-TG analysis measures both heat flow and weight changes in a material as a function of temperature or time in a controlled atmosphere. The complementary information obtained allows investigating the exothermic and endothermic effects of reactions, such as carbon oxidation and dehydroxylation respectively (Cameron, 1977). Figure 7 shows the effect of energy changes (endothermic or exothermic reactions) in a sample.

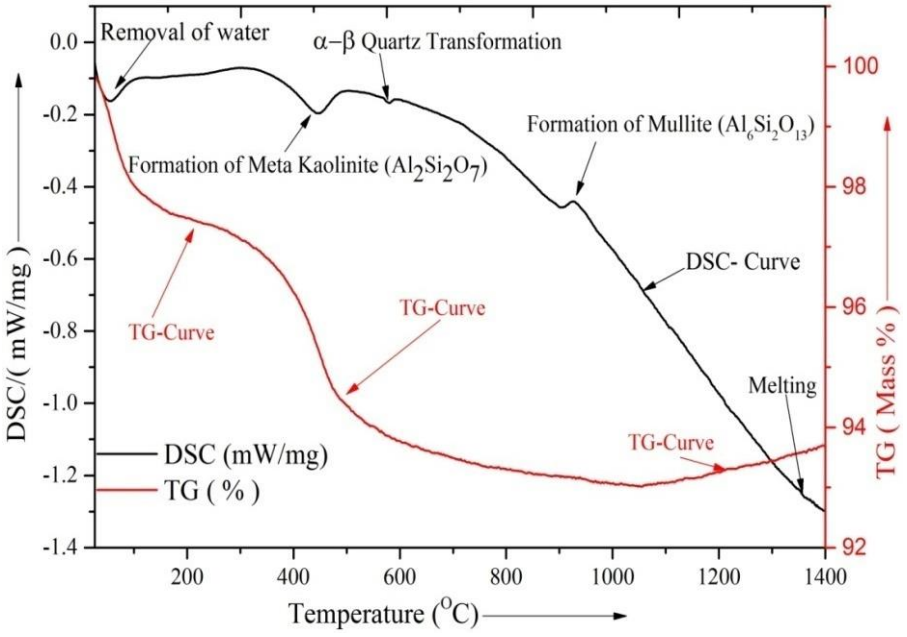

Figure 7. DSC and TG analysis curve of Hobiganj clay

For clays, endothermic reactions involve desorption of surface H_2O (e.g. H_2O on exterior surfaces) and dehydration (e.g. interlayer H_2O) at low temperatures (100^0C), dehydration and dehydroxylation at more elevated temperatures and eventually melting. At high-temperature metakaolinite phase formation occurs at around 456^0C and α-β quartz transformation takes place at 573^0C. Exothermic reactions are related to recrystallization at high temperatures that may be nearly concurrent with or after dehydroxylation and melting (Tanjid, 2004; Huber, 1956; Malaiskiene et al., 2011). From the thermal behavior of this clay, it is evident that Hobiganj clay is ball clay.

CONCLUSIONS

From chemical composition, SEM-EDX, XRD and DSC analysis of Hobiganj clay, it is concluded that Hobiganj clay contains silica and alumina as major constituents and iron, calcium, potassium, and magnesium oxide are present as minor quantities. High amount of free silica causes crack into the brick and tiles. As well as high alumina content improve the refractory properties of clay-related product. From above various properties of clay, it is apparent that Hobiganj clay may be used as an impotent raw material in brick and tiles industries in Bangladesh to produce various structural ceramic related products and has the prospect to lower the dependency of imported structural ceramic materials.

Acknowledgments

The authors thankfully acknowledge financial support provided by Higher Education Quality Enhancement Project, Window-4, University Grant Commission (UGC), Dhaka.

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Paper 7

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Geo-environmental characteristics and evolution of the solid waste landfill sites of Dhaka city, Bangladesh

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1. Abstract

Solid waste management is a complex problem in both developing and developed countries. Globally the amount of solid waste has increased dramatically in the past decades. Improper waste management has led to aesthetic deterioration, obnoxious odor, spread of diseases and most importantly long term surface and groundwater pollution. Dhaka is the capital of Bangladesh and one of the fastest growing megacities of the world. Dhaka alone contributes about 34% of the country's gross domestic product (GDP), indicating the economic importance of the city. To achieve this economic growth, intensive urbanization and industrialization has taken place in the past decades. Within the 300 sq.km of the city, huge number of people and infrastructures are accommodated. As a result, land has become very expensive and scarce, even the low lying wetland areas are filled up. The combination of huge population and small land area resulted in two contrasting combination, i.e. huge amount of municipal solid waste but scarce land for landfill sites. Therefore, the authorities are forced to dump the waste around the low lying wetland areas ignoring all the geo-environmental consequences. Currently solid waste is dumped into two landfill sites. The Matuail landfill site is the oldest, partly sanitary, and the Amin Bazar landfill site is absolutely an open dumping site. No geomorphological, geological or environmental criteria were applied for these site selections. Using multi-temporal satellite images, digital elevation model, borelog information and field survey, this study tried to explore the characteristics and evolution of these landfill sites. In the next step, the geomorphological and geological opportunities and constraints of these sites are explored and lastly for sustainable management of the landfill site few site selection criteria for Dhaka City are recommended. The analysis indicates that both the landfill sites are situated in low lying areas. Matuail site is located adjacent to the wetland of the Eastern Dhaka. The Amin Bazar site is constructed within the vast water bodies of the Western Dhaka. As the Matuail site is situated around the stagnant water bodies, the risk of surface water pollution is particularly high during the monsoon season. In contrast, the Amin Bazar site is situated within the flowing water, the adjacent water is being contaminated every day from this open site and the magnitude of pollution increases during the monsoon season. The strength of the sites is controlled by the underlying geology. The presence of thick impermeable clay layer and the high depth of groundwater aquifer resulted in minor risk of groundwater contamination from both the landfill sites. However, groundwater can be contaminated through the surface water if the aquifer is exposed to the riverbed and through faults and fractures, therefore regular monitoring of groundwater quality is strongly recommended.

Keywords: Solid waste, Remote Sensing, Landfill site characteristics, Geologic control of contamination.

1. INTRODUCTION

Solid waste is an unavoidable by-product of human activities. The estimated quantity of Municipal Solid Waste (MSW) generated worldwide in 2016 is about 2.01 billion metric tons and this number is expected to grow to 3.40 billion tonnes by 2050 under a business-as-usual scenario (World Bank, 2018). In many cases, municipal wastes are not well managed especially in developing countries because of the accelerated pace of waste production (Kumar et al. 2017, World Bank, 2018). Furthermore, not all the

wastes are collected and a significant portion of the wastes are dumped in water bodies, low lying areas or in open spaces (Nagarajan et al., 2012; Yoada et al. 2014). This uncontrolled dumping degrades and inflicts serious stress on the surrounding air, soil and water quality.

Since rapid urbanization is inevitable with the economic development of the country, sustainable development of the country therefore depends intricately on the sustainable urban development. Dhaka is the capital and the largest and the most important urban area of Bangladesh. Since most of the political, economic and socio-cultural activities are Dhaka-centric and most of the services are concentrated here, it is often referred to as the nucleus of the country. The city attracts over 300,000 - 400,000 new migrants each year (BBS, 2013). Consequently, the city is experiencing very high rate of urbanization, far greater than other cities of Bangladesh. Dhaka alone contains about 10% of the total national population of Bangladesh and 37% of the total urban population (RAJUK, 2015). The city is the most densely populated area in Bangladesh as well as in the world with average density of about 44,100 people/km^2 (Demographia, 2016). In such context, waste disposal is a serious issue for the city. The increased waste generation can be primarily attributed to high population growth and changing consumption pattern. Poor management of solid waste imposes serious environmental degradation in the form of groundwater and surface water pollution, blocked drainage, obnoxious odor, health impacts and aesthetic discomfort in the city.

Although there are number of works on the management of solid waste of Dhaka city (Kabir, 2015; Saifullah & Islam, 2016; Sufian & Bala, 2007; Yasmin & Rahman, 2017), there are limited works on the geomorphological and geological characteristics of the landfill sites, on which the wastes are actually dumped. This study tried to analyze the characteristics of two landfill sites in Dhaka city with the following objectives: what was the original landform on which the landfill site was constructed, how these sites are spatially extended with time, what is the subsurface geology of these sites, how it could influence the groundwater contamination vulnerability and lastly what could be the possible site selection criteria for an environmentally safe landfill site of Dhaka city?

2. THE STUDY AREA

Since its foundation about 400 years ago, the boundary of Dhaka City has grown steadily; the pace has been rather slow. Dacca Municipality was first established on August 1, 1864. In 1974, Dhaka got the status of Municipal Corporation and in 1983 as a City Corporation. Four different types of jurisdictional boundaries are recognized for Dhaka City (Table 1).

Table 1: The different types of jurisdictional boundaries of Dhaka City (modified after Corner & Dewan, 2013, Rajuk, 2015).

No	Acronym	Boundary name	Area (sq. km)	Jurisdiction defined by
1	DCC	Dhaka City Corporation	143	North and South City Corporations
2	DMA	Dhaka Metropolitan Area	303	Dhaka Metropolitan Police
3	DSMA	Dhaka Statistical Metropolitan Area	1383	Bangladesh Bureau of Statistics
4	DMDP	Dhaka Metropolitan Development Plan	1528	Rajdhani Unnayan Kortripakhkha (RAJUK)

Although the core urban areas are within the DCC boundary, the DMA is generally referred to as Dhaka City by most of the people and is bounded by the Turag, Balu, Buriganga, and Tongi Rivers (Figure 1). The DCC area is the most densely populated, the DMA area includes the entire DCC area and the eastern and northern fringe areas of the city. The DMDP is the broad planning region and includes the entire DCC area and six adjacent municipality areas (Savar, Narayanganj, Gazipur, Kadamrasul, Siddirganj and Tongi) and a number of adjacent urban areas. The DSMA is slightly smaller than the DMDP area which includes the entire DCC area along with the six adjacent municipality areas and 68 unions. In November 2011, by the Local Government (City Corporation) Act 2009 (Amendment in 2011), Dhaka City Corporation was divided into Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC). The DNCC consists of 36 wards with total area of 75 sq. km and the DSCC consists of 56 wards with area of about 42 sq. km.

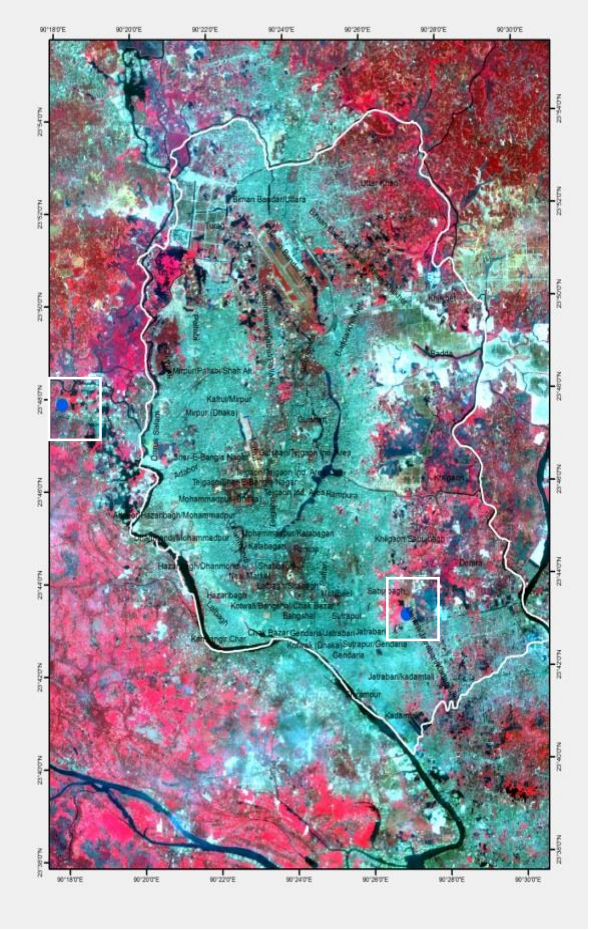

Figure 1: Satellite images of Dhaka Metropolitan Area (DMA) showing two landfill sites.

2.1. CHALLENGES OF SOLID WASTE MANAGEMENT IN DHAKA CITY

The challenges of municipal solid waste collection from Dhaka city is multidimensional, ranging from policy scale, budget constraints, transportation, waste composition and dumping. The DCC (Dhaka North & South City Corporations) is the formal organization responsible for the waste management of the city. The Local Government City Corporation Act (LGCCA) 2009 is the basic law regarding waste collection from the city corporation areas. According to Section 41 (1.4 to 1.7) of the Act, the City Corporation is not responsible for door to door waste collection. Rather it is the residents of the buildings who are responsible for the removal of waste from their premises and dumping the waste to the adjacent dustbins. Due to this gap in policy, waste collection from the buildings and transportation to the so called Secondary Transfer Station (STS) becomes a business. The city corporation collects the waste from the STS and transports it to the landfill site. Due to this gap in policy, considerable amount of wastes are often dumped along the street, open space or in low lying areas. Furthermore, if the in-between link does not work even for a week, waste collection will be a huge problem for Dhaka city.

Secondly, considering the composition of solid waste it is found that organic matters constitute the major portion of the solid waste of Dhaka City (Parvin and Begum, 2018) (Figure 2). Information about composition of solid waste is important to predict the amount of leachate that could be generated from the waste. Leachate generation is a major problem for municipal solid waste. Generally, leachates are generated in landfills which contain large amounts of organic waste (Raghab et al., 2013). The degree of environmental impacts, especially on groundwater and surface water depends on the leachate amount and characteristics (Maiti et al., 2016). Leachate contamination of groundwater is known around the world (Dervišević et al. 2016; Dharmarathne & Gunatilake, 2013, Nagarajan et al, 2012). Furthermore, organic biomass that decomposes anaerobically in a landfill can cause methane emission, which is an important greenhouse gas (Di Maria and Sisani, 2017).

In addition to these issues, there are several other challenges of solid waste management in Dhaka city, which include:

- Increasing waste quantity.
- Indiscriminate waste dumping.
- Inappropriate place for dumping.
- Unsanitary dumping/open dumping.
- Unavailability of land for disposal.
- Lack of efficient waste collection system.
- Lack of efficient waste segregation system.
- Lack of solid waste management legislation (hazardous waste management, landfill site selection, source reduction policy).
- Lack of quality-data about waste (waste quantity, types).
- Lack of monitoring of the dumping site (leachate quality & quantity, emission characteristics, air quality, aquifer monitoring).

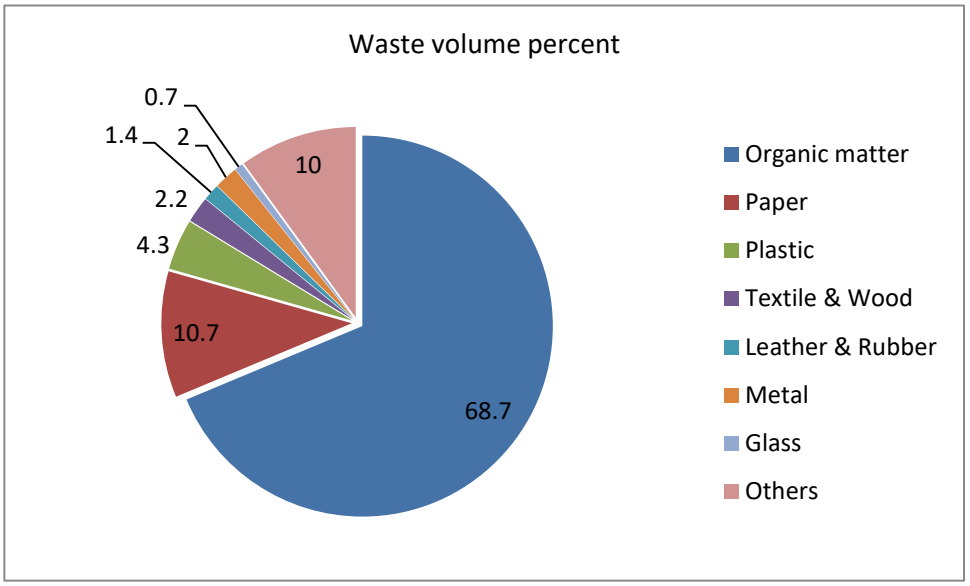

Fig 2: Composition of generated solid waste in Dhaka city (Islam, 2016)

3. DATA & METHODOLOGY

Four types of data are analyzed in this study which includes satellite image, digital elevation model, borehole litholog, and data collected from Dhaka North & South City Corporations. Besides, fieldwork surveys were conducted at the landfill sites to understand the present day dumping conditions. Geotagged photographs were taken during the survey and later the image was imported in the GIS map. Time series satellite images were employed to detect the nature of geomorphic/land cover condition of the landfill sites. Two types of satellite images were employed, the high resolution panchromatic CORONA satellite images were used to detect the original landform condition. The image was captured on 22 April 1972, when the landfill site was still in an undisturbed condition. The resolution of CORONA image is 2 meters, which is sufficient enough for detailed land cover mapping. The CORONA image was georeferenced and the layout of the dumping sites are overlaid on the image to exactly identify the landform condition.

For chronological changes of the landfill areas, time series Google Earth images were employed. In addition, 30 m resolution Landsat images and 10 m resolution Sentinel-2 imagers were analyzed to detect the overall geomorphic condition of Dhaka City. Digital elevation model using 30 m SRTM data were used to detect the landform elevation so that the flood vulnerability of the sites can be assessed. The groundwater contamination vulnerability from the landfill sites are mainly controlled by the subsurface lithlogic condition and were assessed using the borelog information. To understand the quantity of solid waste dumped in the landfill sites, data from the "Waste Management Department" of Dhaka North and South City corporations were collected. However, there are many data gaps and the data collected from the Dhaka North City Corporation was not usable.

4. RESULTS AND DISCUSSIONS

4.1 Site characteristics & evolution of the Amin Bazar landfill site

Built in 2007 (age 11 years) on 52 acres of land, the Amin Bazar landfill site is situated at the western part of Dhaka city outside the city corporation area. Presently it is an open dumping site. This site receives waste from Dhaka North City Corporation area. The site is about 300 m northward from the Dhaka-Aricha Highway (Figure 3). The area mostly represents the floodplain of the Bangshi, Dhaleswari and Turag Rivers. In the northern part, the Bangshi River flows very close to the landfill site which later joins with the Turag-Buriganga River on the east. The area is heavily flooded and there are perennial waters even during the dry season.

Fig 3: Satellite image showing the landform of the Amin Bazar site in 1972. The site is situated within low lying areas surrounded by rivers and wetlands.

Image analysis indicates agricultural landuse around the late 70's but now it is dominated by numerous brickfields. Analysis of digital elevation model indicates that there are populated highland around the western side of the landfill at Baliarpur and Nagar Konda areas where the elevation is around 10-14 meter. In contrast, the elevation of the adjacent floodplain is about 4 m where the site is actually situated. The slope of the area is towards east and south-east, indicating the overall surface water flow direction (Figure 4). Unfortunately there are no borelog available from this area, however personal communication with local people suggest the presence of thick Madhupur Clay at about 3-4 meter depth below the site.

Field survey indicates that the obnoxious odors from the landfill site have a radius of about 2 km and the intensity increases with temperature and after rainfall. Within this radius, a huge land development project called Madumati Model Town was constructed around the year 2000 just opposite the landfill site by filling the wetland. Leachate pond and sanitary landfill system was constructed around 2010. The leachates were collected in two ponds at the south eastern part of the site (Figure 5). However from 2017, the system is not working and the fate of the leachate is not known.

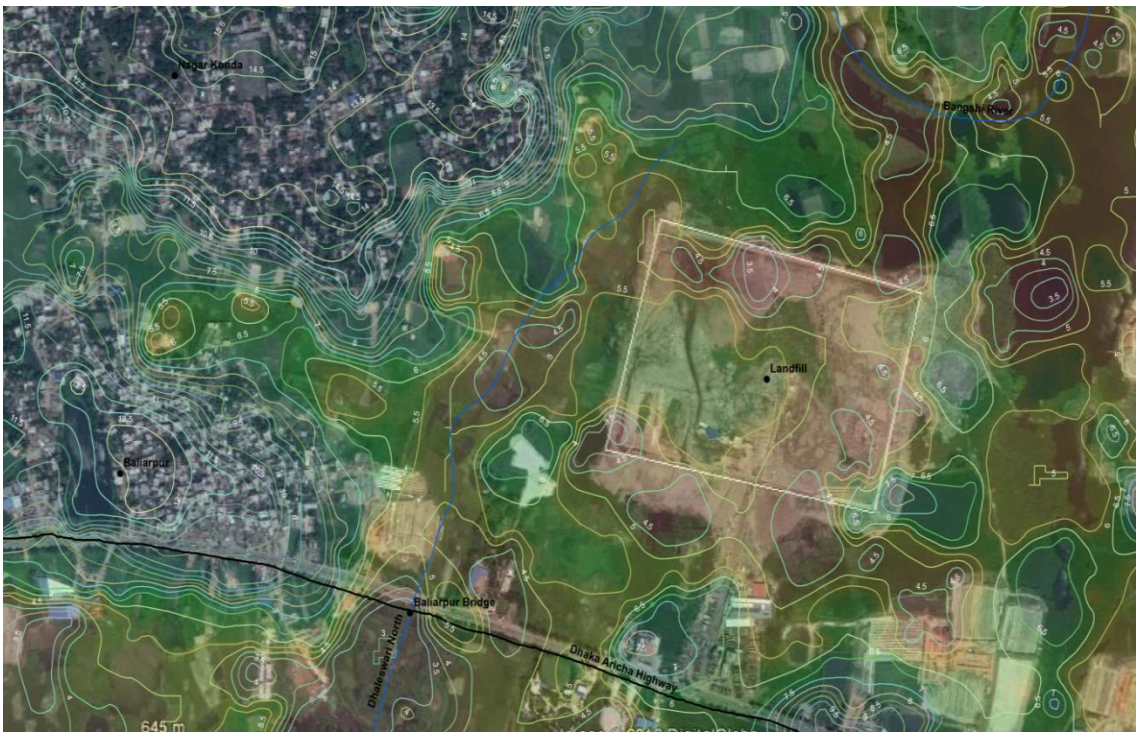

Fig 4: Elevation contour around the Amin Bazar landfill site overlaid on present day site layout. The location of the site is within the depressed low lying area surrounded by water bodies. The elevation difference between the landfill site and the adjacent highland is about 6 meter.

Figure 5: Evolution of Amin Bazar dumping site. The present day layout of the site is overlaid on the left image which was captured on 2004-11-13, shows the extent of the landfill site was completely covered with water during that time. The right image was captured on 2018-04-25 showing how the waste spills over to the adjacent water bodies. The two closed leachate ponds are at the south western part of the site. The area evolved at a rate of about 100 sq. m per year, presently the total area is completely used and the wastes are now piled vertically.

4.2 Site characteristics & evolution of the Matuail landfill site

Established in 1995 (23 years old), The Matuail Landfill site is situated at the eastern part of Dhaka city, about 2 km east of Jatrabari around the Dhaka-Demra Highway (Figure 6). This site now receives waste from Dhaka South City Corporation area. Matuail is the only sanitary landfill in Dhaka, where the leachate is collected, piped to storage facility and treated so it does not contaminate the soil and water. In 1995, total area of the site was about 50 acre (0.2 sq. km), additional 50 acre was added in 2006 (total 100 acre/0.4 square km).

Fig 6: The present day layout of the Matuail landfill site overlaid on the CORONA satellite image of 1972, showing the position of the site within the wetland area of eastern Dhaka.

In the first phase area, the waste height reached about 21 meter and further dumping was not possible. In the second phase area, the current height of the waste heap is about 18 meter and it is predicted that the site can be used hardly for another year (Figure 7). In the absence of a daily soil cover, the waste is accessible to pest, vermin, birds, and other vectors and the gusty winds spread the waste to the surrounding areas.

Figure 7: Chronological evolution of Matuail landfill site. The left image was captured on 2001-03-21 when the site is about 6 years old and the right image was captured on 2018-04-25 showing how land development projects are constructed around the site. .

The landfill site area is on the fringe of a perennial wetland. The land use is mainly residential, sparse at the eastern side and dense at the western part. The elevation at the site is around 6 m, the eastern part has similar elevation but there are highlands of 10 m elevation at the western part (Figure 8). The subsurface geological information of the site is collected from one borehole about 1 km eastward from the site. The borehole (BH 20) was drilled by CDMP (Comprehensive Disaster Management Program). The stratigraphy of the bore indicates about 1.5 meter thick Holocene clay at the top, followed by thick (25.5 meter) Madhupur Clay up to a depth of 27 meter. The Dupi Tila aquifer started from, 27.5 meter depth and continued further (Figure 8). A further 0.35 meter thick (1.1 feet) clay layer was spread at the bottom of the site to prevent leachate migration, however there are no monitoring of cracks in the clay layer.

The high depth of aquifer and thick impermeable clay layer indicated that geologically Matuail is a suitable site for solid waste dumping. In contrast, considering the low elevation, close proximity of surface water and annual flooding, this site is a potentially harmful site for surface water contamination.

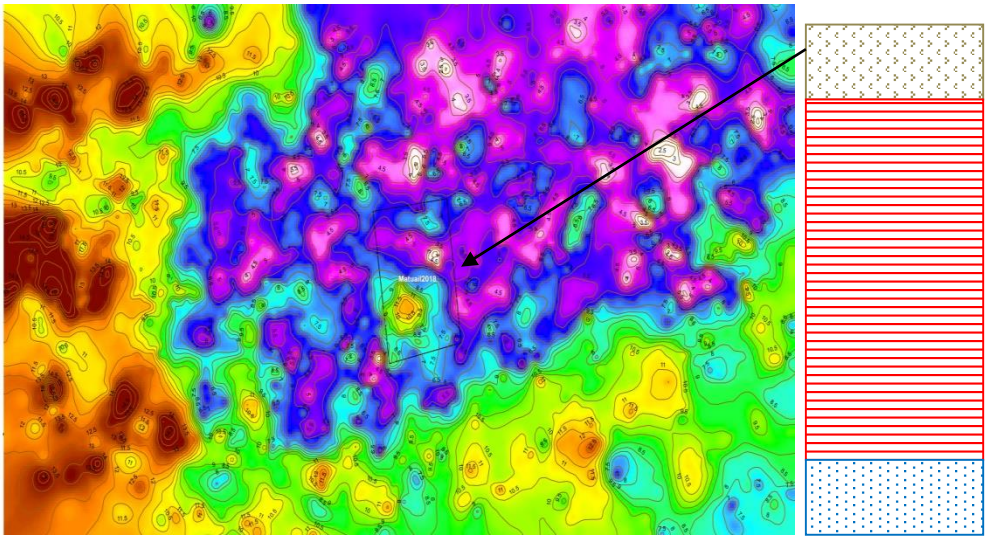

Figure 8: (Left) Digital elevation model of the Matuail landfill site indicates the location of the landfill within the low lying wetlands surrounded by a high elevation area. (Right) Borelog around the landfill site showing presence of thick clay layer under the site and high depth of groundwater.

4.3 Geo-environmental comparisons of Amin Bazar and Matuail landfill sites

Matuail is the first landfill site of Dhaka city. Both Matuail and Amin Bazar sites are situated at low lying areas around the eastern and western fringe of Dhaka city. However, Matuail is situated around the wetland of stagnant water bodies, in contrast Amin Bazar is situated with the flood plain of the Banshi-Dhaleswari-Turag Rivers (Figure 9). The Amin Bazar site is within 200 meters' distance from the Bangshi River. If the surface water around the site is contaminated it will flow quickly to the Buriganga River, exposing more number of people. Even solid waste from the site can spill into the channel of the Bangshi River. Such vulnerability is not present in Matuail site. However, Matuail is very close to the human habitat. Inappropriate management of the site could pose greater health risk around the site. Both sites have thick Madhupur Clay at the subsurface which would act as a barrier for leachate migration to the subsurface aquifer. However, groundwater can be contaminated through the surface water if the aquifer is exposed to the riverbed and through faults and fractures. Therefore, regular monitoring of the groundwater quality and detailed subsurface information is necessary to evaluate the aquifer vulnerability.

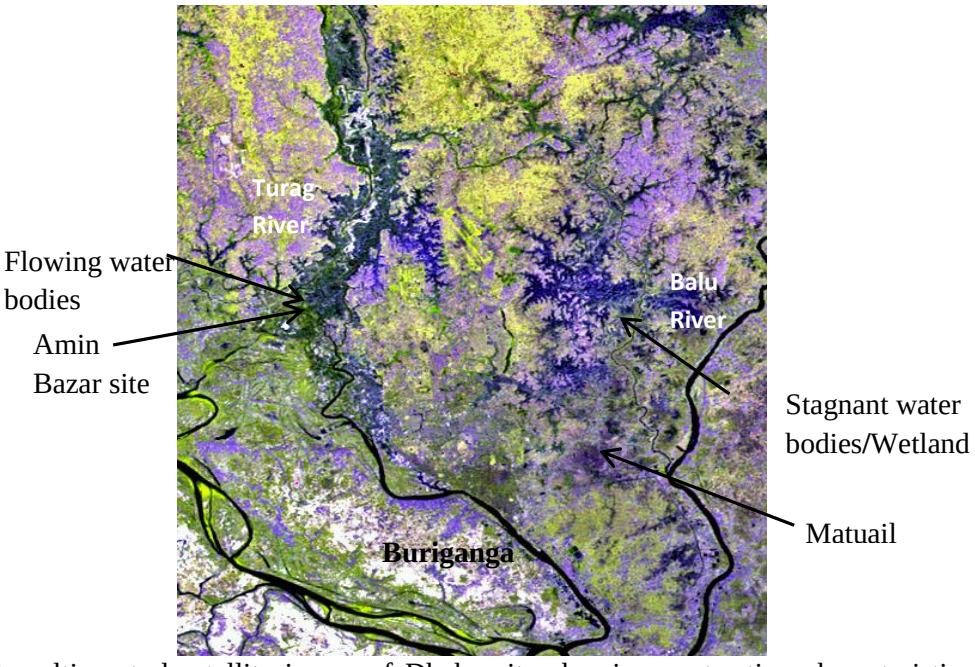

Fig 9: Earliest multispectral satellite image of Dhaka city showing contrasting characteristics of water around the eastern and western parts (Landsat MSS image 1972-12-28 path/row 137/44).

4.4 Suggested geo-environmental parameter for future landfill site selection

Selecting and managing solid waste dumping site is a challenging problem for Bangladesh, due to the lack of proper solid waste management system and policy guidelines. Therefore, significant portions of the generated waste are dumped indiscriminately into the water bodies, low lands or just on the side of the street, which clogs the drainage system and creates water logging and obnoxious odour. Surprisingly in some places the filling of low land areas by dumping solid wastes are encouraged by the authority. The health and environmental impacts are still grossly overlooked and unknown, therefore the existing management system cannot be sustainable.

To select a sustainable waste disposal site, different social, economic and environmental criteria must be analysed. Several methods like AHP (Analytical Hierarchy Process), GIS & Remote sensing are widely used for this purposes (Chowdhury & Das, 2012; Majumder et al. 2017). Generally, at first the capacity of the potential site is predicted then the other parameters are investigated. The ideal landfill site for the low elevation, monsoon dominated climate and organic dominated solid waste of Dhaka city should have two main priorities, avoidance of contamination of i) surface water and ii) groundwater. To avoid the surface water pollution the elevation of the site should be above the long-term (e.g. 50 years) flood level and to avoid the groundwater contamination thick clay layer known as Madhupur Clay must be present between the base of a landfill and the aquifer. The factors that should be considered for the safe management of landfill site, especially for Dhaka city are summarized in Table 2.

Table 2: Geo-environmental parameter necessary for appropriate landfill site selection.

No	Site selection parameters	Properties
1.	Elevation (flood height)	Must be above the local maximum flood height level
2.	Vicinity of surface water (river, wetland)	Minimum 1 km away from flowing or stagnant water
3.	Subsurface lithology	Presence of thick, impermeable layer over the aquifer
4.	Groundwater depth	Depth must be more than 10 meter
5.	Paleochannel (naturally filled up river)	Minimum 500 m away
6.	Subsurface fault	Should be at least 200 m away from faults
7.	Slope	Not on steep slope
8.	Topography	Must not in undulated area
9.	Anthropogenic history	Must not a filled site
10.	Ecologically sensitive area	Away from the reserve forest, wildlife and protected areas
11.	Distance from residential areas	At least 4-5 km away
12.	Transport distance	Not more than 30-45 minutes
13.	Accessing roads	At least two-lane road, the traffic of the roads must be low
14.	Source of fine grained cover material	Must be available near the site
15.	Site life expectancy	Must be used for the next 10 to 15 years

Considering the above parameter it is evident that except lithology, none of the parameters are considered for selection of the Matuail and Amin Bazar site. Moreover, lithological suitability seems to be a mere coincidence.

5. CONCLUSIONS AND RECOMMENDATIONS

- The attitude of a society towards the environment is a good indicator of the degree of sustainable development. Precautions are necessary to protect the environment especially in urban areas where solid wastes are dumped in open landfill sites as in Dhaka city. Open solid waste dumping sites cause serious damage to surface and ground water. Therefore, the most important criteria involved in planning solid waste dumping sites is not the convenience of dumping, rather the protection of the surface and groundwater.
- The solid waste from Dhaka North and South City Corporations are currently dumped in the Amin Bazar and Matuail sites respectively. Historical CORONA image of 1972 was employed to detect the original landform conditions of the landfill sites. Image and digital elevation model analysis indicates that both the sites are situated at the low lying, depressed wetland areas of Dhaka City. However, there are flowing river channels very close to Amin Bazar site which makes the area more vulnerable to surface water pollution. In contrast the Matuail site is away from the river but the surrounded area is flooded during the monsoon season. Both the sites have a thick subsurface Madhupur Clay layer which would prevent the aquifer contamination. However, groundwater can be contaminated through the surface water if the aquifer is exposed in the riverbed and through faults and fractures, therefore regular monitoring of groundwater quality is recommended.
- Considering the topography, climate and composition of the solid waste, few landfill site selection criteria are recommended for the sustainable solid waste management of Dhaka city.
- Groundwater moves through the earth from topographically high areas (called recharge areas) to topographically low areas (called discharge areas). As the cone of depression is now towards the centre of Dhaka city, therefore the peripheral part could act as recharge areas and presence of any landfill site in these areas could increase the groundwater contamination vulnerability of Dhaka city. Therefore further landfill site in the peripheral wetland of Dhaka city is not recommended.

ACKNOWLEDGEMENTS

The authors are grateful to the anonymous reviewer for the useful comments and suggestions.

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Paper 9

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Rethinking the Residential Environment of the Ship Breaking Workers Community

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Abstract

Ship recycling industry and its relevant activities are presenting both threats and opportunities for ship breaking workers and their immediate environment. Despite numerous negative impacts on coastal environment of Chittagong region of Bangladesh, ship breaking industry is flourishing as it is the main source of raw materials of re-rolling mills and provides employment opportunities for 30000 workers. The study shows how they are living in present condition and shows proposal of a conceptual framework for sustainable improvement of worker's residential environment. It is observed from the assessment that most of the workers come from poverty afflicted areas of Bangladesh where they are deprived from employment opportunities. A few residential hazards are observed from survey and study of workers of ship breaking yard. Due to the positive role of ship breaking in national economy, ship breaking cannot be stopped. This paper aims to minimize the adverse consequences and impacts on residential environment of ship breaking workers in the study area through recommending sustainable methodology for better living environment.

Keywords: Awareness, Lifestyle, Ship breaking workers, Safety of workers, Sustainable.

1. INTRODUCTION

Shipbreaking is the process of dismantling and obsolete vessel's structure for scrapping or disposal. Working in a dismantling yard involves a wide range of activities. From removing all the gear and equipment that are on the ships from cutting down to recylcing the ship's infrastructure. Shipbreaking is a challenging process, due to the structural complexity of the ships and the environmental safety and health issues involved. (OSHA, 2001). Due to cheaper labour costs and weaker health and safety regulations, the developing world hosts most ship breaking efforts. Raising the economic benefit, the ship breaking activities are being practiced widely in the coastal areas (Muhibbullah, 2013). Ship breaking activities present both challenges and opportunities for coastal zone with increasing demand of raw materials for metal re-rolling mills and this activity began in 1969 and since then it has earned a good reputation for being profitable at the cost of environmental degradation (Hossain and Islam, 2006). Bangladesh has become 2nd largest ship breaking industry since it was found growing in 1984. Over the last few decades, the concern has risen for the development of environmentally safe ship breaking and recycling industry as well as to ensure sound inhabitation of the workers. Approximately 30,000 workers are involved in this

sector who are mixed with skilled and unskilled labors. This can't be ignored. Besides, there exist Environment Conservation act, rules and laws which hope to influence growth of environmentally sustainable ship breaking industry. With the collaboration of World Economic Forum and Joint Research Centre, Yale University's Center for Environmental Law and Policy and Columbia University's Center for International Earth Science Information Network (Juho Pulli, 2013), created an index of 25 indicators promoting two focus points; reducing environmental stress to human health and promoting ecosystem vitality and sound natural resource management (Juho Pulli, 2013). Adding to that, there is scarcity of pure drinking water, healthy food, hygiene toilet and good living place for workers in the ship breaking yards of Sitakunda. These conditions are direct violations of labourer's rights. Previous studies always focused on the main product of shipbreaking process, but it lacks the attention to the people who are involved in the production. Since they are paid poorly with which must bear their own expenses onsite as well as their families, specifically those workers migrated from other states, their onside residential facilities are not taken care of properly. Ship yard owners rather neglect investing on the residential facilities for worker with the motive of gaining maximum return on their investment. As there are no definite laws on residential aspects of workers, there lies a gap between what should be an expected living condition and what is really happening. The current paper aims to investigate the extent to which this industry's workers are suffering and analyzing these findings against certain standards then proposes a habitation framework.

2. THE STUDY AREA

In Bangladesh, the ship breaking yards were about a 3.45km strip sea-belt in Sitakunda in 1989 which increased to 12.78 km by 2010, a 300 percent increase in two decades. This high rate of expansion of ship breaking yards has caused deforestation and other land use pattern change in Sitakunda (figure 1). The ship breaking yards in Chittagong range are mainly located along the 7km long shoreline of Sitakunda Upazila. Ship breaking yards of Bangladesh are situated in different locations namely Fultola, Baro-Awlia, Kadam-rasul, Jahanabad, Kumira, Kattoli union under Sitakunda Upazila of Chittagong District. At present there are about 48 ships breaking yards (36 yards are active and 12 yards are closed), 23% of total LDT, are laying along Dhaka-Chittagong highway which is 10 km. away from the Chittagong city.

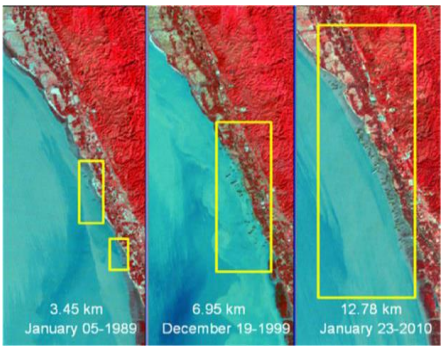


Figure 1: Expansion of ship breaking yards in Sitakunda (Abdullah, 2010)

3. LITERATURE REVIEW

The Responsible Ship Recycling Standard (RSRS) describes the conditions under which ships can be recycled, regardless of the recycling method applied. The RSRS applies to Maersk ships, as defined in the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, reaching end-of-life. As a United Nations Global Compact member, the Maersk Group is committed to conduct business in an ethical, legal and socially responsible manner. As such, the RSRS reflects our respect for universally recognized normative standards such as the United Nations Universal Declaration of Human Rights and the core labour conventions of the International Labour Organization. Furthermore, the Maersk Group supports the ratification of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships. We will therefore act in accordance with the convention, in order to prevent, reduce, minimize and, to the extent practicable, eliminate accidents, injuries and other adverse effects on human health and the environment caused by ship recycling operations. However, it is

observed from the standard of MAERSK group about workers' safety, where every worker needs $2m^2$ area for sleeping (Moller, 2016).

4. METHODOLOGY

The study is based on combinations of primary and secondary data. The primary data were collected through direct field observation on a focused group and questionnaire survey about their livelihood, health issue, and workers' residential facilities. Group comprised of labourers, local village dwellers and ship breaking business owners who were surveyed. This group size was 30. The secondary data are those collected from various sources such as journals, books, internet and others published works. An extensive literature review was explored in order to gather background and historical information.

Direct observation helped to understand the present situation of the area, activities and problems. Data of present condition recorded in the form of photographs, sketches and documented. The reconnaissance survey is performed by walking through ship breaking yard. Then all the data were compared with standard requirements. Last of all, some design solutions are recommended. Also due to time limitation, the study area was limited within the jungle silimpur ship breaking yard only.

5. OBJECTIVES OF THE STUDY

The main objective of the study is to find out the living conditions of workers of Sitakunda ship breaking industry and to make framework for betterment of ship breaking worker's living condition. To achieve this, the study aimed the following outcomes,

1. To learn the actual situation of the labour including their personal information, living condition, job facilities, and problems
2. To make awareness amongst the workers about their rights in working field and living facilities.
3. To draw a comprehensive suggestion for sustainable residential environment for ship breaking workers in the study area.

6. SOCIO-ECONOMIC CCONDITIONS OF SHIP BREAKING WORKERS

6.1 Average age of workers and their income

Most of the labourers are in the age group of 20-30. Some labours can be classified as children and minors who are under the age of 18. Yet, the publicly advertised signages states, "no child labour is in this yard". The fitter groups are paid a 50Tk/hr rate while other groups are paid at 30Tk/hr or less.

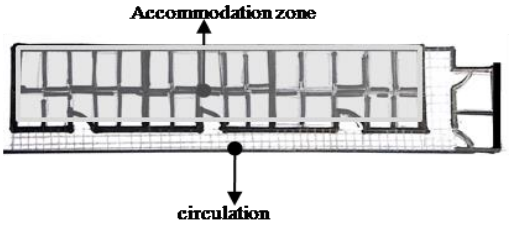
6.2 Housing patterns of workers

Most of the labour forces comes from the northern districts such as Bogra, Dinajpur, Rangpur etc because of poor economic condition, deficiency of employment and education. One-fourth of the labour force is from the hometown in and around the ship-breaking sites located in the southern parts of Bangladesh. It is found from the study that most of the houses (46.24%) of the ship breaking workers are tin-fenced and followed by 24.46% are *Semi-pacca.* Semi-pacca means those made by Brick and Tin shade, 21.09% houses are *Kacha* and 8.20% houses are *Pacca.* Where *Pacca* means full brick wall and concrete roof. Workers live in serried residential condition where an 8'X40' room is allocated for more than 30 workers. They get $0.99m^2$ area per person with shared facilities which are also insufficient. Workers don't get their right wages, so they can't afford to live in better condition. As a result, they compelled to accommodate in places where owner group allocate them. Situation gets worse when they had to sleep in shift basis like

night shift workers sleep during the day at the same place where day shift worker sleeps during night (figure 2).

6.3 Satisfaction level of workers

In context of Bangladesh, five catalysts are recognized as human rights namely; food, clothing, education, living place and medical facilities as they are our lawful civil rights. The labourers of the ship breaking industries must work in hostile and hazardous environment with scant facilities. Almost everyone denied that the food, sanitation, housing and working environment can be described as very good (figure 3). Most of the workers (67.42%) living place and house is not good and only 14.71 said they have good housing facility. In Bangladesh, the most dangerous and risky working place is probably the ship breaking yard.



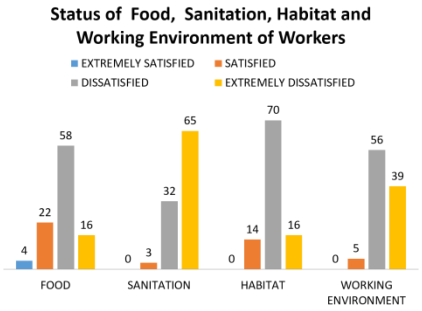


Figure 2: Accommodation condition (Source: Field survey) (left)
Figure 3: Satisfaction level of workers (Source: Field survey) (right)

7. COMPARISON BETWEEN STANDARD & EXISTING CONDITION:

The implementation of measures for health & safety and for the prevention of pollution is not considered essential in developing countries. Every convention stated the safety of workers. Comparing with the standard of MAERSK group about workers' safety that, where every worker needs $2m^2$ area for sleeping but they are provided only with $1.09m^2$ with the deficiency of 49%. Comparisons are given with table.

Table 1. Comparison of Standard and Existing condition

Requirement for Housing	Terms of Reference	Category	Existing
The dormitory or housing facility should meet national and international standards with regards to workers' needs and safety.	ILO C120 / C126 /R115	Major	N/A
The dormitory or housing buildings should be structurally sound; exits are all unlocked and unblocked, and fire emergency evacuation plans are posted and easy to understand.	ILO C120 / C126 / R115	Major	N/A
Sleeping rooms should have a floor area of at least 2 m^2 per resident and should meet local legal requirement.	ILO R115	Major	N/A
Beds should be not shared between day and night shift workers.	UN GC Principles	Major	N/A
The dormitory or housing facility should be provided with toilet and washing facilities, ventilation, waste disposal, and utilities (drinking water, energy, heating and lighting) that meet the needs of the residents and their families.	Article 25 UDHR, ILO R115	Major	N/A
Facilities should be accessible and appropriate for women, pregnant women, disabled persons, elderly, and families with children and other residents with special needs.	UN GC Principles	Major	N/A

8. ARCHITECTURAL STRATEGY & RECOMMENDATIONS

This paper presented the accommodation problems of ship breaking workers. Major issues are poor living condition, poor sanitation system, unhygienic environment and decrease of opportunity of fishing, use of temporary fragile structure and no awareness. All these issues formulate three objectives, as shown below.

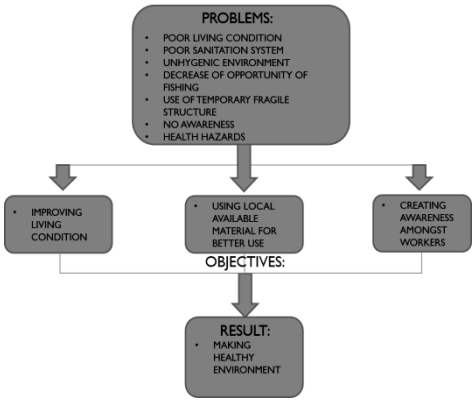
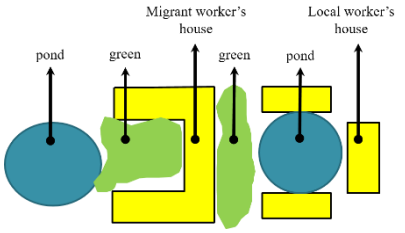
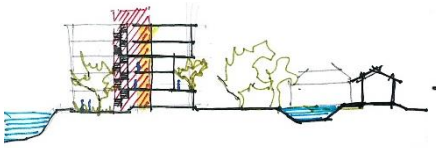


Figure 4: Conceptual framework for improving living condition

As there are two categories of workers, so housing should facilitate both categories with necessary measures. Local workers choose own fish farming as secondary occupation, so if there is opportunity to having a pond in their premises, that would balance their living comfort and earning opportunity. Court yard pond can be provided in between the houses of local workers which will serve the fishing as well as other water services. For migrant workers, there can be buffer zone between migrant and local workers as concern for privacy. There should also have pond for potable drinking water and other washing related services and another green buffer zone for recreational facilities of workers (Figure 5)





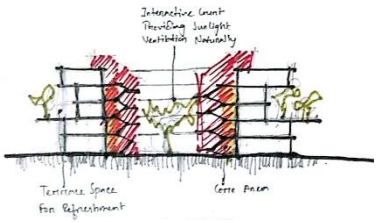
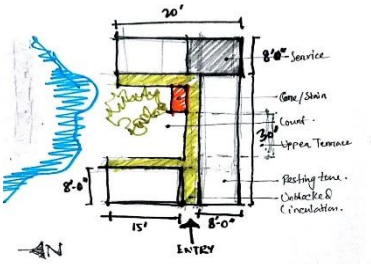


Figure 5: Proposed modular pattern (left)
Figure 6: Proposed cross section of migrant and local worker (centre)
Figure 7: Proposed cross section of housing block defining court (right)

Figure 6 shows a concept of buffer spaces between migrant workers and local workers housing facilitating privacy. It can be constructed multistoried and made from ship containers which are available onsite. Stairs are designed externally to emphasize the unblocked circulation and it'll grow the relationship between internal and external court space. Service spaces are proposed to be zoned in middle corner to make accessible to all (Figure 7, 8). Vertical circulation should be provided at minimum walking distance. High window should provide for cross ventilation to control interior temperature (Figure 9). There should have that kind of environment where workers can get the chance to have quality time. The environment should be interactive and vibrant at the same time communicative. Green space should be enough to have fresh air in the free time. They also have the right to get all kind of refreshments as they are key impetus of our national economy. Workers need proper counselling to make them aware of their rights. There comes a point of landownership of housing blocks. As the workers work under some specific company and workers can be recruited by authority. So as per ILO convention and UN labour right policy, it is the responsibility of owner group to provide land for worker. And making those international policies more implementable by enforcing laws and regulations by the authority thus ensuring those facilities improve productivity of workers.



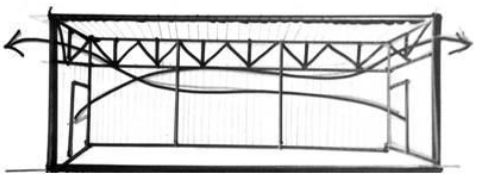


Figure 8: Proposed plan of block with container dimension (left)
Figure 9: Proposed cross ventilation system (right)

9. CONCLUSION

The ship breaking activities is treated as a profitable business and a source of raw materials of scrap iron and metal industries but still there is no separate guideline or rule or enforcement of laws for ship breaking activities. Currently there are no national standard which can be used for designing ship breaker's housing. Improvement of communication between ministries will help development of such standard. Despite the current issues, this industry cannot be banned as there are over 30,000 people's livelihood is dependent on this sector. So, it needs sustainable and eco-friendly solutions for the ship breaking workers living standard in Bangladesh. Some strategic architectural concepts are described in this paper which can be used for Bangladesh and neighbouring countries. Further extension of this study is required to develop the concepts to real solution of living conditions of workers in addition to profitability of ship dismantling product and the yard. This study is a starting point that can lead to develop national policy for these workers' housing system.

ACKNOWLEDGEMENTS

We would like to acknowledge Ar. Sajal Chowdhury, Ar. Mustiafiz-Al Mamun, Ar. Tazia Rahman and Ar. Rezuana Islam for their cordial support and supervision in this study.

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Paper 10

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

The Situation of Non-Biodegradable Waste Management in Dhaka City and Approaches to a Sustainable Solution

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Abstract

Bangladesh is an emerging developing country which has recently been elevated to 'lower middle-income' country status and is likely to be graduated to 'developing country' by 2024. Between 2005 and 2014, urban population has increased from 32.76 million to 41.94 million. It is expected to rise to 78 million in 2025. Consumption of plastic products in Bangladesh has been increasing not only in volume but also in diversity of product uses and this will increase in the coming years mainly due to a rise in per capita income and rise in total population in the urban areas. Urban areas of Bangladesh generate 633,129 tons/year of plastic waste which is non-biodegradable waste. Research shows that with improved recycling, Bangladesh can save US$ 801 million every year. (Waste Concern, 2016).

This whole research is developed on volume-based calculations as the volume of non- biodegradable products used in most households has more impact than weight on transportation process of municipal waste management system. About 60% volume of generated waste is non-biodegradable in the municipal solid waste of Dhaka. From the study it is found that there is no system to separate collection of non-biodegradable waste. An average of 47% of the volume of non-biodegradable waste are separated informally from the collected municipal solid waste and the rest are disposed in lakes, rivers and landfill.

The whole supply chain of the recycling of solid waste lacks proper management and operation. There is absence of a holistic approach, particularly from a sustainable waste management point of view. There are a very few informal ways to collect and recycle the plastic waste, but there are no specific laws, rules and guidelines for municipal solid waste management in Bangladesh. Some national and international organizations are providing financial support for municipal solid waste management. These initiatives are only the starting point of a huge amount of activities required to be taken over time.

Keywords: Recyclable plastic, non-biodegradable waste, residential waste, solid waste management.

1. INTRODUCTION

Plastic products have become an integral part in our daily life as a basic need. It produced on a massive scale worldwide and its production crosses 150 million tons per year globally (CPCB, 2013). Plastic is versatile, lightweight, flexible, moisture resistant, strong, and relatively inexpensive, for this reason, the use of plastic is increasing day by day. Most of the developed countries have a segregated waste collection system which enables easy waste management. Like other developing and low-income countries, Bangladesh does not have any separated collection system. In terms of weight, municipal solid waste of Dhaka has about 80% of biodegradable waste and rest of them are non-biodegradable waste in different forms (DCC, 2005). It has been observed that disposal of plastic waste is a serious concern due to an improper collection and segregation system. However, a few technologies have been

developed to minimize its adverse effects on the environment. Currently a worldwide accepted technology used for the plastic disposal is incineration. However, this is not a preferred option in developing countries like Bangladesh, because it releases toxic gases like chlorinated dioxins and furans, raising several environmental issues. It is worth noting that before adopting any technology, it is necessary to segregate plastic waste from municipal and other solid wastes. Another approach to processing plastic solid waste is chemical recycling, the success of which relies on the affordability of processes and the efficiency of the catalyst. The easiest way is dumping to a landfill site. As Dhaka Municipality practices unsegregated waste collection, dumping it to landfill is the only option in low cost and seems sustainable compared to other methods. Although there is a very small formal approach of collection of recyclable non-biodegradable waste, this is very small and has the potential to become a large business sector with government patronage. There is also an informal sector which is almost equal to the formal sector (only within Dhaka city). These are conducted by personal initiatives of waste collector for their extra benefit by selling those non-biodegradable waste. They keep large bags with their household waste collection vehicle and separate the non-biodegradable product which have high reselling value. The secondary screening and separation are also done informally in a transfer station by the group of people who have access and are involved in waste management. Finally, the low cost non-biodegradable wastes are separated by a group of local people in the landfill. There is also a group of street children and underprivileged people who collect plastic and some resalable non-biodegradable product from roads, sewerage drains, lakes etc.

1.1. Background of the study

Since non-biodegradable products should not be dumped in the ground, plastic recycling is a very important issue in protecting the environment. In Europe, Asia and other regions, many countries are recycling non-biodegradable product but there is a lack of initiative in Bangladesh for this. The studies are also very less on institutionalizing or assessing and acknowledging the informal recycling of non-biodegradable waste. The main objectives of this study are:

- To find out the current situation of non-biodegradable waste management in Dhaka city.
- To find out the recent practice, formal & informal approaches towards non-biodegradable waste management.
- To investigate & recommend the sustainable solution and best management practice to help eradicate the problem.

2. GENERATED PLASTIC WASTE AND ITS DISPOSAL

The major non-biodegradable waste is plastic waste and other major non-biodegradable wastes are glasses and metals. About 124 tons plastic waste, 46 tons glass waste and 27 tons metal waste are generated every day in Dhaka. According to JICA (2005), Plastic waste generation in Bangladesh is rising day by day with increasing income and spending ability of people. Although the total plastic use of Bangladeshi people is very less compared to developed countries like Europe and USA, generation rate is rising very fast. However, generation of plastic waste is not the major problem. The main problem is in management. Proper management of plastic waste and disposal or recycling methods can make plastic waste wealth instead of waste.

2.1. Plastic Waste Generation

Bangladesh started producing plastic toys, bangles and photo frames using handmade molds since 1960 and by the 2000s this industry grew rapidly and possessed a big market. There are about 3000 plastic enterprises. Among them about 2000 are small and 50 are very big. According to Ahmed (2015), annual plastic consumption per capita is about 5kg. Solid waste generation rate is about 0.56 kg per person per day which shows that about 41 kg per capita per year non-biodegradable waste generation.

2.2. Disposal

Disposal of non-biodegradable waste is one of the major issues. The commonly practiced disposal

methods include recycling, combustion, landfilling etc. The separation of non-biodegradable waste starts from collection and is continued until landfill disposal. There are a total of two landfills for Dhaka city. One is at Matuail and the other one is in Amin Bazar. Another big dumping station is Beribadh dumping site. Preparation of some new landfill is ongoing for future service in Dhaka.

3. METHODOLOGY

The study on recyclables (Mostly Plastics and petrochemical products) is conducted by a desktop study of National and International Level Journal review. Some key informant interviews are taken and finally a field survey by questionnaire is conducted across twenty transfer stations among people involved in municipal solid waste management in Dhaka.

3.1. Secondary Data Collection

Secondary data is collected from journal review, online and offline desktop analysis and from some books related to recyclable waste management. For this project, some national and international journals are reviewed to find out the recent condition of recyclable management in developed countries and in Bangladesh. Some reports have also studied municipal solid waste management and plastic waste condition survey of Dhaka city.

3.2. Primary Data Collection

Primary data collection is done in two steps. Firstly, a key informant review is carried out, followed by a field survey questionnaire. In the key informant interview, a total of fifty people are interviewed from different levels of stakeholders which includes residents, City Corporation officials involved in waste management, NGOs, waste collectors etc. In the questionnaire survey, a total of ten questions are prepared to collect information about informal separation of non-biodegradable waste which comprises but is not limited to the daily number of trips from collection points to transfer station, volume of separated waste, type of separation and daily income from separated waste.

4. NON-BIODEGRADABLE WASTE MANAGEMENT SCENARIO

As an emerging developing country, plastic consumption is still at a very low level compared to other countries and regions. The per capita consumption of plastic is lower than that of Sri Lanka (6.0 kg/person/day) and far behind that of developed regions in North America (139.0 kg), Europe (136 kg), and Asia (36 kg) (Waste Concern, 2016). More importantly, plastic consumption is likely to increase in the coming years mainly due to rise in per capita income and total population in the urban areas. Total population in urban areas such as Dhaka has increased dramatically over the years and will continue in the future. Between 2005 and 2014, urban population has increased from 32.76 million to 41.94 million. It is expected to rise to 78 million by 2025. Urban areas of Bangladesh generate 633,129 tons/year of plastic waste and out of this, 51% plastic waste (which amounts 3,23,000 tons/year) is being recycled. Like other urban areas, Dhaka is also producing high rate of non-biodegradable waste. Non-biodegradable waste management is not segregated from bio degradable waste management in Dhaka. Collection and dumping are done aggregately, but some formal collection of non-biodegradable waste is conducted by hawkers and some people who provide some household product in exchange of that. The non-biodegradable waste which are collected formally are being sold or collected before it goes to household waste container. For this reason, this is not within any waste data of Dhaka city. The informal collection is conducted in a different way. The informal collection types and related people found from survey are described in table 1.

A sample-based survey was conducted at four locations of Dhaka. A total ten secondary transfer stations (STS) were visited, where a questionnaire-based survey was carried out on the people on duty. From the survey it is found that 47.2% of total non-biodegradable waste (volume basis) is separated from municipal solid waste, informally, in different stages of formal waste collection. About 62.3% of

the total generated waste (volume basis) is non-biodegradable waste. A visual representation of above data of four locations is given in Figure 1 and 2.

Table 1: Informal Collection of non-biodegradable waste

Collection Location	Types of Collected Non-biodegradable waste	Collected By
Household waste container	Plastic products, polyethylene, Aluminum, metal products etc.	Waste collector and their assistants
Separation in transfer station	Glasses and other remaining petrochemical products, good quality polyethylene, glasses etc.	
Separation in landfill	Mainly polyethylene, remaining petrochemical products, glasses etc.	Local underprivileged people and street children
Streets, lakes, rivers, train and bus stations and institutions	Plastic bags, bottles etc.	

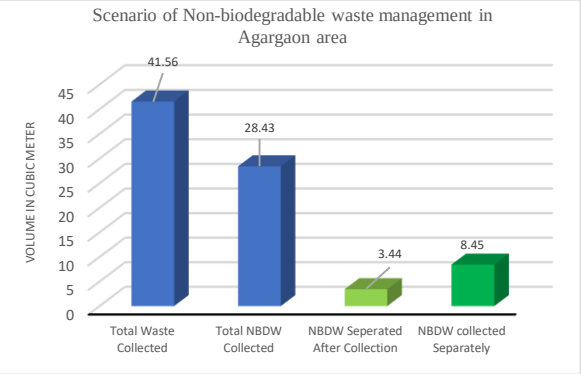

Figure 1: Scenario of Non-biodegradable waste management in Agargaon area

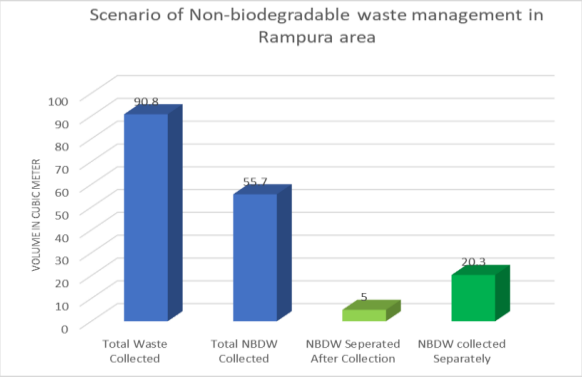

Figure 2: Scenario of Non-biodegradable waste management in Rampura area

In the Agargaon area, an average of 42.56 cubic meter waste is collected from households and markets, of which 28.43 cubic meter is non-biodegradable. The waste management workers separated 8.45 cubic meter at the source and 3.44 cubic meter after collection in the transfer station. About 68% (by volume) of the total waste is non-biodegradable. This percentage is higher than the average because the waste collected from usual market areas is mainly collected from different shops and there is no vegetable market near Agargaon. The average waste collected in different STS in Rampura and surroundings is about 90.8 cubic meter and non-biodegradable waste is about 55.7 cubic meter. 61.34% of total waste

is non-biodegradable out of which 45% is recycled informally. After collection, separation is very low compared to other location of Rampura belt due to the large number of separation during collection time and the waste goes to the primary transfer station before going STS. After it is transferred to STS it is very hard to separate mixed waste.

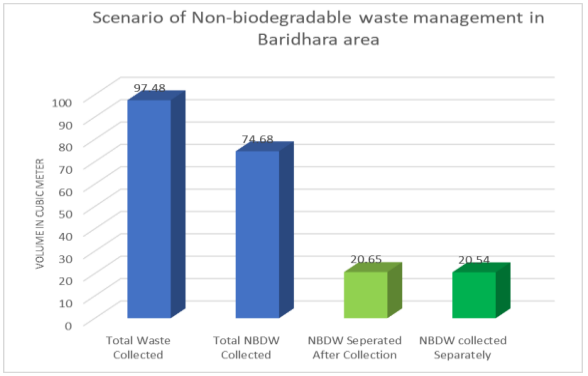

Figure 3: Scenario of Non-biodegradable waste management in Baridhara and Surrounding areas

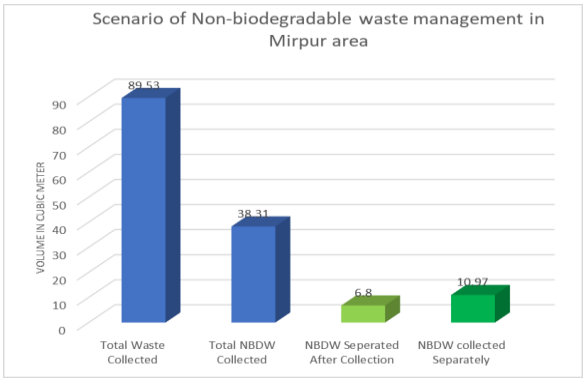

Figure 3: Scenario of Non-biodegradable waste management in Mirpur area

From Figure 3 and 4 we see that the average waste generation rate in Baridhara and Mirpur is about the same but there is a huge difference in non-biodegradable waste generation. Total non- biodegradable waste collected in Baridhara area is about double of Mirpur area. The non-biodegradable waste generation in Baridhara area is the highest among all the survey locations and they have very low amount of non-biodegradable waste generation compared to other survey areas. The scenario is vice versa for Mirpur. From key informant information (KII) it is found that the difference in waste generation between people of Baridhara and Mirpur is influenced by income, living standard and economic stability.

There are also some other important observations that come from KII. Among them, the most important observations that are from different stakeholders is that about 78% of the residents of survey areas are eager to spend for separate container if the government takes the initiative to source separated collection system, only 4% of workers handle waste use partial safety equipment. Individual daily income is about 150-250 BDT per day from informal separation at different phases of household waste collection. The other most frequent comments about management is that manpower should be increased, and new landfill is required.

5. CONCLUSION AND RECOMMENDATION

Disposal of plastic waste into the environment is a big problem due to its very low biodegradability and presence in large quantities. Therefore, finding alternative methods of disposing waste by using friendly methods are becoming a major research issue. For the practical application of any of recycling methods to be successful, it should be stressed that by-products resulting from the various mechanical treatments should have similar properties of commercial grade plastics with respect to their type and monomer origin. Waste-related issues have been mentioned in the 'Environment Law 1995' which indicates types of industrial waste generated by industries that cause environmental pollution. In recent years, several initiatives have been taken in order to improve the waste management in urban areas. A national initiative called 3R (reduce, reuse and recycling) has been launched in 2010. Under this concept, a pilot project is currently being implemented in Dhaka and Chittagong cities. Besides, Bangladesh Bank has included plastic waste recycling plants under its Green Banking refinancing scheme. Development partners, particularly JICA and UNICEF, have been providing financial support for municipal solid waste management. These initiatives are only the beginning of a significant number of actions that need to be taken over time.

5.1 Sustainable Solution

Although the trend in recycling plastics has increased a lot these days, they are not done in a proper and sustainable way. To make a sustainable approach towards recycling non-biodegradable waste we should focus on:

1. Source Separated Collection systems and institutionalization of informal sectors.
2. Institutional and technological upgradation of the waste collection system.
3. Increasing private-public partnership in the waste management business.
4. Upgradation and ensuring proper management of landfill sites.
5. Creating awareness by educational programs in schools and communities regarding source segregation and recyclable waste materials and their ways of disposal.
6. Implementation of existing rules and regulations and increasing monitoring and if required new rules and regulations may need to be formed.
7. Implementing best management practice in waste management sector.
8. Ensuring health safety measures for waste collectors and handlers etc.

The study shows a scenario of recent non-biodegradable waste management in Dhaka city. To improve the situation and find out the more specific sustainable solution further study is required, but it is clear from this study that there is a huge opportunity to turn the waste of Dhaka into a resource if managed properly.

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Paper 14

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

An Index for Sustainable Urban Transportation with Reviews, Analyses, and Recommendations

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Abstract

Urban transportation policies must support the principles of sustainable development to ensure sustainable mobility. Previous studies proposed composite indices such as transport sustainability index (TSI), sustainable urban mobility index (SUMI) and sustainable urban transport index (SUTI) to measure the level of sustainable mobility in an urban area. This paper critically reviews and analyses existing indices and proposes a framework to measure urban transportation sustainability index. The major contribution of this work is the development of the framework itself, which comprises indicators from five different domain areas including social, economic, environmental, and political/ institutional /governance as well as urban transportation systems and services characteristics. The indicators may be flexibly selected considering the relevance of a particular urban area's (city's) development context. Such a flexibility would help a city to assess its own sustainable mobility goals and priorities in a unique way, given its existing state of transportation developments. Also, the index can be applied in any urbanized area (e.g., megacities as well as medium and smaller size cities and towns) of developed and developing nations. The future work would be to develop comprehensive guidelines on how to collect data for each indicator in an efficient and cost-effective manner and implement the proposed methodology

Keywords: Urban Mobility, Sustainable Transportation Index, Urban Transportation.

1. INTRODUCTION

In both developed and developing countries, urban areas have become the powerhouse for economic growth and development in the 21st century. Urban transportation plays a major role in connecting people with the economic opportunities. Realizing the fact, the United Nations with its adaption of UN 2030 agenda in September 2015, further emphasizes the development of sustainable urban transportation systems and services. Toward this end, a number of researchers have proposed indicators and indices generally considering the regional agenda in mind *(Gilbert et. al., 2002, Eads, 2003; Hossein and Manouchehr, 2012; Kumar, 2014; Reisi, et. al. 2014; WBCSD, 2015; Gudmundsson and Regmi, 2017; Jaina and Tiwarib 2017; Espey et. al., 2018)*. However, given the differences in the level of motorization and urban development patterns across the glove, a composite index comprising a flexible set of indicators is needed to monitor and evaluate the transportation systems and services performance as well as to prioritize the policies, programs, and strategies. This research attempts to propose such an index that may be used to measure the sustainable urban transportation development in a flexible manner.

Before identifying the indicators and constructing the index, it requires understanding the common issues, challenges and opportunities of urban transportation. Cities and urbanized areas across the globe have

been striving to provide adequate, affordable, accessible and integrated transportation systems and services to city dwellers in an effort to improve the dwellers quality of life and maintain sustained economic growth as well as to alleviate poverty. As such, the major focus of urban mobility is to ensure access to opportunities for all citizens including disadvantaged people (e.g., senior citizens, poor's and disabled persons). Researchers *(UNDESA, 2012)* have indicated that sustainable transportation development requires three broader strategies that include (1) reducing or avoiding the need to travel, (2) shifting from heavily polluted modes to more environment friendly modes, (3) encouraging technological innovations in the improvement of vehicle technology and renewable energy or cleaner vehicles.

Sound urban transportation policy decisions are needed not only to provide sustainable urban mobility but also to achieve a number of United Nations (UN) mandated sustainable development goals (i.e., goal # 1, 2, 3, 7, 9, 11, 13, and 17) and associated targets *(United Nations, 2017)*. Therefore, at the policy level, decision maker should look at how to move people in a more efficient manner rather than how to move vehicles. Policy should support investment on environment friendly transportation modes (e.g., public transportation, walking, biking and rickshaws etc.). To bring origins and destinations closer to each other, land use planning should be integrated with urban transportation development. Particularly mixed land use supported by public transportation services (e.g., transit oriented development) should be encouraged. This would help to reduce Vehicle Mile Travel (VMT) and emission. For urban transportation systems to be more sustainable, transportation related externalities and negative consequences such as road accidents (fatalities and injuries), human health degradation from air and noise pollution, and greenhouse gas emission must continue to cut down.

2. METHODOLOGY

The report on World (Brundtland) Commission on Environment and Development *(United Nations, 1987)* defines sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". However, there is no consensus definition of sustainable transportation *(Gudmundsson and Regmi, 2017)*. Keeping a consistency with Brundtland's definition, this paper defines sustainable transportation as *"a continuous process of developing and maintaining transportation infrastructures, systems and services for the wellbeing of current and future generations while meeting the socio-economic and environmental/ecological constraints and requirements".* For transportation developments to be more sustainable, sound political and institutional developments as well as commitments for good governance are essential. Therefore, the paper proposes that sustainable urban transportation development should be measured from the perspective of five dimensions/domains including social, economic, environmental, institutional/ governance/ political, and transportation systems and services dimensions. Toward this end, we propose a three-step process to construct the index.

Step-1: Identification of Indicators

The indicators under each domain are identified based on a review of literature and the discussion made in the introduction section. The criteria used to select indicators include specific, time sensitive, measurable, achievable, relevance, and ease of data collection. Similar criterions are set by earlier researchers *(WBCSD, 2015)* as well. Based on a literature review potential indicators are identified and listed in Table 1. It is to note that each indicator may be leveled under more than one domain depending on its relevance. A large number of the indicators, as listed in Table 1, can be measured quantitatively with a few exceptions that may be measured qualitatively. Depending on the size and complexity of an urban area along with the historical transportation development and investment level, a few relevant indicators under each of the five domains are needed to measure the progress toward sustainable transportation development. This study recommends that an urban area (or a city) should flexibly select two to three indicators (while avoiding overlapping or closely related indicators) under each of the five domain areas, for the purpose of index construction. Furthermore, the indicators should be selected on the basis of an urban areas transportation weaknesses and development needs. For example, if an urban area provides extensive public transportation services with large systems/networks but grossly ignores modal integration, then, an indicator that addresses modal integration (transportation hubs with physical,

operational and fare integration indicators) may be more relevant to consider. On the other hand, if an urban area provides substantially inadequate public transportation services and focuses on developing an extensive public transportation network, then a more relevant indicator may be used to find the percentage of area covered by public transportation. Finally, the index contains somewhere between 10 and 15 indicators, which is an acceptable range as per earlier studies (*WBCSD, 2015; Gudmundsson and Regmi, 2017; Jaina and Tiwarib 2017; Espey et. al., 2018).*

Table 1. Potential indicators under various domains/dimensions of sustainability

Factor	Indicator	Dimension/Domain				
		Environmental	Social	Economic	Governance /Institutional	Infrastructure Systems and Services
Air Quality	Particulate Matter (PM10, PM 2.5)	◆	◆			
	Green house Gas Emission (CO2)	◆	◆			
	Percentage of Dwellers Live in Non-attainment Air Quality State	◆	◆			
Energy Use	Percentage Share of Non-renewable (fossil fuel) Eenergy Use	◆				
Safety	Fatality and Injury Rates (Exposure Base)		◆	◆		
Congestion/Travel Time	Average Commuting Time		◆	◆		
Modal Share/Active Transportation Modes/Public Transportation	VMT (by Auto, public transportation, Walk, bike, Rickshaw etc) Per Capita					◆
	Percentage Share of Each Mode Use by Each Income Group					◆
	Percentage of Urban Roadways Containing Sidewalk or Bike Facilities					◆
	Percentage of Area Covered by Public Transportation					◆
Out of Pocket Cost/Affordability of Public	Household Income Devoted to Transportation by Each Income Group			◆		
Open Space	Percentage of Total Land Used for Transportation Purpose (land consumption in transportation)		◆			
Public Participation	Level of Public Participation and Public Decision Making Power		◆			
Modal Integration/Intermodal	Transportation Hubs with Physical, Operational, and Fare Integration					◆
Multimodal and Active Transportation Development	Alternative Modes of Transport (Transit, Walking, Biking etc)					◆
Technology Used for Transportation Purpose	Vehicle Technology, Fuel Technology (power train), Intelligent Transportation Systems (ITS) etc	◆				◆
Power of Local Government	Policy Making and Budgeting				◆	
Public Perception	User Satisfaction by Mode		◆			
Investment level/Infrastructure Status	Expenditure on Infrastructure and Services by Modes				◆	
	Total length of Facility by mode (Walkway, Roadway, Bikeway, Public					◆

Note: The symbol "◆" represents the domain (s) corresponding to a particular indicator

Step-2: Normalization of Indicators

Before using the indicators in the index, selected indicators are required to be normalized by converting each indicator's value from the measuring units to a dimensionless unit, with a proposed scale ranging from 0 to 100. With 0 or 100 being the worst possible case depending on the institutive meaning of the increasing values of an indicator. Indicators with qualitative measures require expert opinion for the scaling purpose. Depending on the positive or negative impact with the increasing values of indicators, the following two equations *(Krajnc and Glavic, 2005; Zito and Salvo, 2011; Reisi, et. al. 2014)* are used.

$$I_n^+ = \frac{I^+ - I_{min}^+}{I_{max}^+ - I_{min}^+} \qquad (1)$$

$$I_n^- = \frac{I_{max}^- - I^-}{I_{max}^- - I_{min}^-} \quad (2)$$

Where I_n^+ and I_n^- are the normalized values of Indicators having positive (more is better) or negative (less is better) impact with the increasing values, respectively. I, I_{max}, and I_{min} are the actual value, maximum and minimum threshold values, respectively.

Step-3: Urban Transportation Sustainability Index (UTSI)

Finally, the index is constructed by utilizing two to three indicators under each domain. The weights are equally divided to each domain and considering that there are five domains, the weight factor for each domain is 0.20 (e.g., 20%). The weight of each domain is further allocated to its indicators as follows: Considering that a particular indicator may be represented by more than one domain (See Table-1), the indicators are defined as non-overlapping (if the indicator belongs to only one domain) and overlapping indicators (if the indicator belongs to more than one domain). The weight of an indicator $I_i^{no}{}_{,j}$ under a domain j is $w_{i,j}$ (see Eq. 3), if the indicator belongs to only one domain (e.g., non-overlapping). However, if an indicator $I_i^o{}_{,j}$ belongs to more than one domain (e.g., overlapping), the weight factor is $0.5w_{i,j}$. Thus,

$$w_{i,j} = \frac{0.2}{N^{no} + 0.5N^o} \quad (3)$$

Where N^{no} = Number of non-overlapping indicators

N^o = Number of overlapping indicators

Finally, the UTSI is constructed as follow:

$$UTSI = \sum\sum(w_{i,j}I_{i,j}^{no} + 0.5w_{i,j}I_{i,j}^o) \quad (4)$$

The identified indicators set and the index (e.g., UTSI) may be used to measure the strength and weaknesses of existing transportation systems and services of an urban area, as well as to improve the transportation systems and services performances. Furthermore, it will help decision makers to take appropriate actions at the policy, planning, programming, design and operational levels in support of a sustainable transportation development. It is worth noting here that the usefulness of a large number of indicators (as listed in Table 1) has already been demonstrated by other researchers *(WBCSD, 2015; Gudmundsson and Regmi, 2017)* and the real world application of the proposed index has been left for a future study.

3. CONCLUSIONS

In this study a framework is developed to construct an urban transportation sustainability index (UTSI) that may be used to measure progress towards sustainable development. The major contribution of this work is the development of framework itself that includes indicators from five different domain areas.
The indicators may be flexibly selected considering the relevance of a particular urban area's (city's) development context. Such a flexibility would help a city to assess its own sustainable mobility goals and priorities in a unique way given its existing state of transportation developments. Also the index can be applied in any urbanized areas (e.g., megacities as well as medium and smaller size cities and towns) of developed and developing nations. The future work would be to develop comprehensive guidelines on how to collect data for each indicator in an efficient and cost effective manner and implement the proposed methodology. After implementation of the proposed methodology, normalized values of indicators used in the index may be presented in a spider diagram/graph. The spider diagram/graph can be used for visual observation of the performance of each individual indicator and identification of systems

and services weaknesses for further improvements as well as for the purpose of comparison of relative competitiveness among similar urban areas/cities *(Gilbert et. al., 2002, Eads, 2003; Hossein and Manouchehr, 2012; Kumar, 2014; Reisi, et. al. 2014; WBCSD, 2015; Gudmundsson and Regmi, 2017; Jaina and Tiwarib 2017; Espey et. al., 2018)*.

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Paper 20

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Sustainability Reduction in Groundwater Resources of Madhupur Tract Aquifer due to Climatic Changes in N-C Region of Bangladesh.

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Abstract

Unsustainable depletion of groundwater from Madhupur tract aquifer (underneath Dhaka and Gazipur city) is an extensive social problem in the North central (N-C) part of Bangladesh. Specifically, Dhaka city, the capital of Bangladesh, suffers from over-extraction in an unsustainable manner. In addition to this phenomenon, natural disasters such as drought are amplified by climate change is a widespread natural hazard in Bangladesh. This study presents the characterization of drought using selected drought indicators developed using ground and global model data in Dhaka district in the North central part of Bangladesh and explores the mutual connection between drought years and the maximum groundwater level depletion years. Meteorological (precipitation, temperature) and groundwater data were collected from the relevant institutions in order to develop and analyze the drought indicators, climatic trends, and the rate of decline of groundwater levels. Where ground-based data was lacking, global model datasets were downloaded from the EartH2Observe WCI portal to compute drought indicator based on appropriate global data. Analysis of drought occurrence shows that moderate to extreme drought occurred sixteen times in the last thirty-three years in the study area, showing that the frequency of severe drought is high. National historical drought impact records show that drought occurred twelve times, although these are not any specified records for Dhaka, as the focus of the impact data is an agricultural impact. The effect of unsustainable overexploitation has been observed for the last two decades because of the extra abstraction of groundwater for the domestic water demand in the Dhaka districts. This was accelerated not only by the demographic explosion but also due to the occurrence of droughts. This study also opens a new horizon of thinking that it is not necessary to use the drought monitoring system only for the agricultural sector. Monitoring of drought is necessary for all the sectors where problems of sustainability may exist. Dhaka has no drought monitoring that looks at the scale of impacts. Drought, however, does occur in the city, and indirectly works on a system and create a negative feedback loop which leads to unsustainability.

Keywords: Groundwater over-exploitation, Unsustainable decline, Climatic changes, Drought.

1. INTRODUCTION

Groundwater is distinguished as the world's largest distributed store of freshwater, especially for drinking water purpose. In Bangladesh, groundwater is an important source of water for irrigation, domestic use as safe drinking water and industrial purposes. Intensive use of groundwater impacts on the groundwater table which has gradually declined in the north-west and north-central regions of Bangladesh. Specifically, in Dhaka city, where groundwater is reported to account for 87% of all drinking water resources, groundwater levels have suffered a decline of up to 75m in some specific location. To fulfill the demand of fresh drinking water for the Dhaka city dwellers, uncontrolled

abstraction of groundwater has been practiced for a long time, which has created problems with sustainability with regard to the management of water resources in the city. We know that sustainable groundwater resources development refers to the efficient management of existing groundwater resources as a source of water supply to meet the needs. But, a natural disaster such as drought which is amplified by climate change and human-induced changes such as excess demand for over depletion makes this resource unsustainable for future uses.

Drought is a fact which is repetitively observed in Bangladesh. In several previous studies about drought monitoring in Bangladesh, meteorological drought had to be considered as a common module to realize the drought pattern. Drought mapping has been done by using meteorological drought index (SPI). The purpose of this study is to evaluate if the drought has exacerbated over extraction and completing drought characterization in Dhaka city to identify is there any relationship between the unsustainable groundwater use and the occurrence of drought. More precisely, searching for interconnection between drought (climatic change) and unsustainable decline of groundwater is the main essence of this research. Finally, how over-extraction is the main cause of unsustainability in natural groundwater resources has been discussed in this paper.

Study area Dhaka lies at the southern edge of the Plio-Pleistocene Madhupur Tract and surrounded by four peripheral rivers. Stratigraphically, the area is characterized by an unconsolidated sequence of Flavio-deltaic deposits hundreds of meters thick that are usually composed of gravels, sands, silts, and clays of Plio-Pleistocene age. The Madhupur Clay formation (aquitard) is composed of red plastic clay to silty clay. The silt is uncomfortably overlain by alluvial deposits and is underlain by fine to coarse-grained micaceous, quartzo-feldspathic sands of the Pliocene DupiTila formation. Covering materials are Holocene alluvial silt, clay and marshy clay for the low-lying areas along the edges of the tract. Principal aquifer underneath the Dhaka city area is the multi-layered DupiTila formation. It is effectively confined by the semi-pervious Madhupur Clay. Based on the grain-size distribution of the aquifer materials and hydraulic properties, the aquifers can be separated into three units. These are Upper DupiTila Aquifer-1, Upper DupiTila Aquifer-2 and Lower DupiTila Aquifer (DWASA and IWM, 2008). **Figure 1.1** shows the location of Madhupur tract aquifer aloft Dhaka city where unsustainable abstractions have been done.

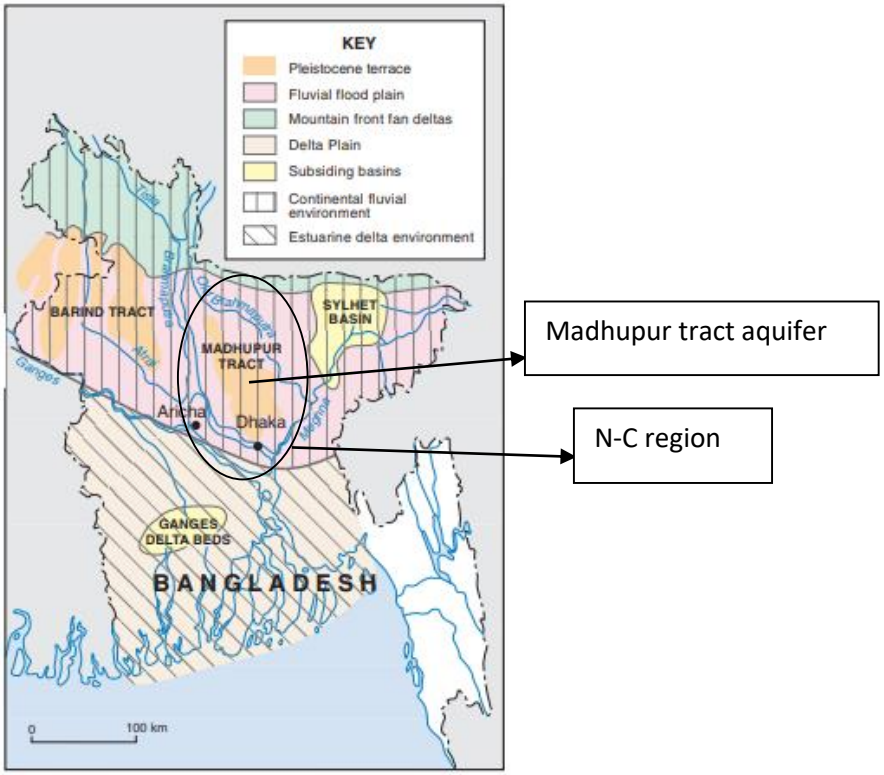


Fig 1.1: Location of Madhupur Tract Aquifer at North-Central Region (Source: BGS and DPHE)

2. OBJECTIVES

Unsustainable use of groundwater in Dhaka is a potential risk factor which gradually affects different uses of water such as domestic water supply, agriculture, and socio-economic wellbeing. For this reason, it is necessary to clearly understand the cause is that lead to this unsustainable use. While the increasing population pressure and the unregulated extraction of groundwater is the cause the declining groundwater levels, the question is whether drought events may be triggers to an increase in the rate of decline. If drought is one of the causes, then it is important to monitor drought to deal with these circumstances. Previous research has monitored drought in the North-Western region of Bangladesh. However, it is necessary to understand the effectiveness of different drought indices by using both ground and global model dataset for Dhaka. This analysis will help to find out if there is any relationship between the occurrence of drought and the unsustainable use of groundwater in Dhaka, especially to, identify feedbacks of whether drought events have changed, or if this is solely attributed to other causes such as population growth.

The main objectives of this study are:

1. To characterize the occurrence of drought in these regions, specifically around the city of Dhaka by using different drought indicators that can be established through ground data, as well as through data derived from the global datasets.

2. Establish an interlink between unsustainable groundwater decline and climatic change effect like drought.

3. LITERATURE REVIEW

For Dhaka city, depth of groundwater table showed a declining trend. Especially after the year 1999, declining slope pattern showed high gradient. Dhaka is dependent mainly on the groundwater resources of the fluvio-deltaic Plio-Pleistocene DupiTila Aquifer, which provides about 87% of the total water supply (DWASA 2008). Groundwater is the first choice for city dwellers as it is superior in quality to surface water. To meet the demand, about 2.0 Mm^3 is withdrawn daily by about 567 DTW (Deep Tube Wells) and delivered to the inhabitants by a 2500-km-long pipeline network. System loss is assumed to be more than 25%. It is estimated that the volume extracted from more than 900 private DTW (Deep Tube Wells) in the city area may be more than 50% of the DWASA withdrawal. The renewable recharge to the aquifer is nearly negligible if it has been compared to the exploitation of groundwater. It is necessary to understand what the reason is for this drastically declining trend after the year 2000. According to the present rate of abstraction due to high water demand and recharge obstacle due to increasing impervious layer, groundwater use is not sustainable for Dhaka city. **Figure 3.1** shows the declining trend of GWL for Dhaka and city.

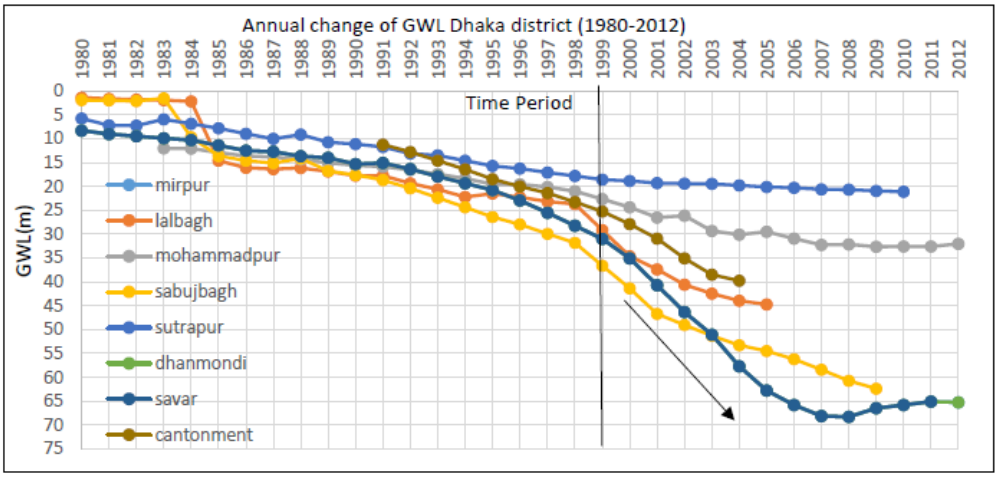


Fig 3.1: Variation of the groundwater table (Dhaka city)

Though North-west region was extensively analyzed for drought occurrence linking drought occurrence for describing any sustainability problem has not been a common practice as revealed in the literature review process. Therefore, this is an important area of research. However, the previous researcher who works with drought use several drought indicators for the impact assessment of drought as well as the monitoring and characterization of drought which is linked with the precipitation, temperature, evaporation, streamflow, groundwater level, and many quantitative variables.

4. METHODOLOGY

Ground data was collected from a different national organization of Bangladesh such as BWDB, BMD, and BIWTA. For assembling global data in the study, WCI portal from the Earth observe project open source database has been used. In addition, some datasets downloaded from open source internet-based data providers. Drought indicators were calculated based on ground and global model data for a common reference time period.

CASE STUDY AREA: The case study area was selected considering as the most vulnerable area for the groundwater depletion and water supply scarcity. The availability of data was also considered. The case study area is situated in the North-Central hydrological region of Bangladesh. North-Central region consists of sixteen districts in which Dhaka district is also included. Dhaka city is the capital of Bangladesh, as well as the most populous city, thus provides a large set of data.

METEOROLOGICAL DATA: The Bangladesh Meteorological Department (BMD) maintains meteorological stations at several places all over the country. They keep records of different meteorological parameters (rainfall, temperature, sunshine, humidity, wind speed, evaporation, etc.) daily. Rainfall data Daily rainfall data were collected from BMD for Dhaka city. Daily data were processed for monthly and annual accumulated precipitation dataset. Temperature data Daily maximum & minimum temperature data were collected from BMD for Dhaka city. Daily data were processed as mean monthly maximum & minimum temperature data. Based on the maximum & minimum temperature data, mean monthly and annual temperature were calculated.

GROUNDWATER DATA: In order to assess the condition of the groundwater level, Bangladesh Water Development Board (BWDB) is monitoring groundwater levels since 1980 all over the country. Groundwater level data for 20 numbers wells in Dhaka metropolitan area and one well in Gazipur city were collected from BWDB. Weekly groundwater level data are available at these wells, although for some of the data a few months of some years was found to be missing. All the water level data of each station were taken as a mean monthly groundwater data to represent groundwater condition of these two areas.

GLOBAL MODEL DATA: There are various global models available which can provide meteorological and hydrological continuous long-time data with acceptable accuracy. As an example, EartH2Observe is a collaborative project to contribute to the assessment of global water resources using new Earth Observation datasets and techniques. The resulting datasets are available through an open Water Cycle Integrator data portal (WCI Portal). Two different models with two different data sets were combined for comparing with observed data. Selected global models are 1. Model: PCR-GLOBWB, University Utrecht and 2. Model: WATERGAP3, University Kassel. SPI analysis has been done for global datasets and for an observed dataset for the same location. Table 1.1 given below to show the combination.

Table 4.1: summary datasets for SPI analysis

Parameter: precipitation, time period (1980-2012)	Model: PCR-GLOBWB, Indicator: Water resources reanalysis V1 (Location Dhaka)
	Model: PCR-GLOBWB, Indicator: Water resources reanalysis V2 (Location Dhaka)
	Model: WATERGAP3, Indicator: Water resources reanalysis V1 (Location Dhaka)
	Model: WATERGAP3, Indicator: Water resources reanalysis V2 (Location Dhaka)
	Observed precipitation Dhaka

OCCURRENCE OF DROUGHT ANALYSIS: There are several drought indices that are proposed by the previous researcher. Such as a tool, called the Standardized Precipitation Index (SPI) derived by McKee et al., 1993 which is a function of precipitation to monitor drought. Besides, Standardized Precipitation and

Evapotranspiration Index (SPEI) is a drought index, an extension of the SPI that includes both precipitation and temperature. SRI was suggested for determining hydrological drought by Shukla and wood (2008) and groundwater resource Index (GRI) has been developed by Mendicino et. al (2008) to quantify groundwater detention. For a proper understanding of the reason for water level declination, several indices have been analyzed for drought which seemed more relevant according to the recharge criteria of the Madhapur-Tract aquifer. Selected indices are Standardized Precipitation Index (SPI) where the input is precipitation and Standardized Precipitation and Evapotranspiration Index (SPEI) where the input is precipitation and evapotranspiration.

TREND LINE AND DECADAL AVERAGE ANALYSIS: Trend lines are a simple and widely used technical analysis to indicate the general course or tendency of a set of points. From the trend-line analysis (linear regression), it is possible to find out if the points follow an increasing or decreasing pattern. In this research, trend-line analysis has been done for observed precipitation dataset of Dhaka city. To reinforce the findings from the trend-line analysis, it is helpful to completed decadal average analysis which is an average of ten consecutive year's period. According to the selected reference period, three decadal averages had been used to find out the pattern where all the precipitation dataset showed lowering or less rainfall and temperature showed an increasing pattern which approximately proved the trend of increasing temperature and decreasing precipitation in the case study area.

RATE OF DECLINE GWL DATASETS: It is necessary to find out the maximum depletion period for the Dupi Tila aquifer from where 87% of domestic water supply for Dhaka district had been managed. In this case, the rate of decline of GWL datasets has been done by lag time and difference method using excel spreadsheets. This difference is the change of GWL for each year which is the depletion rate per year for each set of the dataset. After formulating each dataset, all rate of decline datasets has been plotted in a single graph to visualize the maximum depletion time period within the reference time period.

5. RESULTS

OCCURRENCE OF DROUGHT ANALYSIS: SPI analysis: The SPI time series shows frequent dry period within the selected reference period (1980-2012). According to the SPI analysis with the observed dataset, meteorological drought observed within Dhaka city. Figure 5.1 and Figure 5.2 represents the evidence for the presence of drought in the observed and the global datasets simultaneously. Besides, Table 5.1 and Table 5.2 showed the distribution of drought signal according to the SPI analysis.

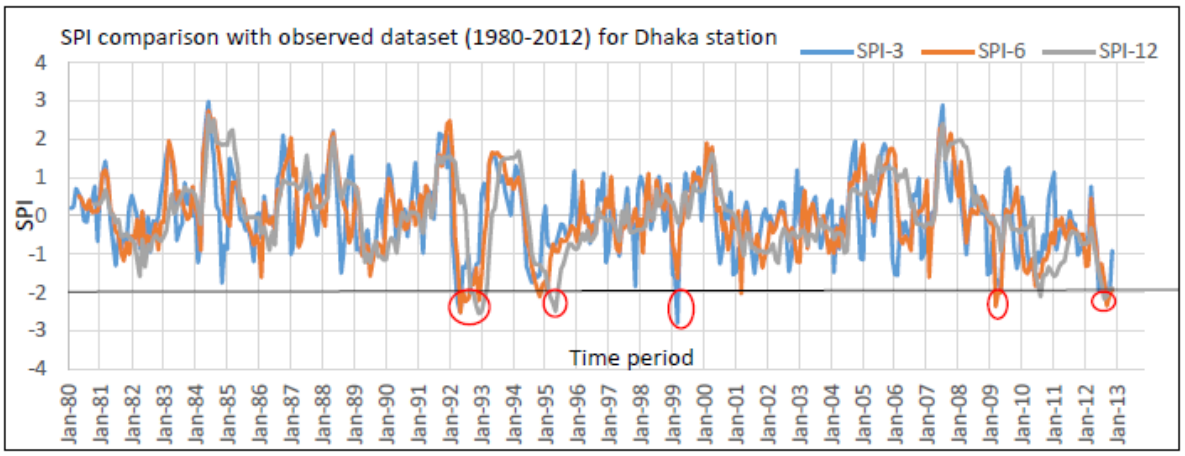


Fig 5.1: Analysis of SPI indicator with observed data (Dhaka)

Table 5.1 Frequency analysis summary for the observed dataset (Dhaka SPI)

Signal analysis	Number of signals				Percentage of signals			
	SPI-1	SPI-3	SPI-6	SPI-12	SPI-1	SPI-3	SPI-6	SPI-12
Extreme Drought	5	5	11	11	1.3%	1.3%	2.8%	2.8%
Severe drought	7	20	19	13	1.8%	5.1%	4.8%	3.3%
Moderate drought	32	36	22	27	8.1%	9.1%	5.6%	6.8%
Mild Drought	138	135	150	154	34.8%	34.1%	37.9%	38.9%
Wet	210	195	186	179	53.0%	49.2%	47.0%	45.2%
Zero	4	3	3	1	1.0%	0.8%	0.8%	0.3%

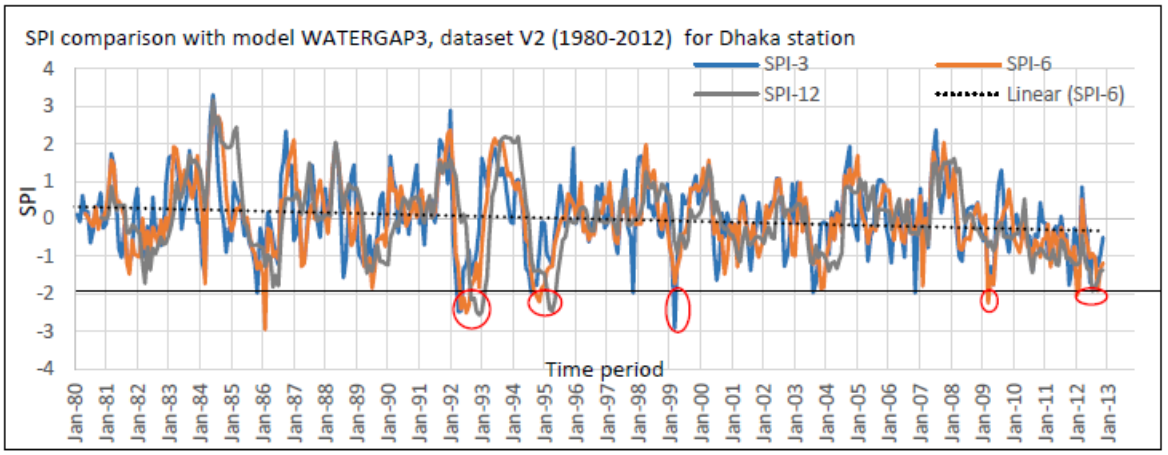


Fig 5.2: Analysis of SPI indicator with global data (Dhaka)

Table 5.2 Frequency analysis summary for the global dataset (Dhaka SPI)

Signal analysis	No of signals				Percentage of signals			
	SPI-1	SPI-3	SPI-6	SPI-12	SPI-1	SPI-3	SPI-6	SPI-12
Extreme Drought	6	3	9	8	1.5%	0.8%	2.3%	2.0%
Severe drought	6	13	16	9	1.5%	3.3%	4.0%	2.3%
Moderate drought	18	42	36	49	4.5%	10.6%	9.1%	12.4%
Mild Drought	124	148	132	129	31.3%	37.4%	33.3%	32.6%
Wet	237	188	196	187	59.8%	47.5%	49.5%	47.2%
Zero	0	0	2	3	0.0%	0.0%	0.5%	0.8%

Here it has been found that for Dhaka the drought pattern is like the observed dataset and that the historical drought events of 1994-95 and 1999 are present in both datasets.

SPEI Analysis: SPEI values have been computed for different monthly scales. Observed data was not available for the full period, so temperature time series from the WATERGAP3 V2 dataset from the global model has been used. **Figure 5.3** shows SPEI value for the Dhaka and **table 5.3** represents the signal analysis for Dhaka.

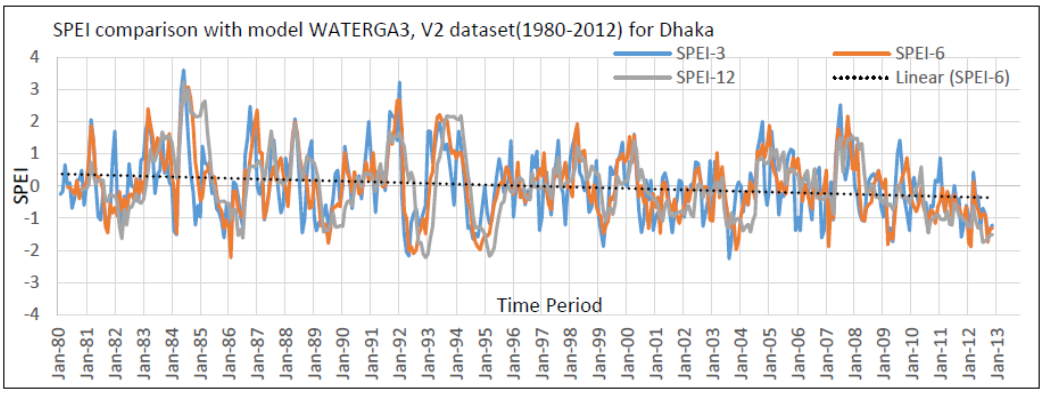


Fig 5.3: Analysis of SPEI indicator with global data (Dhaka)

Table 5.3: Frequency analysis summary for the global dataset (Dhaka SPEI)

Signal analysis	No of signals				Percentage of signals			
	SPEI-1	SPEI-3	SPEI-6	SPEI-12	SPEI-1	SPEI-3	SPEI-6	SPEI-12
Extreme Drought	2	3	3	5	0.5%	0.8%	0.8%	1.3%
Severe drought	15	11	17	13	3.8%	2.8%	4.3%	3.3%
Moderate drought	44	50	42	48	11.1%	12.6%	10.6%	12.1%
Mild Drought	143	143	146	135	36.1%	36.1%	36.9%	34.1%
Wet	192	185	182	184	48.5%	46.7%	46.0%	46.5%
Zero	0	2	1	0	0.0%	0.5%	0.3%	0.0%

After completing SPI and SPEI analysis for 3, 6- and 12-month accumulation period within the case study area, here is the summary of dry period according to all drought indicators. The summary made for only extreme dry periods that are when the value exceeds -2. **Table 5.4** shows all the extreme drought years come from the dry periods.

Table 5.4 Drought year according to indicator analysis:

1982	1985	1986	1992	1993	1994	1995	1997
1999	2001	2003	2006	2009	2010	2011	2012

Trend line and Decadal average analysis: The annual trend-line analysis has not enough for clear identification of the changing pattern of natural parameters. For this reason, decadal average analysis has been done to get clear identification. **Figure 5.4** represents the annual mean precipitation for the selected reference period with a linear trend-line. **Figure 5.5** represents the changing pattern of decadal average rainfall for the 3 consecutive decades and **Figure 5.6** represents a decadal change of temperature within Dhaka city.

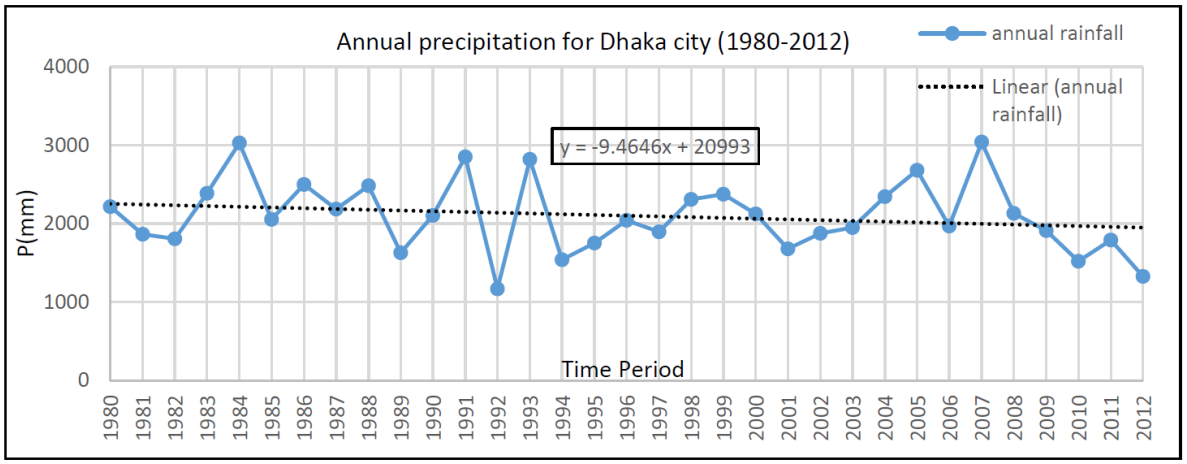


Fig 5.4: Annual precipitation trend line for Dhaka

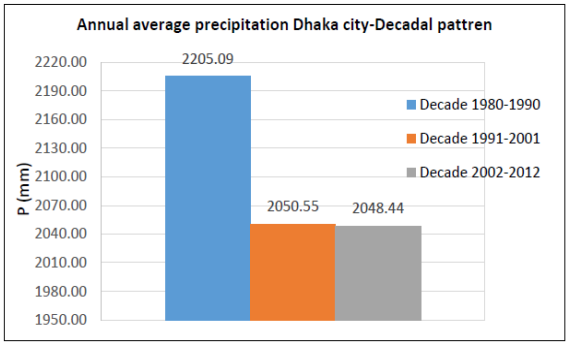


Fig 5.5: Decadal changing of precipitation in Dhaka

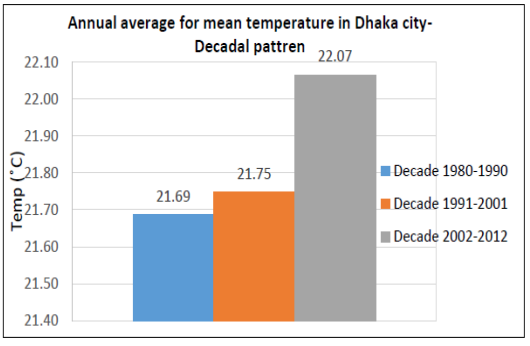
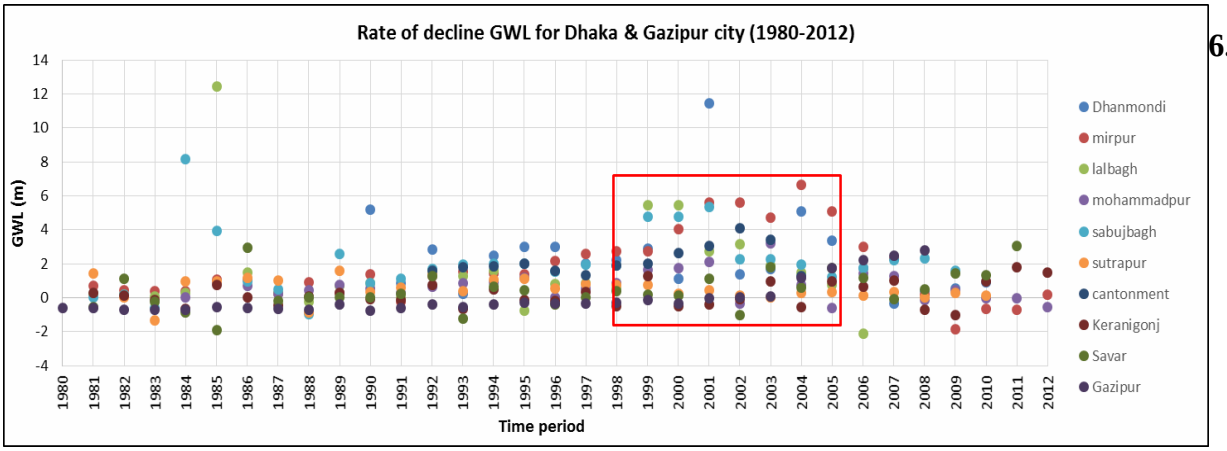


Fig 5.6: Decadal changing of temperature in Dhaka

Analysis of the yearly rate of decline: From the rate of change pattern for ten groundwater level station, there is a tendency that the depletion rate increases with time. Especially after the year 1998, the depletion rate is higher. There is a sudden increase in the year 1984-85 for three different stations though these may be outliers. Finally, it can be concluded that the years 1998-2005 is the maximum depletion period for the study area GWL. Figure 5.7 represents maximum depletion year for 10 GWL stations within the study area.

Fig 5.7: Accumulated results of maximum depletion rate for the case study area.



6.

CONCLUSIONS

In this research, analysis of drought events has been done using both ground and global model data. The major output of this research study is the establishment of selected drought indicators to efficiently describe past drought events in the study area. The determination of this drought indicators and associated thresholds helps to explain the occurrence of drought in the case study area within the reference period. The result of the analysis of past drought events shows that the occurrence of drought is frequent and the chance of severe drought occurring is high. There are sixteen different drought years that have been detected within the thirty-three years of the reference period that have impacts in the study area. The drought events of the year 1992-93 is a common finding in the analysis, whereas a series of drought year detected after the year 2000 was found to have similarities with changes in the rate of groundwater depletion. This study reports that meteorological & hydrological drought is relevant to describe effects on groundwater recharge.

This study also shows some indication of a change of the climatic pattern in the study area. The results from annual and decadal precipitation and temperature it has been found that annual precipitation is decreasing while the temperature is slightly increasing. The results also show some indication of the rate of decline of groundwater levels increasing after drought events, though this effect is not very strong.

Ten different datasets for GWL have been analyzed. All these datasets showed depletion of GWL with time within a selected reference time period (1980-2012). The highest depleted GWL were found in the Mirpur station which is now 68 m below ground. The highest reasonable depletion rate found in the same station which is 6.64 meter in one year. To find out the most depletion rate time period, the rate of decline of all datasets has been computed which shows that 1998-2005 were the years with the fastest depletion in an unsustainable manner.

The research concluded that groundwater level underneath Dhaka depleted more rapidly after the year 2000. Besides, precipitation decreases and temperature increases with time which is more severe after the year 2000. Also, the occurrence of drought is more rapid after the year 2000. So major findings here is, unsustainability in Madhupur tract aquifer underneath Dhaka city is increasing with progressing time which is not only a factor of population growth but also a factor of climate change and natural disaster drought.

ACKNOWLEDGMENTS

We acknowledge Dr. Micha Werner, associate professor of IHE-DELFT and Dr. Mario Franca, professor of IHE-DELFT for their continuous support about research and Bangladesh water development board (BWDB) for supplying necessary ground data.

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Paper 21

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Performance improvement of recycled aggregate

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Abstract

In recent decades, a lot of research effort has been put on waste management i.e. recycling of construction and demolition (C&D) waste as well as its reuse in sustainable construction practices to meet the needs of the society and enhance the quality of life. Large percentages of C&D waste are now recycled and reused in developed economies, which are moving towards adopting plans for zero waste. Recycled aggregate produced from C&D waste is usually divided into (a) good quality feedstock to be used in concrete production (structural and pre-cast) and (b) lower quality aggregate to be consumed in high volume, in road and pavement construction. The recycled aggregate used in concrete (structural and precast) have to comply with most test requirements of the fundamental properties of natural (virgin) aggregate, for example, bulk density, specific gravity, water absorption, the degree of contamination etc. Recycled aggregate have lower density due to less dense and relatively porous residual mortar adhered to the surface of original virgin aggregate particles, their water absorption capacity is variable and generally quite higher than virgin aggregate and their specific gravity is lower. They also usually contain undesired quantities of sulfate and chloride. For the quality improvement of recycled aggregate, various techniques have been researched and proposed which will be discussed in this paper and recommendations on the effectiveness of these techniques will be made based on their performance in recycled concrete.

Keywords: Construction and demolition (C&D) waste, recycled aggregate, contamination, quality improvement, treatment methods.

INTRODUCTION

Australia and most European Union member countries have set a goal to reuse 70 percent of recycled aggregate in civil engineering applications by 2020 Tam and Soomro (2018), meanwhile, to move towards zero waste will mean utilisation of 100 percent of recycled aggregate produced, which would be possible only if the drawbacks of recycled aggregate are overcome.

Recycled aggregate comes with two specific flaws; (a) residual mortar adhered on the surface of recycled aggregate, which increases its water absorption capacity and (b) presence of "weak links" i.e. several types of interfacial transition zones (ITZs) between virgin aggregate and new mortar (ITZ_1), between old mortar and new mortar (ITZ_2) and between virgin aggregate and old mortar (ITZ_3) depicted in Figure 1 Zhao et al (2017), which play a key role in the internal microstructure and mechanical properties of recycled concrete. The ITZ is a zone of about 20-50 µm thickness around the aggregate particles containing little calcium-silicate-hydrate (C-S-H) (with similar composition as in bulk phase), much of calcium hydroxide (CH) Scrivener *et al* (2004), together with ettringite (AFm) and monosulfate (AFt) phases (similar as in bulk phase) and a relatively high capillary porosity Kjellson *et al* (1998).

Poon *et al* (2004) used Scanning Electron Microscopy to study the influence of recycled aggregate and natural aggregate on the microstructure of new concrete. His observations revealed that in normal strength concrete "aggregate-cement ITZ" consisted mainly of loose and porous hydrates, whereas in high-performance concrete "aggregate-cement ITZ" consisted mainly of dense hydrates, i.e. the higher the strength of original concrete, the less porous was the ITZ of recycled aggregate.

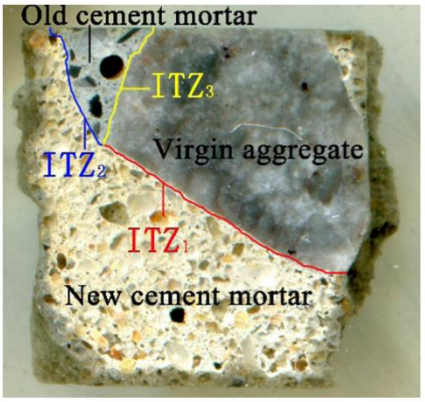

Figure 1. Interfacial transition zones (ITZs) of recycled aggregate in new recycled concrete. Zhao et al (2017)

Some researchers have reported 20% of residual mortar attached to the surface of recycled aggregate, of particle size ranging from 20 – 30mm Nassar et al (2012), while Corinaldesi et al (2010) has reported residual mortar to vary from 25% to 60% depending on the size of aggregate. Since the residual adhered mortar is porous, the water absorption of recycled aggregate is considerably higher and ranges from 3 – 12% as compared to 1 - 5% for virgin aggregate Gómez-Soberón et al (2002). The high water absorption of recycled aggregate can influence the workability in fresh recycled concrete and mechanical properties (shrinkage and creep) in hardened recycled concrete Etxeberia et al (2006).

Therefore to comply with test requirements for the properties such as; bulk density, water absorption, compressive strength etc., improvement in the properties of recycled aggregate are very essential to make them comparable to those of virgin aggregate and the challenges are to effectively reduce the porosity and water absorption, and strengthen ITZ of recycled aggregate which when used to make recycled concrete, will result in the enhanced physical and mechanical properties of recycled concrete due to cumulative effect.

METHODOLOGY

Because of the drawbacks (higher water absorption due to residual mortar porosity and lower strength of the old ITZ in the recycled aggregate), it becomes necessary to improve its quality so that higher percentage of recycled aggregate can be incorporated in recycled concrete without lowering its physicomechanical properties. For such improvement, the treatment methods discussed in the present paper can be classified as follows:

- autogenous cleaning
- pre-soaking (in water and in acid)
- coating with pozzolanic materials (cement slurry, silica fume, fly ash)
- use of water glass (sodium silicate)
- use of polymers
- use of different mixing approaches
- microwave heating and scrubbing
- carbonation of recycled aggregate

The effect of these treatment processes on the enhancement of physicochemical properties and the performance of recycled concrete have been discussed.

DISCUSSION

Although some researchers reported that the recycled aggregate replacements of 25%–40% and 50%–70% were better options, but to adopt zero waste plans will mean utilization of 100% of the recycled aggregate produced from C&D waste. To compensate for the strength loss as well as lower mechanical properties due to the incorporation of 100% of recycled aggregate, different pre-treatments to the recycled aggregate have been researched and proposed, such as (i) autogenous cleaning (ii) pre-soaking (iii) coating with pozzolanic materials (iv) use of water glass (v) use of polymers (vi) use of different mixing approaches (vii) microwave heating & scrubbing and (viii) carbonation of recycled aggregate etc.

(i) *Autogenous cleaning process:*

In this process, the recycled aggregate was placed in a rotating mill drum of 30 cm diameter and 50 cm depth filled up to 33% with "raw" recycled aggregates and rotated at 60 RPM, as depicted in Figure 2. After 10 minute and 15-minute cleaning process, the recycled aggregate was cleaned with water and subsequently dried to remove all the dust and impurities. The results showed a progressive decrease in water absorption capacity of recycled aggregate with the increase in cleaning process duration from 10 to 15 minutes. The results highlight that after autogenous cleaning; the amount of absorbed water was reduced by 50%, while the bulk density increased from 1946 kg/m^3 to 2220 kg/m^3 for 10-minute cleaning and 2261 kg/m^3 for 15-minute cleaning showing improvement in bulk density of recycled aggregate. The evaluated concrete compressive strength for unclean recycled aggregate concrete was 27.5 MPa and 28.7 MPa while for clean recycled aggregate concrete it improved to 29.9 MPa and 33.7 MPa, equivalent to strength increase of 8.0% at 28 days and 14.7% at 60 days of curing.

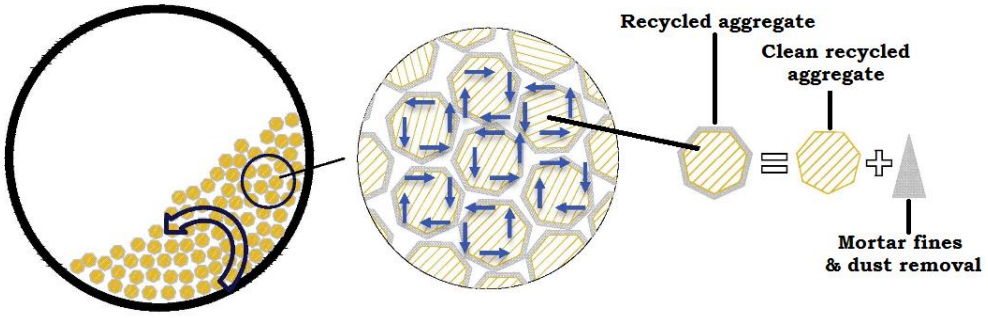

Figure 2. Autogenous cleaning process. Pepe et al (2014)

(ii) *Pre-soaking to remove adhered mortar:*

(a) Pre-soaking in water: Katz et al (2004) used ultra-sonic water cleaning to effectively remove loose and weak adhered mortar from RCA, but he found that the strength increase was only 7% at 28 days.

(b) Pre-soaking in acid: Tam et al (2007) used 0.1Molar solutions of hydrochloric acid, sulfuric acid, and phosphoric acid to soak RCA for 24 hours. This method proved effective since it significantly reduced water absorption but slightly increased chloride and sulfate content, the pH value slightly dropped but the pore solution remained alkaline.

(iii) *Coating with pozzolanic materials and cement paste*:

To strengthen the weaker ITZ as well as to reduce the porosity of adhered mortar on RCA, a coating of pozzolanic materials e.g. silica-fume, fly ash, B.F slag were applied to the surface of RCA by various researchers Katz et al (2004), Tam et al (2007), Behera et al (2014). Liang et al (2015) used cement slurry plus silica solution to coat recycled aggregate which was cured for 7 days and then used to make recycled concrete at water/cement ratio of 0.4 (effective water/cement ratio = 0.43). They found that surface coating improved the bond between residual cement mortar on recycled aggregate and new cement paste, and sealed the porous surface of residual mortar. The recycled concrete exhibited a compressive strength of 34.2 MPa at 7 days and 43.3 MPa at 28 days. Martirena et al (2017) used cement paste to coat 4-8mm RCA with a thin layer of cement. They ascertained that such treatment improved and enhanced the densification of the cement matrix at the interfacial transition zone (ITZ), which reduced the porosity and contributed to the slight increase in strength of recycled concrete. Katz et al (2004) found that

impregnation of recycled aggregate with a 10% (by weight) silica fume solution can increase the compressive strength by 30% at 7 days and 15% at 28 days of curing. Singh et al (2013) found that coating with nano-silica proved efficient in improving the properties of RCA.

(i) *Use of water glass*:

To reduce water absorption of RCA, water glass (sodium silicate) has been used as surface treatment by many researchers. Spaeth and Tegguer (2013) treated RCA (12 – 20 mm) with water glass in two concentrations of 7% and 30%. The RCA were immersed in water glass solution for 5 minutes, then dried at 20^{o}C for 24 hours, then put in an oven maintained at 50^{o}C until the difference in weight (before immersion & after) became less than 0.1%. They found that water glass treated RCA reduced water absorption from 4.5% (untreated) to 3.6% at 7% concentration and 2.1% at 30% concentration. Güneyisi et al (2014) treated RCA (8 - 16 mm) by immersing them in water glass solution for 30 minutes, then held in suspension for 10 minutes to allow the solution to drip out, then dried in an oven for 60 minutes. They found that this treatment effectively reduced the water absorption of RCA from 7.66% (untreated) to 1.77%. Ondova and Sicakova (2016) treated recycled brick aggregate (RBA) (4 - 8 mm) with water glass. The treated RBA reduced water absorption from 18% (untreated) to 3.3% when dried at 20^{o}C and 5.6% when died at 90^{o}C. They concluded that treatment with water glass becomes most effective when the recycled aggregate is dried at lower temperatures which allows part of solution water to stay in the porous system of RBA.

(ii) *Use of polymers*:

Kim et al (1999) used polyvinyl alcohol (PVA) and saline-based polymers to reduce water absorption of RCA. Kou et al (2010) found that the physical and mechanical properties of RCA were improved with 10% PVA solution. Zhu et al (2013) used silicone based silane and siloxane water repellent polymers as a surface coating to reduce water absorption of RCA. Though the method proved efficient, it decreased the compressive strength of recycled concrete. Chen and Thomas (2006) used sodium silicate to surface coat the RCA to improve its properties. He found that 5% concentration with one-hour soaking time proved effective in reducing the water absorption of RCA. However, sodium silicate treatment might introduce alkalis in recycled concrete increasing the risk of alkali-silica reaction Shayan et al (2003).

(i) *Use of different concrete mixing approaches*:

Tam et al (2005) used a two-stage mixing approach (TSMA) to treat RCA in the first stage and improve over-all concrete quality in the second stage. In this approach, RCA, cement and pozzolanic materials were pre-mixed with half of the required water to produce a thin layer of cement slurry on the RCA surfaces, which improved RCA quality and strengthened the ITZ between RCA and new mortar. Babu et al (2015) and Mohant et al (2016) found that two-stage mixing can significantly improve concrete uniformity and improvement in the quality of recycled aggregate resulting in an increase in the concrete strength by up to 8%–10% over conventional concrete.

(ii) Microwave heating and mechanical scrubbing:

Among the improvement methods, microwave heating technology has recently been recognized as one possible and prominent solution for producing cleaner and better quality aggregate from concrete waste. The aggregate and cement phase are different materials, therefore, exhibit differences in di-electric and thermal properties which induce different thermal expansion when subjected to different strength microwaves. This leads to the development of stresses resulting in the weakening of ITZ phase Menard et al (2013), Lippiatt et al (2012). Moreover, the large aggregate particles tend to accumulate more bleed water around them leading to a higher localized water/cement ratio in the ITZ. When it is subjected to microwave, more energy is absorbed due to comparatively higher water content giving rise to more heat and stress, creating higher differential stresses and leading to increasing in fracture and cracks in the ITZ phase. This results in efficient removal of adhered mortar when mechanical scrubbing is applied. Akbarnezhad (2011) reported that microwave treatment alone allowed partial removal of residual mortar and a recycled aggregate of higher quality were obtained when both, microwave and mechanical scrubbing were applied. Figure 3 shows untreated versus microwave treated and mechanically scrubbed aggregate. Bru et al (2014) found that the coarser the aggregate size distribution, the more effective was the microwave pre-treatment with a substantial increase in the liberation degree of residual mortar ranging

from 29.7% for a finer fraction (2-6.3 mm) to 65.1% for a coarser fraction (8-20 mm) of recycled particles. They also found that after microwave and mechanical scrubbing treatment, water absorption of cleaned aggregate reduced to 2.5% for coarse aggregate (8-20 mm) and 9.7% for middlings (6.3-8 mm). As per French Standards (NF P18-545, 2001), the limit value for water absorption of category (A) for natural aggregate = 2.5%, hence the cleaned recycled aggregate exhibited high quality and conformed to the required criteria.

Figure 3. Untreated vs Microwave treated recycled aggregate. Bru et al (2014)

(i) Carbonation of recycled aggregate:

When recycled aggregate adhered with residual mortar were carbonated with CO_2 at pressure limiting to 0.5 MPa, the hydration products present in the residual mortar such as calcium hydroxide $Ca(OH)_2$ (20%), calcium silicate hydrate (C-S-H) (70%), ettringite (AFt) (10%) and monosulfate ((AFm) (10%) reacted with CO_2 to form calcium carbonate ($CaCO_3$), silica-gel and gypsum ($CaSO_4$. $2H_2O$) Shi et al (2012), de Juan and Gutiérrez (2009), Hidalgo et al (2008). After carbonation the solid volume of the reacted products increase by about 13%, which increases the bulk density of recycled aggregate and reduces its porosity and water absorption, resulting in reduced shrinkage and improved strength of recycled concrete Shi, He, and Wu (2012). Recent studies on the performance of concrete made from modified and improved quality recycled aggregate show their suitability for use in structural concrete applications with the use of new innovation called CO_2 Concrete Tam and Butera (2016).

CONCLUSION

Various methods for enhancing the properties of recycled aggregate have been presented and discussed in this paper based on strengthening the ITZ of adhered mortar, reducing its porosity with a coating of pozzolanic materials, removal of residual mortar by microwave heating & scrubbing and its carbonation up to 0.5MPa pressure. The addition of acidic solvents can lead to new pollution; use of water glass for coating can increase the risk of alkali-aggregate reaction while the other methods require extra energy. Considering the cost of treatment, ease of use and the cost of production of recycled concrete, three methods stand-out. The cheapest and easy to adopt is TSMA, carbonation has recently been proved to be efficient, while microwave heating and scrubbing though proved to be efficient in improving the quality of recycled aggregate, is economically a bit costly.

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Paper 22

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Spatial Analysis of Heat Stress Vulnerable Areas in Chittagong City Corporation

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Abstract

Chittagong is the second largest city in Bangladesh, as well one of its major coastal cities. The city has shown great potential in the economic, industrial and tourism sectors, which has created a population boom. This in effect has increased urbanized and developed areas which consist more impervious surfaces than natural vegetation and soil. Impervious surfaces typically have higher heat retention capacity thus the people of the city are becoming vulnerable to heat stress because of the rise in temperature. High temperatures can cause heat rashes, heat cramps, heat exhaustion, heat syncope, and even heat stroke. (Hot Environments, 2016). The main objective of this study is to identify areas of Chittagong City Corporation (CCC) that are vulnerable to heat stress, according to their population density. This study develops a methodology for the integration of remote sensing and census data within a GIS framework to assess the areas of Chittagong City Corporation that are vulnerable to heat waves. Based on information of over a period of the recent 20 years, this study revealed that Sholashahar, Madarbari, Firingee Bazar, Patharghata, Saraipara are places of high heat vulnerable area in CCC.

Keywords: Heat wave, Land cover, Land surface temperature, Vulnerability, Chittagong City Corporation

1. INTRODUCTION

1.1 Background of the Study

Heat stress can be referred as the net heat load to which an individual may be exposed from the combined contributions of metabolic heat and different environmental factors such as, air temperature, humidity, air movement, and radiant heat. As the environment warms-up, the body tends to warm-up as well. The body maintains a constant inner body temperature by pumping more blood to the skin and by increasing sweat production. In this way, the body increases the rate of heat loss to balance the heat burden. In a very hot environment, the rate of heat gain is more than the rate of heat loss and the body temperature begins to rise which results in heat illnesses. (Hot Environments - Health Effects and First Aid, 2016) It is well established that extreme heat poses a serious health risk, causing many excess deaths each year (Field et al. 2012; Smith et al. 2014). No radiant heat gains or loss of the body occurs when the ambient temperature is about 35°C. (Prevention, 2017; Hot Environments - Health Effects and First Aid, 2016)

Chittagong, the second largest city of Bangladesh is also known as the business capital of the country. Population here is growing very fast as a result of high industrial development. The present population of the city is more than 2.5 million with a growth rate of about 2.07% per year (Statistics, 2011). With

the rate of growing population, infrastructural development is proportionally increasing with an increase of impervious surface. Impervious surface is one of the major reasons for the increase in surface temperature. There is a strong and positive correlation between the surface temperature and ambient temperature (Guan, 2011). The global greenhouse gas effect also traps the heat within the atmosphere and gradually increases the ambient temperature. As Chittagong is the industrial capital, some areas of Chittagong city are in very vulnerable conditions as there is a rapid increase in ambient temperature. Nowadays, heat stress has become a concerning issue for all over the world. The extreme heat and its adverse effects can cause Chittagong city a degradation of living quality with the trend of global warming. For this reason, the study tries to analyse the change of late '90s and an of recent year. The study of heat stress vulnerable areas of Chittagong can receive an increasing research attention when it is considered that the population is expected to reach somewhere around 4.5 million. (Hoornweg & Pope, 2014)

1.2. Goal of the Study

To find out the areas that are vulnerable to heat stress for people to live in & its relationship with population density in Chittagong City Corporation

1.3. Objectives

To reach the goal, some objectives have been followed. These are-

- To find out the land cover type of the city;
- To find out the land surface temperature of the study area;
- To find out the relationship between temperature & population density of the city.

1.4. Scope of the Study

This research might provide references for reducing the adverse effects of extreme heat more effectively with Chittagong city corporation area.

1.5. Limitations

Few limitations have been faced during the study has been done.

1. Landsat images that are used for analysis has some cloud coverage
2. Shape file of the Chittagong city corporation is questionable
3. Accuracy of the population data used is unknown

2. STUDY AREA

The total area of Chittagong City Corporation is 160.99 sq. km (Statistics B. B., 2001) which is in place between 22°13' and 22°27' north latitudes and between 91°40' and 91°53' east longitudes. The city is on the coast of the Bay of Bengal. River Karnaphuli is on the eastern south part of the city. It has a population of 25,82,401 & a floating population of 5,42,965 with a growth rate of 2.77%. (Statistics, 2011). The topography of the city is different from the other cities of the country as it is on the hilly regions. The study area was divided into 11 thanas and the thanas were subdivided into 41 wards.

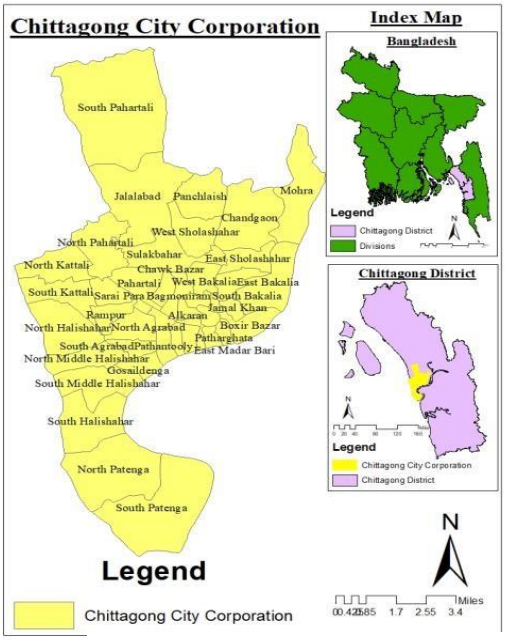

Figure 1: Study Area Map

Figure 1: Study Area Map

3. DATA

To identify heat stress vulnerable areas following data sets of Chittagong City Corporations are required: The shape file of the CCC (Chittagong City Corporation) for area defining. The file was collected from the CCC office. Population data of both the years have also been used to find out the density. Population has also been collected from CCC office and Bangladesh Bureau of Statistics (BBS). Satellite Image of CCC for zonal analysis. Landsat 5 and Landsat 8 data have been used to find out the land cover type of CCC for the years 1998 & 2017 respectively. For temperature analysis, band 6 of Landsat 5 (for year 1998) & band 10 of Landsat 8 (for year 2017) has been used. Landsat data have been collected from the website of United States Geological Survey. (URL: https://earthexplorer.usgs.gov)

Table 1: Satellite Image Information

Year	Landsat scene	Path and Row	Date Acquired	Scene Day/ Night	Spacecraft ID	Cloud Coverage	Resolution
1998	LT51360451998134BKT01	136,45	1998.05.14	Day	Landsat 5	0.00%	30m
2017	LC81360452017122LGN00	136,45	2017.05.02	Day	Landsat 8	0.03%	30m

Table 2: Landsat 5 Thematic Mapper (TM) Spectral Resolution

Bands	**Wavelength (micrometers)**	**Resolution (meters)**
Band 1 - Blue	0.45-0.52	30
Band 2 - Green	0.52-0.60	30
Band 3 - Red	0.63-0.69	30
Band 4 - Near Infrared (NIR)	0.76-0.90	30
Band 5 - Shortwave Infrared (SWIR) 1	1.55-1.75	30
Band 6 - Thermal	10.40-12.50	30
Band 7 - Shortwave Infrared (SWIR) 2	2.08-2.35	30

(U.S. Geological Survey, 2016)

Table 3: Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Spectral Resolution

Bands	**Wavelength (micrometers)**	**Resolution (meters)**
Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
Band 2 - Blue	0.452 - 0.512	30
Band 3 - Green	0.533 - 0.590	30
Band 4 - Red	0.636 - 0.673	30
Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
Band 7 - Shortwave Infrared (SWIR)2	2.107 - 2.294	30
Band 8 - Panchromatic	0.503 - 0.676	15
Band 9 - Cirrus	1.363 - 1.384	30
Band 10 - Thermal Infrared (TIRS) 1	10.60- 11.19	30
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	30

(U.S. Geological Survey, 2016)

4. METHODOLOGY

4.1 Preparation of Land Cover Maps:

Urban area is dynamic with lots of land cover types. A wide variation is very much common in structures. But while considering land cover type, it is very much similar and can be subdivided into a few classes. From many of the tools supervised classification has been used to classify the land surface. Two satellite images (1998, 2017) have been acquired and classified into six broad categories. Details of the land cover types are shown in the table. Supervised classification method has been used here to classify as it is based on knowledge engineering. In order to develop training sites, the images have been used according to their spatial and spectral radiances. Depending on the knowledge engineering, a fixed number of points on the images for each class has been showed as signatures. Most likely number of cells are then come in similar class as output in the supervised classification.

Table 4: Selection criteria for Land Cover class

Land Cover Type	Description
Built up	All man-made Structures: residential, industrial, settlements, road network, mixed use.
Vegetation	Trees, natural vegetation, shrubs, herbs, forests, gardens, agri-lands, crop fields.
Water Body	Sea, lake, river, ponds, canals, low laying areas, open water sources.
Bare soil	All the lands about to be developed: Land fillings, earth, open space, excavation sites.
Sandy soil	Sandy areas along with the bank of rivers and sea shores.

Landsat 5 image:

For Landsat 5 images, band 6 is the thermal band with electromagnetic spectrum range. Equations that are used to determine the temperature from the band given below (M. B. Giannini, 2015):

$$L\lambda = \frac{(Lmax - Lmin)}{(QCalmax - QCalmin)} \times (QCal - QCalmin) + Lmin$$

$$T = \frac{k2}{\ln(\frac{k1}{L\lambda} + 1)} - 273$$

Where,

Lλ = Spectral radiance (W/ (m^2*sr*μm)); Q*cal* = quantized calibrated pixel value in DN,
L*min* = spectral radiance corresponding to Q*calmin* (DN = 0),
L*max* = spectral radiance corresponding to Q*calmax* (DN = 255),
T = Top of atmosphere brightness temperature (K).
k_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number),
k_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number).

For Landsat 5, k_1 = 607.76 & k_2 = 1260.56 for Landsat 5. Other values are found similarly in the meta data of the satellite image.

Landsat 8 image:

Band 10 & 11 are the thermal bands for Landsat 8 images. Here, band 10 has been used. The equations that are followed (Survey D. o., 2018):

$$L\lambda = ML \times QCal + AL$$

$$T = \frac{k2}{\ln(\frac{k1}{L\lambda} + 1)} - 273$$

Where,
Lλ = Spectral radiance (W/(m2 * sr * μm)),
ML = Radiance multiplicative scaling factor for the band (RADIANCE_MULT_BAND_n from the metadata),
AL = Radiance additive scaling factor for the band (RADIANCE_ADD_BAND_n from the metadata),
Q*Cal* = quantized calibrated pixel value in DN.

For Landsat 8 the constant values are k_1 = 774.8853, k_2 = 1321.0789, ML = 0.0003342, AL = 0.1

5. ANALYSIS AND FINDINGS

5.1 Land Cover Change

Land cover type of two time periods have been shown in the graph. All the values are in percentage format. Built up area has been increased significantly over the time period while vegetation is seen to be decreased in very high amount. Change in bare soil and water body are very low according to the other two changes.

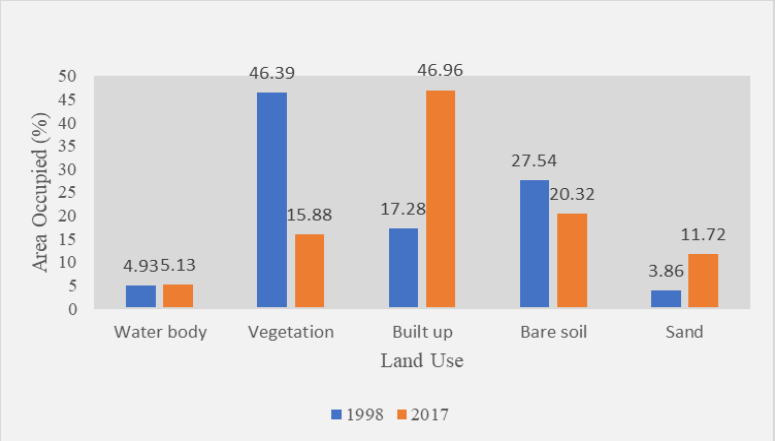

Figure 2: Percentage of land cover change

Loss gain matrix has also been given below from which it is easily understood that which amount of land cover is lost as well as what is gained. Total amount of gain & loss of all the classes can be very helpful to understand the condition of the area over the period. The cell amount of each land cover type was multiplied by the cell size of the image (30×30) to find out the total area. The diagonal line of the matrix which is marked by blue color is the amount of land which remained under the same category within the time period.

Table 5: Loss-Gain Matrix

1998 / 2017	Water (sq. km)	Built up (sq. km)	Vegetation (sq. km)	Sand (sq. km)	Bare soil (sq. km)	Gained area (sq. km)
Water (sq. km)	6.59	0.26	0.006	0.129	1.60	1.99
Built up (sq. km)	.586	27.017	28.967	4.784	20.30	54.64
Vegetation (sq. km)	0.047	0.134	23.963	0.238	2.412	2.83
Sand (sq. km)	0.071	0.73	13.23	.995	4.84	18.87
Bare soil (sq. km)	1.09	1.23	12.79	0.43	17.7	15.54
Lost area (sq. km)	1.79	2.36	54.99	5.58	29.15	93.8

There has been a drastic loss in vegetative area of about 54.99 sq.km and a huge increase in the built up of about 54.64 sq. km. And amount of lost land from vegetation is approximately equal to the gain of built-up area which is a concerning issue for the inhabitants of the city

From the map given, the change in the land cover over the years can easily be understood. Red portion indicates built-up area which has increased significantly with a rapid decrease in vegetation area. All the land cover types over the areas are shown in this map.

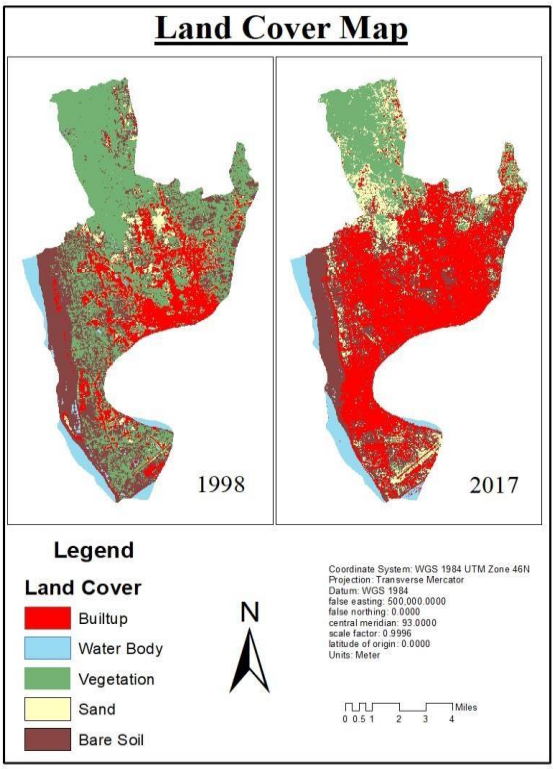

Figure 3: Land cover map of CC

5.2 Land surface temperature change

Along with the change in the surface of the city, temperature also varies. The variation in the temperature is shown in figure 4. Temperature in the central part has been increased very significantly. From the reference work of Centers for Disease Control and Prevention, Atlanta, USA and Canadian Centre for Occupational Health and Safety, 35°C is the range after which a rise in the body temperature results in heat stress. In 2017 summer, huge area generated surface temperature more than 35°C but in 1998 summer, the image does not show areas above 35°C.

Figure 5 shows the changing pattern of temperature within the city over the twenty-year time period. Temperature rise has been found almost all over the areas. Level of increment is shown in this map.

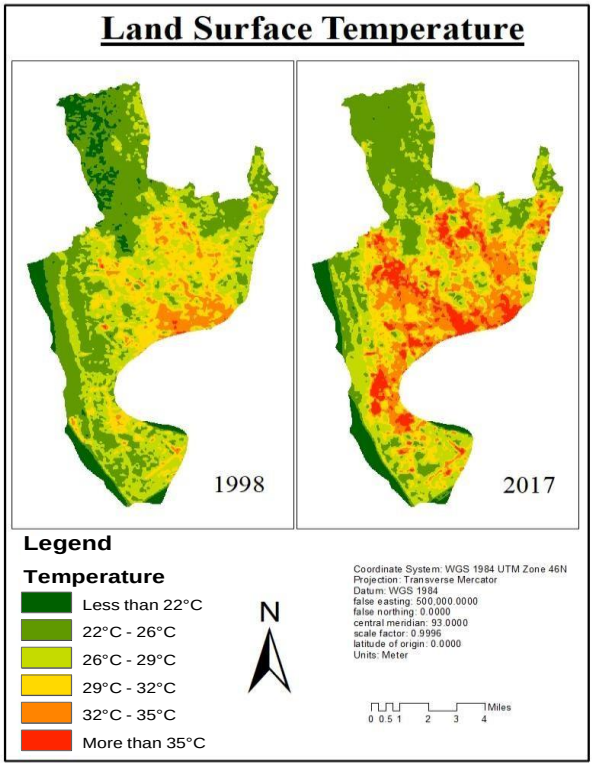

Figure 4: Surface temperature map of CCC

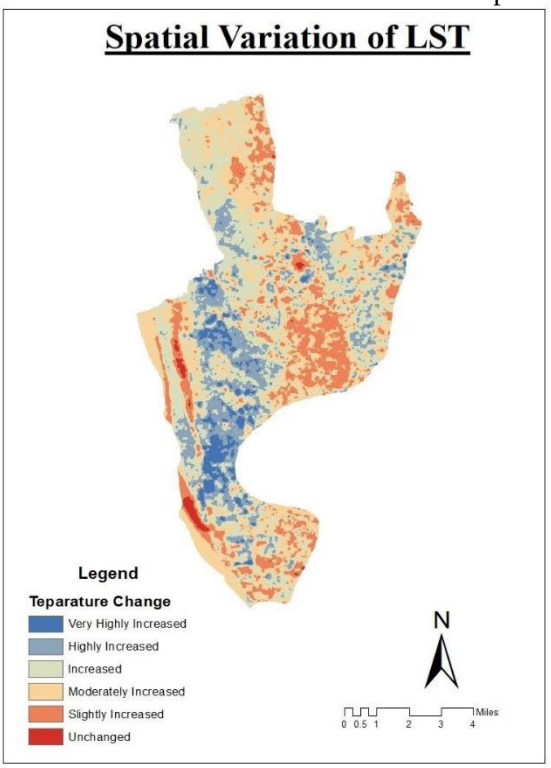

Figure 5: Map of variation of surface temperature

22°C - 26°C

5.3 Relationship between Land Cover and Land surface temperature

By now, it is known that land surface temperature (LST) depends largely on the land cover (LC) of an area. Over a certain long period, there is a high change in the land cover type so as the surface temperature. Figure 6 shows the relationship between these two.

Figure 2 showed the change in LC over the years. It is known from there that vegetation and bare soil has decreased, built-up and sand areas have increased. All these factors cause temperature rise. This is what the graph also represents.

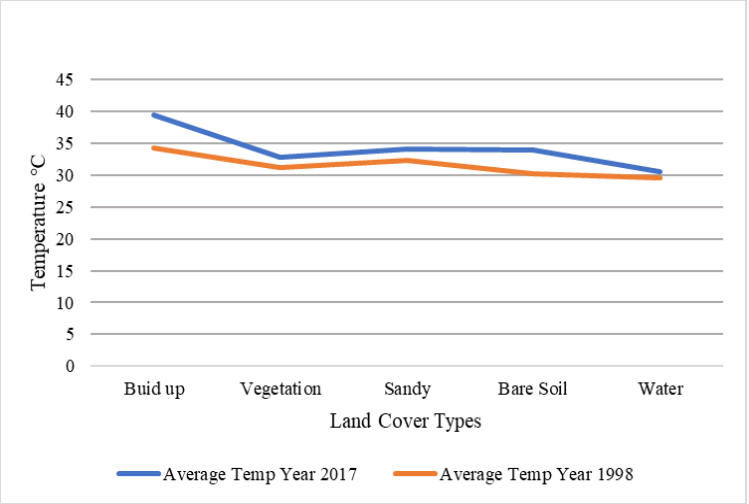

Figure 6: Relationship between LC & LST in CCC

Average temperature has increased against all the land uses within the twenty-year time period. Change in average temperature of water body was very less in amount but temperature of built up area and bare soil increased significantly.

5.4 Ward wise LST and risk zones

Chittagong City Corporation is not a small area. Overall calculation of temperature cannot provide the proper output of the research. So, the wards of the city corporation have been classified according to zonal statistics based on the LST. Average temperature for each of the 41 wards were calculated using zonal statistics tool in ArcMap. Eight wards were identified which had summer temperature of 2017 above 35°C. These are the vulnerable areas for heat stress as more than 35°C can cause heat illnesses. Six classes have been shown where the areas with maximum temperatures (more than 35°C) are considered as the vulnerable zones for heat stress of the city.

High temperature also has a relation with the population density. By analyzing population density according to the wards following outcome has been found (table 6). This shows that there are eight wards with vulnerability among which West Sholashar, Saraipara, Patharghata, Firingee Bazar, East Madar Bari have very high population density.

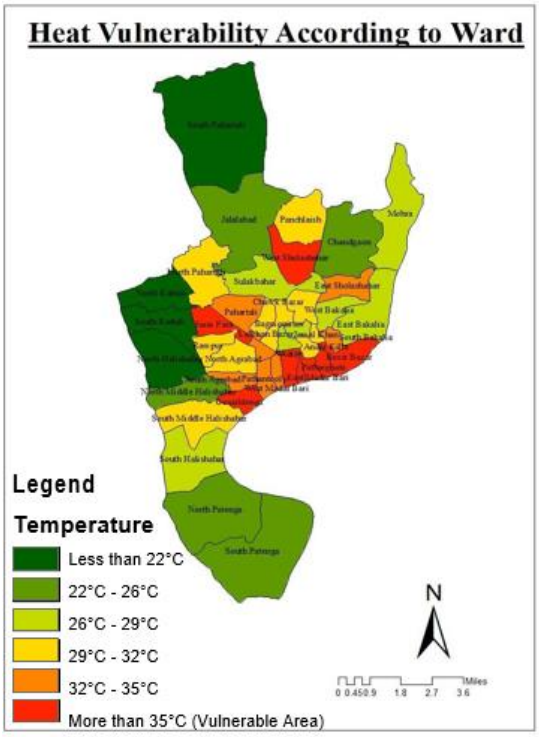

Figure 7: Heat vulnerability of wards

Table 6: Population density of the vulnerable wards

Vulnerable Wards	Population Density (per km^2)
Boxir Bazar	14,046.24
West Sholashahar	49,446.08
Saraipara	36,980.17
Patharghata	44,713.64
Firingee Bazar	50,292.73
Alkaran	25,153.33
East Madar Bari	41,352.98
Gosaildenga	23,772.77

6. CONCLUSION

Within the last twenty years, the Chittagong City Council has gained some heat stress vulnerable areas. Within the 41 wards, 8 become heat stress vulnerable during summer. Vegetation lands has decreased terribly, which has turned into built-up areas. From the analysis, it is found that the destruction of vegetation sector and unplanned growth of built-up area is influencing impacts of the ambient high temperature. As the population is increasing, there is no way to neglect the necessity of new settlements, amenity facilities, industries and other infrastructures to support the growth. And this type of facilities essentially generates heat in the environment due to energy consumed within. So, some corrective measures need to be taken soon, to avoid adverse effects of this industrial era with continuity of urbanization. As a developing country, issue related to heat stress is not getting any attention in Bangladesh as a nation.

ACKNOWLEDGEMENT

Authors would like to thank the Almighty for His grace. Also, thanks to Chittagong City Corporation authority for their help with the required data. Finally, a special thanks to the anonymous reviewers and editors of the iCSNBE2019 (International Conference on Sustainability in Natural and Built Environment).

CONFLICTS OF INTEREST

Authors declare no conflicts of interest.

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Paper 24

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Sustainable Houses of Bangladesh

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Abstract

Bangladesh is a developing country of South East Asia where awareness is low about sustainable living. This economic condition of her people is reflected in their daily life and activities including the house they live in. With the growth of their economic condition, they gradually shift from Tin-Shed houses to Brick-Built Buildings. In this study, we consider the Tin-Shed and Brick-Built building's thermal variability and inside heat index, and try to find out the human comfort zone. We have developed a system containing temperature and humidity sensor to collect data from different kinds of houses to check their heat index. Our work will allow general people to make their living decisions based on comfort level as well as sustainability.

Keywords: Sustainable Living, Living Comfort, Tin-Shed, and Brick-Build House, Environment Bangladesh

1. INTRODUCTION

Bangladesh is a developing country of South Asia, having a population of more than 160 million [8] where living space and conditions are often challenging. Here, living conditions reflect the social status, which in turn, plays a vital role in everyday life. Bangladesh is a compact country considering its area of living and population, where compactness brings frustrating aspects to daily life [9]. People moving from a mud house to a tin shed house (CI Roofed House) are considered to have had social improvement. However, they fail to consider the environmental factors, living conditions along with sustainable living whereas, sustainable form of living is more important for physical and mental health [9].

This research work builds upon the hypothesis of studying environmental parameters among different living spaces throughout the span of a day. Currently, we have considered a) Brick-Built House, b) Tin-Shed House for our field experiment. Though it has been proved in some research work that mud-built houses are more thermally efficient [3, 4], we will still consider it in our future work. The entire data collection has taken place through our custom-built Internet of Things (IoT) enabled system to continuously study temperature and humidity.

Current studies under limited time spans have revealed that the temperature and humidity differences show different level of variability under different conditions in brick-built houses and tin built houses. Tin shed houses show higher level of temperature which remain high during the evening. Again, it has health concerns on the people residing in those houses, considering the tropical weather of Bangladesh. In summary, the contribution of this research is that it explores the sustainable living conditions in the context of Bangladesh, and the findings of this study can be improved and extended in future work.

2. RELATED WORK

Various types of houses are constructed in Bangladesh that varies from region to region. Basically, brick-built houses are made in urban areas and tin-shed and mud build houses are common in Bangladesh. Though the indoor environmental changes are visible in several types of houses, a number of research works demonstrate the thermal comfort inside the houses that are built with several materials. In modern times, cement, steel, bricks etc. are used to replace the local materials as wood, stone, mud, tin, lime etc. for higher durability, and low maintenance [2]. The thermal performance was not considered in the past few decades that results poor thermal comfort in living [2].

Several research studies of Bangladesh show the thermal variety between mud houses and CI roofed brick-build houses, where it proved that CI roofed houses are less comfortable to live considering the temperature [3, 4]. It also varied in different times of the day. In the past, mud build houses were popular everywhere as well as in the Indian subcontinent [1]. However, material like mud bricks are environment-friendly, having higher thermal capacity, and considered as heat sink in unfriendly weather condition [1]. Though mud houses are not well enough in extreme weather conditions, and CI roofed houses are not also thermally friendly to live. That is why mud-brick build houses are recommended. We found similar variety in our study.

There have been development in several microcontroller-based units in other countries to sense temperature and humidity. ZIGBEE based LWSN and WSN sensing, monitoring and controlling system have been developed to sense the humidity and temperature of greenhouses in western countries [5, 6]. Some research proposed a number of models of smart sensing systems too. In previous studies based on Bangladesh, the use of sensors and data logger devices can also be seen [3, 4]. In this research, we introduced Arduino based simplistic temperature and humidity monitoring system that is reliable and cost-efficient system considering the context of Bangladesh.

3. METHOD

Study Parameters: The study is conducted in a brick-built house and tin-shed house studying the temperature, humidity over three different time periods of the day showing parameters in the morning (8 AM), noon (12 PM) and evening (5:30 PM) – taking around 50 to 60 readings during each time frame.

Location: The locations of the study are both in Dhaka city of Bangladesh. It is noted that we have not been able to conduct the study in mud houses, we hope to do so in our future work. The houses are shown in Figure 1(a) and Figure 1(b).

(a) (b)

Figure 1(a) Brick house (b) Tin shed House

Study Apparatus: The field test is conducted using our custom-built low-cost Internet of Things (IoT) enabled technology that continuously monitors temperature and humidity and stores it in a local storage. To develop this, we used widely available low-cost hardware. The major components are a) Arduino Uno Development Board, b) DHT11 Temperature & Humidity Sensor, c) RTC3231 Module, and d) Micro_SD Card Adapter as shown in Figure 2. In this system, temperature & humidity data is collected from the DHT11 sensor. Time and date are collected from RTC3231 adapter and finally, those datasets are logged into a micro-SD card attached to the system via a micro-SD card adapter for further analysis. Our Study findings are presented in the following section.

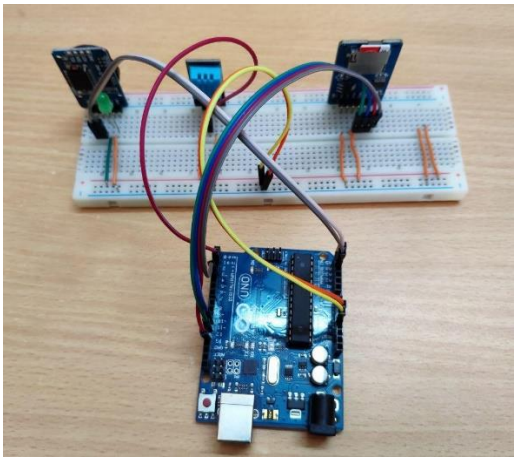

Figure 2 System Implementation

4. FINDINGS

The differences are clearly visible in environmental parameters in brick-built houses and tin-shed houses.

Morning Time Study: In the morning time study, it is shown that the temperature was comparatively stable in the brick-built house while the temperature slowly increased for the tin-shed house. Humidity was in reverse direction as of temperature while the tin-shed house showed higher values, compared to the brick-built house. The values are shown in Figure 3 (a) and Figure 3 (b).

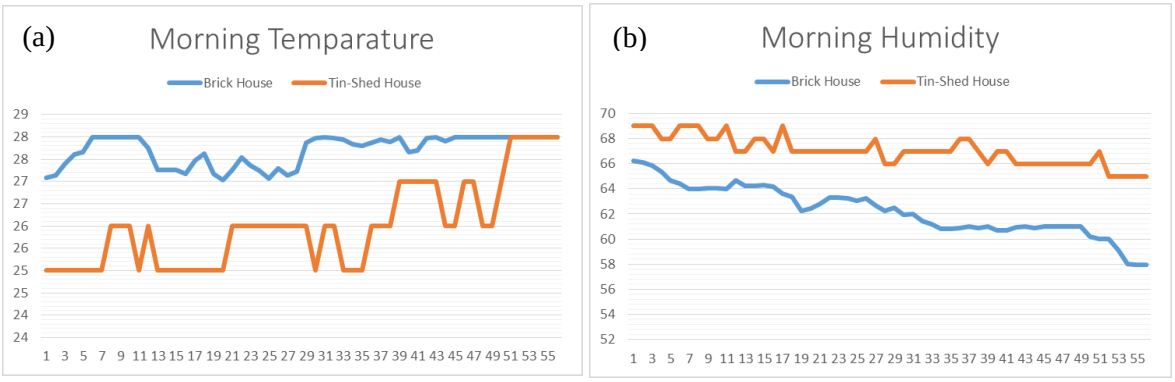

Figure 3 (a) Morning Temperature (b) Morning Humidity

Afternoon Time Study: Major temperature difference is visible in noon when the temperature raised. Higher temperature can be observed in the tin-shed house compared to the brick-built house, while the humidity remains similar in both environments, as shown in Figure 4 (a) and (b) respectively.

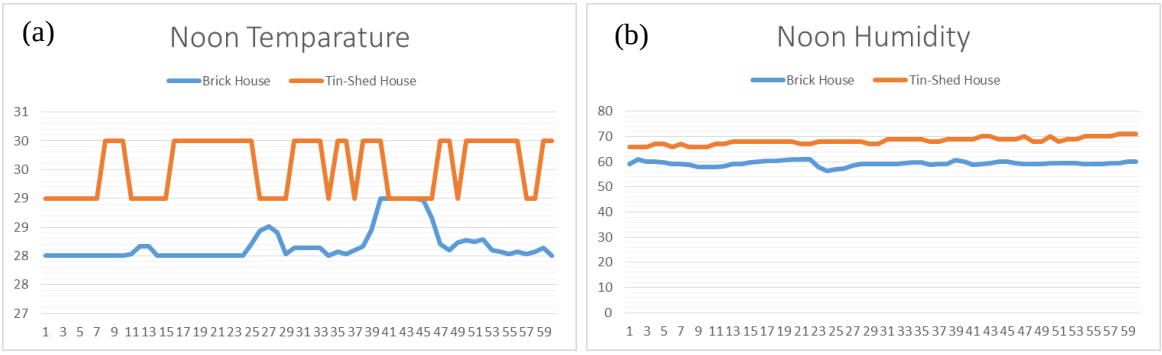

Figure 4 (a) Noon Temperature (b) Noon Humidity

Evening Time Study: The temperature was high in tin shed house even in the evening when the temperature dropped to a relatively lower level. The difference of humidity rises again during this time as shown in Figure 5 (a) and (b).

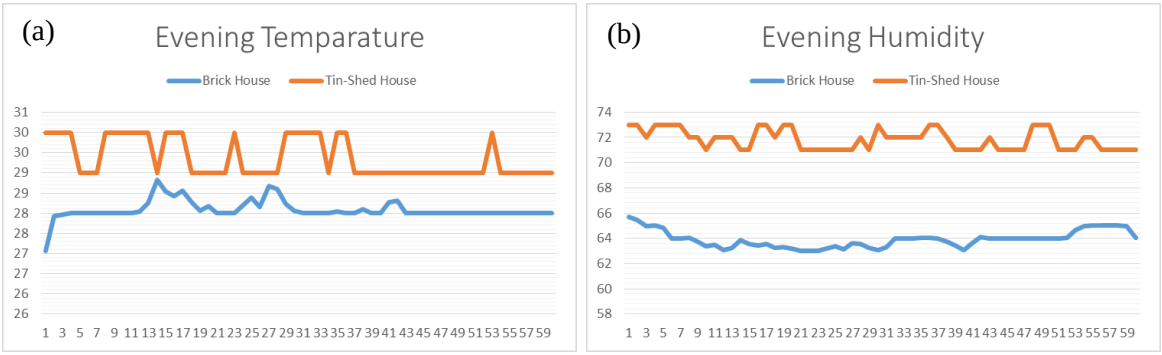

Figure 5 (a) Morning Temperature (b) Morning Humidity

Summary: The heat index shown in Figure 6 (a), (b) and (c) showing temperature during morning, noon and evening. It shows the environmental concern that tin-shed house always stays in higher temperature throughout the day, while the temperature of the house rises once.

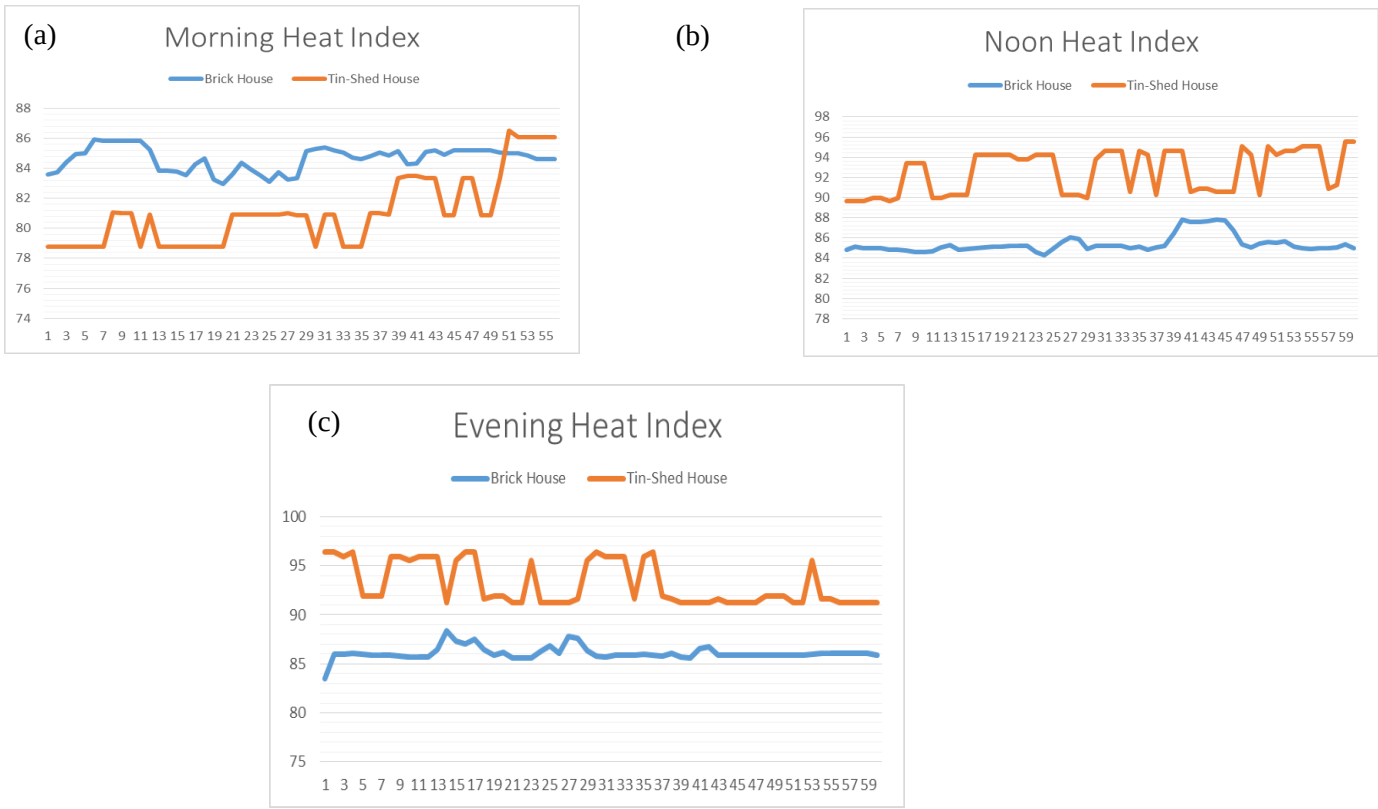

Figure 6 (a) Morning Temperature (b) Noon Temperature (c) Evening Temperature

We were unable to conduct the similar tests on mud houses that leaves comparison of brick-built houses and tin-shed houses, showing the temperature and humidity variability that are impacted from environmental conditions.

5. LIMITATIONS

Current studies only include the result of the comparison of tin shed houses and brick-built houses without any exploration of the mud houses. The study observes environment for a short period of time which is intended to consider long term studies in future. Similarly, the study should be conducted in several locations in Bangladesh that would open up regional contrasts.

6. CONCLUSION

We have explored the current living conditions and the environmental factors using low-cost sensing devices considering brick-built houses and tin-shed houses. It appears that tin-shed houses are more popular choice among the people of Bangladesh. Our further analysis shows extreme temperature readings of tin-shed houses that has negative impact on wellbeing of the residents of the house. We tried to consider mud-built houses too, but could not conduct our long-term data collections in such environment. Our research work will guide people to take decisions on sustainable living in proper houses. We hope to extend the current study and explore further.

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Paper 31

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Evaluation of the Outdoor Thermal Discomfort of Three Major Cities of Bangladesh

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Abstract

Thoms' Discomfort Index(DI) has been employed to determine the outdoor thermal discomfort from 2012 to 2016 in Dhaka, Sylhet, and Chittagong- the three megacities of Bangladesh. Dhaka has been found the warmest and most uncomfortable city during summer, on the other hand, Chittagong was found the most comfortable. However, in recent years, Chittagong has been found more uncomfortable than before. It has been found that maximum people experienced discomfort in all three major megacities from June to September. From June to September in 2016, about 84 days in Dhaka, 81 days in Sylhet and 74 days in Chittagong, most of the population experienced discomfort. The discomfort values were found for all three cities fluctuated repeatedly within these months. Furthermore, the outdoor discomfort condition raised in all three major cities. If the outdoor discomfort condition arises the indoor thermal condition will be influenced consequently and therefore, people will experience more thermal stress in the upcoming years in all three major megacities at Bangladesh.

Keywords: Thoms' Discomfort Index, Thermal stress, Bangladesh, Subtropics.

1. INTRODUCTION

ASHRAE stated that thermal comfort is "that condition of mind which expresses satisfaction with the thermal environment" (ASHRAE, 1966). Human body heat exchange is influenced by environmental factors such as air temperature, humidity, radiation and wind speed. Impacts of weather on human health became an important issue on the aspect of urbanization and urban heat island (Balogun and Balogun, 2014). People living in a large city always have high morbidity and mortality risk (Nastos and Matzarakis, 2006). People who work outside and exposed in solar radiation, experience extensive thermal stress, their productivity reduces (Bhattacharya et al., 2013) and their work efficiency deteriorates (Epstein and Moran, 2006). In addition, outdoor temperature always influences indoor thermal comfort (Nicol et al., 2012).

45% people lived in urban areas in 2000 (Arnfield, 2003), moreover, the estimation said about 60% of world population will be shifted to the urban areas by 2025 (Balogun and Balogun, 2014). The temperature at the growing urban areas was found higher compared to the rural areas. Therefore, assessing thermal comfort in urban areas is considered more essential in terms of human health quality (Polydoros and Cartalis, 2014) for both indoor and outdoor environments.

Many studies have been carried out to establish an empirical model to analyze thermal comfort on the basis of climatic perimeters (Angouridakis and Makrogiannis, 1982) e.g. air temperature, relative humidity, and wind speed, (Thom, 1959; Matzarakis and Mayer, 1996). Thoms' Discomfort index (DI) (Thom, 1959) provides a measure of the degrees of different discomfort conditions of the outdoor environment. It is a widely used bioclimatic index (Stathopoulou et al., 2005) used for analyzing thermal discomfort by considering temperature and relative humidity (Yousif and Tahir, 2013). The discomfort index has been employed in Greece, to climatize "Thessaloniki" city by Angouridakis and Makrogiannis (1982), DI were also used for finding out the climatic variations between urban and rural areas by Assael et al., (2010). In Asia, it has been used for evaluating the effects of climatic changes and its impacts on human discomfort at Beer Sheva by Potchter and Ben-Shalom (2013). Moreover, this index was also employed by Yousif and Tahir (2013), to evaluate thermal discomfort at Khartoum State in Sudan. In Nigeria, the discomfort index has been used for assessing the differences between urban and rural environments, by Balogun and Balogun (2014). In 2014 discomfort index was also used in Greece to assess the thermal risk of summer waves, by Polydoros and Cartalis (2014). In Bangladesh, Thoms discomfort index was used by Talukdar et al. (2017) to evaluate the trend of outdoor thermal discomfort in Mymensingh.

Bangladesh is a subtropical country of the northern hemisphere, and the climate of Bangladesh is a monsoon climate. During summer periods, temperature and humidity are found comparatively higher than any other seasons. In this period, people suffer an extreme amount of thermal discomfort in Bangladesh, but no such studies have yet been done to evaluate the thermal comfort conditions in Bangladesh. Dhaka, Sylhet, and Chittagong are the three major and most urbanized megacities of Bangladesh. Based on their locational characteristics, population density, regional physiology and different climatic characteristic, it is essential to evaluate the thermal comfort conditions of these cities. Therefore, the present study has been aimed to evaluate the thermal comfort scenario of these three major cities based on Thoms' discomfort index in order to minimize the research gap in the subtropics.

2. MATERIALS AND METHODS

This study employed Thoms' Discomfort index to explore the outdoor thermal discomfort conditions within three major cities of Bangladesh, i.e. Dhaka, Sylhet, and Chittagong from the 5-year period between 2012 and 2016. Discomfort index (DI) expresses different degrees of discomfort by evaluating air temperature and relative humidity. Therefore, temperature and relative humidity data recorded from 2012 to 2016 at three different meteorological stations have been examined in this study. The data used for this present study were collected from Bangladesh Meteorological Department (BMD), and analyzed by the following method of Thoms discomfort index (Yousif and Tahir, 2013):

$$DI = T - (0.55 - 0.0055\ RH)\ (T - 14.5) \quad (1)$$

Where, T is air temperature in ^{o}C, and RH is relative humidity in %. The expressions of Thoms' Discomfort Index are given in table 1:

Table 1: Thoms' discomfort index expressions (Yousif and Tahir, 2013)

DI ranges	Discomfort conditions
< 21	No discomfort
21-24	Less than 50% of people feel discomfort
25-27	More than 50% of people feel discomfort
28-29	Most people feel discomfort
30-32	Everyone feels stress
>32	Medical emergency

3. RESULTS AND DISCUSSIONS

3.1. Monthly Average Air Temperature and Monthly Average Relative Humidity

The data collected from BMD were used for assessing the trends of temperature and relative humidity at three major cities in order to understand the typical weather conditions. The monthly average is shown in figure 1, and the discussions are as below:

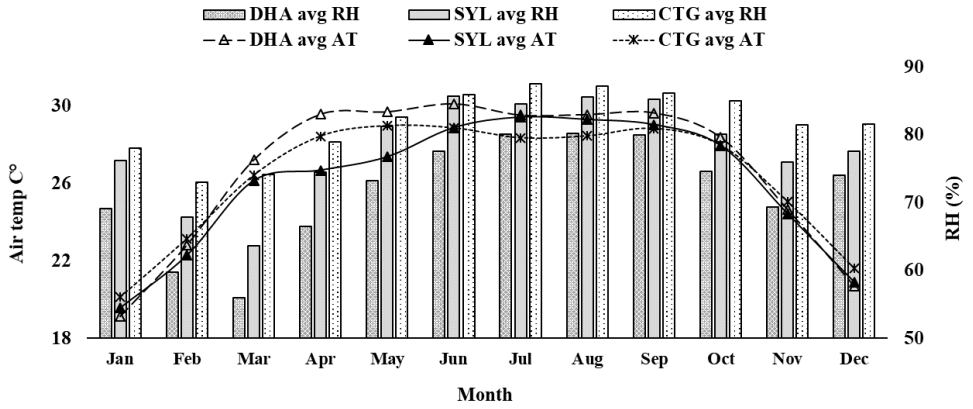

Figure 1. Variation of monthly average air temperature and monthly average relative humidity in Dhaka, Sylhet, and Chittagong during the period from 2012-2016

Figure 1. represents the monthly average air temperature and the monthly average relative humidity from 2012-2016 at three major cities of Bangladesh - Dhaka, Sylhet, and Chittagong.
From April to September, monthly average air temperature in Dhaka and Chittagong were found >28°C, nevertheless, the same range was also observed in Sylhet from June to September. Moreover, it has been observed that the air temperature at Dhaka was comparatively higher. An extensive range of relative humidity (>84%) typically exists in Chittagong from June to October. The same range was also found in Sylhet from June to September.
The climate of oceanside cities are influenced by the oceanic climate, therefore the excess of humidity typically exists in Chittagong. Relative humidity in Dhaka was typically lower than Sylhet and Chittagong and not more than 80.5% during summer. Relative humidity and temperature both were observed extreme from June to September, so it could be considered the warmest period and therefore it could also be said that people suffered more discomfort during these respective months.

3.2. Different Discomfort Conditions Within Four Months (June- September)

Figure 2a shows that during June the discomfort index (DI) values found for Dhaka were comparatively higher than Sylhet and Chittagong, and the values found for Chittagong were typically lower. In Chittagong, DI fluctuated rapidly during June and found to be comparatively higher than Dhaka and Sylhet in recent years. In Sylhet, DI values were typically higher during July (Figure 2b) and August (Figure 2c), on the other hand, DI values in Dhaka were typically higher than Sylhet and Chittagong during June and September (Figure 2d).

Although the DI values found for Chittagong were typically lower compared to Dhaka and Sylhet, the DI values at Chittagong fluctuated spontaneously. Some exceptional DI values were observed in Chittagong in June 2015 (Figure 2a), in August 2015 (Figure 2c), and September 2015 and 2016 (figure 2d). The respective DI values indicated either more than 50% people, or majority population experienced discomfort in these three major cities in most months from 2012 to 2016 when the DI values were ranged between 25-27 or 28-29, respectively.

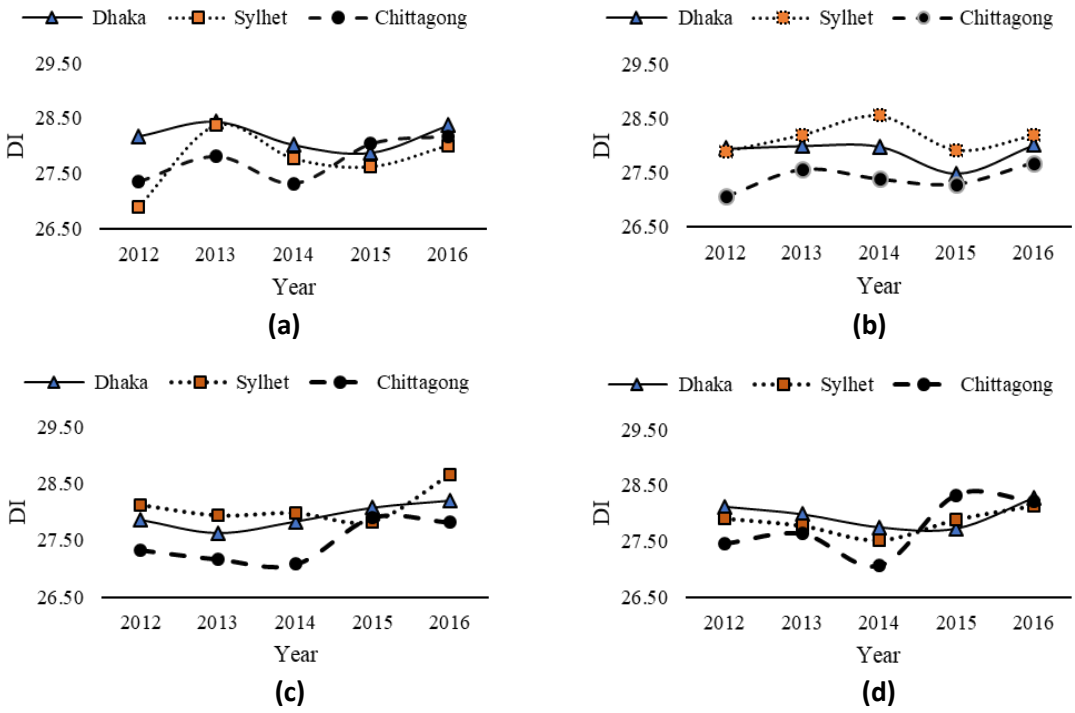

Figure 2. Variation of different discomfort conditions in (a) June (b) July (c) August and (d) September months in three major cities - Dhaka, Sylhet, and Chittagong during 2012 to 2016

3.3. Frequencies of different discomfort conditions in four months

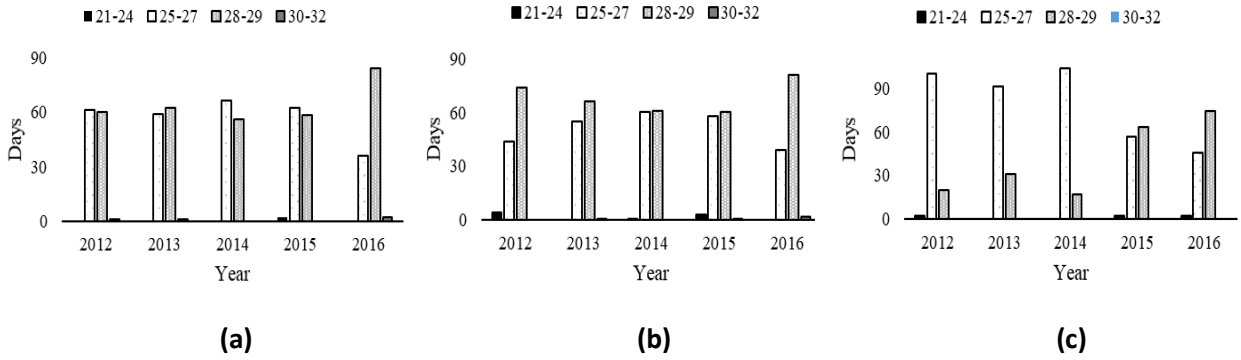

Figure 3: Variation of frequencies of different discomfort conditions in four months (June - September) from 2012 to 2016 in (a) Dhaka, (b) Sylhet and (c) Chittagong

The variation of different degree of discomfort that occurred from June to September during the period of 2012 to 2016 in Dhaka, Sylhet and Chittagong are illustrated in Figure 3a, 3b and 3c, respectively.

It has been observed from Figure 3a that during summer, in Dhaka, about 61 days in 2012, 59 days in 2013, 66 days in 2014, 62 days in 2015 and 36 days in 2016, over 50% of the population experienced discomfort where the discomfort values were found within the range of 25-27. On the other hand, about 60 days in 2012, 62 days in 2013, 56 days in 2014, 58 days in 2015, and 84 days in 2016, most of the population in Dhaka city experienced discomfort when the discomfort values were found within the range of 28-29 according to Thoms' discomfort condition.

It is noticed that (Figure 3a) the total number of days when more than 50% of the population experienced discomfort for DI range 25-27, are comparatively same as the total number of days when most of the population experienced discomfort for DI range of 28-29 from 2012 to 2015. It is evident that either more than 50% of the population or most of the population suffered from discomfort in Dhaka from 2012 to 2015 according to Thoms' explanations. By contrast, it has been found that in 2016 in Dhaka city, most of the people suffered from discomfort during maximum number of days, which is almost double than the days when more than 50% population experienced discomfort in Dhaka.

From Figure 3b, it is observed that in Sylhet, from June to September, about 44 days in 2012, 55 days in 2013, 60 days in 2014, 58 days in 2015, and 39 days in 2016, more than 50% people suffered from discomfort when the discomfort values were found within the range 25-27. In addition, about 74 days in 2012, 66 days in 2013, 61 days in 2014, 60 days in 2015 and 81 days in 2016, most of the people suffered from discomfort in Sylhet when the discomfort values were found within the range 28-29. It can be said that the number of days more than 50% of people experienced discomfort at Sylhet was comparatively the same as the days when most of the population experienced discomfort in this city. Moreover, an exception observed in 2016, about 39 days over 50% people felt discomfort on the other hand about 81 days most of the population felt discomfort in Sylhet, which indicates majority population experienced almost double discomfort in the recent year.

From Figure 3c, it has been observed that about 100 days in 2012, 91 days in 2013, 104 days in 2014, 57 days in 2015 and 46 days in 2016, over 50% population suffered from discomfort. About 20 days in 2012, 31 days in 2013, 17 days in 2014, 63 days in 2015 and 74 days in 2016 most of the population suffered from discomfort during June to September in Chittagong. It could be said from 2012 to 2014 in Chittagong over 50% people suffered from discomfort in maximum days from June to September, hence in recent two years e.g., 2015 and 2016 most of the population suffered from discomfort in the respective months.

A previous study that was conducted by Talukdar et al. (2017) found that from June to September relative humidity and from July to September air temperature were higher in Mymensingh. In these respective months relative humidity and air temperature in Mymensingh were found to be more than 85%, and 28.25°C, respectively. Moreover, the present study has observed quite a similar range of air temperature in Dhaka and Chittagong from April to September, and in Sylhet, from June to September. In addition, the monthly average relative humidity observed at three major cities were also found within the same ranges as Mymensingh. This study also reported, except for some variation, that in majority days from June to September maximum people experienced discomfort during 2012 to 2015 in Mymensingh, Bangladesh. The statements derived from the previous study also support the arguments of the present study that the outdoor thermal condition has been changed.

Therefore, it can be stated that people in all three major cities of Bangladesh experienced more discomfort in recent years than the previous years. The discomfort condition in Dhaka and Sylhet are comparatively similar and more uncomfortable than compared to Chittagong on the basis of total number of discomfort days. Moreover, the overall condition was comparatively comfortable in Chittagong. In Dhaka, maximum number of people experienced more discomfort in maximum days than the two other cities from June to September during 2012 to 2016.

4. CONCLUSIONS

Both urbanization and agglomeration have profound impacts on the urban climate, moreover, the risk of morbidity and mortality are always higher in megacities. Previous research claimed for an agglomeration in the urban areas by the upcoming decades, so assessing thermal comfort or discomfort is becoming more essential in terms of human health quality in urbanized areas such as Dhaka, Sylhet, and Chittagong. No bioclimatic analysis has yet been employed to evaluate the thermal comfort condition in Bangladesh, and therefore, the present study has been aimed to minimize this research gap.

The present study has found that Chittagong was more comfortable than Dhaka and Sylhet. It has been observed that discomfort values in Chittagong fluctuated spontaneously within different months, and in recent years Chittagong city has been found more uncomfortable than it was before. Primarily, it can be assumed that the rapid growth of air temperature might have influenced and changed the comfort level in Chittagong. Therefore, further empirical analysis is required to explore the absolute reasons.

In recent years most of the population experienced discomfort almost double the number of days than they have experienced in the previous years. Indoor temperature is typically higher than outdoor, so it could be assumed people also experienced more discomfort inside the buildings that they have experienced in the outdoors, and in the upcoming years, they might experience more thermal stress. The present study evaluated only five years; and, we strongly recommend further empirical studies on thermal comfort in Bangladesh in order to explore the actual thermal comfort or discomfort conditions and any adaptive measures in subtropics.

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Paper 33

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Informed Implementation of Greening as an Urban Heat Mitigation Measure in Melbourne, Australia: A Remote Sensing Study

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Abstract

The urban surface is heterogeneous due to natural ecosystem diversity, complex morphology, variability in soil characteristics, anthropogenic activities and climatic forcing. As a result, surface characteristics vary on a wide range of spatial scales and exert a significant impact on the energy and water balance and the resulting microclimate. The overall effects of urbanization on urban climate include the urban heat island and are reported for many cities. The physical properties and configuration of the urban surface, termed as urban surface 'characteristics', comprise a land cover, land use and it's vertical heterogeneity. These characteristics have a significant impact on urban climate through urban physical processes such as urban-canyon radiative transfer, turbulence exchanges of momentum, mass and heat within and above the canyon, and the thermal conduction of artificial surfaces. In this study, the potentiality of vegetation cover to mitigate the urban heat island (UHI) in three selected areas of Melbourne, Australia has been assessed using LiDAR data and Landsat TM5 satellite images. This investigation included the quantitative estimation of the spatial variability of land cover and land surface temperature (LST) and analysis the influence of surface characteristics on the land surface temperature. The results of the analysis showed that the total impervious land cover has a positive correlation with LST whereas grass and tree have had a negative correlation. From this statistical analysis it can be stated that for each 10% increment of tree cover, the LST decreases by about 0.7°C to 1.03°C. However, such influences were less for grass cover. For each 10% increment of grass, the LST decreases around 0.28°C to 0.54°C. On the other hand, for each 10% addition of an impervious cover, the LST increased about 0.61°to 1.02°C during summer and 0.77ºC to 0.56°C during winter.

Keywords: Urban heat island (UHI), remote sensing, LiDAR, Landsat TM5.

2. INTRODUCTION

The urban heat island (UHI) is the excess urban warmth compared to the surrounding rural area. It is the most noticeable effect of urbanization on urban climate and is reported from many cities of the world. Since the last twenty years, numerous studies demonstrate the occurrence of an UHI in Melbourne ranging from a mean of around 2°C to 4°C, with daily peak as high as 7°C, depending on the location, time and seasons (Morris & Simmonds, 2000; Coutts et al., 2008). Further, over the last two decades, Melbourne experienced a prolonged period of drought and has endured a number of weather-related hazards, including heat waves, bushfires and floods and health-related issues including general discomfort, respiratory difficulties, heat cramps, heat strokes and heat-related mortality (Loughnan et al., 2010). Melbourne is the second largest city in Australia and is rapidly growing with an anticipated population of up to 5 million by the year 2030.

This anticipated growth will require approximately 620,000 new households along with roads, parking area, other service areas. This will transform the natural land to built-up areas and would increase the urban heat island footprint. Coutts et al., (2009) mentioned that in Melbourne transformation of the natural landscape even with low-density development may significantly reduce the evapotranspiration (ET). Consequently, the availability of energy for heat storage and the atmospheric heat will tend to increase, driving a greater UHI intensity. However, most of the previous studies focused on small subsets of the urban area while little is known about the city scale impacts at which many policymakers generally operate.

To reduce the UHI and achieve human thermal comfort as well as climate change adaptation, several studies suggest the addition of green space and vegetation as an important heat mitigation option (Akbari et al., 2001, Shashua-Bar et al., 2000). However, such planning requires detailed information about land surface heterogeneity, spatial relations between land use and land surface temperature (LST) distribution patterns (Coutts et al., 2013; Grimmond, 2007). For such information, remote sensing and geographic information system (GIS) techniques are widely used (Weng, 2012). Using remote sensing data, this research investigated the spatial relationship between land surface characteristics and urban climate to assess the potential of increasing the vegetation cover to mitigate the urban heat island (UHI) in Melbourne. This relationship was explored through detailed estimates of land cover (vegetation and imperviousness) and fractional land cover using LiDAR data with estimated land surface temperature (LST) using Landsat TM5 data.

3. STUDY AREA, DATA, AND METHODOLOGY

Three local government areas (LGA) in the Melbourne metropolitan area, namely Melbourne City Council, Monash City Council, and Darebin City Council, were selected for this research (Figure 1). Each of the LGAs is different in characteristics such as settlement age, geology, geographical setting, population density, land use, business types, and other attributes. These areas are chosen to accommodate the spatial variations of metropolitan Melbourne.

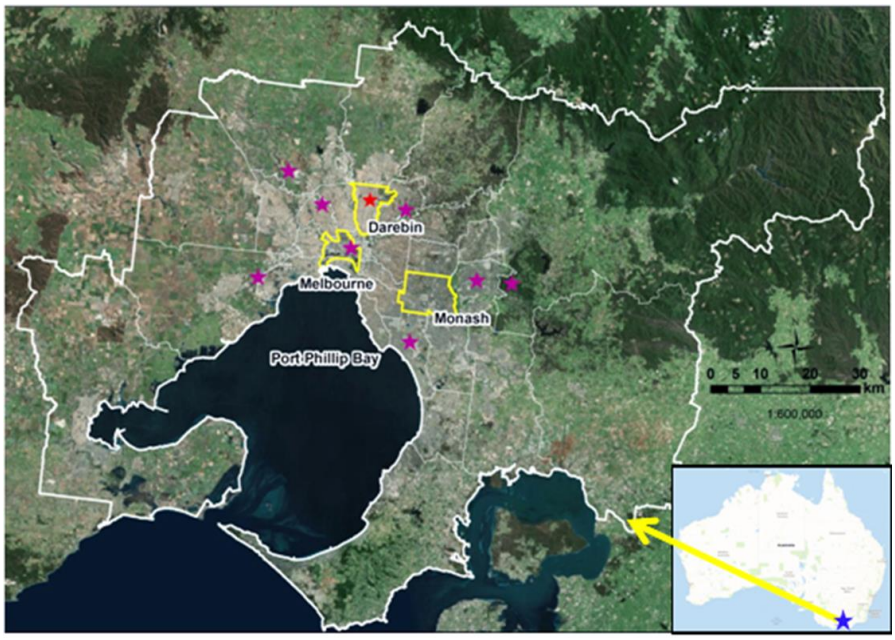


Figure 1: Location of the study areas. The blue star on the inset map indicates the location of Melbourne. The yellow boundaries represent three study areas: Darebin, Monash and Melbourne LGAs. Magenta stars are representing the location of weather stations and the red star shows the location of the Preston flux tower in Darebin. Google Earth image has been used as the base image.

A schematic of workflow and use of a different dataset for this study is shown in Figure 2. Land use zones of the study area have been derived from the Victorian Planning Scheme data (2004) and clipped for these LGAs. The data is primarily derived from Vicmap Property cadastral mapping compiled at 1:2,500 (metropolitan Melbourne), 1:10,000 and 1:25,000 scales (DSE, 2004).

Detail land cover map and a morphometric parameter of these the LGAs were derived using filtered LiDAR data based on Class code (LAS 1.2 specification code of ASPRS based on return number) and were provided by the local government authorities with metadata.

Vertical accuracy of this data is (+/-) 0.10 m and horizontal accuracy is 0.03 m.

Unlike other remotely sensed data, LiDAR is an airborne optical remote-sensing data focuses solely on geometry rather than radiometry. This emerging remote sensing technology measures the three-dimensional structures of the elements and the height of features on the ground and above the ground at higher density and accuracy (Pfeifer et al., 2007; Sampath & Shan, 2006).

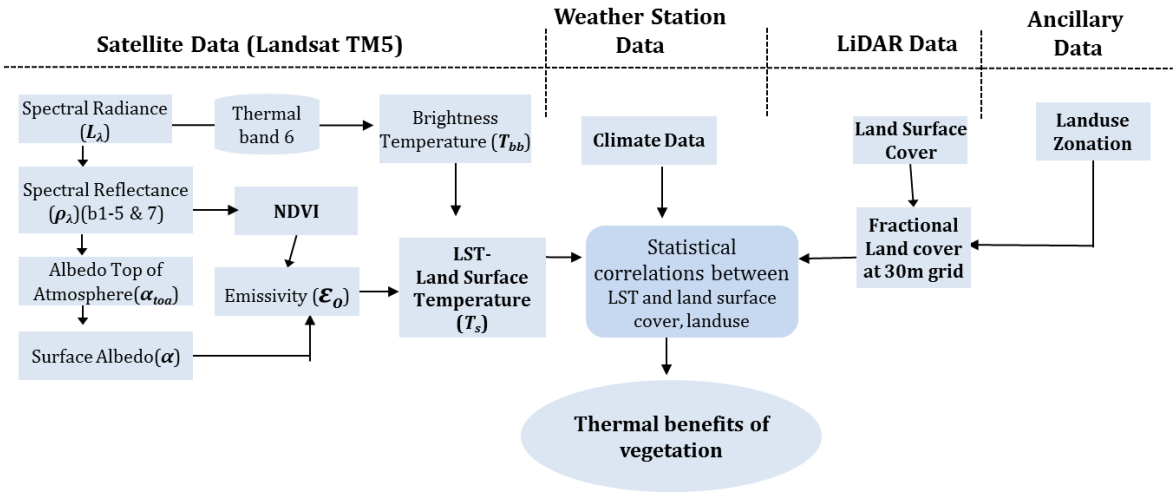


Figure 2: A schematic representation of the research workflow.

The climate data were collected from the Australian Bureau of Meteorology (BOM). Within the study area, there are five climatic stations (Essendon Airport, Laverton RAAF, Melbourne Regional Office, Melbourne Airport and Preston) which have long-term data and matches with the satellite overpass time. For the study area, a total of 8 cloud-free Landsat TM5 images were selected between 1989 and 2006 (date 1989-10-14, 2003-09-03, 2003-12-24, 2004-11-24, 2005-04-01, 2006-09-12, 2005-11-01, 2005-02-28). The images were downloaded from the Land Processes Distributed Active Archive Centre (LPDAAC) of the United States Geological Survey (USGS) through Earth Explorer. LPDAAC provide orthorectified and resampled Landsat images with metadata. All bands, including the thermal band which is originally acquired in 120 m resolution, were individually resampled and supplied as 30m resolution, (USGS, 2011). Radiometric, atmospheric and geometric corrections are applied on the Landsat TM5 images. The necessary raster and vector processing were performed through ENVI 5, ArcGIS 10 and Global Mapper 13 software. All the input images and geospatial data were projected to GDA 1994 MGA Zone 55 to maintain the spatial consistency.

The surface temperature (Ts) was computed according to Liu et al., (2007).
T_s = T_bb/(ε_O)^0.25 ……..(1) and T_bb=K_2/ln(K_1/L_6 +1) ……(2)

where ε_O is surface emissivity. The surface brightness temperature (T_bb) at each pixel was computed from the spectral radiance of the thermal band (band 6) of the Landsat 5 TM image following equation 2 of Markham & Barker (1986). K_1 (607.76 Wm-2 sr-1 µm-1) and K_2 (1260.56 Wm-2 sr-1 µm-1) are constants for Landsat TM (Markham & Barker, 1986). In this study, emissivity was estimated based on a combination of NDVITHM methods following Rhinan et al. (2012) and Sobrino et al. (2004 & 2012). NDVI is defined as the ratio of (NIR – Red) and (NIR + Red), where NIR is the reflectance in the near-infrared band and red is the reflectance in the red band (Tucker, 1980). In Landsat TM5 image the Band 4 corresponds the NIR reflectance of 0.76 – 0.90 µm wavelength and Band 3 corresponds the Red reflectance of 0.63 – 0.69 µm wavelength. During the analysis, the large water body and some pixels with shadow effects were excluded.

The UHI studies have traditionally been conducted for isolated locations and with in-situ measurements of air temperature and its intensity is often estimated using the difference between urban and rural temperatures from individual observing locations (Oke, 1995).

The SUHI (Surface Urban Heat Island) refers to the relative warmth of urban surfaces compared to surrounding rural surfaces. The atmospheric UHIs tend to be larger at night while SUHIs are larger during the day (Erell & Williamson, 2007). From the literature review, it is evident that there is no universal methodology for SUHI estimation using RS data that can be immediately applicable to any city. Different authors measure this phenomenon differently. Zhou et al., (2010) define SUHI intensity as the maximum difference between urban LST and the terrestrial average LST. Klok (2012) calculated a SUHI for each district by comparing their surface temperature with the average surface temperature of rural areas (mainly grassland). Mallick (2013) demarcated the SUHI as the difference between the mean LST of land use classes with the mean values of two urban and rural areas. Zhang et al. (2012) described SUHI intensity by the difference between the surface radiative temperature in the city minus the average temperature of the city and outlying zone.

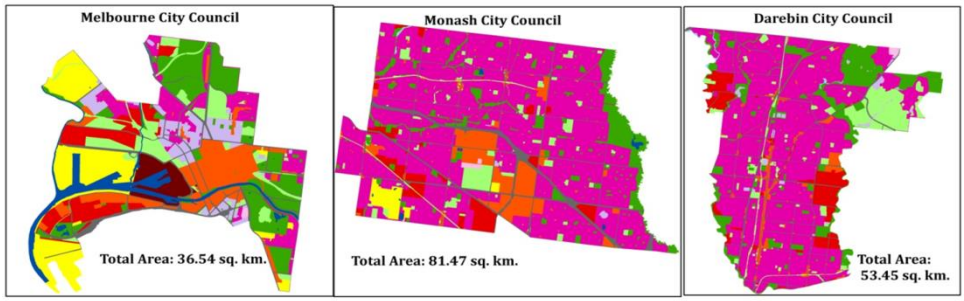
In this study, mean LST was estimated for summer and winter considering LST of all three LGAs. As all of the three LGAs are within the metropolitan area, mean LST was considered as the threshold limit to delineate the intra-urban thermal variation. In this study, the probable SHUI area is defined as any point that has higher LST values than this threshold limit. These areas are not absolute representations of SUHI, but rather represent relatively warmer areas than average.

Landsat images provide information at the 30m-pixel resolution and at the surface, this 30m by 30m land area could include different types of land cover. To compare derived LST and SUHI with high-resolution land cover information, a regular 30m by 30m vector grid was created with similar spatial extent from the satellite data. Within this 30 m grid, the fraction of each land cover type was calculated. The value of fraction ranges between 0 and 1 (Figure 3). If any grid shows 0.9 for building and 0.05 for grass and 0.05 trees it means 90% of that pixel is covered by building, 5% by grass and 5% by trees.

Figure 3**:** (A) Black lines on the land cover map are representing a regular 30m by 30m vector grid derived from Landsat image. (B) Magnified view of an individual grid and (C) Example of an estimated land cover fraction for each 30m by 30m vector grid.

4. RESULTS

The Victorian Planning Scheme dataset has many land use zones (39), however, for the purposes of this study they were re-grouped into eleven (11) land use zones. The three LGAs of Melbourne, Monash, and Darebin are completely different in terms of their land uses (Figure 4A). The Melbourne area is situated very close to the coast and includes the central business district (CBD). Therefore, a large area of Melbourne is used for business, mixed-use, industry and special use zones that include the Docklands, recreational areas, and other special usages. In contrast, Monash and Darebin are predominantly residential (more than 60%) compared to Melbourne (10%). Another remarkable contrast is that more than 7% of the area in Melbourne is open water whereas Monash and Darebin have only ~0.5% area of open water. The public use zone (PUZ1) mainly consists of parks, reserves, cemeteries and recreational areas and this zone is mostly vegetated. PUZ1 occupies more than 17% in Melbourne, 13% in Darebin and 9% in Monash. These contrasting land uses among the LGAs provides an opportunity to examine the spatial variability of surface characteristics such as urban land cover and their impact on urban climate.



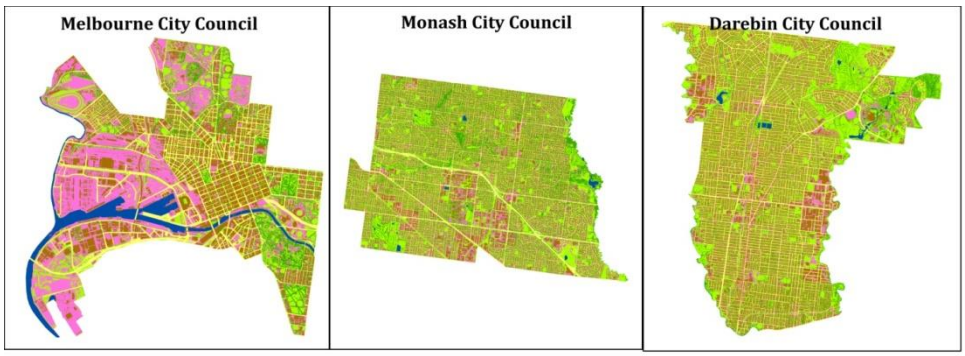
Legend

- BZ : Business Zone
- DZ: Dockland Zone
- INZ: Industrial Zone
- RDZ: Road Zone
- RUZ: Rural Use Zone
- RZ: Residential Zone
- SUZ: Special Use Zone
- UFZ: Urban Flow Zone
- Water
- LDRZ: Low Density Residential Zone
- CDZ: Comprehensive Development Zone
- PUZ1: Public Use Zone1 (Park, Recreation, Reserves, Cemetery)
- PUZ2 : Public Use Zone2 (Health, Education, Community, Road)

Area percentage (%) of different landuse zone of three LGAs according to planning scheme

Landuse Zone Code	Melbourne City Council	Monash City Council	Darebin City Council
RZ	10.01	66.67	63.07
RDZ	7.42	5.89	4.36
INZ	8.14	4.14	6.38
BZ	12.72	7.42	2.85
PUZ1	17.62	8.89	13.17
PUZ2	9.73	4.51	8.51
MUZ	6.25	0.08	0.56
SUZ	15.71	1.71	0.00
Water	7.38	0.31	0.47
RUZ	0.16	0.23	0.29
DZ	3.74	0.00	0.00

(A)



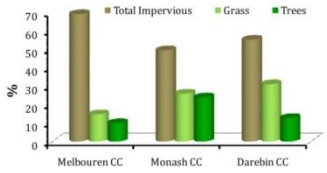
Legend

Class Name
- Building
- Grass
- Other_Imper
- Road
- Trees
- Water

Area (%) covered by different land cover types in three LGAs

Land Cover Type	Melbouren CC	Monash CC	Darebin CC
Building	21.79	19.52	25.23
Grass	14.77	26.03	31.13
Other Impervious	32.06	14.55	13.41
Road	15.36	15.46	16.67
Trees	9.98	24.01	12.76
Water	6.04	0.42	0.81

Comparison between three LGAs



(B)

Figure 4 (A) Detailed land use (B) land cover maps of Melbourne, Monash and Darebin LGAs. The same color codes are used for all three LGAs.

From the LiDAR data six types of land cover information were extracted for each LGA comprising: 1) building, 2) road, 3) trees, 4) grass, 5) other-impervious area and 6) water as shown in Figure 4(B). To assess the accuracy of the derived land cover map, a classification error matrix was developed according to Pfeifer et al. (2007). From each LGA, five locations, with an area frame of each 30m by 30m (900m2), were randomly selected for this assessment. The overall accuracy of derived land cover maps is 94% based on the used reference data i.e. 94% of the derived classes correctly represent the surface land cover information. The spatial distribution of cover type in Melbourne is significantly different than Monash and Darebin areas. To compare this difference, the area percentage of each land cover type of the respective LGAs was computed. Total impervious cover type includes the buildings, roads, and other impervious covers. Total vegetation includes grass and trees. From the result it is found that in the Melbourne LGA, about 69% of the area is covered with impervious surfaces, 14% is covered by grass, 10% is tree covered and the rest is water areas.

The spatial distributions of LST indicate the low LST values are distributed around parkland, vegetated areas and water areas whereas higher LST's are distributed mostly in built areas and around the business and industrial areas. In particular, most of the Melbourne LGA shows higher LST compared to Darebin and Monash areas. The distribution indicates that the Melbourne LGA had a more developed SUHI than the Monash or Darebin LGAs and also follows a definite urban geometric pattern and land use influence (Figure 5A).

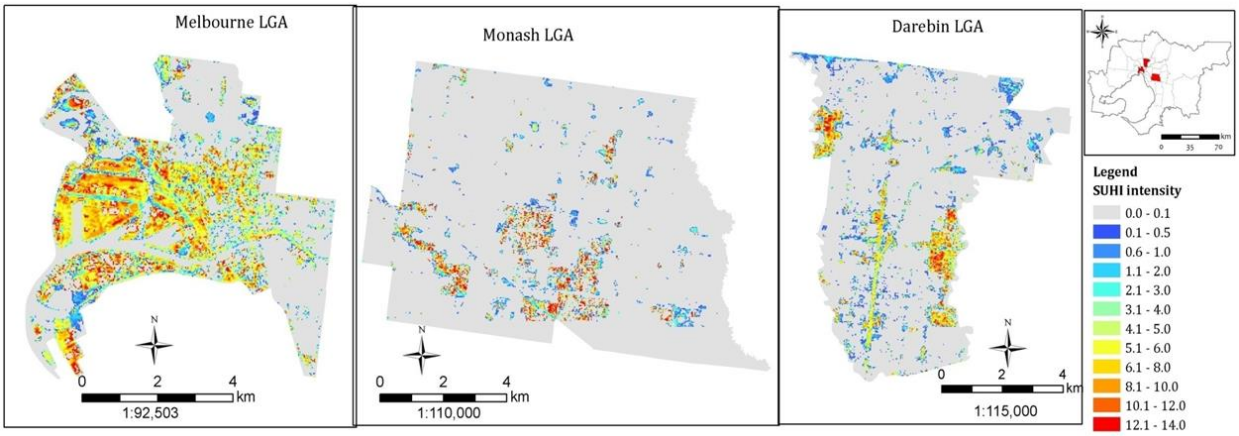


Figure 5A: Spatial distributions of SUHI areas of the three LGAs derived from estimated mean summer LST using the Landsat TM5 image.

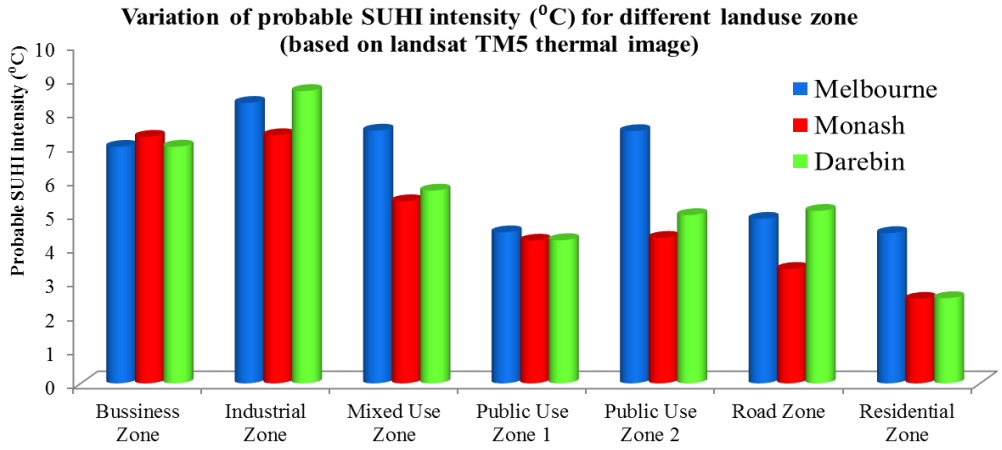


Figure 5B Comparison of SUHI intensity (ºC) for different land use zones of the three LGAs derived from estimated mean summer LST using Landsat TM5 imagery.

In the Melbourne LGA, more than 44% of the area showed probable SUHI effects but in Monash and Darebin, this effect only extended over 7.8% and 14.4% respectively. It was also evident that within each LGA, the SUHI effect can vary from 5.0ºC up to 15.0ºC. Considering the land uses of the study areas, the analysis of Landsat thermal data indicates that SUHI intensity varies between different land use zones in all the three LGAs (Figure 5B). The Industrial zone (INZ) in Darebin had a maximum SUHI intensity of more than 8.5ºC. The same zone in the Monash area had a SUHI intensity of less than 7.5ºC. The Business Zone (BZ) and Public Use Zone 1 (PUZ1) had more or less similar SUHI ranges in all three LGAs. During the day, the Residential Zone (RZ) showed a 2.0ºC higher SUHI influence in Melbourne compared to the Monash and Darebin areas and the Public Use Zone 2 (PUZ2) was 3.0ºC higher. The SUHI intensity of roads was 1.0ºC higher in Darebin and Melbourne compared to the Monash area. Compared to Monash and Darebin, the Melbourne LGA is dominantly impervious; vegetation is mostly located within parks and recreational areas. These factors might have increased the relative urban warmth, hence the SUHI intensity of the Melbourne LGA.

5. CORRELATIONS BETWEEN LAND COVER TYPE AND LST

To understand the relationship between the land surface cover, the LST, the mean land cover fraction values for each land cover type were plotted against the mean land surface temperature value of the respective class. From the scatter plots, statistical correlations were calculated to estimate the influence of land surface characteristics on the LST. Correlations were calculated for the three types of land cover (e.g. total impervious cover, trees, and grass) with (for?) mean summer and winter land surface temperatures (Figure 6). The six scatter plots of the three LGAs showed similar trends and relationships between LST and land cover (i.e. temperature increases with increasing impervious fraction and decreases with increasing grass and tree cover fractions). Therefore, it can be noted that the total impervious land cover has a positive correlation with LST whereas grass and tree has a negative correlation.

In all of these plots, tree cover showed more influence in reducing LST than the grass cover. On average, a completely tree covered fraction was nearly 5°C cooler than a fully grass covered fraction, whereas, a complete impervious fraction was about 10°C warmer than a fully tree covered area.

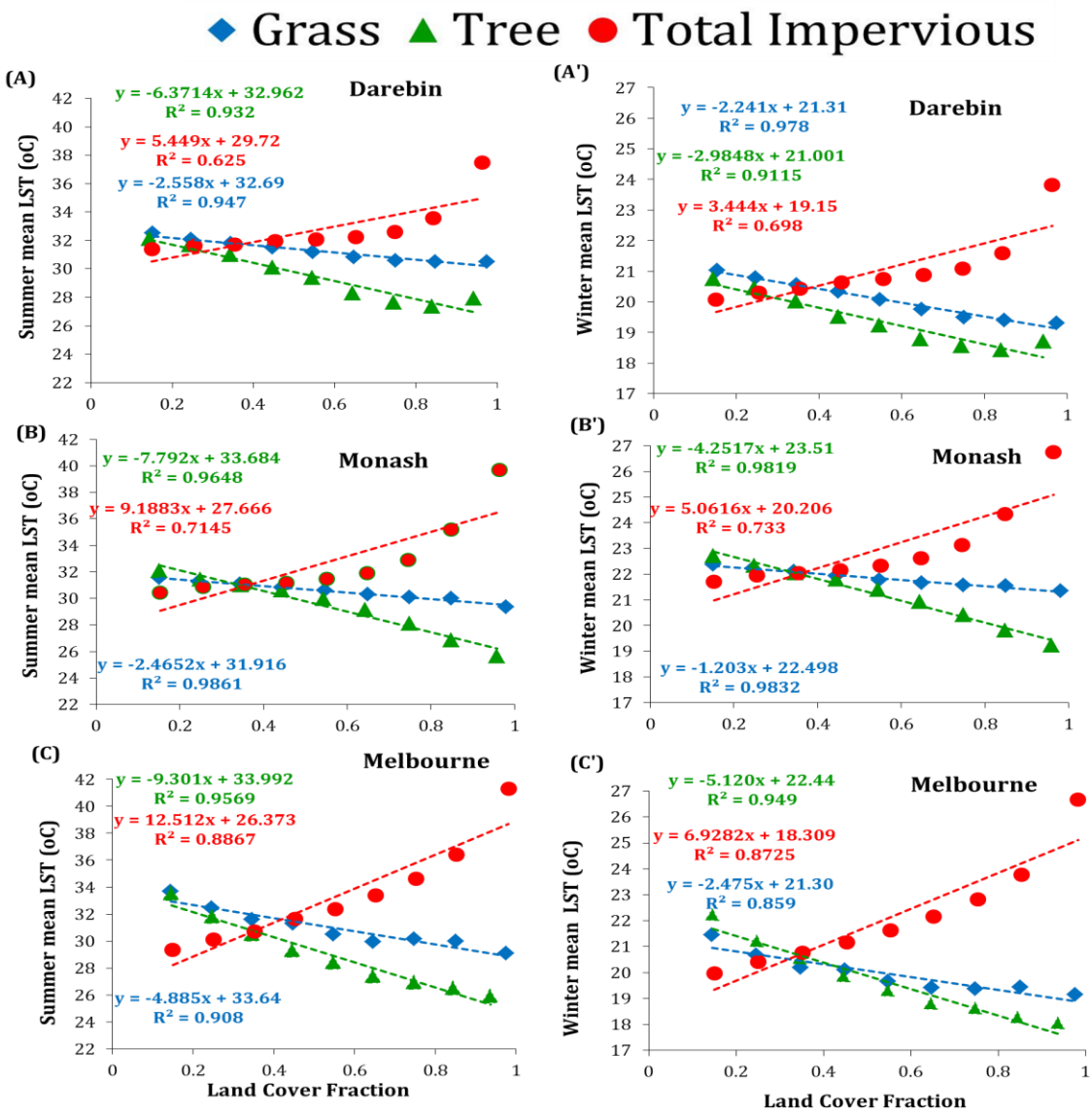


Figure 5: Scatter plots showing correlations between land cover fraction and land surface temperature (ºC) for the three LGAs. Plots A, B, and C show summer and A″, B″ and C″ show winter LST vs. land cover fraction values. Three different colors represent the three different cover types: red represents total impervious, blue is grass, and green is tree cover.

LST is normally defined as soil surface temperature for a bare soil surface. For densely vegetated ground, LST is the canopy surface temperature. For sparsely vegetated ground, LST is determined by the mixed temperature of the vegetation canopy, the vegetation body and the soil surface (Weng 2009). Among these, in the study area vegetation has the lowest surface temperatures and grass cover has a larger mean LST than tree cover, for both the summer and winter periods. These findings agreed with those of Wickham (2012), who found that the average annual land surface temperature for cropland is higher than the average land surface temperature for trees. Davin and Noblet-Ducoudré (2010) argued that evapotranspiration from trees produces a larger cooling effect than from the croplands or grass. Besides tree species, the location and surroundings of trees also play an important role in energy partitioning (Leuzinger et al., 2010). According to his study, the trees in a park were significantly cooler (26.0°C) than trees surrounded by (impervious?)sealed ground (27.0°C) except for the coniferous species that did not vary in temperature with location and exhibited foliage temperature close to air temperature. Generally, small-leaved trees remained cooler than large-leaved trees. This information is useful for planning the urban tree plantation in order to optimize water use, management cost, and human comfort. The resultant r-values in all cases are larger than 0.5, which indicates a very strong relationship exists between the land-cover type and the LST (Table 1).

All the resultant p-values were close to 0 and indicated strong evidence against a null hypothesis and most likely a strong relationship between land cover and land surface temperature. The intercept coefficient and x variable coefficients are also important. For tree and grass cover, the intercept coefficient values were higher than for total impervious cover fraction for all three LGAs, both in summer and winter. For tree and grass, the x variable coefficients were negative and for a total impervious cover fraction, the x variable coefficient was positive. These coefficient values were divided by the number of observations to get the slope. The slope indicates the rate of LST change for changes of the respective land cover fraction.

Table 1: LST and land cover fraction correlation statistics for the three LGAs.

Statistics	Tree						Grass						Total Impervious cover					
	Melbourne		Monash		Darebin		Melbourne		Monash		Darebin		Melbourne		Monash		Darebin	
	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W
	0.98	0.97	0.98	0.99	0.97	0.95	0.95	0.93	0.99	0.99	0.97	0.99	0.94	0.93	0.85	0.86	0.79	0.84
	0.96	0.95	0.96	0.98	0.93	0.91	0.91	0.86	0.99	0.98	0.95	0.98	0.89	0.87	0.71	0.73	0.62	0.70
square	0.95	0.94	0.96	0.98	0.92	0.90	0.90	0.84	0.98	0.98	0.94	0.98	0.87	0.85	0.67	0.69	0.57	0.66
or	0.57	0.34	0.44	0.17	0.50	0.27	0.47	0.30	0.09	0.05	0.18	0.10	1.34	0.79	1.70	0.89	1.24	0.66
	75.66	83.77	98.76	177.83	84.25	99.34	93.99	92.31	472.09	619.33	235.96	276.24	25.38	29.75	20.67	28.71	30.54	36.72
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
efficient	33.99	22.44	33.68	23.51	32.96	21.00	33.65	21.30	31.92	22.50	32.69	21.32	26.37	18.31	27.67	20.21	29.72	19.16
oefficient	-9.30	-5.12	-7.79	-4.25	-6.37	-2.98	-4.89	-2.48	-2.47	-1.20	-2.56	-2.24	12.51	6.93	9.19	5.06	5.45	3.44
	-1.03	-0.57	-0.87	-0.47	-0.71	-0.33	-0.54	-0.28	-0.27	-0.13	-0.28	-0.25	1.39	0.77	1.02	0.56	0.61	0.38

From this statistical analysis at 30m grid resolution, it can be stated that for each 10% increment of tree cover, the LST decreases by about 1.03°C in Melbourne, 0.86°C in Monash and 0.70°C in Darebin during the summer; and 0.56°C in Melbourne, 0.47°C in Monash and 0.33°C in Darebin during the winter. However, such influences were less for grass cover. For each 10% increment of grass, the LST decreases around 0.54°C in Melbourne, 0.27°C in Monash and 0.28°C in Darebin during the summer and 0.28°C in Melbourne, 0.13°C in Monash and 0.24°C in Darebin during the winter. On the other hand, for each 10% addition of an impervious cover, the surface temperature increased about 1.39°C, 1.02°C and 0.61°C during the summer and 0.77ºC, 0.56°C and 0.38°C during the winter respectively for Melbourne, Monash, and Darebin LGAs.

The present findings seem to be consistent with other research, including that of Xu et al, (2010) and Yuan & Bauer (2007) who found that impervious areas have significantly higher surface temperatures than other land cover types. Generally, impervious surfaces like paving and building materials are mostly dark, have a large heat capacity and low reflectivity and therefore has high mean LST. In comparison, natural land covers benefited from the cooling effect of soil moisture, evaporation and transpiration. Zhou et al., (2011) also found that the amount of LST becomes higher as the land use changes from vegetated to a more built-up landscape. They also argued that the surface temperature of different bodies is a function of their internal properties including heat capacity, thermal inertia, and thermal conductivity.

6. CONCLUSIONS

The analysis shows a strong and significant linear relationship between Land Surface Temperature (LST) and the percentage of different types of land cover. The relationship shows that by increasing the total vegetation-cover the LST decreases; contrast, the LST increases linearly with increased imperviousness. As LST has a direct influence on air temperature, trees will, therefore, be more effective at reducing air temperature as well as mitigating day and night time urban warmth. These relational values can be used to inform planning different land cover percentages for various land use zones in support of sustainable, climate-friendly, future urban development. In this study, vegetation cover represents both non-irrigated and irrigated trees and grass collectively. In future research, the influence of irrigation on LST reduction can be explored. These differences appear to be related to different surface properties and environmental conditions of the three LGAs. This analysis does not include types of roof material, variations of tree species, soil moisture conditions and geological properties of soils, but in addition to climate, these properties also have a significant influence on local thermal conditions.

ACKNOWLEDGMENTS

We acknowledge Monash University, Melbourne, Australia for providing the financial support as with MIPRS and MGS grants and a top-up scholarship from the "CRC for Water Sensitive Cities", to pursue this research at Monash University. The first author expresses her sincere gratitude to the Geological Survey of Bangladesh for providing permission and granted leave to undertake this research in Australia.

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Paper 38

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

CFD Analysis of a Floating Offshore Vertical Axis Wind Turbine

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Abstract

Vertical axis wind turbines appear to be promising for the condition of high as well as low wind speeds. Offshore wind turbines have recently been substantiated efficacious for generating electricity due to high wind power. A detailed numerical analysis is conducted in this work on an offshore floating type Darrieus wind turbine at different wind velocities. The blade, modelled on NACA 0015 profile, is operating under stalled condition. Unsteady 2-D simulations are performed using ANSYS Fluent 16.2 employing the realizable k-epsilon model. Characteristics of the developed flows are investigated, and the normal and tangential forces, as well as the power coefficients, are calculated. Different types of vortex and pressure variation are observed. The turbine is observed to generate both the positive and negative power at certain azimuthal angles under the dynamic conditions. Results show that force, as well as the power, is proportional to the wind velocities and for every case, net average power is positive. Moreover, force, as well as power, varies periodically with the azimuthal angles after the turbine has come to a steady state condition. Finally, the power coefficients are calculated—that increase with the wind velocities.

Keywords: Darrieus wind turbine, offshore wind power, dynamic stall, and pressure coefficient.

1. INTRODUCTION

Wind energy provides a variable and environmentally friendly option in the eve of decreasing global reserves of fossil fuels. It is estimated that roughly 10 million MW of energy is continuously available in the earth's wind. Wind turbines are used to harness and convert wind energy into electrical power (Herbert et al., 2007). Though initially the wind turbines were analysed and developed for ground purposes, however, with the increase of energy demand, scientists are now inclined to seashore (onshore and offshore) wind turbines. The modern onshore Vertical axis wind turbine was developed in 1973 based on the patent by Georges Darrieus (Shires, 2013). In the 1980s onshore wind farms were commercially developed in the US (Eriksson et al., 2008). During the 1980s and 1990s, the Darrieus wind turbine was largely developed in the UK (Musgrove, 2010). A plethora of research on onshore wind turbines have been executed and reached a relatively mature level. However, nowadays, there is a strong interest from the wind energy community to harvest the energy within the offshore environments— wind farms are moving further and further offshore into deeper waters. But in water depths greater than 50m, bottom-mounted (i.e. fixed) support structures are not economically viable (Jonkman and Matha, 2011). Consequently, a transition from fixed to floating support structures is essential (Borg et al., 2014). One of the key features of the Floating wind turbine is to allow the turbine structure to tilt to a certain angle range to reduce impacts on the support structure as well as the cost of the device (Haans et al., 2005). Though Horizontal axis wind turbines are inherently more efficient [6], in tilted or skewed flow conditions, the reverse case occurs (Van Bussel et al., 2004). A myriad of research has been carried out on Floating wind turbines and still continuing. Analytical prediction and experimental determination of the performance of an H- Darrieus wind turbine was done by

Ferreira (Ferreira et al., 2006), in a tilted condition. Mertens (Mertens et al., 2003) presented the aerodynamic characteristics of an H- Darrieus wind turbine both experimentally and numerically under the skewed flow condition.

Floating vertical axis wind turbines exhibit very complex, unsteady aerodynamics (Svorcan et al., 2013 and Qin et al., 2011) for the cyclic motion of the blade, induces a large variation in the angle of attack to the blade, even under uniform inflow conditions. Consequently, if the aerodynamic loading fluctuates, it can manifest as a dynamic stall (Scheurich et al., 2011) - a phenomenon involving a series of flow separations and reattachments occurring on the lifting surfaces subject to a rapid unsteady motion (Hutomo et al., 2016). The dynamic stall inception could lead to a violent flutter causing a harmful impact on the blade structure (Bangga et al., 2017). This paper aims to investigate the flow characteristics of a floating single-bladed Darrieus wind turbine using computational fluid dynamics (CFD) methods. Though Darrieus wind turbines are mainly used for household purposes, in this analysis, it was used as an offshore floating wind turbine to arrange a probable inception of a new power production system. The blade was constructed of NACA 0015 shape and operating under different wind velocities. The CFD results from the dynamic cases were presented and the resulting aerodynamic forces were evaluated. Moreover, the average Power coefficients were calculated.

2. COMPUTATIONAL SETUP

To generate the blade profile, the NACA 0015 airfoil coordinates were taken from the Airfoil tool (NACA) website and the coordinates were imported to the ANSYS Design Modeller. The computational domain was constructed of two different zones, namely, the stationary zone and the rotating zone including the blade (Bangga et al., 2017). The rotating zone was generated bi-directionally from the blade surface resulting in an annulus shaped zone which rotates at a predefined angular velocity as shown in Figure 1. The domain dimension, based on chord length (C) is 25C every side from the centre of the rotating zone which is also taken by Mohamed (Mohamed et al., 2015).

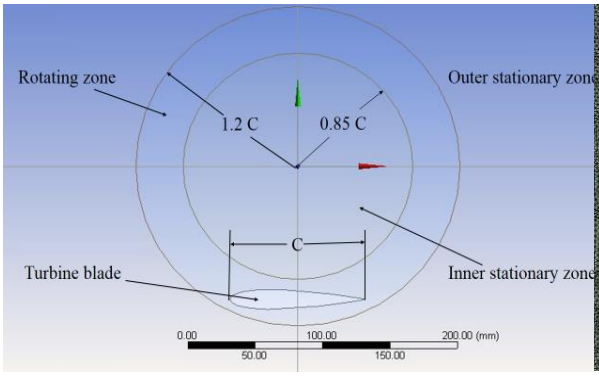

Figure 1. Domain of numerical analysis

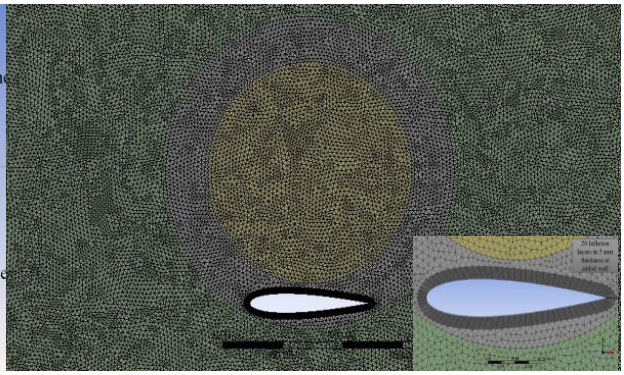

Figure 2. Generated mesh around the domain

Different sizes of unstructured mesh were employed in this analysis, combining an element size of 0.003 mm near the blade for precisely analysing the flow characteristics and an element size of 0.008 mm was used further from the blade. 20 inflation layers were used with 5 mm thickness in the vicinity of the blade surface to better resolve the boundary layer. The combined grid was chosen, instead of single grid, to reduce the complexity of mesh generation. Similar techniques were employed in the literature (Qin et al., 2011, Hutomo et al., 2016 and Bangga et al., 2017) and good agreements with the measurements were shown. The stationary and rotating zones were linked via the sliding interface boundary conditions that allow to conserve the mass and flow quantities between the zones as illustrated in Figure 2.

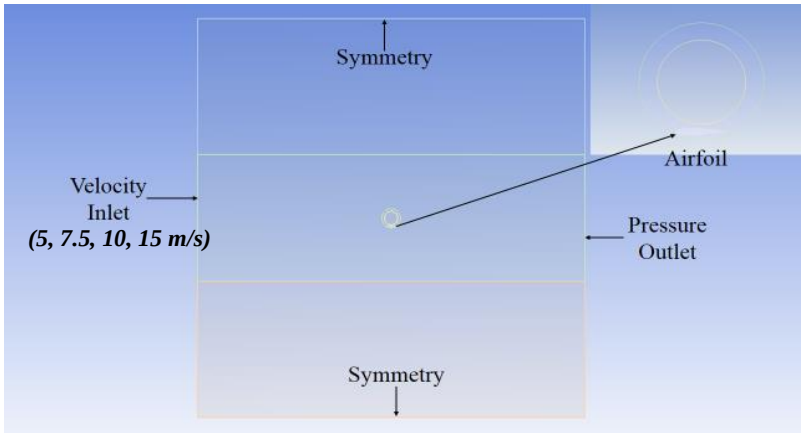

Figure 3. Boundary conditions for computational set up

Different boundary conditions were applied to the computational domain for performing the analysis. Velocity inlet and pressure outlet boundary conditions were used at the upstream and downstream sections respectively, and symmetrical conditions were used at the other two sides to reduce the computational effort as done by Castelli (Castelli et al., 2013 and Anderson, 2010). The airfoil was placed in the rotating zone that can rotate where the angular velocity between the stationary zones is the same, as shown in Figure 3. No slip wall is set as the boundary condition on the blade surfaces. To perform the analysis, the turbine blade was set with an initial clockwise rotation and the air was allowed to flow around the turbine blade at a known velocity. Due to the wind velocity, a net torque was developed for the combined effect of the air kinetic energy and the blade rotation at every position of the blade rotation. Lift and drag forces were also developed on the blade at every position from where the normal and the tangential force, as well as the power had been calculated. A realizable k-ε turbulence model (Mohamed et al., 2015), was used for rotating zones due to several benefits including an improved performance in flow circulation, strong pressure gradients, flow separation, and non-reliance on an assumed relationship between the Reynolds stress tensor and the strain rate tensor. A simple pressure-based solver was selected along with a second order implicit transient formulation. All solution variables were solved via the second order upwind discretization scheme that is also followed by Bangga (Bangga et al., 2017). Scalable wall function was used and Y+ ≥11.126 was ensured for the analysis.

3. NUMERICAL MODEL VALIDATION

Model validation is very important for any numerical analysis. In this analysis geometry, mesh and time dependency were checked and then the analysis was finalized in accordance with the dependency tests. For a dependency test, the blade is rotated 1.5° and then the pressure coefficient curve was taken for comparison.

3.1 Domain Independence Test

Different domain sizes were taken for the geometry dependency test. The dimensions of the domain are shown in Table 1.

From Figure 4, it is observed that there is less than 1% deviation between geometry 3 and the other geometries. So, geometry 3 was finalized for this analysis. When the lager domain was taken, the computation time was higher. On the contrary, if a smaller domain was selected, the flow phenomenon was not captured properly. So, geometry 3 was chosen as a mediocre dimension that can capture the flow phenomena properly with lower computation time.

Table 1. Dimension of different domains

Geometry	Large Rectangular Domain Size			Small Rectangular Domain Size		Circular Domain Size	
	Inlet Distance	Outlet Distance	Wall Distance	Upper Vertical Wall Distance	Lower Vertical Wall Distance	Inner Circular Radius	Outer Circular Radius
Geometry 1	10C	15C	10C	3C	3C	0.85 C	1.2 C
Geometry 2	15C	20C	15C	4C	4C	0.85 C	1.2 C
Geometry 3	25C	25C	25C	8C	8C	0.85 C	1.2 C
Geometry 4	20C	25C	20C	5C	5C	0.85 C	1.2 C
Geometry 5	15C	25C	15C	6C	6C	0.85 C	1.2 C

The domain independency test result is shown in the Figure 4.

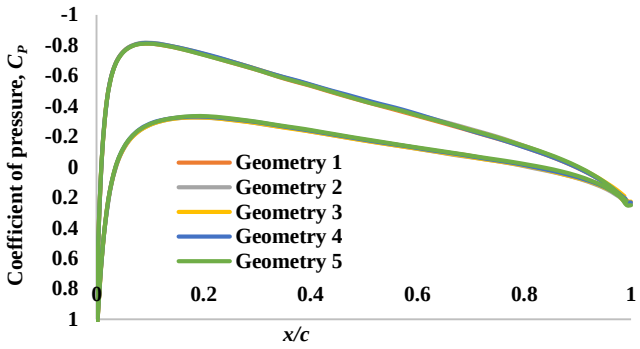

Figure 4. Pressure coefficient for different geometries at 1.5° azimuthal angle

3.2 Grid Independence Test

Mesh sensitivity analysis is another paramount parameter for any CFD analysis validation. After the geometry 3 of Table 1 is finalized by domain dependency test, different numbers of nodes and elements were taken as listed in Table 2. Then numerical simulations with geometry 3 using different meshes (nodes and elements size) were carried out and the mesh dependency test result is shown in Figure 5.

Table 2. Number of nodes and elements

Mesh	Number of Nodes	Number of Elements
Mesh 1	1232362	2459030
Mesh 2	2471666	4935750
Mesh 3	8951519	17890152
Mesh 4	753807	1502883
Mesh 5	525219	1046262

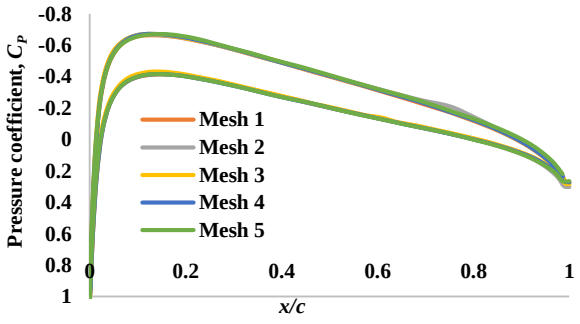

Figure 5. Pressure coefficient for different meshes at 1.5° azimuthal angle

Results show that there is approximately 1% deviation between mesh 1 and the other meshes. So, mesh 1 was selected for this analysis. When the mesh with higher node and element number was selected, the computational time was higher, and when the mesh with less node and element number was selected there was a possibility of some error in the simulation result.

3.3 Time Independence Test

An imperative factor for any unsteady analysis is the time step size which indicates how minimally the flow characteristics are caught by the software. After geometry 3 and mesh 1 is selected from Table 1 and 2, respectively, different time steps were taken such as 0.001, 0.002, 0.004, 0.005, 0.008 and their dependency had been tested as illustrated in Figure 6. Finally, 0.005 is selected for the analysis.

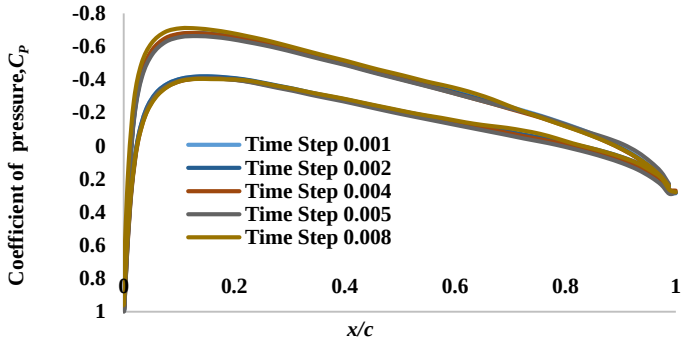

Figure 6. Pressure coefficient for different time step sizes at 1.5° azimuthal angle

From the above Figure 6, it is observed that the deviation of other time steps is less than 2% from time step 0.005. So, the time step 0.005 was selected for this analysis. When a smaller time step was taken, the computation time was higher. On the other hand, when a lager time step was selected, the flow phenomenon was not captured precisely. So, the time step 0.005 was chosen as an optimum time step that can capture the flow characteristics precisely with lower computation times. When all the dependency had been tested; geometry 3 (Table 1), mesh 1(Table 2) and time step size 0.005 were selected for the final analysis.

4. RESULT AND DISCUSSION

The simulations were carried out for 10 blade revolutions and the last three revolutions were extracted and averaged (Bangga et al., 2017). Flow characteristics around the blade are observed and different types of vortices are analysed. The tangential (F_T) force, normal (F_N) force and the average power coefficient for different wind velocities have been calculated from the simulation data.

4.1 Flow Field Analysis

Flow characteristics such as pressure coefficient (C_p) contours and velocity contours have been determined after every 30° interval of azimuthal angle (θ) in the analysis. C_p is a dimensionless number that describes the relative pressure throughout a flow field (Anderson, 2010). It is observed from Figure.4 (a) initially C_p at the upper surface of the blade is less than the lower surface. Air strikes the turbine tip and maximum pressure occurs— defined as the stagnation point. Theoretically, no lift force is generated; Velocity at the upper surface is high Figure.5 (a); Flow separates from the trailing edge and a counter-clockwise vortex is formed. The more the turbine rotates, the more the flow separates from the leading edge— stall formation occurs. Maximum C_p occurs at the lower surface at $\theta = 30°$ Figure.4 (b). Moreover, the flow separates from the blade tip and velocity at the upper surface is high, as shown in Figure.5 (b). High C_p occurs near the leading edge of the upstream at $\theta = 60°$ while lower C_p occurs at the trailing edge Figure.4 (c). Flow separation occurs from both the leading edge and trailing edge due to the dynamic stall.

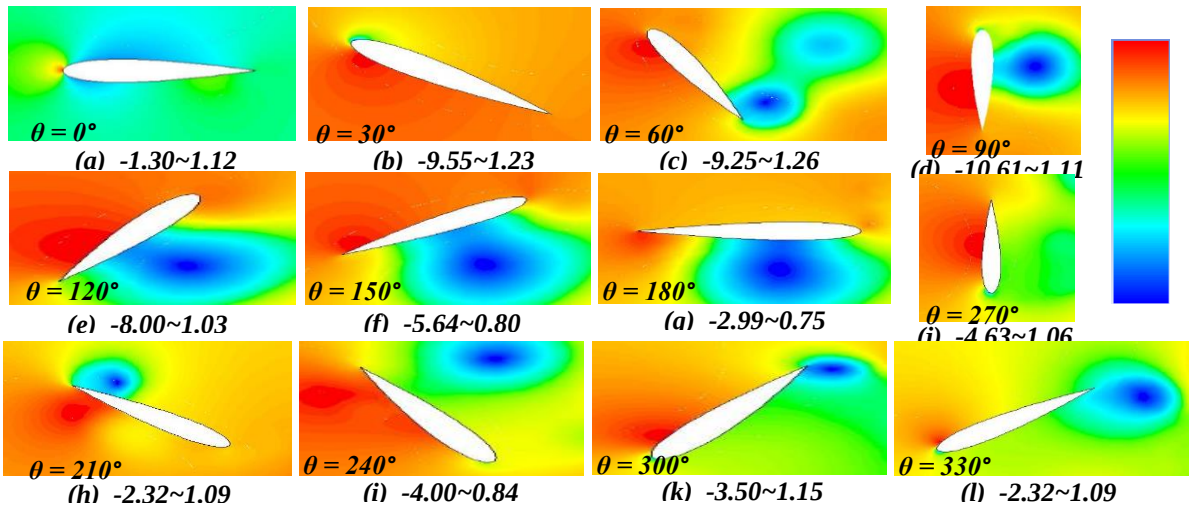

Figure 7. Contour of pressure coefficient with different azimuthal angle θ at 5 m/s wind velocity. The minimum and maximum values of the color legend are mentioned below the figure.

Maximum velocity occurs near the trailing edge where a counter-clockwise trailing edge vortex is formed Figure.5 (*c*). When $\theta = 90°$, high pressure drag occurs upstream due to high air kinetic energy Figure.4 (*d*). Separation occurs from both the leading edge and trailing edge and maximum velocity occurs at the leading edge Figure.5 (*d*). Moreover, a higher flow velocity region is visible downstream; however, the velocity at the leeward side is very low. The clockwise leading edge vortex is formed which departs from the blade ($\theta = 90°$) and formation of a counter-clockwise trailing edge vortex starts. At $\theta = 120°$ flow separates from the trailing edge and the trailing edge vortex reaches near the middle of the blade; C_p is maximum at the windward side as shown in Figure.4 (*e*). Velocity at the downstream is more Figure.5 (*e*). Flow characteristics are almost the same in nature at $\theta = 150°$ and 180°. Lower C_p occurs near the middle of the blade Figure.4 (f) and (g), respectively; clockwise vortex is formed at the downstream and velocity near the middle of the blade is maximum Figure.5 (*f*) and (*g*). At $\theta = 210°$, a clockwise trailing edge vortex is formed and C_p is minimum near the leading edge and maximum at the blade upstream Figure.4 (*h*), where different vortices generate due to DS. Velocity near the trailing edge is maximum Figure.5 (*h*). However, low C_p occurs near the leading edge at $\theta = 240°$ Figure.4 (*i*) and the trailing edge vortex tends to move to the leading edge Figure.5 (*i*). C_p is high at the blade upstream at $\theta = 270°$ Figure.4 (j); flow separates from the trailing edge and higher flow velocity is observed which forms a clockwise trailing edge vortex Figure.5 (*j*). At $\theta = 300°$ and 330° low C_p occurs at the trailing edge which inclined to detach from the blade with increasing θ as observed in Figure.4 (*k*) and (*l*). Flow separation occurs both from the leading edge and trailing edge and Maximum velocity occurs Figure.5 (*k*) and (*l*).

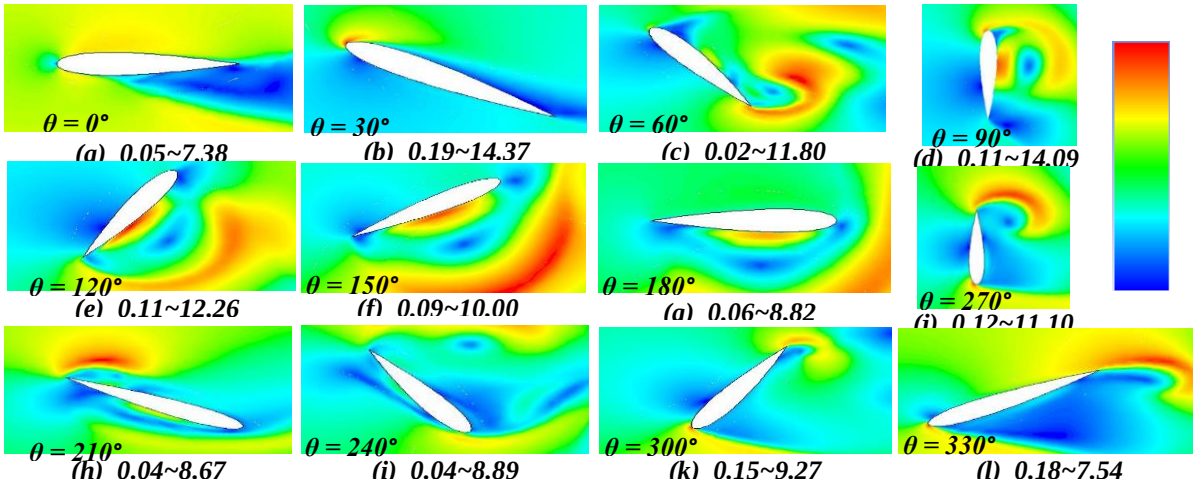

Figure 8. Contour of velocity profile with different azimuthal angle θ at 5 m/s wind velocity.The minimum and maximum values of the color legend are mentioned below the figure.

4.2 Tangential and Normal Force

The tangential (F_T) and normal (F_N) forces vary periodically with the azimuthal angle (θ) after the 7th revolution of the rotor blade. Both the forces are proportional to the wind velocities. Initially, both the forces are zero; however, with the increase of θ, forces increase positively. As lower C_p occurs, at the blade upper surface, ($\theta = 45°$) the direction of F_T changes (Figure 6). Then low C_p detaches (60°)— F_T tends to increase up to 90°. However, high-pressure drag occurs at the blade upstream— force tends to decrease(90°). When low C_p detaches from the upper surface(120°), F_T tends to increase again. Different vortices form around the blade at 150° and F_T decreases up to $\theta = 210°$ for blade-vortex interaction. When the vortices detach (240°) F_T increases. However, for higher wind velocities F_T fluctuates more due to turbulence that occurs due to dynamic stall. At 15 m/s, the force fluctuates highly near $\theta = 90°$ and 300°. It can be resolved that there was a decrease in the blade-vortex interaction for the second half of the cycle. Moreover, for the first half of the cycle, F_T is positive.

The F_N changes dramatically around the blade due to dynamic stall and $C_p$variation as shown in Figure 7. It is evident that from $\theta = 90°$ to 270° that the net F_N is negative and for other positions F_N is positive. However, F_N shows very unpredictable nature for high wind velocities. Moreover, at 7.5 m/s the force does not follow the similar nature. F_N highly oscillates throughout the whole cycle, even though the net positive and negative force are similar.

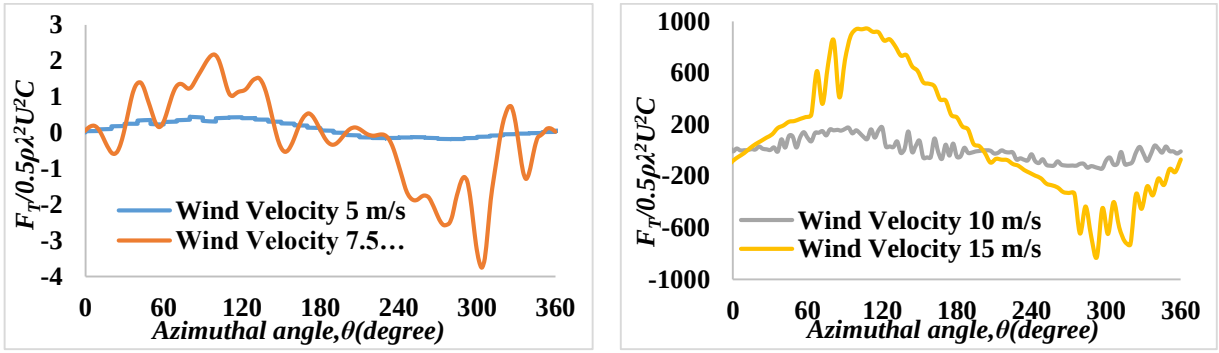

Figure 9. Variation of non-dimensional Tangential Force with Azimuthal Angle for different Wind Velocities

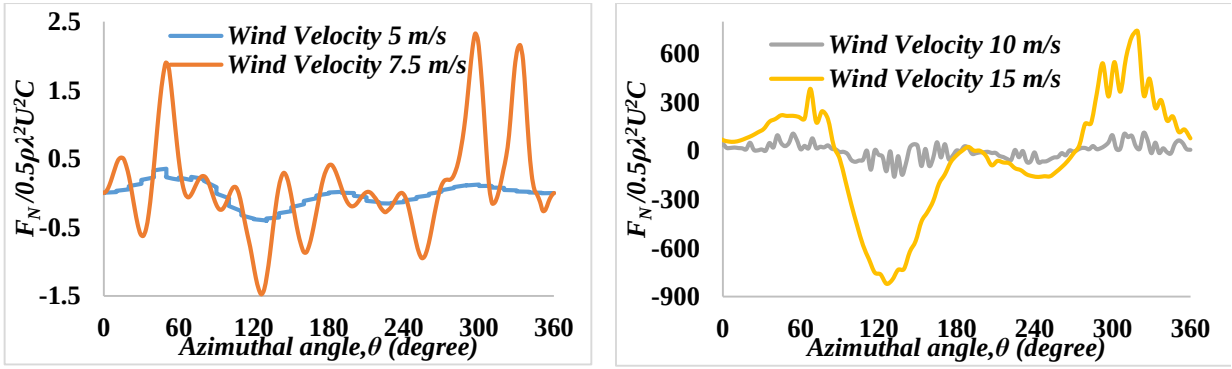

Figure 10. Variation of non-dimensional Normal Force with Azimuthal Angle for different Wind Velocities

4.3 Power Coefficient

The Power coefficient is an important parameter for wind turbine configuration. Though the Power coefficient of the Horizontal axis wind turbines are comparatively high, in the case of changed condition, like offshore floating ones, sensitive performance of flow skewness is a problem (Chowdhury et al., 2016). The Power coefficient is the ratio of the generated output power (P) and the theoretical input power (P_{in}). As the turbine rotates in the clockwise direction, negative F_T generate the positive power i.e. $P = -\omega R F_T$ and vice versa (Bangga et al., 2017). The theoretical input power is $P_{in} = \frac{1}{2}\rho A V^3$. Variation of Power coefficient is similar to the variation of F_T with θ.

It is observed that the average Power coefficient is proportional to wind velocities.

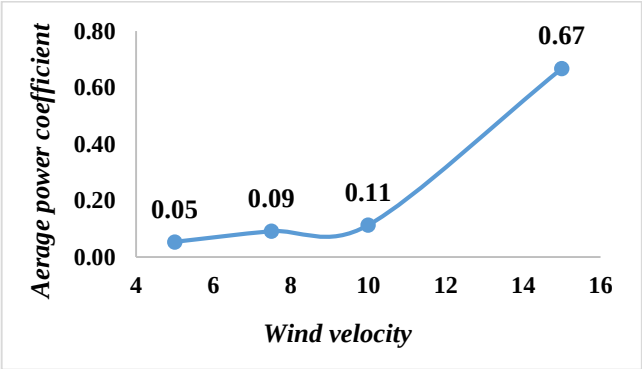

Figure 11. Average power coefficient at different wind velocities

5. CONCLUSIONS

CFD analysis has been carried out to study an off shore floating single-bladed Darrieus wind turbine at different wind velocities. Though Darrieus wind turbine is basically used for household purposes, however, in this analysis, it was used as offshore floating wind turbine to inaugurate a probable inception of a new power generation method. Flow characteristics around the bladed surface were investigated and highlighted as the main focus of the paper. Moreover, the F_T and the F_N and the average Power coefficient had been calculated. It is resolved that different types of vortices are generated around the blade surface as a consequence of dynamic stall. Moreover, C_p varies considerably around the blade— affecting F_T highly. Power generation, along with F_T, varies positively and negatively with θ. The force as well as the power is proportional to the wind velocities. The average Power coefficients at the steady state condition of the turbine are positive— indicating that the turbine can produce a net positive power in this arrangement.

ACKNOWLEDGMENTS

The author would like to express his gratitude and profound respect to his honourable supervisor Dr. Mohammad Ilias Inam, Associate Professor, Department of Mechanical Engineering, Khulna University of Engineering & Technology, and Dr. Abdullah Al-Faruk, Assistant Professor, Department of Mechanical Engineering, Khulna University of Engineering & Technology, for their continuous guidance and valuable suggestion to complete the work.

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Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

A Study on Mode Choice Behaviour of Working Population in Dhaka: A way towards Sustainable Transportation

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Abstract

Work trips constitute about 44% of the daily trips in Dhaka according to the Dhaka Structure Plan (2016-2035). The increasing trend of registered automobiles over the past decade warranted for a closer insight into the mode choice decisions made by working people. The study attempted to identify the factors influencing the modal choice for work trips using the Household Income Survey (HIS) data. Binary logit models were used to explore the impact of socio-economic and built environment factors on choosing non-motorized, private vehicle and public transport. The study revealed that vehicle ownership status, income, and driving license is likely to influence the modal choice of all three modes. Other variables like the size of the areas, fare, mode preference and availability of alternate modes also impacted the model. Income plays a major role in mode selection and vehicle ownership is connected to it. With the increase in income, people tend to own cars and change their mode choice behavior and this issue has a massive impact on the sustainability of the environment of the city. Since Dhaka is a populous city, the available public transport system can be a sustainable medium for working trips. However, for this, the public bus has to overcome the issues of safety, comfort and improper service provision which are just some of the factors deterring the majority of female passengers. According to the findings of the study, private automobiles have almost 2.5 times higher carbon emission than the public bus at per person per kilometer and thus, are likely to have a high impact on the sustainability of the transportation system of Dhaka. Since work trips constitute a noticeable share of the daily trip, these results may aid in planning upcoming strategies and management of sustainable transportation systems in the cities of developing countries like Dhaka.

Keywords: Working population, Binary model, Modal choice, Sustainable transportation.

1. BACKGROUND

Bangladesh is a developing country having a population of 16.7 million. Dhaka, the capital and the only megacity of this country has a population of about 1.04 million (Worldometers, 2018; World Population Review, 2018). Currently, Dhaka is facing the problem of rapid unplanned urbanization. The population growth with rapid unplanned urbanization trend has had a great influence on the transportation system of Dhaka (The Daily Star, 2018). Each day 34.88 million trips are made of which 44% trips are made for work purpose (RAJUK, 2016). In Dhaka, the existing transportation system consists of both motorized and non-motorized vehicles. Since almost half of the trips are work trips, it is required to have a closer insight into the factors influencing the mode choice behavior of the working population. Moreover, the increasing traffic of Dhaka and unplanned urbanization trend has a great impact on the environment of Dhaka city.

Hence, it is essential to study the mode choice behavior and its impact on the urban environment.

Although almost half of the trips in Dhaka are generated for work purpose, still a handful of researches have been conducted to study their mode choice behavior. Anwar (2013) developed a nested logit model with a relatively small and under-representative sample, to study travel behavior without any indication of its effect on environment and sustainability. To fulfill the gap, this study was conducted and discrete mode choice models for different modes were developed considering several socio-economic and built environmental factors. The influence of these factors on mode choice and how the increase of private automobiles could impact the environment were also discussed. This study intended to draw the scenario of the existing environmental deterioration caused due to mode choice behavior.

2. METHODOLOGY

2.1. Data Sources

The study used 'Household Income Survey (HIS) of 2010' dataset under the study of 'Dhaka Urban Transport Network Development Studies in Bangladesh (DHUTS)' to develop regression models for mode choice behavior. The study was conducted from March 2009 until March 2010 and the entire Dhaka Metropolitan Area including sub-urban areas like Savar, Narayanganj, and Tongi were considered as the study area. Through the Household Income Survey (HIS), socio-economic information of households such as their residence location, age, gender, member number, working place, household income, household type, car ownership, and license ownership were collected. Apart from these data, their daily trip information including trip purpose, travel time, travel mode, and distance were also collected. While collecting their trip information, data regarding comfort, vehicle availability, reliability issue, and alternative mode availability were also collected. In order to identify the influence of the built environment on mode choice behavior for the study, the land use data was collected from the 'Detailed Area Plan 2010'. The relation of population density with mode choice was also investigated, for which the density value was collected from 'Population and Housing Census 2011: Community Series Dhaka'. To assess the relation of accessibility with mode choice, the total person employed in different employment sectors was collected from 'Economic Census 2013: Community Series Dhaka'.

2.2. The Selection of Working Population

From the database of HIS survey, the data regarding the working trips were extracted and used for this survey. Therefore, people belonging to the age group of 15 to 64 years old were considered as the working group and were addressed in the study as the target group of people (Liton and Molla, 2017).

2.3. Determination and Description of the Variables

For the concept of sustainable transportation along with mode choice behavior of people of Dhaka, an extensive literature review of both local and global context was carried out. Nasrin (2017) observed that cost, comfort, time and option of alternative modes played significant roles in modal selection for university students of Dhaka. In previous studies, it was seen that the commuters of Dhaka revealed to be significantly affected by socioeconomic conditions, land use and availability of proper facilities (*Rahman et al, 2009*; Rahman 2017). Models can be used to represent the travel behavior revealing the factors that dictate mode choice which plays a major role in the level of pollution caused by the transportation system in a city (Khattak, Miller, and Fontaine, 2017). It was learned that factors from the socio-economic, built environment and trip characteristics played important roles which dictated the mode choice behavior. According to the attainments from previous studies in this field, the variables were considered in the first phase. Initially, 24 independent variables of different aspects were considered and based on these variables, the mode choice models were developed. In the models, only mode choice was the dependent variable.

Table 1. List of Initially Considered Independent Variables along with their Statistical Measurements

Data Aspects	Variables	Meaning	Statistical Measurements
Spatial Characteristics	Area	Area of the corresponding ward of the respondent	Maximum value= 14.6 sq. km Minimum value=0.2 sq. km
	Proportion of residential land use	The proportion of residential land use in the area of the corresponding ward of the respondent	Maximum value= 0.88 Minimum value=0
	Proportion of commercial land use	The proportion of commercial land use in the area of the corresponding ward of the respondent	Maximum value= 0.42 Minimum value=0
	Proportion of mixed land use	The proportion of mixed land use in the area of the corresponding ward of the respondent	Maximum value= 0.26 Minimum value=0
	1. Accessibility of the ward for 30 minutes travel time	A comparative value representing the ability to reach employment opportunities in other wards within 30 minutes	Maximum value= 25844.9 Minimum value=0
Trip Characteristics	Transportation cost	Monthly expenditure of respondent behind transportation	Maximum value= 25000 taka Minimum value= 0 taka
	Trip frequency	Number of trips made by the individual respondent	Maximum value= 10 Minimum value=0
	Travel fare	Typical fare to the workplace by the usual travel mode	Maximum value= 500 taka Minimum value= 0 taka
	Trip time	The average time taken to reach the workplace in minutes	Maximum value= 160 minutes Minimum value= 0 minutes
Rider preferences	Affordability	Does fare affect mode choice behaviour?	Yes=3467, No=102
	Reliability	Does reliability affect mode choice?	Yes=1102, No=207
	Time-Saving	Does time-saving affect mode choice?	Yes=924, No=207
	Comfort	Does comfort affect mode choice?	Yes=439, No=213
	Convenience	Does convenience affect mode choice?	Yes=431, No=229
	Safety	Does safety affect mode choice?	Yes=564, No=214
	Parking problem	Does parking problem affect mode choice?	Yes=260, No=249
Rider Characteristics	Gender	Gender of respondent	Male=4494, Female=521
	Age	Age of the respondent	Maximum age=78 Minimum age=16
	Education level	The education level of the respondent	Below graduation=2659 Graduate=1114 Above graduate=1239
	Employment type	Type of employment in which respondent is engaged in	Full-time=4842, Part-time=51, Casual=10, Others=112
	License ownership	Whether or not the respondent has a driving license	Yes=663 No=4352
	Occupation	Occupation of the respondent	Government service=776 Non-government service=2152 Others=2087
	Industrial sector	Sector of the industry of the member	Agriculture=2 Livestock=6 Fishing/forestry=17 Mining/quarrying=1 Manufacturing industry=259 Construction=158 Trade and commerce=346 Transportation and storage=99 Communication=114 Agricultural labour=3 RMG=217 Shops=1118 Service=2536 Others=141
	Income	Monthly personal income of the respondent	Maximum value=7,50,000 taka Minimum value=0 taka
	Car ownership	Car ownership status	Yes=1106, No= 3909

Table 1 provides the list of variables considered for developing the mode choice models. All of these variables were correlated to the dependent variable whereas, there were no internal linkages among these variables themselves.

2.4. Classification of Modes

Apart from the variables, the existing transportation modes of Dhaka were also classified to learn about the factors influencing the mode choice behavior. In this study, three categories were considered while deriving the mode choice models and factors influencing the mode choice behavior in these categories were identified and discussed. In Table 2, the classification of existing modes is provided.

Table 2. Classification of Existing Transportation Modes of Dhaka

Class	Considered Modes
Non-motorized	Walking, Rickshaw, Bicycle
Private automobile	Car, Motorcycle, Microbus
Public Transport	Public bus, Human Hauler, Leguna

Based on the classification of Table 2 the models were developed and factors influencing the mode choice behavior is discussed.

3. RESULTS AND DISCUSSION

3.1. Model Estimation and Discussion

In order to identify the factors affecting mode choice, binary logistic regression was used where mode choice was the only dependent variable for all the three models for each form of mode. Spatial characteristics, trip characteristics, rider characteristics, and rider preference variables were used for the study. These aspects would enhance the understanding of how personal user characteristics and preferences combined with spatial features and trip characteristics may dictate mode choice. The B value obtained from the regression model acts as a coefficient for the variables defining the dependent variable.

It helps to predict the dependent variable based on the independent variable through the odds ratio.

Table 3. Estimated Binomial Logit Model of Mode Choice

Variable Characteristics	Model 1: Private Automobile			Model 2: Public Transport			Model 3: Non-motorized Vehicle		
	Variables	B value	Odds ratio	Variables	B value	Odds ratio	Variables	B value	Odds ratio
8.5	-	-	-	Log Area	-0.21	0.81	Log Area	-0.68	0.51
Trip Characteristics	Log Fare	0.51	1.67	-	-	-	Log Fare	-0.62	0.54
	-	-		-	-	-	Member Trip Frequency	0.25	1.29
Rider Preferences	Affordability	-0.42	0.66	Reliability	0.22	1.25	Mode Preference	3.19	24.22
	Other Transport Option	-0.19	0.83	Mode preference	2.67	14.45	Parking problem	1.56	4.74
	Parking problem	0.43	1.54	Time-Saving	0.14	1.14	Comfort	0.71	2.03
	-	-	-	Other Transport Option	0.47	1.60	-	-	-
	-	-	-	Affordability	0.60	1.83	-	-	
Rider Characteristics	Log Income	0.45	1.56	Log Income	-0.51	0.60	Log Income	-0.69	0.50
	License	1.21	3.34	Car Ownership	-0.50	0.61	Car Ownership	-1.19	0.30
	Car Ownership	1.07	2.92	License	-0.55	0.58	License	-0.62	0.54
	Education level	0.14	1.15	Gender	-0.66	0.52	-	-	-
	Gender	0.61	1.83	-	-	-	-	-	-

Nagelkerke R Square 0.507 (Private automobile)
Nagelkerke R Square 0.467 (Public transport)
Nagelkerke R Square 0.633 (Non-motorized modes)

Model 1 of Table 3 shows that the likelihood of using private cars decreases for people with greater importance on the affordability of transportation cost (low odds ratio); that is, users concerned about affordability are less likely to avail private automobiles. Users are more likely to use private vehicles if they are driving license holders (high odds ratio). Model 1 also shows that car owners and individuals with high income are more likely to use their private vehicles. These variables, although do not affect one another significantly, are connected as with the increase in income, the likelihood of owning private car rises as shown by PPRC (2016) and BRTA (2018) reports. The model suggests that women tend to prefer private cars over other modes which confirms the results of a study by Saha and Rahman (2015). However, individuals with multiple transportation options are less likely to use private automobiles (low odds ratio). The inclusion of spatial characteristics and trip characteristics shows that although spatial features have no effect on the choice of private vehicles, people are more likely to use private vehicles as fare rises which reduce the gap in transportation cost using the modes. Finally, model 1 shows that rider preferences and characteristics are the major influences dictating the choice of private automobiles.

Model 2 from Table 3 shows that individuals with a preference for public transport are most likely to use public transit while women were least likely to avail this mode based on odds ratio. The model shows that users having a driving license, car ownership, and high income are also less likely to use public modes. Compared with model 1, it is noticed that these factors increase the likelihood of using private modes rather than public modes. This matches with PPRC (2016) as when income rise, the tendency to use private vehicles rise and public transport falls.

However, individuals concerned about affordability and having alternate transportation options are more likely to use public transport. This may be explained by the median income value of the data used which is Tk 18,000. Although the model suggests that trip characteristics do not affect the choice of public transit, spatial characteristics are seen to affect it. People living in larger travel analysis zones are less likely to use public transport. This may be explained by the shortage of bus stops which make it difficult to avail public transportation in larger areas (Sen, 2016).

Model 3 in Table 3 shows that likelihood for using non-motorized vehicles is the most for individuals who already have a modal preference of non-motorized modes while it is least likely to be used by car owners (based on odds ratio). A reason for this may be that the majority prefer non-motorized mediums of travel for short trips (*Hoque et al, 2014*). Furthermore, the likelihood of using non-motorized modes increases with the increase of parking problem which is acting as a force for shifting usage away from private vehicles. The findings of the model match with Hoque et al (2014). Based on the responses in the database in Dhaka, the model also suggests that users who prioritize comfort are also likely to use non-motorized modes. However, individuals are less likely to use non-motorized modes with a rise in income and an increase in the area of their travel analysis zones. Increased area increases travel distance making non-motorized modes unsuitable as the average distance for non-motorized travel is only 2.34 km (*Hoque et al, 2014*). A rise in income is followed by car and license ownership which reduces the use of non-motorized modes. Trip characteristics also influence modal choice. While users who have to make frequent trips are more likely to use non-motorized modes, the likeliness for use of this mode falls with rising trip fares. This can be explained by the fact that the majority of the non-motorized mode users are from the middle-income background. Model 3 concludes that unlike the model 1 and model 2, the variables from spatial characteristics, trip characteristics, rider preferences, and rider characteristics determine the use of non-motorized modes.

3.2. Impact of Increasing Car Ownership on The Environment

The models discussed in the previous sections illustrates that the use of private automobiles is influenced by factors like income, car ownership and license ownership.

An increment in income would result in an increment in car ownership and the usage of public transport will decrease. These things affect the sustainability of the urban environment. In the case of Dhaka, mostly private automobiles use petrol and CNG as a medium of energy source and public buses mostly use diesel and CNG. These are major sources of carbon dioxide emission and affects the sustainability of the environment. In Table 4, the level of carbon dioxide emission by private automobile and public transport is discussed

Table 4. Emission Level of Carbon-dioxide by Private Automobiles and Public Transport in Dhaka

Vehicle Type	Capacity (no. of persons) *	Fuel Type**	Total Number of Vehicles***	Vehicle activity (km/day) ****	Emission (Ton/day) **	Emission (gram per km per person in one vehicle)
Private car	4	Petrol	15219	40	157.06	64.50
Private car	4	CNG	95066	40	901.22	59.25
Public transport	40	Diesel	3448	130	397.61	22.18
Public transport	40	CNG	10801	130	1359.16	24.20

Source: *Jahan et al (2013), **Labib et al (2014*), ***BRTA (2018), ****Khaliquzzaman (2006)

Table 4 depicts that each day if a person travels one kilometer by private automobile, it would emit carbon-dioxide which is almost 2.5 times higher than the emission by public transport, considering both modes at maximum seating capacity. Moreover, the carrying capacity of a private automobile is quite less than public transport. But the private automobile holds almost 64% of total modal composition whereas, for public transport, the value is 2% (*Labib et al, 2013*). This high percentage of private automobiles add to the emission of carbon dioxide into the environment and makes the community more vulnerable.

So, the increasing trend of car ownership would lead to the destruction of the environment. In this case, the increment in public transport usage would make the scenario better.

4. CONCLUSION

The future of the environment depends on the greenhouse gases released into the atmosphere. Since transportation is a major source of environmental pollution (*Fuglestvedt et al, 2007*), it is imperative that an in-depth study is conducted. In this aspect, this study models the behaviors of work trip makers using three different transportation modes in order to identify the factors affecting their mode choice. It was realized that gender, car ownership, license ownership, affordability, the option of alternate modes and parking played important roles during the selection of modes in the models. The models suggested that the selection of private automobiles and public transport primarily depends on rider characteristics and preferences while for non-motorized modes, spatial and trip characteristics also determined their selection. With a rise in income, individuals are likely to use more private vehicles and less public transport. These result in more carbon emissions into the environment. For a sustainable urban transportation system, non-motorized vehicles should be the most preferred modes, followed by public transport for motorized transport while discouraging the use of private modes. However, in Dhaka, people are increasingly getting interested in using cars with the rise in their income. The Strategic Transportation Plan (Revised and Updated) 2015-2035 shows that Dhaka is moving towards an unsustainable future as car ownership and usage rate has been increasing in the last five years. The public transport system should be updated and improved in order to solve the current issues of gender equality, safety, and rider experience to attract users towards a more environmentally sustainable means of transport. Furthermore, while the study has been conducted on the work trip makers, it can be extended to non-work trips in order to confirm the variables affecting mode selection.

ACKNOWLEDGMENTS

We acknowledge the officials from DTCA for providing us with valuable data of DHUTS. We would also like to thank our alumni from RAJUK for providing us with landuse data and the officials from BBS for cooperating with us throughout the research.

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Paper 40

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Statistical Study of Mixtures Characteristics in Carbon-Conditioning Recycled Aggregate Concrete Performance Using Machine Learning

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Abstract

Environmental impact concerns are increasing in today's society globally. The Greenhouse effect is an important aspect to be taken into consideration in different industries, especially construction. Carbon dioxide (CO2) is the most common gas emitted and is rapidly increasing around the world. Australia's emissions have risen in the past three years and emissions in 2020 are projected to be 551 Mt CO2-e. The construction industry can potentially contribute to the decrease of CO2 emissions by the use of sustainable materials such as carbon-conditioning recycled aggregate concrete. Although recycled concrete is an eco-friendly material, it has performance limitations when used for structural purposes. Thus, finding ways to model and statistically compare different concrete mixtures and its results, can be a set of important tools to improve recycled aggregate concrete mechanical properties. As such, this paper presents a study of some statistics and machine learning techniques to investigate how well they can model the main characteristics of recycled concrete aggregate (RCA): compressive strength, modulus of elasticity, tensile strength and flexural strength. The data set characteristics and the technics that can be used for parts of these information to achieve better results will also be explained. This will contribute to the industry through the construction of programs to facilitate further studies and the concrete mixture optimization and statistics metrics to evaluate the contribution of the mixtures' components on the RCA mechanical properties.

Keywords: Machine learning, Statistical techniques, Carbon -conditioning recycled aggregate, Recycled aggregate concrete, Optimisation

1. INTRODUCTION

Aggregate used in the construction industry is one of the most widely consumed minerals. In the middle of the first decade in the 21st century, 16 European countries were recorded an average consumption of 6-10 tons/inhabitant/ year. In the United States, the rate was 8 tons/inhabitant/ year. The Asia/Pacific region registers as one of the largest producers in product sales, as construction activity is rapidly rising, particularly in China and India. China alone accounts for half of all new aggregate demand worldwide during the 2010-2015 periods (Concrete Construction 2012). Considering the environmental impact using natural aggregates, construction and demolition waste aggregate are revealed as a sustainable and efficient alternative to produce recycled concrete (Tam et al. 2016).

The planning and execution of concrete tests are important in the development of new materials. However, for each study, plenty of mixtures are demanded and time in the curing process. In addition, a significant effort expended performing mechanical tests (compression, tensile, shear, elastic modulus, etc.).

Thus, the study of techniques aiming to facilitate the modeling of engineering problems can have advantages in making the process less costly and leading more reliable results. For example, there is also the inverse problem, where is desired a mixture that will achieve a certain 28 days compressive strength. In order to obtain alternatives to model, the mechanical behavior of concrete as an option to regression analysis has been found in the literature since the 1990s. Yeh (1998) studied the use of a backpropagation ANN to model the compression strength of high-performance concretes with better results than those obtained by regression analysis. In an attempt to give a destination in the ashes of hospital solid wastes, Al-Mutairi, Terro and Al-Khaleefi (2004) studied its effects on property compression strength when these ashes are mixed with concrete. For this research, the author made statistical evaluations and used a prediction model based on ANNs.

Taking advantage of the trend, Tam, Tam, and Wang (2007) used ANNs to improve mixture methodology to obtain a higher performance of RACs. Using ANNs and fuzzy logic (ANFIS – Adaptive neuro-fuzzy inference systems) techniques, Topcu and Saridemir (2008) modeled the compressive and splitting tensile strengths for recycled aggregate incorporated silica fume.

Studying RACs and their characteristics for structural applications and following an experimental design using similar RACs, Kotrayothar (2012) developed a significant number of tests which will be used as the database of this work. This decision was made considering that the recycled aggregate is a heterogeneous material and the use of a database generated in similar conditions can achieve relevant ANNs results in comparison to the authors who sought to compose their databases by gathering information from the most varied sources. Continuing the research, Tam et al., (2016) developed a regression analysis to predict target characteristic compressive, tensile and flexural strengths from 44 mix designs.

Recently, the use of machine learning tools has provided significant results in previous projects. In order to model the behavior of the modulus of elasticity at 28 days of RAC, Duan, Kou, and Poon, (2013) constructed two ANNs and compared them with their experimental results and the results obtained by conventional regression analysis. The training of the first ANN was based on a dataset with 324 records drawn from 21 international papers, while the training of the second ANN considered these same 324 records plus 16 datasets from experiments done by the authors. The authors chose 16 characteristics as ANN entries and obtained precise results for both networks, with low values of Root Mean Square Error (RMSE) and Mean Absolute Percent Error (MAPE). As an extension of the previous paper, they used the same ANNs based on the same data sources and with the same input parameters to explore in detail the applicability of using ANNs in modulus of elasticity of RAC.

Some researchers (Şimşek, İç and Şimşek 2016; Paul, Panda and Garg 2018) executed a reduced experimental program and with little representativeness in certain regions of the input parameters. Several authors (Dantas, Batista Leite and De Jesus Nagahama 2013; Duan and Poon 2014) seek previous data to improve their analysis.

This paper aims to model the compressive strength of recycled concrete using regression analyses and a machine learning technique such as Artificial Neural Networks (ANNs) to evaluate which method leads to a more precise response.

2. METHODOLOGY

The methodology used in this work follows the determined flow:
- To organize the data to be used in the modeling problem focused on compressive strength;
- Train some MLP ANN;
- Use the ANN and compare their results with Regression Analysis (RA) results and the tests values.

The characteristics of the data used in the modeling, as well as details related to ANN and the RA results, will also be commented.

2.1 Materials

Recycled aggregate samples collected from a south-eastern Australia centralized recycling plant was adopted to produce the concrete. The recycled aggregate utilized within the paper neural network can be identified in Table 1.

Table 1. Aggregate Properties

Source	Natural aggregate	Recycled aggregate
Grading	Pass	Pass
Water absorption (%)	1.02 (10mm); 0.42 (20mm)	5.02 (10mm); 5.63 (20mm)
Particle density on oven-dried basis (t/m^3)	2.59 (10mm); 2.47 (20mm)	1.44 (10mm); 1.30 (20mm)
Particle density on saturated and surface-dried basis (t/m^3)	2.61 (10mm); 2.48 (20mm)	1.51 (10mm); 1.37 (20mm)
Apparent particledensity (t/m^3)	2.66 (10mm); 2.50 (20mm)	1.55 (10mm); 1.40 (20mm)
Aggregate crushing value (%)	21	34
Contaminant (%)	0	2
Flakiness index	28.27 (10mm); 22.52 (20mm)	15.12 (10mm); 9.78 (20mm)
Misshapen particle (%)	3.02	0.88

2.2 Data characteristics used to model the problem

The data used in this work were obtained from laboratory tests. This type of procedure is usually expensive and time-consuming. Thus, depending on the type of the study desired, a previous analysis of the variables must be done in the construction of an experimental design that allows the construction of a surrogate mathematical model. The variables considered in the construction of the model are:

- Cement type: Discrete information of cement types (1 to 4);
- Admixture: Discrete information of admixture use or not (yes or no);
- Two-stage process: Discrete information of two stages use technics (yes or no);
- Aggregate type: Discrete information (NA, MRA, and RCA);
- Water: Continuous information of water use in Kg;
- Cement: Continuous information of cement use in Kg;
- Sand: Continuous information of sand use in Kg;
- Water to cement ratio: Continuous information in percentage;
- Chamber property 1: Continuous information;
- Chamber property 2: Continuous information.

Even for the construction of a very simple model, by traversing each discrete variable at least once and each continuous variable three times (minimum value, maximum value and average value) the number of mixtures to be tested will be:

$$\text{Mixtures} = 4 \times 2 \times 2 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 = 34992$$

This number of concretes would be very difficult to obtain in the laboratory, besides not allowing the construction of satisfactory mathematic models since the continuous variables are not well represented.

To improve the distribution of the continuous variables and consequently the results obtained by models based on this information, it was decided to reduce the spectrum of the problem. In this way, a specific case will be studied of the discrete variables for a cement type, without the use of admixture, without the use of the two-stage process and for one type of aggregate.

The number of blends available is 49 laboratory tests. ANNs are expected to succeed in modeling the compressive strength property based on the information available on that data set.

2.3 Artificial Neural Networks

The choice of the ANN approach comes from the good results that this technique has obtained in the most varied fields of knowledge to solve problems of classification, regression and time series prediction. This is because the technique copes well with non-linear and complex problems.

An ANN is a computational technique that constructs a mathematical model with learning capacity, generalization, association and abstraction based on information contained in data. The design of this technique was inspired by a simplified biological neural system where information is presented to the network that tries to learn its patterns in a repetitive process that must be stopped at an optimal time. During this iterative process of learning, ANN adapts its characteristics and connections between neurons in order to reduce its error in the construction of its model based on this data.

After training, testing and evaluating the results of several ANNs: A Multilayer Perceptron neural network (MLP) were chosen to model the problem.

Additional information about ANNs, as well as other techniques, can be found in references (Golub, G.H. and Loan, 1993; Haykin, 1999).

2.4 Regression Analysis

In statistics, regression analysis is a set of statistical processes for estimating the relationships among variables and describes how an independent variable is numerically related to the dependent variable. Any statistics software has a module to calculate them and even spreadsheet programs. That`s the reason why regression analysis is always the first choice to model data into an equation that rule one problem.

This study presents a multiple regression analysis based on the 7 (seven) mix design variables leading to the equation (1) aiming to predict the compressive strength of carbon-conditioning recycled aggregate concrete. Due to its confidential agreement of the project, the following equation is intentionally hidden the details.

$$f`_c = Constant + (A\ R_{wc}) + (B\ R_{rca}) + \left(C\ C_{p1}\right) + \left(D\ C_{p2}\right) + (E\ Q_C) + (F\ Q_w) + (G\ Q_{sand}) \quad (1)$$

Where:
R_{wc} = water to cement ratio
R_{rca} =recycled coarse aggregate replacement ratio (%)
C_{p1} = Chamber property 1
C_{p2} = Chamber property 2
Q_C =quantity of cement (kg)
Q_w =quantity of water (kg)
Q_{sand}= quantity of sand (kg)

3. RESULTS AND DISCUSSIONS

To evaluate the MLPANN model and the Equation acquired, some statistics error measures were used to compare properly the compression strength results. These numbers represent absolute error values, percentage error values and the correlation of these outputs when compared to the values measured in laboratory tests. Some general statistics, shown in Table 2, will also be presented with the results ranges for each model, as well as their means and standard deviation.

Table 2. General Statistics for Compressive Strength

	Equation (1)	MLP_ANN	Experimental Data
Maximum value	41.78	40.64	43.19
Minimum value	25.08	24.50	24.22
Average value	34.93	34.87	34.93
Standard Deviation	4.73	4.81	5.04

It is easy to notice that equation and the ANN acquired good results modeling the problem, with small errors measures and a good correlation to the laboratory results, when it is analyzed Table 3. However, the ANN obtained a smaller set of error measures, in addition to a better correlation, closer to 1.

Table 3. Error Models Statistics for Compressive Strength

	Equation (1)	MLP_ANN
Mean Absolute Error (MAE)	1.30	0.75
Min. Absolute Error	0.00	0.02
Max Absolute Error	3.74	3.22
Mean Squared Error (MSE)	2.90	1.19
Root Mean Square Error (RMSE)	1.70	1.09
Mean Absolute Percentage Error (MAPE)	4.01	2.33
Multiple R	0.94	0.98
R Square	0.88	0.95

This better ANN performance compared to Equation (1) is also easily observed by analyzing the graphs. Graph 1 shows that the results obtained by ANN are closer to the results obtained in the laboratory than those of Equation (1).

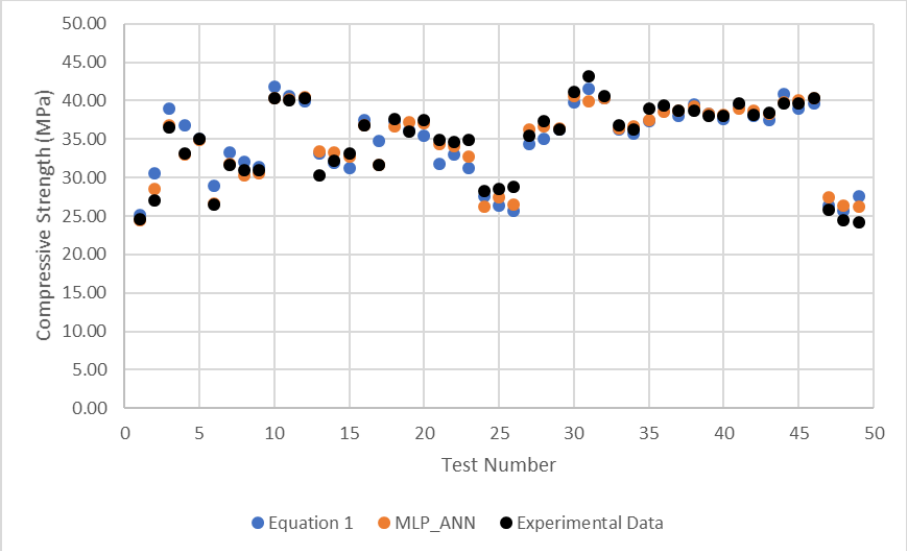

Figure 1 – ANN and Equation(1) vs Experimental data

A useful visual method to analyze the model accuracy is using cross-plot graphs like the scatter plot confronting the results of each model in one axis against the experimental data results in the other axis of the plot. Thereby, for each point plotted it is possible to compare the value of the reference versus the value that was obtained by the ANN or RA model. So, the closer these values are, the more the points present the configuration of a 45-degree line and consequently, the greater the accuracy of the model. In this study, these graphs presented at figures 2 to 3, confirm the reliability of ANN techniques as an important tool to predict compressive strength of recycled concretes confirming the statistical measures of table 2.

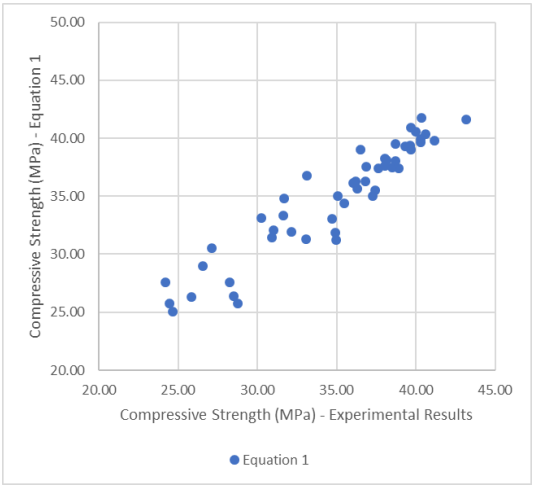

Figure 2 – Experimental data versus Equation (1) Scatter Plot

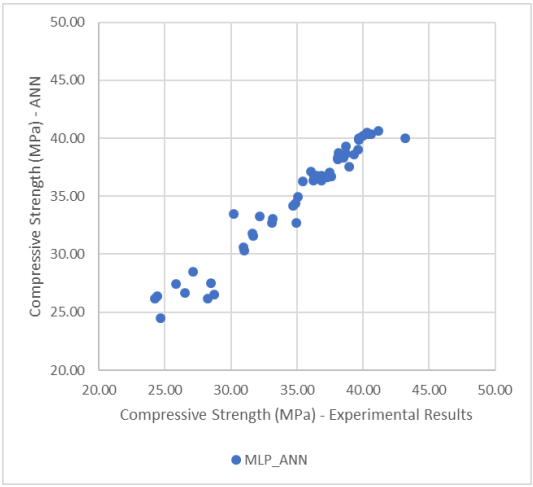

Figure 3 – Experimental data versus MLP ANN Scatter Plot

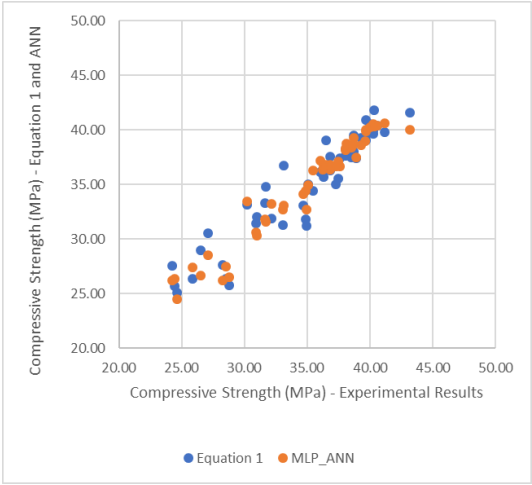

Figure 4 – Experimental data vs ANN and Equation (1) Scatter Plot

4. CONCLUSION

This paper investigated the use of ANNs for modeling the RAC compressive strength for a particular data set. The results showed that the MLP ANN tested provided accurate responses modeling the compressive strength with low errors (MSE, RMSE, and MAPE) and a R-square (R^2) close to 1. The MLP ANN model provided better predictions than the regression analyses models.

This research reveals the importance of obtaining a more accurate model aiming to predict concrete properties. The use of most innovative techniques of machine learning is expected in the future, aiming gains for the industry in relation to an increase of reliability of the model and in obtaining data, saving time and reducing costs. This study, focusing on compressive strength, demonstrate that the use of machine learning technics has a huge potential and can be adopt this approach to study other properties such as flexural strength, tensile strength, elasticity modulus, or durability.

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Paper 41

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Experimental Study and Performance Test of Composite Internal Fins

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Abstract

Heat transfer performance for both brass and composite (Al+SiC) finned brass pipe has been investigated experimentally. The composite finned tube was designed, fabricated and heated electrically after installation. The same was done for a brass finned tube in order to make comparison. The heat transfer coefficient for composite finned tube is about 1.09 to 1.11 times higher than that of brass finned tube. Higher thermal conductivity of composite material is responsible for this heat transfer enhancement. The composite finned tube in this study results in significant heat transfer enhancement at the same Reynolds number than that of brass finned tube.

Keywords: Heat transfer, composite fin, thermal conductivity.

1. INTRODUCTION

Internal fins are used in phase change material storages (PCM). PCM are used to balance the temporary temperature alteration and to store energy in several practical fields such as automobile industries. The rate of heat transfer from fluid flowing through the micro channels can be greatly enhanced by use of internal fins. Kanthimathi and Naga (2016) focused on the study of the use of radial composite fins to increase the heat transfer rate in many applications. Reddy et al (2015) fabricated circular pin fins made of different metals such as aluminium, copper, a combination of aluminium and copper and a combination of brass and copper as composite bars and analyzed their performance in terms of fin efficiency, heat transfer rate and temperature distribution along the fin. Jiang et al (2014) measured the performance of conventional silica gel coated heat exchanger (SGCHE), where a novel composite silica gel coated heat exchanger (CCHE) was proposed and fabricated. Xuehong et al (2014) investigated the performance of air-side heat transfer and fluid flow by numerical simulation for Reynolds number ranging from Re = 304 to 2130. The objective of the research is to study the effect of composite internal longitudinal fins inside a circular tube based on heat transfer characteristics in the entrance region as well as in the fully developed region.

2. DESIGN AND CONSTRUCTION

Sand casting was used in this experiment to manufacture the brass pipe. Composites were made from 98% pure aluminum. In this experiment pure SiC was used in 10 % weight fraction with aluminum. Magnesium (1% wt) was added to improve the wettability and incorporation fraction of ceramic particles. Micro-sized SiC particles were used to reinforce pure aluminum to fabricate as-cast aluminum matrix composite. Adhesive was used to join the composite fins with the brass pipe.

2. **Figure 1: Composite (Al+SiC) rectangular fins with brass pipe**

3. EXPERIMENTAL SETUP

An experimental set up was designed, fabricated and installed to study the heat transfer performance of circular tube having internal longitudinal fins. Air was used as the working fluid.

3.1. Dimensions of pipe and fins

Length of the cylindrical pipe, L= 25.5 cm = 0.255 m
Inner diameter of the tube, D_i = 8.38 cm = 0.0838 m
Outer diameter of the tube, D_o = 8.89 cm = 0.0889 m
Height of fin, H = 0.013 m
Thickness of fin, W = 0.003 m
Total number of fins, N = 4

3.2. Procedure of Experiment

The fan was first switched on and run for a few minutes so that the transient characteristics died out. Then the electrical heating circuit was switched on. The readings for the velocity were taken by a hot wire anemometer along the diameter of the pipe. Firstly, the variation in the wall thermocouples were observed until constant values were attained; then the outlet air temperature was monitored.

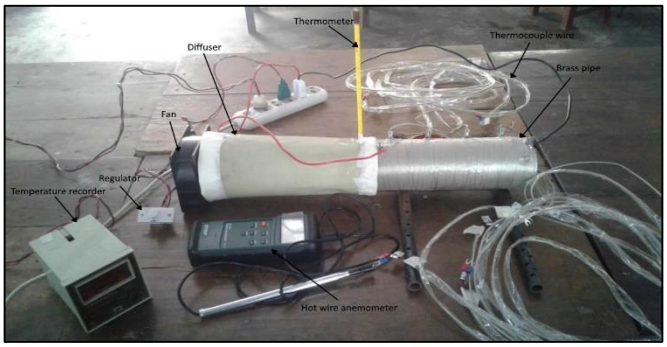

Figure 2: Composite (Al+SiC) rectangular fins with brass pipe

After one run of the experiment at a particular Reynolds number, the Reynolds number was changed with the help of the flow control regulator keeping the electrical power input constant. All the thermocouples readings were taken from each axial direction for each run of the experiment. The same experimental procedure was applied for both brass and composite (Al+SiC) finned tube.

4. EQUATIONS

4.1. Reynolds Number:

$$\mathbf{Re} = \frac{\rho V D_i}{\mu} \quad (1)$$

Mean velocity of test section,

$$\mathbf{V} = \frac{M}{\rho A_{xf}} \quad (2)$$

Properties of fluid are taken at its bulk temperature

4.2. Heat transfer calculation:

Total heat taken by air, $Q = MC_p(T_o - T_i)$ (3)

Heat taken per unit area, $Q' = \frac{Q}{A_h L}$ (4)

The local bulk temperature of the fluid can be calculated according to the following way:

$Q' = \frac{Q}{A_h L} = \frac{MC_p \Delta T}{A_h L}$ (5)

Therefore, $\Delta T = \frac{Q' A_h L}{MC_p}$ (6)

Now, bulk temperature, $T_{bx} = T_i + (\Delta T)_x = T_i + \frac{Q' A_h L}{MC_p}$ (7) Local convective heat transfer coefficient is given by

$h_x = \frac{Q'}{(T_w - T_b)_x}$ (8) Local Nusselt number, $Nu_x = \frac{h_x D_i}{K}$ (9)

4.3. List of symbols

A_{xf}	Cross sectional area of finned tube (m)
C_p	Specific heat of air (kJ/kg ^oC)
M	Mass flow rate (kg/s)
Q	Rate of heat transfer (W)
T	Temperature (^oC)
X	Axial distance (m)
ρ	Density or air (kg/m^3)
T_{bx}	Bulk temperature of fluid (^oC)
T_{wx}	Wall temperature of brass pipe (^oC)
h_x	Local heat transfer coefficient (W/ m^2 ^oC)
N_{ux}	Local Nusselt number

5. EXPERIMENTAL RESULT

Table 1: Brass finned tube – heat transfer data

X(m)	T_{bx} (^oC)	T_{wx} (^oC)	h_x (W/m^2 ^oC)	Nu_x
0.03	25.98	110	24.97	55.38
0.09	27.94	121	23.86	52.92
0.16	29.89	133	23.37	51.83
0.23	31.85	142	23.16	51.37

Table 2: Composite (Al+SiC) finned tube – heat transfer data

X(m)	T_{bx} (°C)	T_{wx} (°C)	h_x (W/m^2 °C)	Nu_x
0.03	26.22	105	43	87.75
0.09	28.67	122	51	75.17
0.16	31.12	129	62	72.71
0.23	33.57	132	68	71.54

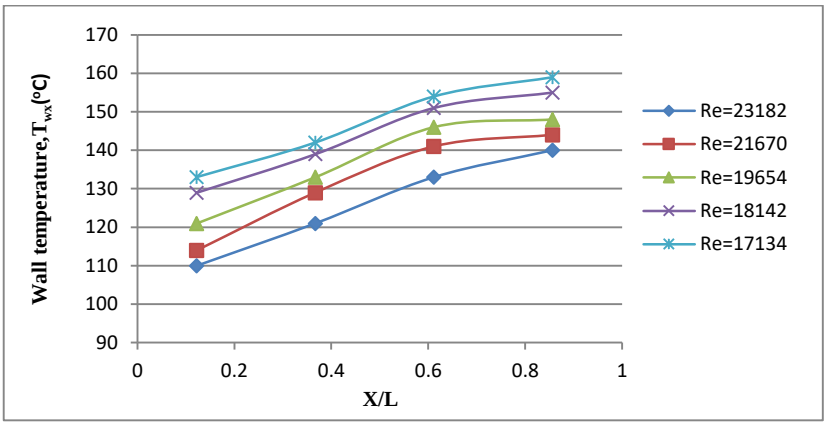

Figure 3: Wall temperature distribution along the length of the brass finned tube

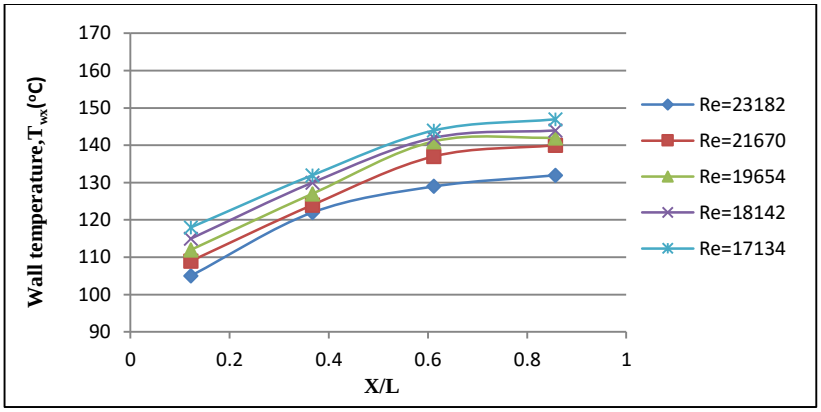

Figure 4: Wall temperature distribution along the length of the composite (Al+SiC) finned tube

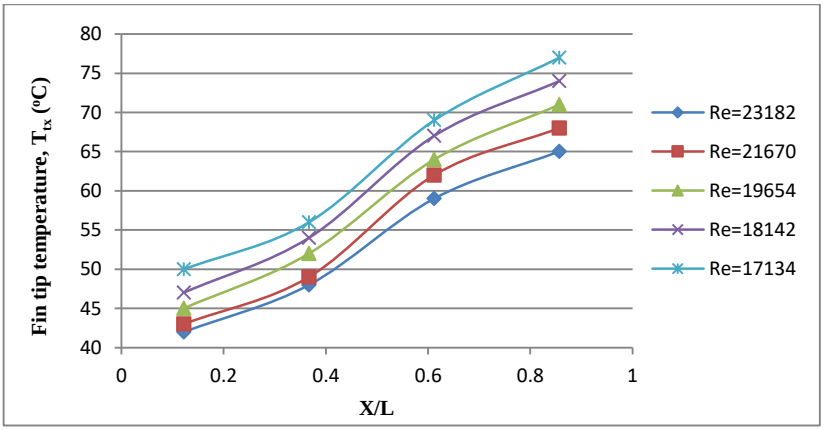

Figure 5: Fin tip temperature along the length of the brass finned tube

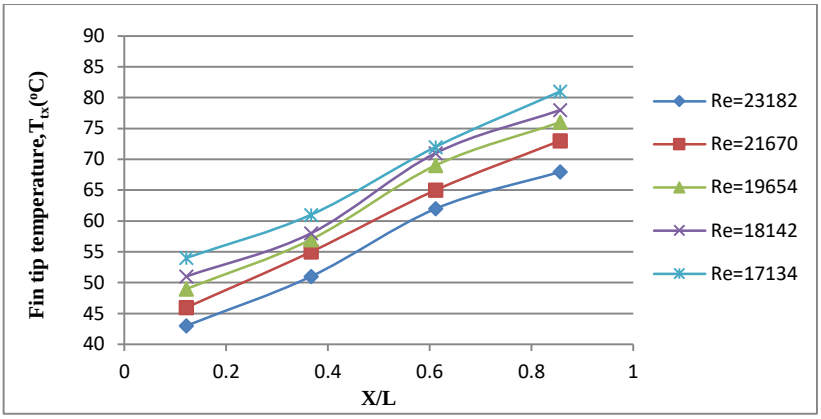

Figure 6: Fin tip temperature along the length of the composite (Al+SiC) finned tube

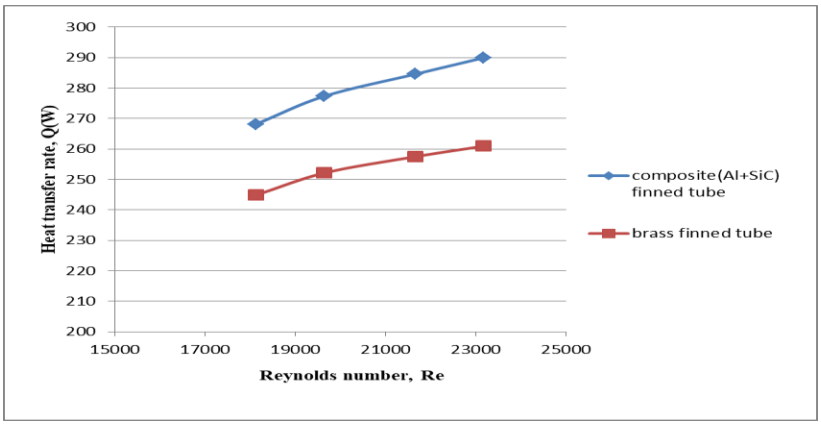

Figure 7: Variation of heat transfer rate with Reynolds Number

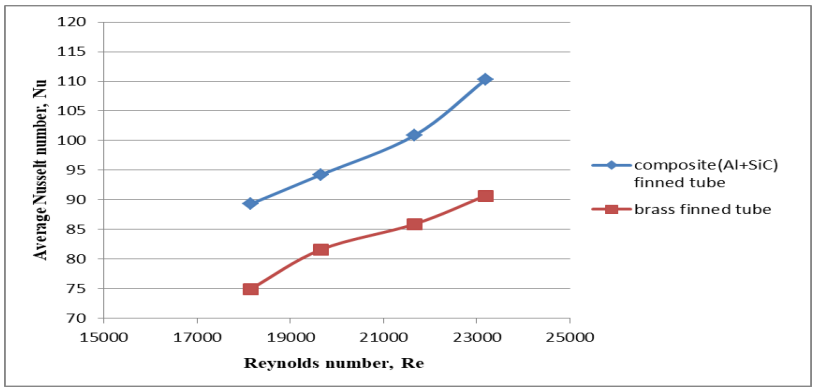

Figure 8: Variation of Nusselt number with Reynolds Number

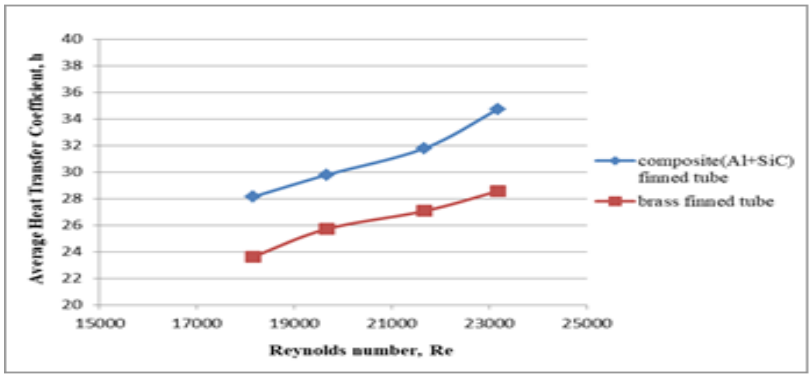

Figure 9: Variation of average heat transfer coefficient with Reynolds Number

6. DISCUSSION

Figure 3 and 4 shows the wall temperature distribution along the length of the finned tube for different Reynolds numbers based on the inner diameter. At a higher Reynolds number the-wall temperature is low because more heat is taken away by the air. The Nusselt number is large in the entrance region due to the development of a thermal boundary layer at the entrance section. It decreases with the increase in axial distance approaching fully developed values. Beyond this point it continues to increase with the axial distance which is very unusual and needs further investigation. Figure 7 shows that at higher Reynolds number the heat transfer rate.

7. CONCLUSION AND RECOMMENDATION

In this experiment heat transfer performance was studied. Steady state fluid flow and heat transfer performance of a circular tube with internal longitudinal brass finned tube and composite finned tube were studied experimentally. Results indicate that the heat transfer performance for the composite finned tube is higher than that for a brass tube. For both tubes, the local heat transfer coefficient is higher in the entrance region as the cold air comes in contact with the hot tube. The heat transfer coefficient then decreases with increasing axial distance approaching the fully developed value.
Heat transfer for the composite finned tube is 1.07 to 1.09 times higher than that of brass finned tube for comparable Reynolds number. The results thus show that composite finned tube results in heat transfer enhancement.

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Paper 42

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Comparative Analyses of Prefabrication Technologies, Innovation and Sustainability between China and Australia

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Abstract

Globally, construction is one of the most important industries as it contributes significantly to the gross domestic product (GDP). Considering the increasing demand for construction worldwide, the consequences concerning the environmental impacts are heightened. For example, the energy consumption, raw materials extraction and greenhouse gas emission in the sector combined with waste generation leave the environment edging closer to the depletion of natural resources while polluting the eco-system. Also, the construction industry has a very high risk for serious injuries or death. In order to overcome the lack of environmental control inherent to the on-site construction, prefabrication has been heavily promoted internationally due to its potential to improve construction sustainability, quality, safety and productivity. In China, the government vigorously promotes prefabricated buildings to reduce construction waste and dust pollution, encouraging powerful construction companies to research and develop the prefabricated construction. On the other hand, in Australia prefabrication is relatively small compared to the other countries, only 3% out of the total of construction industry. For example, in Sweden prefabrication accounts for roughly 80% of the market. This paper aims to compare the prefabrication techniques and innovations in China and Australia. The results present the outcomes of demand, policy, barriers and incentives in each country.

Keywords: Prefabrication, Construction, Sustainability.

1. INTRODUCTION

Prefabrication is promoted in the society as the means of improving the efficiency, quality and also the environmental performance of the housing industry in Australia at the same time decreasing the time, money and waste produced (Steinhardt et al. 2013). It is recognized by both design and construction professionals as one of most common methods where the benefits include its facilitation towards achieving high quality construction, reducing health and safety risks, improving in the planning, control and innovation environments, as well as, facilitating organizations to be more successful preventing injuries particularly related to hazards of sustainable elements such as "construction at height, overhead, with energized electrical systems, and in confined spaces" (Jiang et al., 2016; Zuo and Zhao, 2014).

According to J. Hong et al. (2016) the life-cycle energy use of prefabricated components ranged from 7.33 GJ/m³ for precast staircase to 13.34 GJ/m³ for precast form. Also, the recycling process could achieve 16% to 24% energy reduction.

Australia's prefabrication (prefab) industry is relatively small. Some researches (Steinhardt et al. 2013; Dave et al. 2017) suggest the factors as lack of research, funding and training; small scale market in Australia are not encouraging for prefabrication stakeholders. Additionally, the government in Victoria and Queensland are more inclined towards the prefabrication when compared with the government of NSW. In NSW, the government is taking steps to redesign the classrooms with the prefabricated buildings which can be replaced anywhere and gives the same convenience as that of the permanent classrooms (Robertson 2017). Australia is prone to bushfires and there will be a need for temporary residency or relief residency. According to Quezada et al (2016) 'The prefabricated manufacturing part of the construction industry is expected to grow at 5 per cent per annum out to 2023, compared to a growth rate of 2.3 per cent for the industry as a whole. The current prefabricated building market in Australia is still comparatively small, with only A$4.5 billion of the total A$150 billion construction industry, it is expected to contribute to more affordable housing stock and to take a much greater share of creating multi-story buildings' .

At present, there are 56 national prefabricated residential bases and 11 prefabricated residential pilot cities in China, and the industry is booming. In view of various aspects, it is a common trend to vigorously promote the development of fabricated buildings. In 2016, the newly-built prefabricated building area in China is around 110 million square meters. The output value of related supporting industries (such as clean energy, integrated decoration, smart home, etc.) is about 106.8 billion yuan. In 2016, the total output value of China's fabricated construction industry was about 316.8 billion yuan. China issued the "Guiding Opinions on Further Development of Prefabricated Buildings". It is pointed out that it is necessary to promote the region with the three major urban agglomerations of Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta. Other cities with a permanent population of more than 3 million are actively promoting the region and the remaining cities are also encouraged to promote the region. In terms of the intensity of advancement, opinions differed in three ways: "focus on promotion", "active advancement" and "encourage promotion". But there are still some barriers to promoting prefabricated building: the main material, the cost of labor, new prefabricated technologies and machines, prefabricated design cost, transportation cost, intellectual property protection, local governmental policy, profit and tax, and various unpredictable expenses.

Table 1 presents the contextual factors of prefabrication of the residential sector in three countries: China, Australia

Table 1 - Contextual factors of the prefabricated house

Factors	China	Australia
Prefabrication use	In 2016, the total area of Prefab construction in China was 114 million square meters, which was an increase of 11.4% year-on-year, accounting for 4.9% of the newly constructed buildings in urban areas.[C2]	Estimated that 3% of the current new housing market uses significant prefabrication [A2]
Annual production	2014: 1.450,000m^2 2009: 1.,200,000m^2 2007: 600.000 m^2 [C2]	2014: 173.842 m^2 2004: 164.210 m^2 1994: 173.384 m^2 1984: 145.840 m^2 [A3]
New housing vs. renovations	none	5% of the value of residential building work accounted for by "alterations, additions or conversions" [A4]
New housing funding models	none	2% of all newly completed dwellings not accounted for by the private sector [A4]
Development	Originated in the 1950s Developed from 1960s till 1980s; Stagnated from 1990s; 2016 is known as the "first year of policy" for the development of prefabricated buildings. "Standard for assessment of industrialized building"(2016)[C2]	1. Fast forward to the post war era in 1940s; 2. Prevalent in the 1960s 3. A largely utilitarian, industrial scaled mass-production of prefabricated buildings in 1990s.[A1]

Components	By 2020, the proportion of prefabricated buildings in new buildings will be more than 20%, and the municipalities, cities with separate plans and provincial capitals will be more than 30%, and the proportion of affordable construction projects will be over 40%. [C3]	New residential builds (2015): 52% detached houses 35% multi-residential 13% semi-detached Recent shift away from detached, cf. 2006: 70% detached houses 16% multi-residential 14% semi-detached [A4]
References	[C1] Chu, X. F. (2009). [C2] Arif, M., & Egbu, C. (2010) [C3] Standard for assessment of industrialized building (2016).	[A1] Australian Bureau of Statistics (ABS). (2012). 1268.0.55.001—Functional classification of buildings, 1999 (Revision 2011) (1268.0.55.001). Retrieved from Canberra. [A2] Australian Bureau of Statistics. (2015a). 8731.0 Building approvals, Australia (TABLE 20). Number of Dwelling Units Approved in New Residential Buildings, Original—Australia. Retrieved from Canberra. [A3] Australian Bureau of Statistics. (2015b). 8752.0 Building activity, Australia (TABLE 21). Value of Residential Building Work Done by Sector, Australia. Retrieved from Canberra. [A4] Australian Bureau of Statistics. (2015c). 8752.0 Building Activity, Australia

2. OVERVIEW OF PREFABRICATION: PROS AND CONS

The literature ((Steinhardt et al. 2013; Boafo et al. 2016; Dave et al. 2017) refers prefabrication as any part of the building or a structure fabricated at any other place other than its final location and present three types, namely, semi-prefabrication, comprehensive prefabrication, and volumetric modular building (3D prefab). Table 2 presents the pros and cons of the system's different types. Also, some authors adopt the following definitions:

- Panelised system or 2D prefab - these are non-volumetric systems. However, these can be easily transported to site and can be assembled to form 3D prefab.
- Modular system or 3D prefab - these are volumetric system and built almost completely in a facility and transported to the site for the final installment. More than 85% of the work is done in the factory or warehouse
- Hybrid system - is a combination of more than one system and most normally a combination of panelised and volumetric systems

Table 2 - Prefabrication industry: Pros and Cons

Type of Prefab system	Advantages	Disadvantages
2D (Hajkowicz 2016)	-Flat panel units are easily transported and is less expensive compared to the modular units for the transportation. - Few alternatives for customization - Larger commercial properties opt for panelised as it is possible to enable a higher ceiling and long span use.	The prefab components have limited customization

3D – Modular (Smith 2014)	-Faster construction. They can be completely done within 15 weeks and can be installed in the site in 1 day. - Controlled environment as most of the work is done in the factory. - The site of the location can be prepared simultaneously with the construction of the structure as it is done offsite. - Building quality control - Waste reduction.	The risk of transporting heavier and larger components as precision is really important. The road limitations with length and width will make the manufacturers split the buildings into two or more sections and they are transported in different trucks to the site where they are combined on site
Hybrid system (Steinhardt et al. 2013; Smith, 2014; Hajkowicz 2016)	-Time reduction. Construction schedule for offsite construction can be less when compared with the onsite construction - Cost accuracy. Cost for the construction can be predicted more accurately as they are constructed in a controlled environment - Increase in safety and security of the crew members and equipment -A warehouse site generally provides high quality tools and these high-quality tools ultimately help in producing high quality buildings when compared with the conventional way	Limited number of designs. The prefabricated structures are standardized, presenting a limited number of designs

3. CASE STUDIES – CHINA AND AUSTRALIA

This study aims to compare the prefabrication technologies and innovations within residential sector between Australia and China. Table 3 presents an actual picture some of the residential projects in China and Australia.

Table 3 – Summary of Site Visit –China and Australia

Site Details	**China Vanke Co., Ltd.**	**China Anyfun Home Construction Co., Ltd.**	**Australia Built smart**	**Australia Hi Tech Homes**
Sector	 Commercial, Residential	 Commercial, Residential and Villages	 Commercial, Residential and Villages	 Caravan
Category	2 D	2 D/ 3D	3D	2 D / 3 D
Recycling wastes	Reduction of 40.6% of scrap steel, 52.3% of waste wood, 55.3% of waste bricks, and reduce the construction process by 19.3%. Water Consumption and 2.9% power consumption.	70% of building materials can be recycled	Modular factories can achieve 50% to 75% less waste than homes built on equivalent sites through precision cutting and factory processes	93% of the materials are recyclable

Production rate	The total construction period has been shortened by nearly three months compared to the traditional model	The construction period can be shortened by more than 1/2 compared with traditional buildings	Building life cycle is 21 days in the factory + 7 days on site	Building life cycle is 1 month
Quality Control/ Certification	Beijing residential industrialization pilot project	The "prefabricated-type construction industry" recognized by the Ministry of Housing and Urban-Rural Development	GreenSmart Professional HIA member Master Builders Association member	All services, such as electrical, plumbing etc. are per formed according to the Australian building codes.
Building Materials	Concrete frames (floor), shear walls, double glazing windows	Concrete frames (floor), light steel frame for walls, double glazing windows	Steel frames (floor), timber frame for walls, double glazing windows, weatherboard	Steel / Timber
Limitations	Installation of the shear walls	Transport	Transport – truck dimensions	Two-story homes Transport: up to 100 km from Bringely NSW

4. CONCLUSION

There are signs for the growth of prefabrication in Australia, mainly in Victoria, but it is still small compared to other countries, such as China. Off-site construction has many advantages when compared with the onsite construction regarding the controlled environment of the components production. At this stage, it is possible to say that it is increasing the viability of traditional construction is gradually replaced by prefabrication in both countries. China is a representative example using new technologies and enhancing innovations in terms of sustainability and automation. In Australia it is evident that the limitations and barriers are related to the lack of government incentives and projects customization constrains. Also, cultural aspects are related to the fear to change and the shortage of skilled labors in this industry.

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Paper 46

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Evaluation of Rural Piped Water Distribution Systems in Bangladesh

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Abstract

In Bangladesh, the rural population has access to safe water within 150 meters of their households. The main source of water is groundwater aquifer. Despite many Government and non-government efforts, people are still being exposed to arsenic at present. The National Policy for Drinking Water Supply and Sanitation, 1998 aims to bring changes in service delivery by decentralization and users' participation through local government and community organizations. The Bangladesh Arsenic Policy and Implementation Plan, 2004 opted piped water supply as an alternative option to provide safe water. The Management of rural piped water distribution is the challenge Bangladesh facing for the last two decades. The water distribution system in the arsenic affected areas are suffering from the financial deficit; collected tariff can't meet the operation and maintenance cost. Survey and analysis are the methods applied in the study. The survey on facility users conducted in eleven Upsala's (sub-districts) under seven districts; Atchara, B. Baria, Narail, Barguna, Dhaka, Pabna and Dinajpur. The north and north-east districts have arsenic contamination in the shallow aquifer. The southern districts are in coastal areas where deep aquifer have salinity intrusions. Responses from water users of eleven schemes had been taken by the household survey; conducted from January to March 2018. The sustainability of the distribution system depends greatly on resource availability for operation & maintenance, willingness to pay and the amount willing to pay. The survey for this study revealed information about resource availability for O&M and willingness to pay and amount willing to pay for the service. In the analysis, revenue generation, collection, and break-even connection numbers are calculated on two sets of population and households. One set of population and household was from the Bangladesh Rural Water Supply and Sanitation project survey 2014 and the other one derived from the DHHE-JICA 2008 report of the evaluation of the performances, village piped water supply system. Other related information was also taken from the same project for the analysis. To identify financial challenges and review obstacles to the sustainability of rural piped water distribution systems is the purpose of the study. Study findings could contribute to the policy makers and those involved in the management of the piped water system in making decisions, implementing policies, and regulations for distribution systems.

Keywords: Arsenic, Sustainability, Rural piped water

1. INTRODUCTION

Bangladesh is one of the most densely populated countries in the world with more than 142 million populations in 147,570 km^2. About eighty-one percent (81%) of the population live in rural areas (BBS, 2011). By the end of the 1990s, almost a hundred percent (100%) of urban and ninety-seven (97%) of the rural population had access to safe water (Hossain et al., 2015).

Population in rural areas access the shallow aquifer by hand tube wells. Approximately 10-12 million hand tube wells are being used as drinking water sources in rural areas (Ahmed and Ahmed, 2002). However, the country's apparent success with safe water access ended in 1993. Department of Public Health Engineering (DPHE) and the national institute for water supply and sanitation noticed arsenic in the shallow aquifers for the first time.

Vast stretches of the shallow aquifer were contaminated by naturally-occurring arsenic. It was estimated about 29 million people were potentially at arsenic contamination risk (Ahmed and Ahmed, 2002).

The government of Bangladesh made arsenic policy and implementation plan in 2004; it opted piped water distribution as an alternative option in the affected areas. The arsenic mitigation plan suggested introducing piped water distribution systems in rural and urban areas as a long-term goal; preferably on surface water. Under such situation, piped water distribution in rural Bangladesh is considered as a long-term solution for safe water in arsenic affected areas.

Report on the evaluation of the performance of 120 villages piped water supply by DPHE-JICA (2008) showed forty-eight percent (48%) rural water distribution systems are functioning properly, thirteen percent (13%) partially functioning and remaining thirty-nine (39%) is not functioning at all. These piped water distribution systems are the source of safe water in many Arsenic affected villages in the country. From DPHE information, 141 rural water distributions had been constructed so far in affected areas. Among these, more than 100 schemes are not delivering water because of management and maintenances failures.

Management of rural piped water distribution is the challenge Bangladesh facing for the last two decades. The distribution system in the arsenic affected areas are suffering from the fiscal deficit; collected tariff can't meet the operation and maintenances cost. The revenue generated from water services is the main source of O&M expenditure. The sustainability of the scheme largely depends on revenue generation and collection success. Break-even analysis is used to determine the connections to make schemes "no profit, no loss" situation. When schemes are in break even, it neither loses nor generates revenue after covering the operating costs.

The analysis (revenue generation, collection, and break-even analysis) and survey on water users are the methods applied in the study. The object of the study is to identify financial challenges and review obstacles to the sustainability of rural piped water distribution system. The survey on facility users conducted in eleven Upzilas (sub-districts) under seven districts, named Satkhira, B. Baria, Narail, Borguna, Dhaka, Pabna and Dinajpur. Responses from water users of eleven schemes had been taken by household survey during January to March 2018.

2. FINANCIAL

Resources availability: Many schemes, operating in arsenic affected areas are suffering from financial deficit. Generated revenue cannot meet up O&M demand. The survey (figure 1) revealed 43% respondents mentioned not to have sufficient or small amount of resources, 46% have sufficient resources. It's the challenge for sustainability. Many times, fewer house connections, irregular tariff payment, and service unavailability are one of the main reasons for not generating sufficient resources.

O&M resources: Collected water tariff is the source of O&M expenditure of distribution system. Unfortunately, fund availability at the community level is not satisfactory. The survey (figure 2) indicated 63% respondents mentioned to have small or almost zero (2%) available funds for troubleshooting. Necessary fund available was mentioned by 35% respondents. The more funds available for repair and maintenance, the more sustainable schemes are. Many surveyed schemes were running successfully but had small available funds for maintenances. If some unusual incident happens, few schemes have the capacity to repair within a short time.

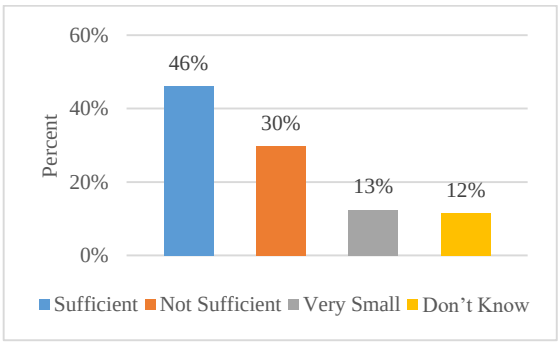


Figure 5 Revenue collection

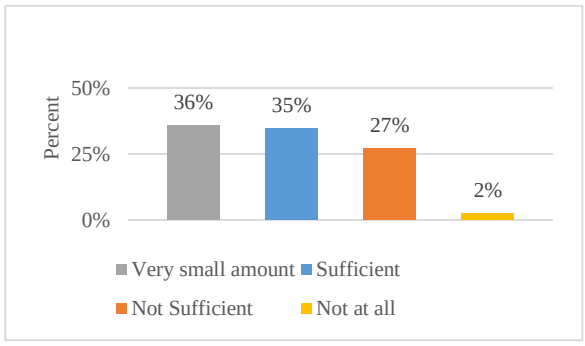


Figure 6 Fund availability for O&M

Willingness to Pay

User's satisfaction: Piped water supply provides a long-term solution over other arsenic mitigation technologies. User's satisfaction is an indicator to measure sustainability. For functional distribution system, respondents were asked for satisfaction with water quality and quantity. Those found satisfied were asked whether willing to pay more for better service or not. Out of all respondents (figure 3), 59% was happy with water, 39% was very happy with supply. A number of respondents (17%) reported dissatisfaction; 24% not so happy with supply. It indicates more scope for improvement in water quality and management.

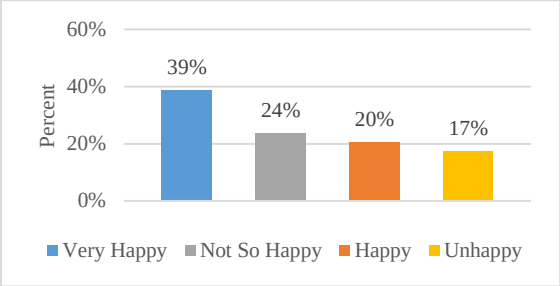


Figure 3 Satisfaction with water quality and quantity

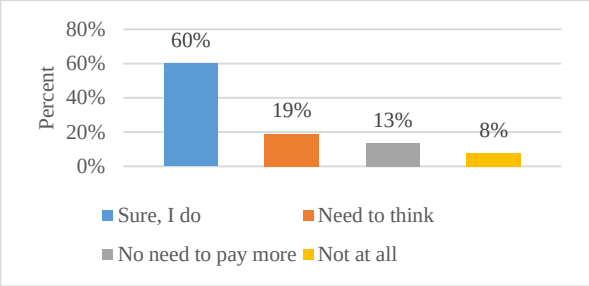
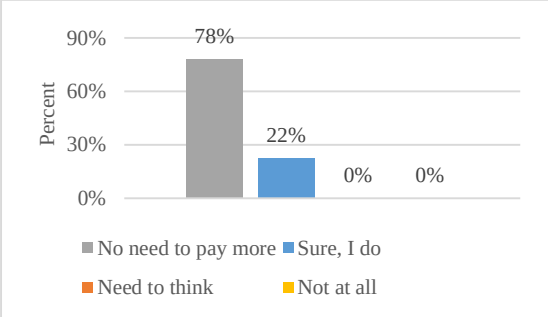
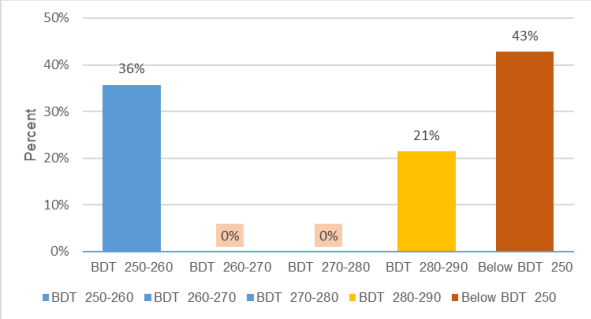


Figure 4 Willingness to pay





Amount Willing to Pay

Amount willingness to pay is another significant index to measure scheme sustainability; the more willing to pay, the more sustainable scheme is. Out of all respondents (figure 4), sixty percent (60%) is willing to pay more for better service, because it fulfills their drinking, cooking and other demands. For unsustainable cases (figure 5), twenty-two percent (22%) respondents still want to pay if service is up to minimum demand. It indicates there is a strong demand for safe water in affected areas. If we look at figure 6, thirty-six percent (36%) respondents want to contribute between BDT 250-260; the range between BDT 280-290 is 21%; The respondents who want to pay less than BDT 250 is 43%. The analysis for population 2300 and 4300 showed water tariff (Table 1) for sustainable management is BDT 330 and BDT 256 respectively (first year of operation). For population 2300 and household 445, the tariff is more (1st-year BDT 330 and 12th-year BDT 266). Forty-three percent (43%) respondents want to pay less than BDT 250 as tariff; which is below the requirement. It is the current scenario of unsustainable distribution systems in rural areas. People are in need of safe water; unfortunately, 43% of the population do not want to pay. In rural areas, many people think that water supply is the responsibility of the Government so there is no need to pay. Motivational and better service delivery can improve the situation as well as the sustainability of schemes.

Generally, the schemes Department of Public Health Engineering implementing, have a population range from 2500 to 4500 and 400 to 900 households. Two sets of population and household were used to compare the analysis results for water tariff, revenue generation, collection, and break-even connection numbers. Information about population and households collected from the Department of Public Health Engineering were: Population 4300, HH: 830 (Project survey 2014, Bangladesh Rural Water Supply and Sanitation Project). For the second set of data, population 2300, HH:450 were calculated on basis of DPHE-JICA (2008) report information (Appendices E).

Table 3 Water tariff for sustainable distribution system

Water Tariff				
	Population 2300, Household 445		Population 4300, Household 830	
	(BDT)	(USD)	(BDT)	(USD)
Year 1	330	4.08	256	3.16
Year 2	324	4.00	251	3.10
Year 3	318	3.93	246	3.04
Year 4	311	3.84	241	2.98
Year 5	304	3.76	236	2.92
Year 6	299	3.69	231	2.86
Year 7	293	3.61	227	2.80
Year 8	287	3.55	223	2.75
Year 9	281	3.47	218	2.69
Year 10	276	3.41	214	2.64
Year 11	271	3.35	209	2.58
Year 12	266	3.28	205	2.53

3. ANALYSIS

The rural piped water distribution system consists of production wells, distribution networks, construction, and mechanical expenses. All these outlays are termed as fixed costs. Again, operation and maintenance, depreciation and loan repayments expenses are running costs. There are other variables relating to expenses, but these outlays differ mostly on population and household (HH) of the system. Population and HH are considered as a variable for analyses.

The Department of Public Health Engineering implementing the schemes with population 2500 to 4500 and household 400 to 900. Two sets of population and household were used to compare the analysis results for water tariff, revenue generation, collection, and break-even connection numbers. Information about population and households collected from the Department of Public Health Engineering were: Population 4300, HH: 830 (Project survey 2014, Bangladesh Rural Water Supply and Sanitation Project). Schemes operation periods are twelve years. Other related information like costs breakdown

loan conditions, house connections etc. formed the same project survey. For the mentioned project, each household of the scheme was surveyed in the year 2014 to 2015 for collecting household income, expenditure, occupation, literacy, water use, water source, water fetching time, amount of money spent for water and other related information. For the second set of data, population 2300, HH:450 were calculated on basis of DPHE-JICA (2008) report information (Appendices E).

There are four categories of connections; 12mm diameter single and shared connections; 19mm shared and commercial connections. For population: 4300 HH: 830, 593 were 12mm diameter single connection (total 675); that is 88% of total connections. For Population:2300, HH:450: 313 were 12mm diameter single connection (total 358); that is 87% of total connections. Only 12mm diameter connection was considered for analysis.

Revenue generation and collection data were collected from the Bangladesh Rural Water Supply and Sanitation Project survey data. For revenue collection, 85%, 90% and 95% water tariff collection efficiency were calculated to find out the net income of the investor. For 93% collection efficiency of revenue made the revenue and expenditure ration 1.00. Revenue collection is the challenge the schemes are facing for financial sustainability.

3.1 Revenue Generation

The revenue generated from water services is the main source of O&M expenditure. The sustainability of the scheme largely depends on revenue generation and collection success. Many times, revenue decreases for fewer house connections, unsatisfactory service, operational & maintenances failures, water quality deterioration and irregular tariff payment by users. Two sets of the population and household data are compared to calculate minimum sustainable revenue by decreasing the 10%, 20%, 25%, 30%, and 40% respectively.

Population 4300 Household 830: The expected net revenue generation during 12 years of operations is BDT 8,633,389.00 1). If revenue decreases @ 10%, scheme faces no loss during the operation period. 2). If it decreases @ 20%, no loss during the same period. 3). Again, if it decreases @ 30%, scheme faces loss during the first five years; sixth to twelfth year, it would again generate revenue and stand BDT 268,671.00. 4) If revenue decreases @ 40%, scheme faces loss during operation period; it would not generate any revenue; a net loss would be 2,519,568.00. This indicates scheme can tolerate decrease up to 25% (no loss in every twelve years of operations); above this, the loss will start and over 40%, there will be no revenue generation. Table 2 describes the decrease and revenue generation briefly.

Table 4 Twelve mm diameter connection for population 4300

Revenue decrease	Net revenue (BDT)	Remarks
10 %	5,845,150.00	No loss during twelve years operation period
20 %	3,056,911.00	No loss during twelve years operation period
25 %	1,662,791.00	No loss during twelve years operation period
30 %	268,671.00	loss during the first five years; sixth to twelfth year, it would generate revenue
40 %	2,519,568.00 (negative revenue)	loss during twelve years' operation; would not generate any revenue;

Population 2300 Household 450**:** The expected net revenue generation during 12 years of operation is BDT 6,716,709.00. 1). If revenue decreases @ 10%, scheme faces no loss during the operation period. 2). If it decreases @ 20%, no loss during the same period. 3). Again, if it decreases @ 30%, it faces loss during the first three years; from fourth to twelfth year it would generate revenue and would stand at Tk. BDT 755,145.00. 4). If it continues to decreases @ 40%, scheme faces loss during operation period; it would not generate any revenue; a net loss would be BDT 1,232,043.00. The analysis indicates scheme can tolerate revenue decrease up to 25% (no loss in every twelve years of operations); above this, the loss will start and over 40%, there will be no revenue. Table 3 describes the decrease and revenue generation briefly.

Table 5 Twelve mm diameter connection for population 4300

Revenue decrease	Net revenue (BDT)	Remarks
10 %	4,772,295.00	No loss during operation period
20 %	2,742,333.00	No loss during operation period
25 %	1,748,739.00	No loss during operation period
30 %	755,145.00	loss during the first three years; fourth to twelfth year, it would generate revenue
40 %	1,232,043.00 (negative revenue)	loss during twelve years' operation; would not generate any revenue;

For both cases of population and households, @25% revenue decrease can be tolerated by the schemes. If revenue continues to decrease @30%, scheme faces loss at first three to four years and after that, it again generates revenue. If it goes beyond @40%, schemes face losses for 12 years' operation periods. For sustainability of schemes, decrease up to 25% can be tolerated; a loss will start after the limit and above 40% no revenue would generate, the scheme would not sustain for the population between 2300 to 4300.

3.2 Revenue Collection

Enough revenue generation and its collection success are one of the important factors for sustainable rural piped water supply management in Bangladesh. For many reasons like unsatisfactory service delivery, unwillingness to pay and absence of motivational activities are the main reason for collection failures. Here, 85%, 90% and 95% collection efficiency are considered to calculate Net Present Value (NPV) of benefit and Revenue/Expenditure ratio. Out of four types of house connections, 12mm diameter pipe connection consists 88% of total connections; here twelve-millimeters diameter connection is considered for the analysis. The Government invested 70% of total construction cost and the remaining 30% by the sponsor (local NGO or investor).

The sponsor (the World Bank used this terminology in Bangladesh Rural Water Supply and Sanitation Project) would run the scheme for 12 years with operation and maintenances by collecting water tariff from the users to recover the cost.

Population 4300 Household 830: For mentioned population and HH, revenue collection efficiency is considered as 85%, 90% and 93%; for this increment, net present value of profit (NPV) per month stands BDT 19,680.00 (Revenue/Expenditure 0.64), BDT 26,532.00 (Revenue/Expenditure 0.86), and BDT 30,644.00 (Revenue/Expenditure 1.00) respectively.

Table 6 Twelve mm diameter connection for population 4300

12mm diameter water connection			
Population:	**4300**		
Households:	**830**		
Tariff Collection efficiency	85%	90%	93%
Sponsor's investment (BDT)	4,426,200.00	4,426,200.00	4,426,200.00
NPV of Benefit (BDT)	2,833,972.00	3,820,665.00	4,412,680.00
Revenue/Expenditure ratio	0.64	0.86	1.00
Net Income of investor/Month (BDT)	19,680.00	26,532.00	30,644.00

Population 2300 Household 450: For mentioned population and HH, revenue collection efficiency is considered as 85%, 90% and 93%; for this increment, Net Present Value (NPV) of profit per month stands BDT 13,202.00 (Revenue/Expenditure 0.63), BDT 17,880.00 (Revenue/Expenditure 0.85), and BDT 21,155.00 (Revenue/Expenditure 1.01) respectively.

Table7 Twelve mm diameter water connection for population 2300

12mm diameter water connection			
Mean population:	**2300**		
Mean Households:	**450**		
Tariff Collection efficiency	85%	90%	93%
Sponsor's investment (BDT)	3,029,313.00	3,029,313.00	3,029,313.00
PV of Benefit (BDT)	1,901,148.00	2,574,856.00	3,046,452.00
Revenue/Expenditure ratio	0.63	0.85	1.01
Net Income of investor/Month (BDT)	13,202.00	17,880.00	21,155.00

For both cases of population and households, 93% water revenue collection efficiency made the scheme sustainable; 85% and 90% collection efficiency made the scheme unsustainable as revenue to expenditure ration is less than one for both cases. With compare to the socio-economic conditions of the people living in the rural areas, 93% collection efficiency is a very high target to make the scheme sustainable. Though rural piped water supply is operating in Bangladesh for the last two decades, it requires more time to attain 93% revenue collection efficiency.

3.3 Break-Even Connections

Break-even analysis is used to determine the connections to make schemes “no profit, no loss” situation. When schemes are in break even, it neither loses nor generates revenue after covering all the operating costs. Here, 12-year expecting household connections are compared with the breakeven numbers by two different sets of the population and household data. Depreciation is calculated on the production of well, submersible pump, water meter, chlorination tank (life cycle of asset 10 years). For each item, depreciation charged @ 10%, except for chlorination tank (@ 20%. On the basis of rate, yearly depreciation was calculated. Generally, schemes, the Department of Public Health Engineering implementing, have a population range from 2500 to 4500 and 400 to 900 households. Two sets of population and household were used to compare the break-even connection numbers.

Population 4300 Household 830: For breakeven scheme,1st year it needs 502 house connections (58.82%), 555 (65.08%) at 6th year, 626 (73.15%) at 12th year. The average breakeven number for 12-year operation period is 562 (65.79%). Table 4 indicates during 12 years' operation, only 562 (65.79%) water connections make scheme break-event. The scheme is expecting to have an average 756 numbers of connections over the same operation period, which indicates good revenue strength.

Table 8 Break-even Connections

Particulars	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Mean**
Monthly tariff (BDT)	267	261	256	251	246	241	236	232	227	223	218	214	239
Break-Even connections	502	512	522	533	544	555	566	577	589	601	613	626	562
Percent with HH	58	59	61	62	63	65	66	67	69	70	71	73	65
Expecting connections	675	689	703	717	732	747	762	777	793	809	826	843	756

Population 2300 Household 450: For breakeven scheme, 1st year it needs 265 house connections (58.82% of households), 293 (65.08%) at 6th year, 329 (73.15%) at 12th year. The average breakeven number for 12-year operation period is 296 (65.79%). Table 5 indicates, during 12 years' operation, only 296 (65.79%) water connections make the scheme break-event. The scheme is expected to have an average 400 numbers of connections over the operation period, which indicates good revenue strength.

Table9 Break-even Connections

Particulars	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Mean**
Monthly tariff (BDT)	345	338	332	325	318	312	306	300	294	289	283	278	310
Break even connections	265	270	275	281	287	293	299	305	311	317	322	329	296
Percent with HH	58	59	61	62	63	65	66	67	69	70	71	73	65
Expecting connections	358	365	372	380	388	396	404	412	420	428	436	445	400

For making schemes sustainable, 66% of households are needed to be connected for the population between 4300 and 2310.

4. CONCLUSION

Management of rural piped water distribution is the challenge Bangladesh facing for the last two decades. The sustainability of distribution systems depends greatly on resources availability for operation & maintenances, willingness to pay and amount willing to pay. The survey revealed forty-three percent (43%) respondents mentioned not to have enough or small amount of resources, forty-six percent (46%) have sufficient revenue. Resources unavailability is one of the main challenges for sustainability. The survey also indicated sixty-three percent (63%) respondents mentioned to have small or almost zero (2%) available funds for troubleshooting. The more funds available for repair and maintenance, the more sustainable schemes are. Many surveyed schemes were running successfully but had small available funds for operation and maintenances.

The survey indicated sixty percent (60%) respondents are willing to pay more for better service because it fulfills their drinking, cooking and other demands. For unsustainable cases, twenty-two percent (22%) respondents still want to pay if service is up to minimum demand. It indicates there is a strong demand for safe water in affected areas. Minimum water tariff for the sustainable scheme is BDT 256 (Population 4300) and BDT 330 (Population 2300) on the first year of operation. Forty-three percent (43%) respondents want to pay less than BDT 250 as tariff; which is below the requirement.

People are in need of safe water; unfortunately, almost half of population want to pay less than the minimum sustainable tariff. In rural areas, many people think water supply is the responsibility of Government, no need to pay. In the analysis, revenue generation, revenue collection, and break-even connection numbers are calculated. The analysis reveals twenty-five percent (25%) revenue decrease can be tolerated by the scheme; a loss will start after that limit. Above forty percent (40%), no revenue would generate, the scheme would not sustain for the population between 2300 to 4311. Ninety-three percent (93%) water revenue collection efficiency can make the scheme profitable; 85% and 90% collection efficiency made the scheme unsustainable. Many of the constructed schemes are not sustainable because of less water tariff collection efficiency.

Sixty-six percent (66%) households of schemes area are needed to be connected for making break-even or sustainable scheme for population 2300 to 4300. If the above-mentioned household is connected, it would deliver service for long times; break-even or sustainable.

The survey also reveals that there is a shortage of available resources for operation and maintenance. People are in want of safe water but only fifty-seven percent (57%) population want to pay the minimum water tariff; remaining forty-three percent (43%) people want to pay less than the minimum water tariff. The revenue generation, collection and break-even number discussed above give an indication that there is scope for more revenue generation and collection efficiency to make the scheme sustainable.

Rural piped water distribution system can be more sustainable if revenue generation and collection efficiency are increased. Motivation and campaign not to drink arsenic contaminated water can increase the house connection. In long run, it would increase the revenue and sustainability of the scheme. For limitation of time and resources, small sample size was used; ten to fifteen respondents from each scheme.

ACKNOWLEDGMENTS

The survey and analysis in the study is part of my graduation dissertation at the University of Seoul, the Republic of Korea in June 2018. I would express gratitude to my supervisor Professor Hyunook Kim, Ph.D., Department of Environmental Engineering, the University of Seoul for invaluable guidance. Without his precious advice, it was not possible for me to complete the study. I would like to extend my appreciation to thesis advisory members, Committee Chair, Professor Hyeon Park, Vice-Dean, International School of Urban Science, University of Seoul and Member, Professor Chun Ho Yeom for invaluable guidance and suggestions to improve the dissertation.

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A: Revenue Generation (Population 4300, HH 830)

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Total
Projected Revenue (BDT)	2,183,951	2,209,352	2,234,745	2,260,132	2,285,518	2,310,897	2,336,270	2,361,636	2,387,002	2,412,361	2,437,631	2,462,899	27,882,393
Yearly outflow (BDT)	1,604,084	1,604,084	1,604,084	1,604,084	1,604,084	1,604,084	1,604,084	1,604,084	1,604,084	1,604,084	1,604,084	1,604,084	19,249,004
Net Revenue (BDT)	579,867	605,268	630,662	656,049	681,434	706,813	732,186	757,553	782,918	808,278	833,547	858,815	8,633,389
Revenue reduced 10%													
Projected Revenue	1,965,555	1,988,416	2,011,271	2,034,119	2,056,966	2,079,807	2,102,643	2,125,473	2,148,302	2,171,125	2,193,868	2,216,609	25,094,154
Net Revenue (BDT)	361,472	384,333	407,187	430,035	452,882	475,723	498,559	521,389	544,218	567,042	589,784	612,525	5,845,150
Revenue reduced 20%													
Projected Revenue (BDT)	1,747,160	1,767,481	1,787,796	1,808,106	1,828,414	1,848,717	1,869,016	1,889,309	1,909,601	1,929,889	1,950,105	1,970,319	22,305,915
Net Revenue (BDT)	143,077	163,398	183,713	204,022	224,331	244,634	264,932	285,226	305,518	325,806	346,021	366,235	3,056,911
Revenue reduced 25%													
Projected Revenue (BDT)	1,637,963	1,657,014	1,676,059	1,695,099	1,714,138	1,733,173	1,752,202	1,771,227	1,790,251	1,809,271	1,828,223	1,847,174	20,911,795
Net Revenue (BDT)	33,879	52,930	71,975	91,016	110,055	129,089	148,119	167,144	186,168	205,187	224,140	243,090	1,662,791
Revenue reduced 30%													
Projected Revenue (BDT)	1,528,765	1,546,546	1,564,322	1,582,093	1,599,862	1,617,628	1,635,389	1,653,146	1,670,901	1,688,653	1,706,342	1,724,029	19,517,675
Net Revenue (BDT)	-75,318	-57,538	-39,762	-21,991	-4,221	13,544	31,305	49,062	66,818	84,569	102,258	119,945	268,671
If revenue reduced 40%													
Projected Revenue (BDT)	1,310,370	1,325,611	1,340,847	1,356,079	1,371,311	1,386,538	1,401,762	1,416,982	1,432,201	1,447,417	1,462,579	1,477,739	16,729,436
Net Revenue (BDT)	-293,713	-278,473	-263,236	-248,004	-232,773	-217,546	-202,322	-187,102	-171,883	-156,667	-141,505	-126,344	-2,519,568

Appendices-B: Revenue Generation (Population 2300 HH 455)

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Total
Projected Revenue (BDT)	1,509,370	1,536,014	1,562,660	1,589,319	1,615,980	1,642,643	1,669,308	1,695,975	1,722,644	1,749,314	1,775,986	1,802,669	19,871,881
Yearly outflow (BDT)	1,096,264	1,096,264	1,096,264	1,096,264	1,096,264	1,096,264	1,096,264	1,096,264	1,096,264	1,096,264	1,096,264	1,096,264	13,155,172
Net Revenue (BDT)	413,106	439,750	466,396	493,055	519,716	546,379	573,044	599,711	626,379	653,050	679,722	706,404	6,716,709
Revenue reduced 10%													
Projected Revenue (BDT)	1,358,433	1,382,412	1,406,394	1,430,387	1,454,382	1,478,379	1,502,377	1,526,377	1,550,379	1,574,383	1,598,387	1,622,402	17,884,693
Net Revenue (BDT)	262,169	286,148	310,130	334,123	358,118	382,114	406,113	430,113	454,115	478,118	502,123	526,137	4,772,295
Revenue reduced 20%													
Projected Revenue (BDT)	1,207,496	1,228,811	1,250,128	1,271,455	1,292,784	1,314,114	1,335,446	1,356,780	1,378,115	1,399,451	1,420,789	1,442,135	15,897,505
Net Revenue (BDT)	111,232	132,547	153,864	175,191	196,520	217,850	239,182	260,516	281,851	303,187	324,524	345,871	2,742,333
Revenue reduced 25%													
Projected Revenue (BDT)	1,132,028	1,152,010	1,171,995	1,191,989	1,211,985	1,231,982	1,251,981	1,271,981	1,291,983	1,311,986	1,331,989	1,352,002	14,903,911
Net Revenue (BDT)	35,763	55,746	75,731	95,725	115,721	135,718	155,717	175,717	195,718	215,721	235,725	255,737	1,748,739
Revenue reduced 30%													
Projected Revenue (BDT)	1,056,559	1,075,210	1,093,862	1,112,523	1,131,186	1,149,850	1,168,516	1,187,182	1,205,851	1,224,520	1,243,190	1,261,868	13,910,317
Net Revenue (BDT)	-39,705	-21,055	-2,402	16,259	34,922	53,586	72,251	90,918	109,586	128,255	146,926	165,604	755,145
Revenue reduced 40%													
Projected Revenue (BDT)	905,622	921,608	937,596	953,591	969,588	985,586	1,001,585	1,017,585	1,033,586	1,049,588	1,065,592	1,081,601	12,519,285
Net Revenue (BDT)	-190,642	-174,656	-158,668	-142,673	-126,676	-110,679	-94,680	-78,679	-62,678	-46,676	-30,673	-14,663	-1,232,043

Appendices-C: Break -Even Connections (Population 4300, HH 830)

Particulars (BDT)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Average
Yearly O&M Cost	654,000	654,000	654,000	654,000	654,000	654,000	654,000	654,000	654,000	654,000	654,000	654,000	654,000
Depreciation	315,325	315,325	315,325	315,325	315,325	315,325	315,325	315,325	315,325	315,325	315,325	315,325	315,325
Repayment of Loan	634,759	634,759	634,759	634,759	634,759	634,759	634,759	634,759	634,759	634,759	634,759	634,759	634,759
Total Yearly outflow	1604084	1604084	1604084	1604084	1604084	1604084	1604084	1604084	1604084	1604084	1604084	1604084	1604084
Average monthly Tariff	267	261	256	251	246	241	236	232	227	223	218	214	239
Yearly Tariff/connection	3198	3133	3071	3011	2950	2891	2834	2780	2724	2670	2615	2562	2,870
Break even connections	502	512	522	533	544	555	566	577	589	601	613	626	562
Percent with HH	60.43	61.68	62.93	64.18	65.51	66.85	68.19	69.53	70.95	72.38	73.90	75.42	67.66
Expecting connection	675	689	703	717	732	747	762	777	793	809	826	843	756

Appendices-D: Break -Even Connections (Population 2300, HH 450)

Particulars (BDT)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Average
Yearly O&M Cost	368,849	368,849	368,849	368,849	368,849	368,849	368,849	368,849	368,849	368,849	368,849	368,849	368,849
Depreciation	333,925	333,925	333,925	333,925	333,925	333,925	333,925	333,925	333,925	333,925	333,925	333,925	333,925
Repayment of Loan	393,491	393,491	393,491	393,491	393,491	393,491	393,491	393,491	393,491	393,491	393,491	393,491	393,491
Total Yearly outflow	1096264	1096264	1096264	1096264	1096264	1096264	1096264	1096264	1096264	1096264	1096264	1096264	1096264
Average monthly Tariff	345	338	332	325	318	312	306	300	294	289	283	278	310
Yearly Tariff/connection	4141	4062	3985	3901	3821	3743	3669	3598	3529	3463	3399	3331	3,720
Break even connections	265	270	275	281	287	293	299	305	311	317	322	329	296
Percent with HH	58.82	59.98	61.13	62.45	63.76	65.08	66.40	67.71	69.03	70.35	71.66	73.15	65.79
Expecting connection	358	365	372	380	388	396	404	412	420	428	436	445	400

Appendices-E: Mean population and households

Project Name	Duration	Scheme Number	Average household	Total household	Total population	Mean Household	Mean Population
GoB-4 Project	1995-2004	86	500	43,000	223,342	445	2310
GoB-5 Project	2004-2010	3	100	300	1,558		
Bangladesh Arsenic Mitigation Water Supply Project	1998-2006	3	300	900	4,675		
Social Investment Program Project	2003-2007	4	500	2,000	10,388		
Bangladesh Water Supply program Project	2005-2009	3	300	900	4,675		
GoB-UNICEF Project	2007-2013	7	228	1,596	8,290		
Bangladesh Rural Water Supply and Sanitation Project	2012-2017	35	400	14,000	72,716		
Total		141					

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Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN:978-0-6482681-4-7

Strategies to improve energy use in urban university campus design in Bangladesh

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Abstract

The North South University permanent campus in Bashundhara residential area has served as a pioneer for urban university campus design in Bangladesh. Many private universities in later years have adopted the model to develop other urban campuses in the city. However, a major setback with the design has emerged, namely a large energy demand for campus operation. Operational costs are significantly higher compared to traditional campus design approaches. Land scarcity and the resulting necessity of compact development require this kind of design. Studies are therefore essential to help improve the energy performance of these types of campuses in the country. This paper describes an energy simulation analysis of the North South University permanent campus buildings to assess the pattern of their cumulative energy use and look for possible energy saving potentials. The simulation model was developed using eQuest software, which uses the simulation engine developed by the US Department of Energy. Local climate models along with existing equipment and building use data have been used in the simulation to mimic the energy use patterns of the campus. The results have been verified against the energy use data from the Dhaka Electric Supply Company for validation. Subsequently selected strategies have been proposed regarding how the energy demand of this type of campus design can be reduced in the future. It is proposed that the adoption of such strategies can be an important criterion for future urban campus designs to address sustainability.

Keywords: Energy Efficiency, Urban Campus Design, Sustainable Architecture, North South University.

1. INTRODUCTION

An energy audit helps in the assessment of the overall energy expenditure of a building by identifying quantitatively (1) the energy needed to achieve the building's function and maintain staff comfort, (2) the possible maintenance and saving potentials and (3) the potentials for reducing overall energy consumption. A survey of 30 buildings in Dhaka which are on average 10 years old or more was done jointly by the International Finance Corporation (IFC) and the Housing and Building Research Institute (HBRI) in 2013 (IFC, 2013). Their findings state value of 26 kWh per square foot. From the annual utility billing information of the North South University (NSU) campus we found that with a gross floor area of 1,250 thousand square feet (Ahmed, 2016) the campus had an energy use intensity of 8 kWh per square foot in 2015 and 6.75 kWh per square foot in 2014 against 2 kWh and 2.3 kWh as recorded in 2012 and 2011 when parts of the campus was not completed. A significant trend is a rise in energy use intensity by almost four times between 2011 and 2015. The utility rates have also increased all along this time with the result that the amount spent on utilities by the university has grown from BDT 2.5 crores annually to about BDT 4.1 crores in 2014 and 3.4 crores in 2015. The NSU campus has acted as a model for other private universities, which have adopted similar compact urban university campus layouts that rely heavily on mechanical cooling, ventilation, artificial lighting and adoption of digital technology, all of which significantly increase their operational energy consumption.

2. IMPORTANCE OF ENERGY ASSESSMENT IN ARCHITECTURE

Since the latter part of the last century, architectural design has moved away from the use of passive energy technologies based on generalized climatic factors by dominant macro level regional traits (Baweja, 2008) to those of heavy reliance on energy-intensive electro-mechanical solutions. Mohanty et.al. (2012, p. 14) attributed the cause for this to globalization, economic integration and greater media reach leading to consumers adopting the high energy intensive lifestyle patterns of those in the developed world. Pachauri (2007, p. 1) has used the 2006 World Energy Assessment report by the Paris based International Energy Agency, to show that energy consumption in India and other fast-growing developing countries has increased rapidly with the rise in the Gross Domestic Product (GDP). Bangladesh with a similar socio-cultural structure has recorded steady GDP growth of 3.7 percent in the 1980s to 4.8 percent in the 1990s and a 5.8 percent in the 2000s (The World Bank, 2012). A 2012 study commissioned under the Bangladesh Investment Climate Fund found that "current construction techniques in Bangladesh are not energy and water efficient which leads to high energy and water demand in the building sector" (WSP, DDC, 2012).

3. SIMULATION AS A TOOL FOR ARCHITECTURAL ENERGY ASSESSMENT

Energy efficiency in highly mechanized buildings operation is typically addressed by whole building energy simulation. Simulation literature usually traces the adoption of this methodology to the needle experiment leading to the development of the Monte Carlo method by Buffoon in 1777, later augmented by Laplace in 1812 (Goldsman, Nance, & Wilson, 2010). From random number generation challenges in the 1940s, simulation became a recognized powerful problem-solving technique in the 1950s and 1960. It gradually spread in its application to multi-disciplines becoming user-friendly since the 1970s and 1980s (Goldsman, Nance, & Wilson, 2010). Today simulation techniques in the field of architecture are generally applied for, primarily, four types of problem solving cases as follows: for programming and budgeting before the design phase, for architectural schematic design development, for load calculation and HVAC (Heating Ventilation and Air Conditioning) system sizing and for economic assessment (Richard, 2013).

Reliability of simulation results depends significantly on the validity and effectiveness of the data input, the degree of accuracy of the modeling and simulation algorithm and the accuracy of the modeling and simulation exercise from the user end. The US Department of Energy publishes an official list of software sponsored by it for development which includes DOE 2. Other official websites such as the Lawrence Berkeley National Laboratory also enlist DOE 2 as reliable software for accurate outputs. For this exercise described in the subsequent sections, we have used the DOE 2 software which complies with the recognized software list. The comparative reliability of the results of DOE 2 has been discussed in detail by Crawly et.al. (Crawley, Hand, Kummert, & Griffith, 2005) indicating it to be particularly validated by several testing methods for reliability in traditional HVAC system sizing; while Maile et.al. (Maile, Fischer, & Bazjanac, 2007) has also shown it to be reliable with the major limitations being restrictive options for newer HVAC systems. Cho and Haberl (2006, p. 6) have identified specific systems that DOE 2 has limited or no functionality for. These include Under Floor Air Distribution System, Dual Path System, Displacement Ventilation, and Natural Ventilation. The case described in this paper does not use any of these, but an HVAC system installed in the 1990s which is already twenty-three years old. It is a constant volume, water chilled type and therefore falls within the library of HVAC systems available in the DOE 2 software environment.

4. METHODOLOGY OF THE STUDY

The North South University permanent campus became operational from 2009. The roughly ten storied campus building complex is centrally air-conditioned with five chillers with a total cooling capacity of 2,750 tons (5 numbers 550RT, YORK water cooled chillers) and 123 Air Handling Units and 396 Fan Coil Units, 86,000 feet of piping and 5,80,000 square feet of sheet metal ducting distributed across the campus. In addition, there are 133 ventilation fans for air circulation in the basements, toilets, and plant areas. Electric power is provided with a 4 MW (3 x 1.34 MW) DEUTZ gas generators, backed with 3MW grid power from DESCO. In addition, there are 3 stand-by diesel generators. The campus has its own water supply pumping system with deep tube wells and automated water level monitoring system (Ahmed, 2016).

Two primary methods were adopted for this study (1) physical energy audit and (2) whole building energy simulation. A sample year for the simulation was set at 2012 and data inventory available for 2012-2013 was used in the simulation. The overall work process adopted for this study is shown in Figure 1 and the eQuest model is shown in Figure 2.

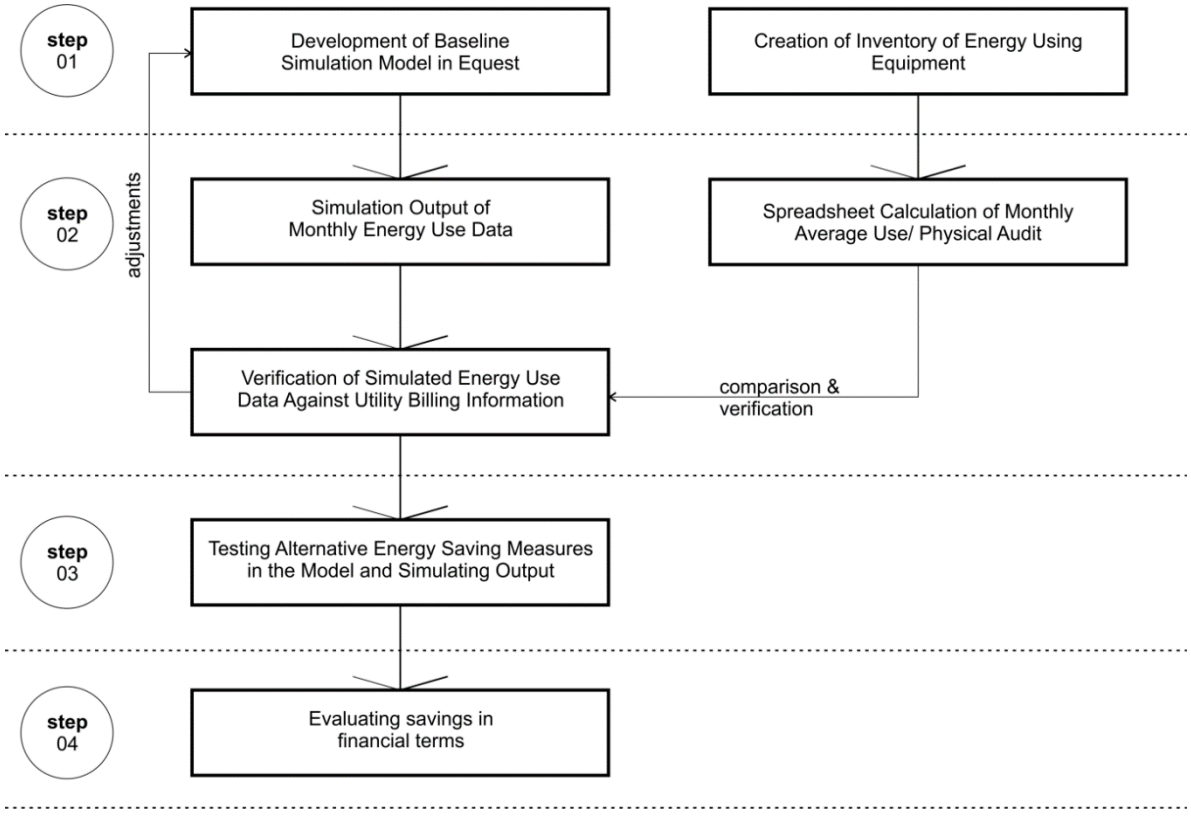

Figure 1: Methodology

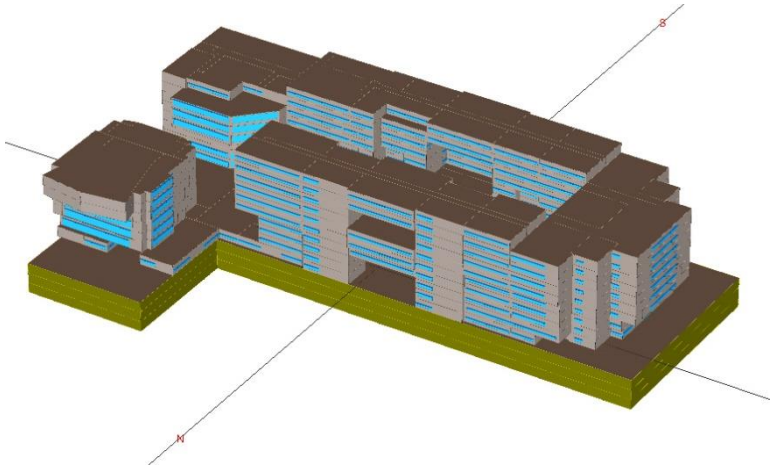

Figure 2: Simulation model in EQuest software

The factors that were not included in the model are external equipment energy use such as perimeter lighting, water treatment, and related facility energy usage, special equipment use if any, and the fresh air supply fans.

5. FINDINGS AND RECOMMENDATIONS

ASHRAE (2003) identifies three levels of energy audits: (1) walkthrough, (2) energy survey & analysis, and (3) detailed analysis of capital investment modifications. Our study was limited to energy survey and analysis (a level-2 audit) with a limited application of energy simulation software and a significant degree of generalization. These generalizations included: (1) the use of utility billing data from the Dhaka Electric Supply Company (DESCO) and the Titas Gas generation company to determine the total energy use of the building without any calibration of the metering systems; (2) no external equipment energy use was included, such as perimeter lighting, water treatment and related facility energy usage, such as special lab and security equipment, and the fresh air supply fans; and (3) no physical sub-metering were used and operation time was assessed based largely upon a word of mouth approximation by the related professionals in charge of operation and maintenance within the campus. These generalizations were adopted primarily due to unavailability of reliable information and testing equipment, as well as, the ongoing facilities extensions process posed a difficulty in keeping up with data updating. These factors were assumed as relatively constant over the time in question, a comparison with the baseline year 2012, indicated that the simulated data when multiplied with a constant correction factor of 0.1 it closely compared with the observed metered readings from DESCO and TITAS. This gave an energy usage value for the baseline year as 2,480,786 kWh (directly metered) against a simulated model value of 2,448,513 kWh, with a difference of 32,273 kWh or 1.3% deviation from the total metered annual billed amount. While the usage figures changed significantly due to increased time of operation of the facilities in 2014 and 2015, the correction factor had to be modified to 0.4081 to yield a total usage value of 9,993,935 kWh to closely compare with the metered annual usage of 9,989,179 kWh giving a difference of 4,756 kWh or +0.048% deviation from the total annual metered use of 2015. A comparative chart of the adjusted simulated data with the two year series of available metered information is provided in Figure 3.

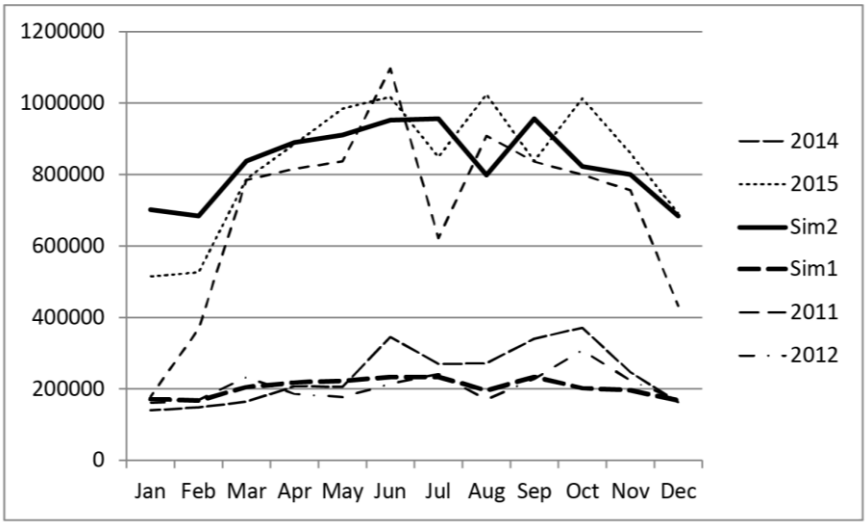

Figure 3: Utility Company generated energy use compared with simulation value

The simulated data follows a more conservative variation as compared to actual metered energy use, while the total annual consumption remains close to average due to the correction factor applied. With these adjustments to the simulation results, a number of energy saving potentials were tested in the simulation model, to identify impacts of different strategies to possibly contribute towards overall energy efficiency of the campus with respect to billing figures of 2014 and 2015. These are discussed below:

(a) Energy system use control:

Typically, NSU thermostats are set at 23^{O} Celsius which can be raised to 26^{O} Celsius with a practice of wearing light clothing. This has the potential to save 11% of the total metered energy annually.

(b) Lighting systems and lamps

Compact fluorescent lamps are used in NSU which are less energy efficient. By replacing these with LED lights energy savings of about 10% can be achieved on the meters annually.

(c) Alternative energy systems

Solar panels may be installed on 50% or more of the roof area of the main academic blocks. These can harvest up to 15% of the campus energy requirements.

(d) Motors

Using variable speed drive motors can save fan energy significantly and simulation results indicate that this has a metered energy saving potential of about 10% annually.

These measures alone provide an energy saving option in the range of 45% annually in the NSU campus. More savings are possible with careful planning, cost-intensive modifications in the system, replacement with more efficient energy components and integration of renewable energy devises, including options c and d above. Human factors that can contribute to further energy saving that has not been quantified in this study, but is fairly reasonable to assume, could be the following:

(e) Turning off lighting, equipment, and air-conditioning and using less peak time electricity

Energy savings can be increased by removing unnecessary lighting, adding switched circuits, using motion sensors and light-sensitive controls and automated on-off controls based on usage time. In addition, energy cost, as opposed to energy saving, can be achieved by adjusting the timing of the system starts and stops. Fourteen (14%) electrical energy is used at peak rate; therefore, while energy cannot be saved by offsetting use time, billing cost can be reduced by 14% by offsetting peak-time electricity use.

From the above discussion, it is clear that with conservative estimates a monetary saving of about 1.75 to 2.0 crores per year can be easily targeted (based on electricity rates of 2014-2015). New university campus designs that follow the NSU model may want to emphasize these design and management measures early on in the design and planning phase to realize large operational energy reductions.

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Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Investigation of Soils' Behaviour by Using Lime

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Abstract

Two important parameters which are used to pavement design are subgrade soil strength and traffic loading. The aim of this paper is to find out the changes of soils strength by the use of lime. For these, three different types of lime-ratio, say 3%, 4%, 5% by weight, are mixed with soil. The load-bearing capacity is measured by unsoaked CBR values. Tests were performed for both raw soils without lime treatment and soil with lime treatment. From the result, it is found that the increment of the lime ratio has increased the soil's load-bearing capacity. This result indicates that lime can be used in strengthening the subgrade of the pavement.

Keywords: Subgrade, unsoaked CBR, lime, load-bearing capacity

1. INTRODUCTION

Soils with low plasticity, low compressibility, and high strength under loads, are suitable as a base material for any engineering construction projects. Many methods are available to increase the soil strength as well as decrease the plasticity and compressibility of soil. Among various methods, lime stabilization is a common, applicable, and easy-to-use approach that can improve the geomechanical and geotechnical properties of clayey sand fills (Arabani, 2017)

Expansive soil is very sensitive and can be shrinkage or expanded in a great amount with the little change of moisture content and introduces the damages in construction. Soils with low bearing capacity should be improved by stabilization (Panjatan, 2014). Through the stabilization, the bearing capacity of soil can be improved and plasticity of soil may be reduced.

Wiqoyah divided the soil into four types according to their plasticity index which is showing in table 1 (Panjaitan, 2014).

Table 1: Plasticity of soil according to their plasticity index

PI	Plasticity	Soil Properties
0	Non plasticity	Sand
< 7	Low plasticity Medium plasticity	Silt
7 – 17	High plasticity	Silt-clay
> 17		Clay

California Bearing Ratio (CBR) value indicates the bearing capacity of the soil. CBR value is an important soil parameter in the design of flexible Pavement as it is considered as the strength measuring parameter (Roksana, 2018). If soil it's mixed with lime, its CBR value increases. It is because when lime ($Ca[OH_2]$) is mixed with soil with the presence of optimum moisture content, the calcium (Ca^{2+}) ions and hydroxyl (OH^-) ions dissociate into the solutions, and increases the pH value of the soil solutions. It courtesies the exchange of Ca^{2+} ions from lime with the monovalent ions such as -Na^+, K^+, etc. present in the diffused double layer (DDL) of negatively charged soil minerals. As a result, the plasticity index reduces instantly with improved workability and increased the strength of soil (Cherian, 2015).

Amadi, (2017) showed the most noteworthy effect of lime on fine-grained soils. He established that adding lime into the soil can decrease the plasticity, swelling, shrinkage potential and increased the workability as well as the strength of soil (Amadi, 2017). According to Clare, (1957), hydrated lime can be used to stabilize the soils with high clay content. And its main benefit is increasing the elastic limit of the clayey soil (Clare, 1957). Besides that, Jayanthi has also been reported that the relative stabilizing effect correlates well with the calcium oxide (CaO) content of various limes (Jayanthi 2016). Ingles and Metcalf provides some criteria for lime in the mixture which are given below (Ingles, 1972)

Table 2: Criteria for adding lime into different soil

Type of soil	Modification	Stabilization
Fine crushed rock	(2% - 3%)	-
Well graded clay gravels	(1% - 3%)	3%
Sands	-	-
Sands clay	-	5%
Silty clay	(1% - 3%)	(2% - 4%)
Heavy clay	(1% - 3%)	(3% - 8%)
Very heavy clay	(1% - 3%)	(3% - 8%)
Organic soil	-	(3% - 8%)

2. LITERATURE REVIEW

The improvement of in-situ and reclaimed soils undergone by lime treatment have been more widely employed in the past recent years, especially in stabilization of soils for various applications (Ingles and Metcalf, 1972; Mitchell, 1981; IRC, 1976; Macham et al., 1977; Kezdi, 1979; Broms and Boman, 1979; Markus et al., 1979; NAASRA, 1986; TRB, 1987; Hausmann, 1990; TRL, 1993; Bell, 1993). Stabilization by chemical admixtures such as lime is intended to modify the interactions between lime, water, and soil by surface reactions in such a manner as to make the behavior of the soil with respect to water and hardening agent effect most favorable for the given purpose.

Lime stabilization is widely recommended for construction of roads (Ingles and Metcalf, 1972; NASARA, 1986, Hausmann, 1990). The pressure injection method of lime stabilization has been used in Jackson, Mississippi, in Calexico, California and in Tucson, Arizona (Chen 1975).

3. METHODOLOGY

For this study, the soil sample was collected from Noakhali district, Bangladesh. Geographically the location is 22.9833^0N 91.2333^0E. The sample was surface soil and collected at disturbed state. Before starting the experiment, a soil sample was air dried and crushed by wooden hammer and sieved through 4.75mm sieve. For the modification of soil, an appropriate amount (3%, 4%, and 5% by dry weight of soil) of lime was separately added to the soil.

Figure 1: Location of Senbag, Noakhali District (Study Area)

The sample was surface soil and collected at disturbed state. Before starting the experiment, a soil sample was air dried and crushed by wooden hammer and sieved through 4.75mm sieve. For the modification of soil, an appropriate amount (3%, 4%, and 5% by dry weight of soil) of lime was separately added to the soil.

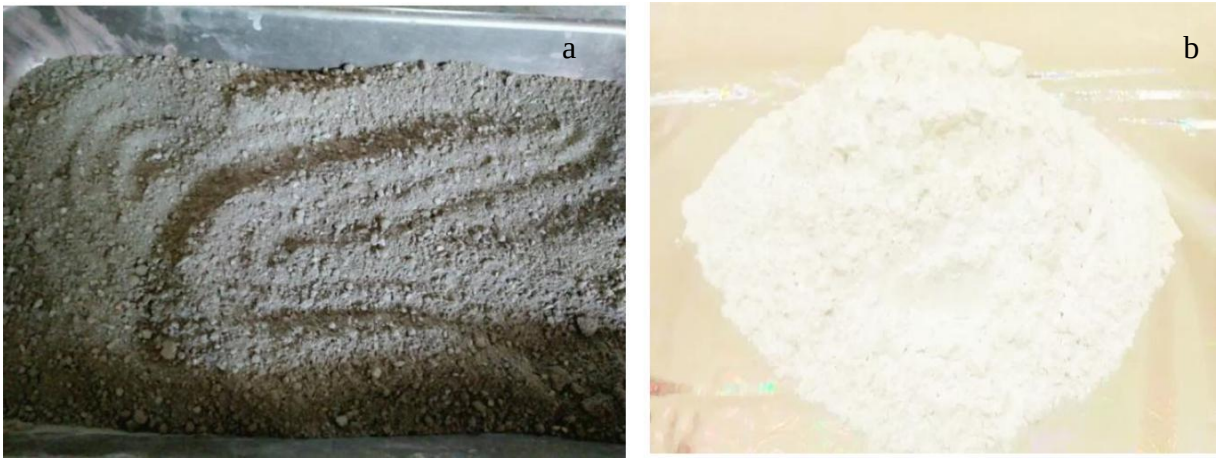

Figure 2: Materials -a) Soil b) Lime

First of all, index properties such as specific gravity, grain size analysis, Atterberg limit, i.e. liquid limit, plastic limit and plasticity index, and shrinkage limit were measured. AASHTO or ASTM method was used for these test.

The standard Proctor test described by AASHO was used to determine the compaction characteristics of a soil. Compaction test was done to find out the maximum dry density (MDD) and optimum moisture content (OMC) of soil. The standard Proctor test was conducted by making 3 layers, applying 25 blows each of a 5.5lb hammer falling from a height of 1 ft. using 1/30 ft^3 mold.

The California bearing ratio (CBR) test carried out to measure the strength characteristics of the soil. Unsoaked CBR value was used by using standard Proctor method. The CBR value was calculated for 10, 25 and 56 blows for fresh soil. Then the same was conducted by using a different amount of lime.

4. RESULT AND DISCUSSIONS

The soil is classified as clay soil with high plasticity index because its plasticity index is greater than 17%. This soil sample is classified as CL or lean clay according to USCS (Unconfined Soil Classification System).

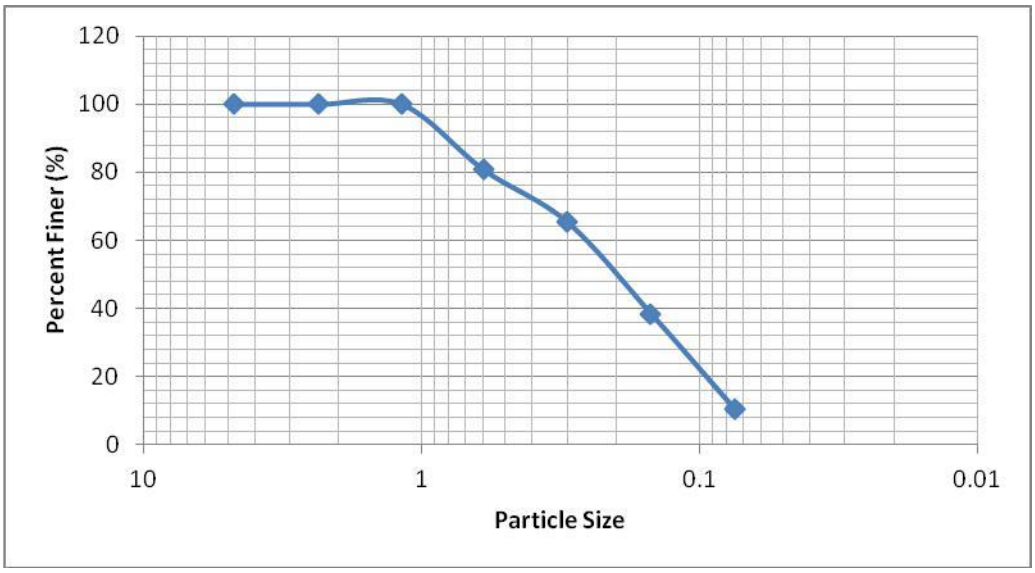

Figure 3: Grain Size Analysis

The important physical characteristics of the untreated soil sample are given below.

Table 3: Physical Properties of Soil

Index Properties	Experimental value
Liquid Limit	37.4 %
Plastic Limit	14.43 %
Shrinkage Limit	12.9 %
Plasticity Index	22.1%
Specific Gravity	2.69
Maximum Dry Density	104.9 lb/ft^3
Optimum Moisture Content	16.9%

CBR Values of raw soils was calculated in unsoaked condition. Effect of lime on properties of soil is very much dependent on the percentage lime mixed in the soil. Various percentage of lime into the soil can change its load-bearing capacity.

Test results of CBR values with various percentage of lime addition are given in table 4 and graph 4.

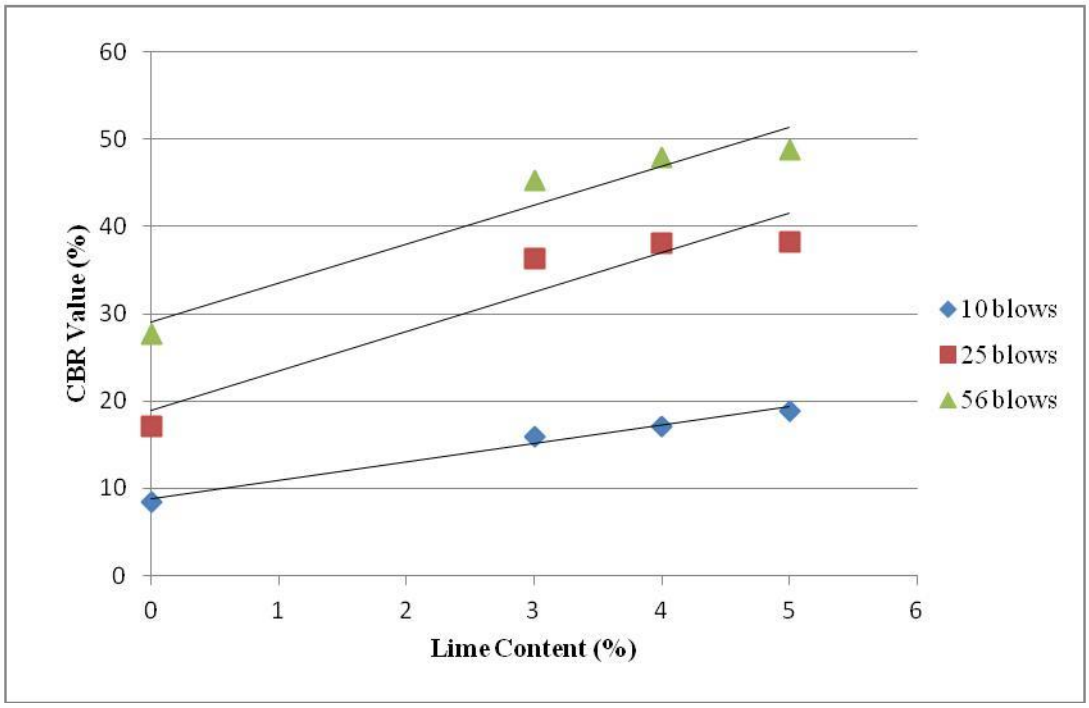

Figure 4: CBR value versus lime variation for 10, 25 and 56 blows

Figure 4 shows 3% added of lime increase the CBR value for 10 blows approximately 77%. CBR value is increasing with the lime addition gradually. For 4% and 5% addition of lime, CBR value is increasing by approximately 110 % and 122 % respectively. For 25 blows, 3% added of lime increase the CBR value approximately 113%. For 4% and 5% addition of lime, CBR value is increasing approximately 122 % and 124% respectively. For 56 blows, 3% addition of lime increase the CBR value approximately 64.2%. For 4% and 5% addition of lime, CBR value is increasing by approximately 73 % and 76 % respectively.

Table 4: Result CBR value with adding of lime

No. of blows	CBR Value (Raw Material)	Increase in CBR value with addition of 3% lime (%)	Increase in CBR value with addition of 4% lime (%)	Increase in CBR value with addition of 5% lime (%)
10 blows	8.49	87	101	123
25 blows	17.10	113	123	124
56 blows	27.66	64	73	76

From this test result, it can be stated that CBR value is changed progressively by the adding of lime. Formation of cementations compounds termed calcium- silicate- hydrate (C-S-H), calcium- aluminate- hydrate (C-A-H) and calcium- aluminate- silicate- hydrate (C-A-S-H) was happened by the hydration of the lime and the pozzolanic reactions (Amadi, 2017). That's why CBR value was increasing gradually.

5. CONCLUSION

This investigation was done to determine the characteristics of selected soil sample and evaluate the performance of soil by addition of lime. Several Characteristics of soil were investigated. According to USCS classifications, the soil sample is classified as CL or lean clay which is inorganic clay. From the test results, it is found that the sample was clayey soil with high plasticity index. To increase its load bearing capacity as well as soils' strength, lime can be added within the marginal limit. Load bearing capacity of a soil is increasing with the increasing of lime content. In this study CBR value of soil was increasing for 3%, 4%, and 5% of lime addition. Optimum moisture content of the sample was not found within the range as it was done in a limited range. This indicates that a broader range is needed to find the optimum moisture content of the sample.

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Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

National Climate Fund Projects in Urban Areas of Bangladesh: A Study of Their Spatial Distribution and Association with NAPA (2005) and BCCSAP (2009)

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Abstract

According to IPCC, Bangladesh is one of the most vulnerable countries to climate change. The impacts of climate change are likely to affect population distribution by increased in-migration to urban areas which is most likely to create burden to existing services and facilities. Bangladesh has 532 urban areas and these urban areas accommodate 36.5% of the total population. These urban areas also contribute to 65% of GDP (Gross Domestic Product). Again, the urban population will exceed the rural population by 2030. Climate change related risks are affecting people, their health, livelihoods and assets. Therefore, climate change has negative impact on local and national economies and ecosystems in these urban areas. In 2009, Government of Bangladesh established the Bangladesh Climate Change Trust Fund (BCCTF) and Bangladesh Climate Change Resilience Fund (BCCRF) to finance mitigation and adaptation programs. There are around 463 projects under these funds and among them 157 projects are located in urban areas. The aim of this research is to identify the spatial distribution and nature of these projects along with their association with national climate related policies and plans. This research identifies whether there is consistency among the allocation of these national climate funds in the urban areas and national adaptation programme of action (NAPA) and Bangladesh climate change strategy and action plan (BCCSAP). Most projects under national climate funds, emphasized on water management, environmental and infrastructural improvement, improvement of drainage system and waste management. This research would help policy makers, planners and other stakeholders to understand whether there is proper allocation of climate funds according to the national climate change policies and plans.

Keywords: Climate change, Climate funds, Urban areas, NAPA, BCCSAP.

1. INTRODUCTION

IPCC (Intergovernmental Panel on Climate Change) has identified Bangladesh as one of the most vulnerable countries to climate change which is facing consequent diversified natural hazards because of its unique physiographic feature, location and different socio-economic factors (Das and Hossain, 2017; Ayers et al., 2014; Kabir, 2014; Ahmed 2012; Das, 2010; Rahman and Alam, 2003). Bangladesh loses 1.5% of its GDP (Gross Domestic Product) due to increased frequency and intensity of natural disasters as a result of climate change (Ministry of Environment and Forests, 2012). Urban climate change-related risks such as rising sea levels and storm surges, heat stress, extreme precipitation, inland and coastal flooding, drought, water scarcity and air pollution are increasing with widespread negative impacts on people, their health, livelihoods and assets and also on local and national economies and ecosystems (Revi et al., 2014). Moreover, climate change will have profound impacts on a broad spectrum of infrastructure

systems, services, the built environment, and ecosystem services (Revi et al., 2014). Climate change will also increase rural urban migration which would add to the existing challenges of the big cities of Bangladesh from socio-economic and environmental context (Martin et al., 2013; International Organization for Migration, 2010).
Bangladesh has 532 urban areas classified into twelve City Corporations and 318 Pourashavas (BBS, 2011; LGED, 2017). About 60% of the urban population reside in the city corporations, while 40% live in Pourashavas (Parvin et al., 2013; LGED, 2017). These urban areas accommodate 36.5% of the total population and the urban population will exceed the rural population by 2030 (Department of Economic and Social Affairs, 2017). The contribution of these urban sectors to GDP was about 65% in 2012 (Ahmed and Ahmed, n.d.).

In terms of climate change adaptation specific planning, Bangladesh developed National Adaptation Programme of Action (NAPA) in 2005 and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009 (Ayers et al., 2014; Das and Hossain, 2017). The objective of BCCSAP is to reduce or eliminate the risks of climate change, increase the country's resilience to climate change, and expedite development of the country following a low-carbon path through an integrated approach of socio-economic development and management of climate change issues (Ministry of Environment and Forests, 2012). In 2009, Government of Bangladesh established the Bangladesh Climate Change Trust Fund (BCCTF) and the Bangladesh Climate Change Resilience Fund (BCCRF) to finance mitigation and adaptation programs and thereby ensure the implementation of the six pillars of BCCSAP, 2009 (Das and Hossain, 2017; Kabir, 2014). The main objectives of BCCTF and BCCRF are to address most vulnerable communities, farming communities and research activities (Das and Hossain, 2017).

As most of the population and income generating activities are concentrated in the urban areas, climate change would have huge impact in urban areas. Bearing this in mind, this research aims at exploring the spatial distribution of climate change funds in the urban areas of Bangladesh along with its association with national plans.

2. RESEARCH FRAMEWORK

IPCC (2014) shows that, climate change would have influence on water supply systems, waste water system, energy systems, food systems, transportation systems, housing, human health, key economic sectors and services, livelihoods and access to basic services in urban areas. This study is primarily based on secondary database. A dataset showing the list of 452 BCCTF projects taken till 2017 along with the name and objectives of the projects, implementing body, timeline and budget allotted for the project have been collected from Bangladesh Climate Change Trust (BCCT). Among the 452 BCCTF projects, 155 projects in urban areas have been selected. Projects in urban areas under BCCRF till 2016 have been analyzed. A GIS Shape file showing the urban areas of Bangladesh has been collected (Rahman et al., 2017). Spatial allocation of the projects of BCCTF and BCCRF has been identified. NAPA (2005) and BCCSAP (2009) have been reviewed to understand the strategies which have been stated to control the climate change effects in the urban areas of Bangladesh. Finally, BCCTF and BCCRF projects in urban areas have been investigated on the basis of the six pillars of BCCSAP, 2009 to assess their compatibility with the action plan. In this research, the projects undertaken only in the urban areas have been selected for detail analysis and sector specific projects were not considered.

3. ALLOCATION OF BCCTF AND BCCRF IN URBAN AREAS

3.1. Spatial Distribution of BCCTF and BCCRF

Figure 1 shows that, most of the urban projects under BCCTF are located in Dhaka Division (33) and Barisal Division (31). Vector overlay of different types of climate hazards and Natural Break (Jenks) methods have been used to identify the most vulnerable areas to climate change (Tabassum and Ishrat, 2019). According to Figure 2 below Barisal division is one of the most vulnerable areas for climate change.

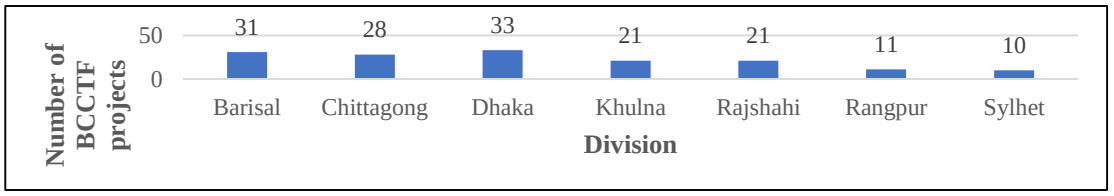

Figure 1: Distribution of BCCTF projects in urban areas of Bangladesh (BCCT, 2017)

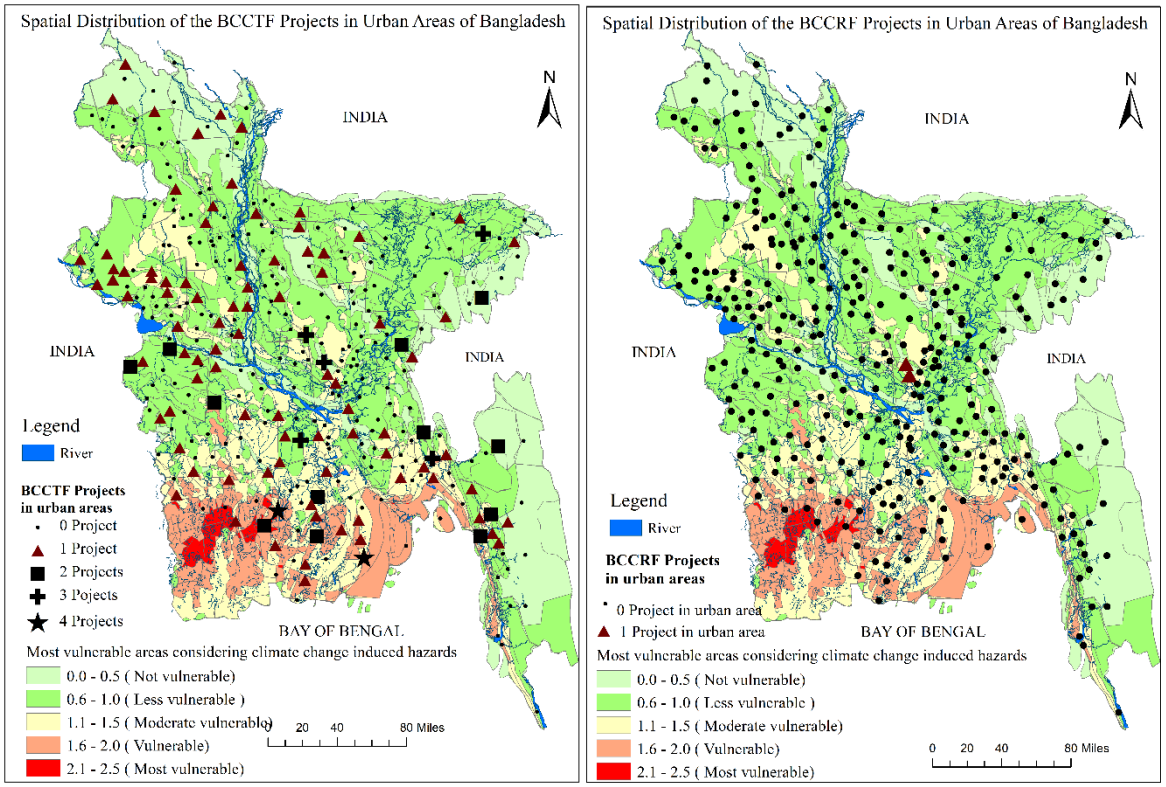

Figure 2: Spatial distribution of BCCTF and BCCRF *(Base map source: Tabassum and Ishrat, 2019)*

Again, 226 urban areas do not have any project under BCCTF or BCCRF and 10 of those urban areas are in the vulnerable zone (Figure 2). Most of the projects under BCCTF are distributed in different urban areas while there are only two BCCRF funded projects in Dhaka city (Figure 2). Both of the projects under BCCRF address the issue of urban flood (The World Bank, 2016).

3.2. Implementing Ministry and Agency

Tables 1 and 2 show the implementing ministries and agencies of BCCTF projects. Most projects (132) are implemented by Local Government Division. However, 123 BCCTF projects are implemented under municipality (Table 2). Fund allocation also shows that, most of funds are allocated for BCCTF projects under Local Government Division. BCCRF projects are implemented by The World Bank.

Table 1: Implementing ministry of BCCTF projects *(Source: BCCT, 2017)*

Implementing Ministry	BCCTF projects	Total Cost (in lakh BDT)
Local Government Division	132	41211.04
Ministry of Education	2	199.99
Ministry of Environment and Forests	6	5872.38
Ministry of Shipping	1	2218.00
Ministry of Water Resources	14	9801.95

Table 2: Implementing agency of BCCTF projects *(Source: BCCT, 2017)*

Implementing Agency	BCCTF projects
Municipality	123
Bangladesh Inland Water Development Authority	1
Bangladesh Water Development Board	14
City corporation	4
Department of Environment	4
Department of Forests	3
Dhaka University	2
Local Government Engineering Department	4

3.3. Fiscal Year of BCCTF Projects

Figure 3 shows the fiscal year of the projects of BCCTF in urban areas till 2017. It shows that, initially after the formulation of BCCTF in 2009, the projects under BCCTF fund were very few. Only 21 projects have been initiated in the urban areas before 2013. However, the number of projects increased with time and 51 projects have been initiated in the fiscal year of 2015-16.

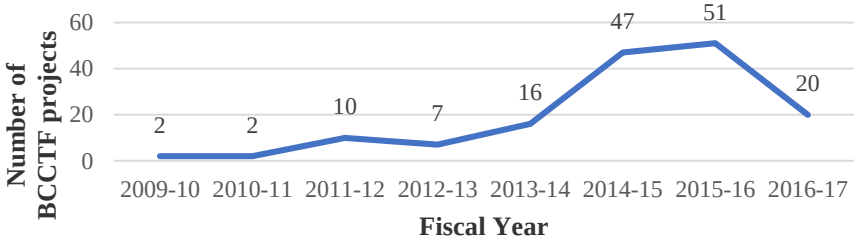

Figure 3: Fiscal year of the BCCTF projects (BCCT, 2017)

3.4. Estimated Budget of the Projects

Table 3 shows that most of the projects have fund less than 250 lakh BDT. Only seven projects have cost more than 1000 lakh BDT. Again, both projects under BCCRF have cost more than 1000 lakh BDT.

Table 3: Estimated cost of the climate funds in lakh BDT
(BCCT, 2017; Ministry of Environment and Forests, 2009)

Estimated cost in lakh BDT	BCCTF Project	BCCRF Project
< 250	76	0
250-500	59	0
500-750	4	0
750-1000	9	0
> 1000	7	2
Total	155	2

4. ASSOCIATION OF BCCTF AND BCCRF WITH NAPA AND BCCSAP

NAPA (2005) have put emphasis on reduction of climate change induced hazards through coastal afforestation with community participation, provision of safe drinking water to combat enhanced salinity due to sea level rise, capacity building for integrating climate change in planning, construction of flood shelter and information centre to cope with enhanced recurrent floods in major floodplains, enhancing resilience of urban infrastructure and industries, promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future etc. (Ministry of Environment and Forests, 2005). Allocation of BCCTF and BCCRF also shows that most of the projects emphasize on urban infrastructural development, provision of safe drinking water and sanitation, waste management, provision of solar light etc.

Table 4 shows the distribution of BCCTF and BCCRF projects on the basis of six pillars of BCCSAP. Most of the projects addresses pillar three (129 projects). These projects are mainly for infrastructural or structural improvement, road construction, drainage improvement etc. Most of these projects are implemented by Local Government Division. The projects under pillar one are adaptation projects to improve human health, provision of safe drinking water and sanitation, waste management etc. BCCTF projects under pillar five are mainly development of eco-park, forestation, provision of solar light etc. Only two projects have been taken under pillar four and both of them are implemented by University of Dhaka. The projects under pillar two include community-based adaptation programs to tackle climate change. Again, both projects under BCCRF addressed pillar two and they focus on building local resilience to disaster risk and innovations in flood risk mitigation in Dhaka city (Ministry of Environment and Forests, 2009). Though, the issue of capacity building and institutional strengthening has been an important issue both in NAPA (2005) and BCCSAP (2009), the allocation of BCCTF and BCCRF shows that, it is quite neglected in urban areas.

Table 4: Distribution of BCCTF and BCCRF Projects on the Basis of Six Pillars of BCCSAP

Pillars of BCCSAP (2009)	BCCTF Project		BCCRF Project	
	Number of projects	Total Cost (in lakh BDT)	Number of projects	Total Cost (in lakh BDT)
Pillar 1: Food Security, Social Protection and Health	15	7038.63	0	0.00
Pillar 2: Comprehensive Disaster Management	2	899.00	2	6731.91
Pillar 3: Infrastructure	129	47562.76	0	0.00
Pillar 4: Research and Knowledge Management	2	199.99	0	0.00
Pillar 5: Mitigation and Low Carbon Development	7	3602.98	0	0.00
Pillar 6: Capacity Building and Institutional Strengthening	0	0.00	0	0.00

CONCLUSION

Bangladesh is one of the most vulnerable countries to climate change and urban climate change-related risks are increasing with widespread negative impacts on people, their health, livelihoods and assets and also on local and national economies and ecosystems. To address the impacts of climate change, 155

BCCTF and two BCCRF projects have been taken in urban areas of Bangladesh. Most of these projects are situated in Barisal and Dhaka division and implemented by local government division. Municipalities are mainly responsible for implementing the projects and most of these projects were initiated in the fiscal year of 2014-15 and 2015-16. The association of BCCTF and BCCRF with NAPA and BCCSAP shows that, though capacity building and institutional strengthening has been an important issue both in NAPA (2005) and BCCSAP (2009), it is quite neglected in urban areas. Again, most of the projects addressed pillar three and these projects are mainly for infrastructural or structural improvement, road construction, drainage improvement etc. Again, only two projects have been initiated under BCCRF fund and both of them addressed the issue of urban flooding in Dhaka city. However, 226 urban areas do not have any projects under BCCTF or BCCRF and 10 of those urban areas are in the vulnerable zone. So, these neglected urban areas should be considered for future fund allocation. Again, capacity building and institutional strengthening, research and knowledge activities, mitigation policies, comprehensive disaster management, adaptation program etc. should also be included in the future projects for climatic impact mitigation in the urban areas.

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Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Integration of Productive Landscape and Urban Development: Continuous Productive Urban Landscape of Border City

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Abstract

Every city has to face the pressure of urbanization and change, according to the national, regional and local forces. In addition to that the border cities have to deal with the global forces as it shares the country border with another country. Benapole is such a Border city containing the largest land port of Bangladesh. Everyday commuters are increasing pressure for the city. From 2007 "Asian- Highway- Corridor" has been the national priority through the Jessore- Benapole highway to fulfill the international economic demand. Due to these reasons the process of urbanization has sped up and the productive landscape is consumed by the unplanned development of the city. On the other hand, the profitable income opportunities offered by the development is provoking the former agrarian community to non-agrarian occupation. Both of the phenomena caused by urbanization are indicating the future food insecurity. Food insecurity poses a major threat with both short- and long-term impacts on human survival and well-being. As a border city, the international economic demand should be fulfilled. On the other hand, the future food security should be secured. In this context, the research will focus on the question of how productive landscape can be integrated with the urban development to ensure the future food security. The objective of the research is to investigate the present condition of the productive landscape of Benapole and analyse the impact of urbanization on it and finally, to explore the prospects and challenges of productive landscape of Benapole. The research will be a qualitative research using photographic and mapping analysis method. The research can be expected to provide some intervention strategies and a design scheme for Continuous Productive Urban Landscape (CPUL) to integrate productive landscape with urban development.

Keywords: Border City, Productive Landscape, Continuous Productive Urban Landscape

1. INTRODUCTION

Bangladesh, a small predominantly agrarian country is now experiencing a very high rate of urbanization. Benapole is the most important land port of Bangladesh sharing the India-Bangladesh border with Petrapole of India. The total area of the Benapole municipality is 8.6 sq. km. and constitutes a total population of 36524. Benapole was a Union Parishad before 2006. It became a municipality at 2006, and within 5 years of the establishment it was promoted from category C to A in 2011 (UDD 2012). The existing Jessore-Benapole highway has passed through the municipality. The land port facilities are located beside the highway constituting an area of 1200m long and 100-250m width. The land port facilities occupy an area of approx. 60.2 acres to the west of Benapole municipality. The heavy land port facilities like the bus terminal, import-export truck terminal, parking area adjacent to the highway has cut through the municipality into two divisions spatially and physically. Total emerald network of the municipality is disconnected already because of that.

More over the highway has been playing an important role in increasing the bilateral ties between the two countries, it has been proposed as an important national Highway (Bhatiapara-Norail-Jessore-Benapole). This Highway (N706) is a part of The Asian Highway 1 (AH1), which is the longest route of the Asian Highway Network, comprises over 141,000 km of roads passing through 32 member countries of UN ESCAP (Bala 2017). Many manufacturing industries like export processing zones are

also proposed to support the demand of the international corridor. These profitable income opportunities are provoking the former agrarian families to the non-agrarian work leaving agro-based livelihood. This will cause a fall in our future food production.

On the other hand, to support the land port, the everyday commuters, migrated people from villages and the growing economic needs, various urban facilities took place beside the highway. The urban area is expanding towards the north and south part of the municipality consuming the agricultural land and encroaching the river day by day. Both the reasons caused by urbanization and pressure of land port is a threat to the productive landscape and could result in food insecurity in the near future. Food insecurity poses a major threat to contemporary societies with both short and long term impacts on human survival and wellbeing. So, it can be said that the urban development of Benapole as a border city is not sustainable. Being a land port city, Benapole has to fulfill the demand of international economy and along with it, the productive landscape of Benapole should be conserved and increased to fulfill the future demand of food of the city as well as the region. To ensure the sustainability of a border city it should be prepared to deal with the increasing demand of urban development without the depletion of productive lands.

If the open spaces of urban areas can be integrated in a productive way, it can offer sustainability in three dimensions. First the economic sustainability by using the unused land in a productive way like food production, recreation, work place for the people of former agricultural society. Though it depends on the cost of land. Food miles is the distance food is transported from the time of its production until it reaches the consumer (Engelhaupt 2008). The reductions of expenses in food miles will also be an economic benefit. Environmental sustainability results from the reduction in food miles and therefore embodied energy and associated carbon dioxide emissions (Department for the Environment Farming and Rural Affairs 2005). If organic agriculture is practiced, the elimination of energy intensive artificial fertilizers makes a further contribution to reducing environmental impact. And finally the socio-cultural sustainability will be enhanced by the green corridor, community involvement in producing urban food and by conserving as well as enhancing the tradition of agrarian society. In addition to that another extra benefit will be added as Benapole is a border city. The CPULs also create a true image of our country as an agrarian one to the everyday tourists also.

Basically this study focused on three major objectives. At first the study will investigate the present condition of productive lands and analyze the impact of urbanization on it. Then the study will explore the prospects and challenges of productive landscape of Benapole. Finally, it will provide strategies of Continuous Productive Landscape to integrate productive landscape within urban design

2. CONTINUOUS PRODUCTIVE URBAN LANDSCAPE (CPUL)

Cities have spread rapidly but not uniformly; urban expansion is not a consistent process in all directions beyond the built up area (Aguilar 2008). Different types of transition zones between urban areas are created by the unplanned development. Because some areas are uniform with compact and extensive developments, some urban areas contain small urban patches with open spaces among them and others constitute lines of development along corridors like roads or rivers. In 1990, Allen referred to the patchy network of cities and conceptualized an idea that agriculture could fit into the contemporary urban fabric (Allen 1999). Integration of agriculture with urban development can contribute to the creation of sustainable cities without compromising the urbanity and the sustainability of a compact city.

Productive landscape is based on the mixture of uses, where they all support each other to create a harmonious space. Productive urban landscape comprises of open urban spaces planted and managed in such a way so as to be environmentally and economically productive. On the other side Continuous Landscape is an idea of a network of planted open spaces in a city which is spatially continuous, such as linear parks or inter-connected open patches, sometimes referred to as a green infrastructure. Overlaying the sustainable concept of Productive Urban Landscapes with the spatial concept of Continuous Landscapes proposes a new urban design strategy which would change the appearance of contemporary cities towards an unprecedented naturalism.

Continuous Productive Urban Landscape (CPUL) is defined as a strategy for the coherent integration of urban agriculture into urban space planning (Viljoen and Bohn 2009). CPULs will be open landscapes productive in economical, sociological and environmental terms. It will be city-traversing open spaces running continuously through the built urban environment, thereby connecting all kinds of existing inner-city open spaces and relating, finally, to the surrounding rural area. Vegetation, air, the horizon, as well as people, will be able to flow into the city and out of it. Partially, the city will become open and wild (Viljoen and Howe 2012).

CPULs will be productive in various ways, offering space for leisure and recreational activities, access routes, urban green lungs, etc. More especially they will provide open space for urban agriculture, for the inner-urban and peri-urban growing of food. The urban land itself, as well as the activity happening on it, will become productive: occupants will act and produce on the ground and with the ground.

3. METHODOLOGY

This is a qualitative research because the approaches and methods used in this research are of a qualitative manner as the research is spread on the basis of qualitative data or content, which are collected from the stakeholders at different levels. Besides, this research wants to understand the contexts or settings in which participants in a study address a problem or issue (J. Creswell, 2012), which tends to the use of qualitative research. The focus of qualitative research is on understanding the phenomenon being explored, rather than solely on the reader, the researcher, or the participants being studied (J. Creswell, 2012). The study focuses on the impact of urban development on productive land of the Benapole municipality. A case study based approach involves the study of an issue explored through one or more cases within a bounded system (i.e., a setting, a context), the approach of this study tends to be a case study based approach.

The first objective is achieved by the study of secondary sources like Plan Book of UDD and pilot survey of the Benapole municipality. Photographs, maps from Google Earth are used to investigate the present condition of productive lands and its relation to the rapid urban development. The second objective is based on detailed survey of the municipality and analysing the data from the survey. Possibilities, prospects of CPUL are studied through different types of mapping and photographic analysis of the municipality. After that the theories and practices of urban design, urban agriculture and CPUL have been studied and a detailed survey was done to achieve the second objective of the research. Case study of regions and cities where productive lands are threatened by development and where strategies of CPUL has been introduced as an alternative of urban design are being studied. Finally, the integration of these data and the analysis report of the previous objectives will provide some strategy to promote CPUL as an integration of urban development and productive lands.

4. FINDINGS AND ANALYSIS OF BENAPOLE MUNICIPALITY

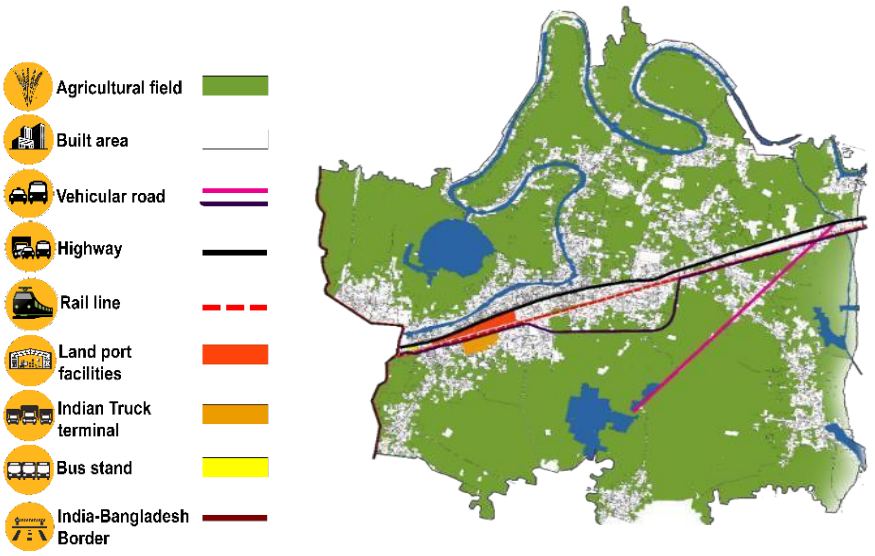

Figure 1. Existing agricultural field area of Benapole Municipality

4.1 Existing condition of Agricultural area of Benapole

Nevertheless, agriculture is still the most predominant land use form for Benapole Paurashava covering more than 40% (4.52 sq.km) of its total area. Rest of the man-made structures incorporate other land use (residential, circulation network, government services, commercial, mixed use, education and research, transport and communication, religious, etc.) covering another 34% (UDD 2012). The major agricultural production is wet rice, jute and vegetables (BBS, 2013). If the morphological development of Benapole is analysed, one will find the depletion of agricultural lands and increase of physical development. The development-driven encroachment by human built-form and settlement is clearly noticed in the following images ("Benapole."23°02'54.55" N and 88°54'36.53" E. Google Earth. January 06, 2018).

Fig 14(a) Agricultural field area of Benapole paurashava at 2003 Source:"Benapole."23°02'54.55"N and 88°54'36.53"E. Google Earth. April 15,2003. January 06,2018.

Fig 14(a) Agricultural field area of Benapole paurashava at 2010 Source:"Benapole."23°02'54.55"N and 88°54'36.53"E. Google Earth. December 12, 2010. January 06, 2018.

Fig 14(a) Agricultural field area of Benapole paurashava at 2016 Source:"Benapole."23°02'54.55"N and 88°54'36.53"E. Google Earth. April 9 ,2016. January 06, 2018.

In figure 2 (a, b, c), the same area marked in white shows the footprint of physical developments whereas green shows the agricultural and forest landscapes. From the following images it is clear that within a time span of 13 years (2002-2016), the white mark has increased alarmingly while at the cost of significant decrease in the productive landscape.

Benapole, Jessore Road and Hakor River act as datum for its linear growth. So, with time, through development and urbanization, the future expansion is expected to engulf most of its agricultural lands

Figure 3. (a) Existing agricultural field area of Benapole municipality (b) prediction of depletion of agricultural field area in the next 20 years (c) prediction of depletion of agricultural field area in the next 40 years

Resulting in possibly an imbalance in local food production. As seen in fig 3 (a, b, c), with the previous pattern of decreasing agricultural land, the prediction of the possible loss of agricultural fields in future is illustrated. With the present rate, within 40 years of time, most of the agricultural fields should be replaced by development as shown in figure 3(c).

4.2 Aquaculture and Productive agro-based economy of Benapole

Total 8.93% of Benapole is covered with fresh water which is used for aquaculture of Benapole. The primary sources are Hakor river, pachuar baor and marshy land of the south part. The secondary sources of fish are the community dighees like "boro dighee" and the tertiary sources are private ponds. Encroaching river, filling the ponds and dumping waste into the waterbodies are threatening the fish supply of future. Six existing rural markets are serving as a commercial hub for rural Benapole where the farmers can sell their agricultural products and fish to the local people. From there the food for the urban area is supplied by other businessmen which is not profitable for the farmers.

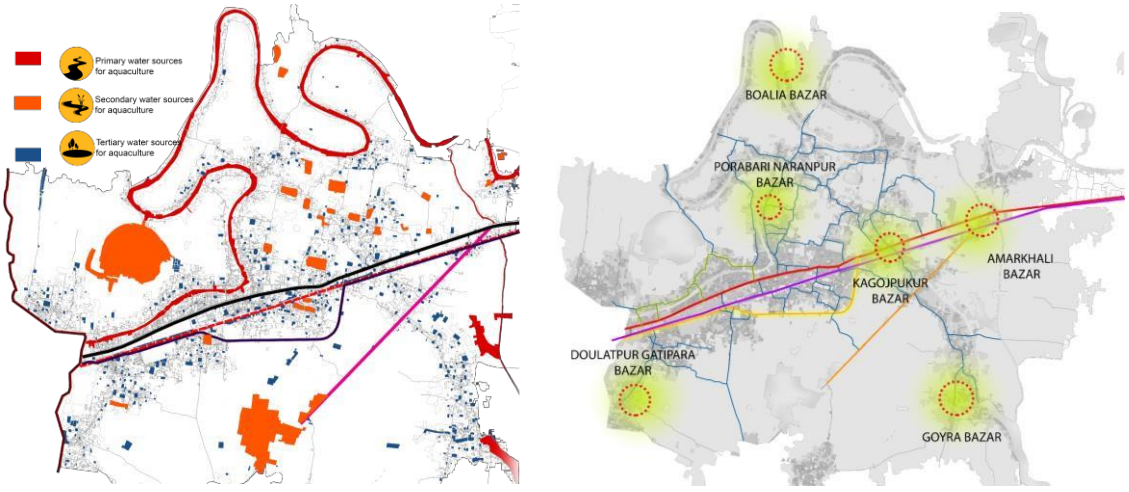

Figure 4. (a)Water sources for aquaculture of Benapole & (b) Existing rural markets in Benapole

4.3 Land port facilities and development

About 80% of total import and export of goods between Bangladesh and India includes passengers passing the land port (UDD 2012). As a port city, Benapole represents the National image to the

passengers. But there has been little effort in this, neither from Central Government nor from the Local Government, especially considering rich natural landscape heritage and agrarian way of life. As shown in fig 5(a), the passengers experience and often encounter a rather congested and enclosed corridor with its two sides being walled up, standing trucks and other vehicles create a haphazard condition on Jessore Road and contributes to the image of the town and the nation in general. All these leave a less than desired image in the memory of passengers. For an otherwise green and landscape-rich nation, the "image of the city" hence falls far from demonstrating the real image of Benapole and the county.

Figure 5. (a)Congested and polluted image of city in entrance of land port and surrounding area (b) & (c) Image of enclosed corridor with its two sides being walled up

4.3 Identified Issues of beanpole Municipality (Based on agriculture)

- Highest amount of agricultural land use compared with Jhikorgachha and Jessore
- Gradual conversion of agricultural lands into nonagricultural functions
- Existence of different agriculture based recreational activity, for example Nobanno Festival
- Lack of support to agro based industries, for example rice mill, wheat mill, storage facility, flower storage etc.
- Potentiality of agriculture unaddressed in the process of urbanization
- Non-agrarian city image while the main land use of the municipality is still agriculture
- Lack of awareness about the depletion of agricultural land and its impact on the future
- Growing interest on non-agrarian occupation over the agro-based income opportunity

5. INTEGRATING PRODUCTIVE LANDSCAPE WITH URBAN DEVELOPMENT IN BENAPOLE CITY

Productive landscape refers to the use of land in ways that helps facing the global challenge of food crisis and achieving food security. For producing food for an ever-increasing number of populations, land so far have been regarded as the most essential component. But because of rapid urban expansion, agricultural lands are shrinking day by day in an alarming rate. Before being too late, the present urbanization and land use pattern should be rethought, and diverted towards a more productive way. Many innovative ideas are now coming forward to enhance the productivity of landscape. Strategy for CPUL of Benapole can be achieved through 5 ideas of intervention.

- Conserving Agricultural lands towards ensuring food security
- Incorporating Agriculture at different public projects and spaces through edible landscape approach
- Promoting support to Agro-industries to encourage agrarian society
- Upholding agriculture as prideful identity

Intervention strategies for CPUL of Benapole

- Rethinking Pachuar Baor area as an agro-ecological park to conserve the existing productive lands
- Emphasizing walkability in Jessore-Benapole highway through eco-friendly landscape
- Restriction of vehicles from Kagojpukur to Port Gate
- Relocation of land port facilities to nearby buffer zone and away from the city core.

- Promoting agricultural nature park to be developed in public open space (Pachuar Baor, present port storage area)
- Providing mini-storage facility and expert zone at existing rural markets.
- Promotion of agro based industries at existing rural markets.
- Introducing productive agricultural technologies to the agrarian community.
- Raising consciousness among community to practice household scale farming by word level workshops
- Setting up Agriculture Service Centers (Krishi Kendro) near wet markets to provide various services to the farmers.

Proposed Scheme for CPUL integrating productive landscape with urban development in Benapole

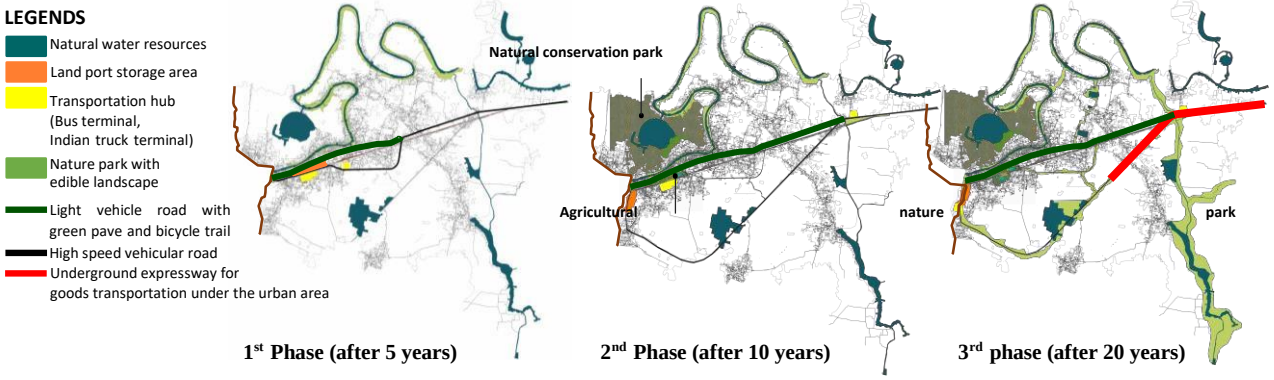

Figure 5. Proposed design scheme for CPUL of Benapole

6. CONCLUSION

Benapole the border city is chosen for the study for its rapid urbanization impact on productive landscape. Following developed countries like UK, Slovenia developing countries like Iran, Mexico are applying CPUL as an approach of urban design to secure the future and reduce ecological footprint. Due to rapid urbanization the ratio of productive lands is decreasing also in Bangladesh. Though ours is an agrarian country, it's also facing the threat of food insecurity in near future. So, Strategies of CPUL can be an approach of urban design for cities of Bangladesh. As the research is qualitative research it lacks in quantitative analysis and supports. The study focuses on a case as well as a specific context so that the global perspective is comprised in some points of the study. It will open up a scope for the urban designers to research further.

ACKNOWLEDGEMENT

This paper is based on a portion of chapter five of an undergoing book called "Re-thinking Benapole: Propositions for an inclusive city", which is an outcome of 1st year 2nd term Design Studio of MSc. in human settlement program under the Architecture discipline of Khulna University. Authors would like to solely thank Prof. Dr. Sheikh Serajul Hakim and Sk. Kabir Ahmed for guiding the whole project. We are grateful to UDD of GoB for funding this study. Also we are thankful to our supportive group mates Muhaiminul Islam Rahi andPuja Mallick. Finally, the author is grateful to many anonymous informants of Benapole municipality, especially the City Corporation Mayor for their keen participation.

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INVITED

Paper 57

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Organic Material Design Strategy for Efficient Organic Photovoltaic Cells

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Abstract:

Bulk heterojunction (BHJ) organic photovoltaic cells (OPVCs) based on a blend of pi-conjugated electron-donor oligomers/polymers and electron-accepting fullerene/nonfullerene derivatives have attracted considerable interest due to recent achievement of power conversion efficiencies (PCEs) of 13%~17% single cell and multi-junction cells with many advantages, such as mechanical flexibility and low-cost solution processing on a plastic substrate for flexible and portable photovoltaic devices. Recently, remarkable and rapid progress has been made in OPVCs technology via polymer structural elucidation, morphology control, and device architecture optimization, etc. Understanding the structure-property relationships for the optimization of plastic semiconductors has become an important topic in the field of material chemistry. However, OPVCs material development has progressed via a trial-and-error approach with a limited understanding of the materials' structure-property relationships and the underlying of materials design and synthesis concept. This work describes several important conceptual aspects of the emerging OPVCs by highlighting key contributions that provided fundamental insights regarding rational material design, donor-acceptor pair matching, blend morphology control and the reduced voltage losses in fullerene/non-fullerene organic solar cells. We also discuss the key challenges that need to be addressed to develop more-efficient fullerene and non-fullerene organic solar cells. This work also gives the guideline how OPVCs will be the next generation solar technology for indoor and outdoor applications.

Keywords: Bulk heterojunction, organic photovoltaic cells, power conversion efficiencies

Paper 58

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Service Area Analysis of Hospitals in Chittagong Using Geographic Information System

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Abstract

The development of Geographic Information System (GIS) technology with transportation modules integrating the geographical accessibility of services and facilities is an added advantage for analysing the built urban environment. In this context, a reconnaissance survey has been conducted on the service area coverage of hospitals providing service to patients, with specialized medical and nursing staff and medical equipment, as a case study in Chittagong City Corporation (CCC). Applying the ArcGIS Network Analyst extension, it has been found that within a 500 m service area, the extent of hospital coverage is significantly low (only 5 % of the CCC area). In case of emergency service only 15 % of the CCC area is served by hospitals in a 1000m coverage. Obtained health utilization indices and rates demonstrated that patient travel patterns are highly political, infrastructural and developmental determinants. Due to the possible long distances, an ambulance usually requires considerable time to reach the site of the incident and from there to an appropriate hospital. Our analysis with computation of optimized service and facility revealed that additional hospitals at optimal locations are required to be built all over the CCC area. For emergency service an emergency map is shown to be effective when used in an integrated manner with CDA, CCC and other government organizations. The result of the study would help decision makers, planners and engineers to provide optimal cutting-edge-technology based services through hospitals in city of Chittagong.

Keywords: Accessibility, Hospital, Service Area, Network Analyst Tool.

1. INTRODUCTION

Over the success of Millennium Development Goals (MDGs), in the seventieth session of the UN General Assembly on 25 September 2015, all the member states have adopted the Sustainable Development Goals (SDGs). The main title was declared as "Transforming our world: the 2030 Agenda for Sustainable Development" and the powerful message portrayed regarding the SDGs was, "No one to be left behind" (UN DESA, 2018). Furthermore, the SDG Goal 3 is "Ensure healthy lives and promote well-being for all at all ages" and Goal 11 is "Make cities and human settlements inclusive, safe, resilient and sustainable" (UN DESA, 2018).

Health facilities are one of the basic needs of humans and hospitals being health care institutions which provide patient treatment with specialized medical and nursing staff and medical equipment (BBC News, 2010), are the prime health facilities people rely on. Cities are now home to more than half of the world's population and this proportion is expected to reach two-thirds by 2050 (UNDP, 2017). As a result, a huge amount of pressure is being exerted on the cities' existing facilities, especially in the health care service sector. In the city area, motorized road transport is the main mode of movement for passengers, especially for long-distance travelling, during emergencies, it becomes very difficult to find acaccessibility in the busy city road. Accessibility is an important ingredient both in the aspects of socio-organizational and geographical terms. The development of Geographic Information Systems (GISs)

technology with transportation modules integrating the geographical accessibility of services and facilities is an added advantage to analyse the built urban environment. Geographical accessibility refers here to the ease with which patients of a given area can reach health services and facilities (Apparicio et al., 2008 and Joseph et al., 1984).

The service areas created by the Network Analyst tool of ArcGIS evaluates accessibility and concentric service areas to show how accessibility varies with impedance (ArcGIS for Desktop, 2018). In an emergency case like a road accident, a patient may require immediate treatment. Due to the potential long distances, an ambulance usually requires considerable time to reach the site of the incident, as well as reaching an appropriate hospital from the site. Chittagong is the second largest metropolitan city of Bangladesh and is considered to have great industrial, commercial and institutional potential the government of Bangladesh has even declared it the 'Commercial Capital' of the country.

For this reason, this city suffers from heavy traffic and traffic conditions are worsening. For emergency services, an emergency map is shown to be effective when used in an integrated manner. So, the objective of the study is to determine the service area of hospital in Chittagong City Corporation using network analyst of ArcGIS.

2. STUDY AREA

Chittagong is the second largest city and the main sea port of Bangladesh, situated on the banks of the Karnafully River. The city, under the jurisdiction of City Corporation, has a population of about 2.5 million and is constantly growing (CDA, 2014). In this context, a reconnaissance has been conducted on a detailed study on the service area coverage of hospitals providing service to patients with specialized medical and nursing staff and medical equipment as a case study in Chittagong City Corporation (CCC). In CCC area there are approximately 124 hospitals. Figure 1 represents the location of hospitals in CCC and figure 2 represents the location of hospitals in CCC with respect to the road network of CCC (Spatial Relation between road network and hospital).

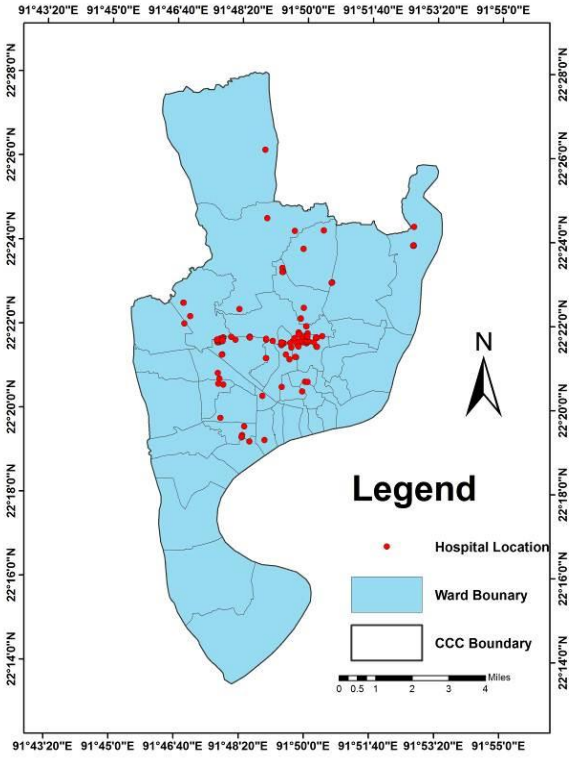

Figure 7. Location of Hospital in CCC

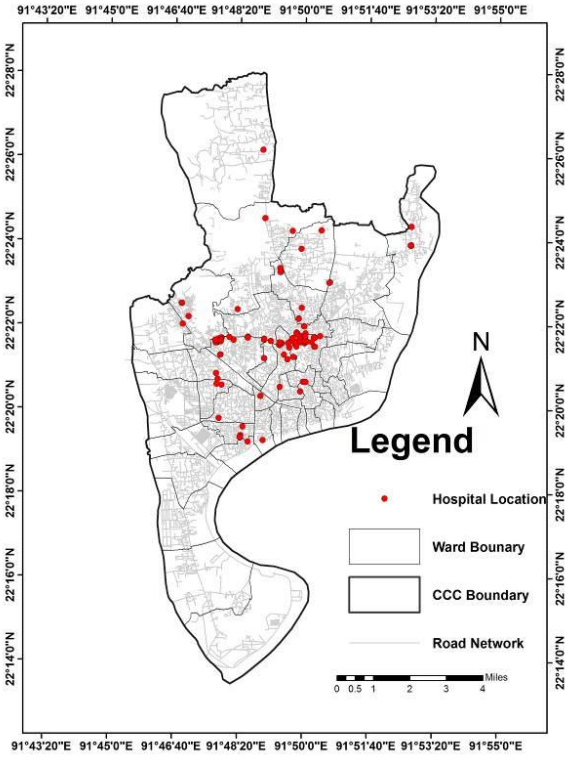

Figure 2. Location of Hospital in CCC in respect with road network.

From the above figure 01 and 02 geological position of hospital in respect of existing road network of CCC. It has been seen that most of the hospital is situated in the central area of CCC.

3. Method

At first, the problem has been identified and based on the problem and literature review, the topic has been selected. Several types of data have been collected, the main type being secondary data from different sources. For conducting this study, crucial secondary data like GIS data base on the CCC area was collected from the Chittagong Development Authority (CDA). Many papers and documents such as journals, reports, and conference papers have also been collected from the internet. At first, the location of the hospitals has been identified. Then, the service area analysis layer has been created from the Network Analyst toolbar by opening new service area of hospital. The service area analysis parameters have been set for 500m, 1000m, 2500m and 5000m radius. Finally, the service area of hospital in Chittagong City Corporation has been found. This full work has been done using Network Analyst toolbar of Arc-GIS. Figure 3 describes the flow chart of preparing the service area of hospital in Chittagong City Corporation using GIS.

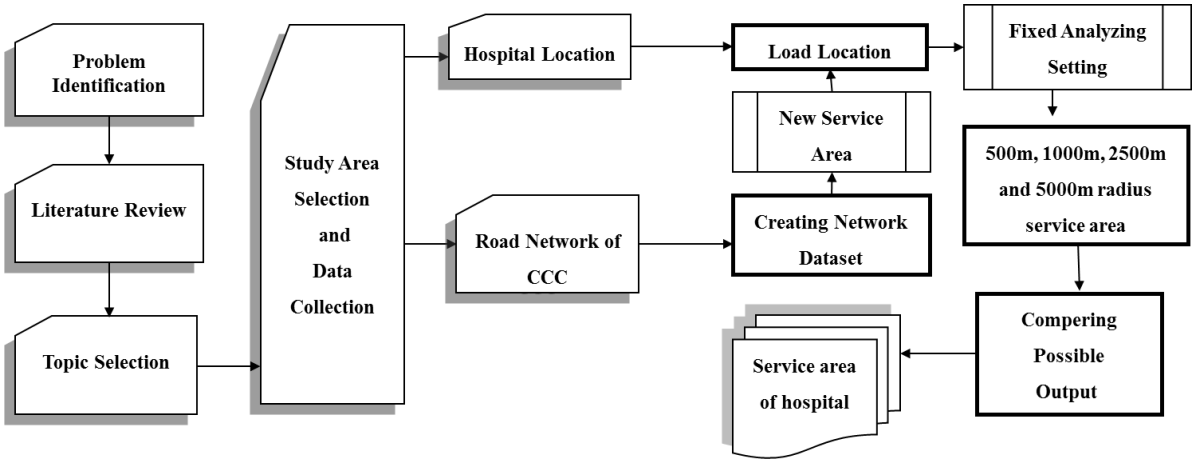

Figure 3. Flow chart of preparing the service area of hospital in Chittagong City Corporation using GIS.

4. Analysis and Findings

Using the Network analysis tools of ArcGIS service area has been created which can help to evaluate accessibility. Results found from the network analysis are based on distance. In some case patients have to refer to various health services to receive specific treatments or, the required treatments may not be available in neighboring health facilities. The comprehensive type of planning practice needs to evaluate accessibility of all health services. Therefore, during emergencies, people living in different parts of the urban area or city can use these maps for selecting the hospitals or clinics. In Chittagong City Corporation (CCC) area approximately 124 hospitals have been found with specialized medical and nursing staff as well as medical equipment for tackling emergency situations. Using the Network analysis tools of ArcGIS service area of hospital has been created in 500, 1000, 2500, and 5000m radius considering minimum 5 min to maximum 50 min. Figure 4 represents the service area of hospital in 500m radius, figure 5 represents the service area of hospital in 1000m radius, figure 6 represents the service area of hospital in 2500m radius and figure 7 represents the service area of hospital in 5000m radius.

Table 1. Service area of hospital

Service area	Condition
Service area of hospital in 500 m radius	Cover 5% portion of CCC area
Service area of hospital in 1000 m radius	Cover 15% portion of CCC area
Service area of hospital in 2500 m radius	Cover 50% of CCC area
Service area of hospital in 5000 m radius	Cover 75% portion of CCC area

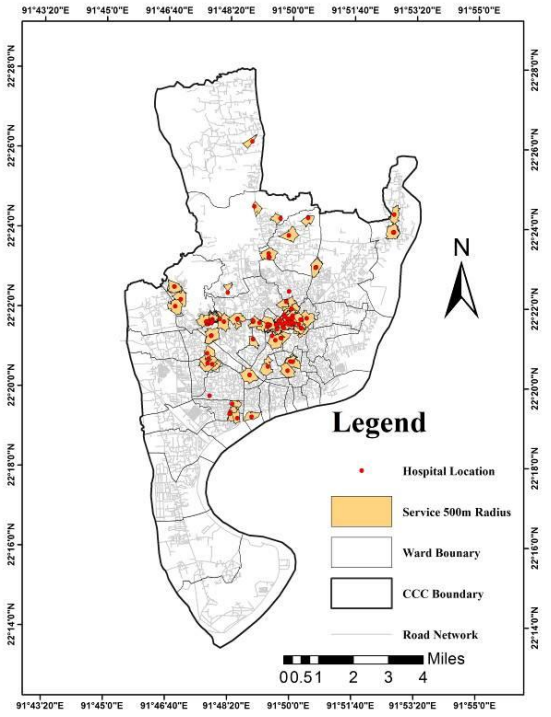

Figure 4. Service area of hospital in 500m radius.

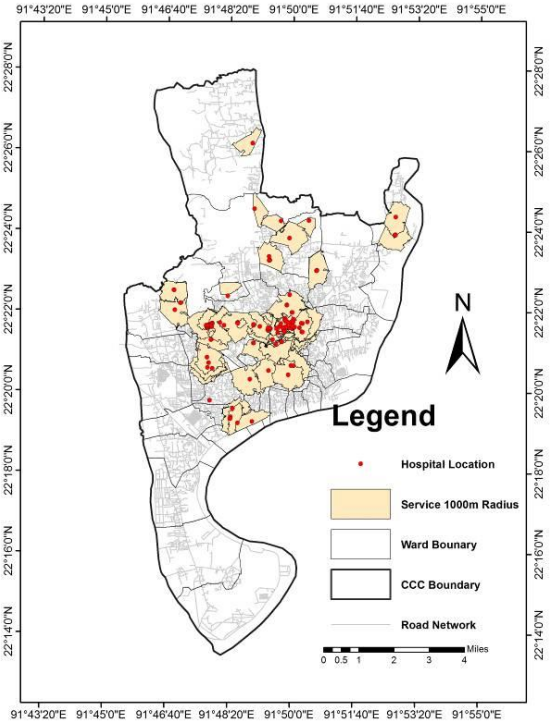

Figure 5: Service area of hospital in 1000m radius.

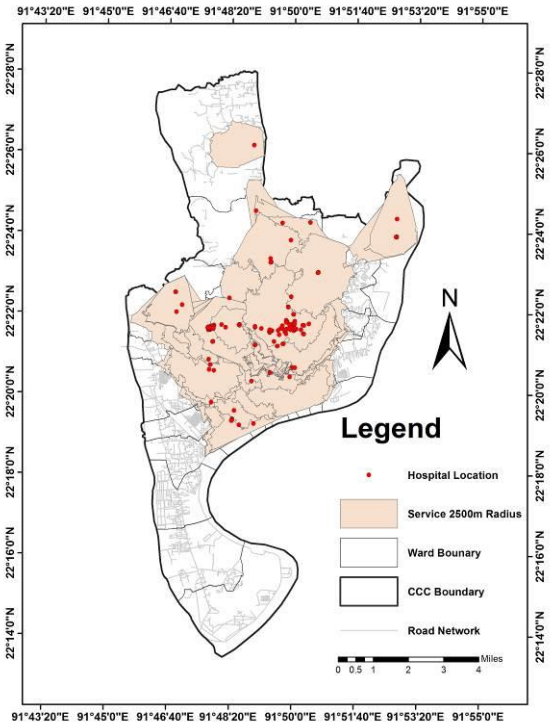

Figure 6: Service area of hospital in 2500 m radius.

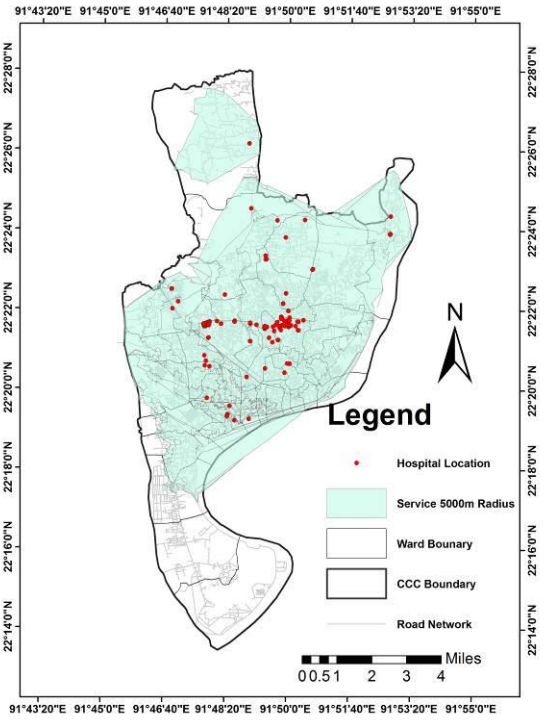

Figure 7: Service area of hospital in 5000 m radius.

From the above figure 4, 5, 6 & 7 describe the service area of hospital around CCC. It has been seen that in any emergency case like 1000m radius of service area covers only 15% of CCC.

5. Recommendation and Conclusions

From our analysis, it has been found that a 500m service area radius of hospital covers only 5% of the CCC area. In emergency cases, only 15% of the CCC area is serviced by hospitals in a 1000m radius. Thus the following recommendations have been given for this situation:

- Considering the coverage area of hospitals, more hospitals can be built all over the CCC area. Figure 9 represents proposed hospital locations in CCC with respect to road network.

An emergency map can be built and used for emergency situations. Figure 8 represents an existing emergency map of hospitals in CCC considering a 1000m service area (A preliminary attempt to make emergency map using Google earth image, road network and service area of hospital).

- Necessary steps can be taken by CDA, CCC and other government organization.
- Harmonization of institutional mandates like inter-organizational coordination among CCC, CDA and other government organization.

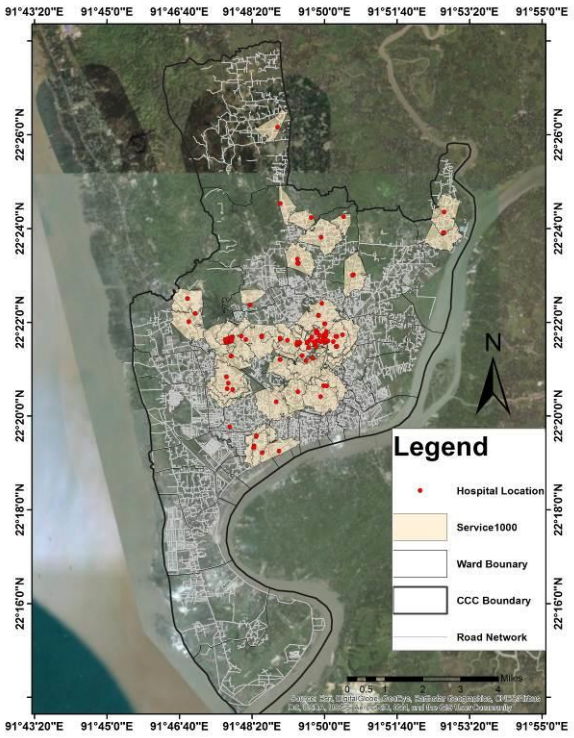

Figure 8. Existing Emergency Map of Hospital in CCC Considering 1000 m Service Area.

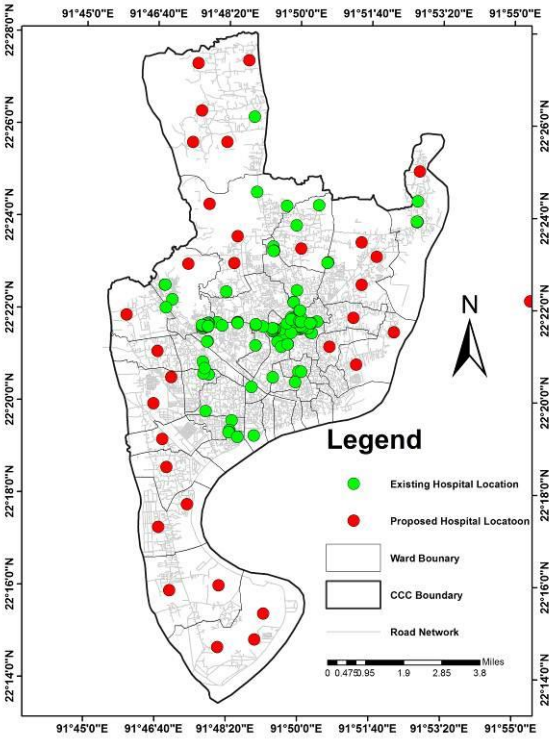

Figure 9. Proposed Hospital Location in CCC in respect with road network.

Considering the Sustainable Development Goals (SDGs) and health utilization indices and rates demonstrated, patient travel patterns require a more detailed analysis, keeping in mind the political, infrastructural and developmental determinants. Due to the possible long distances, an ambulance may require considerable time to reach the site of the incident and even from there to the appropriate hospital. Using the emergency map one can easily find out the closest location of hospitals from any incident area, which ensures better health care facility and sustainability. The results of this study will also help the decision makers, planners and engineers to provide hospitals in city of Chittagong.

ACKNOWLEDGMENTS

We are grateful to Sourab Das, Lecturer, Department of Urban and Regional Planning, Chittagong University of Engineering and Technology for providing GIS data.

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Appendix

Table 2. Details of the Projection system & Geographic Coordinate System.

Item	**Description**
Projection	**Transverse Mercator**
Spatial Reference	WGS_1984_UTM_Zone_46N
Linear Unit	Meter (1.000000)
Angular Unit	Degree (0.0174532925199433299)
False Easting	500000
False Northing	-2000000
Central Meridian	93
Scale Factor	0.9996
Latitude Of Origin	0
Datum	D_WGS_1984

INVITED

Paper 60

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Partial Nutrient Budget of Shrimp Culture Ponds in Southwest Coastal region of Bangladesh

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Abstract:

The horizontal expansion of coastal aquaculture in Bangladesh poses risks in a degrading environment. This study aimed to estimate partial mass budgets for Nitrogen (N) and Phosphorus (P) in three representative shrimp ponds, in the upazilla Dumuria under the coastal district of Khulna, Bangladesh. It was found that shrimp culture practices were extensive systems to improved extensive system, with an average 230.6 kg/ha production rate. An estimation of nutrient mass budget per hector indicates that fertilizer was the highest nutrient contributor both for total nitrogen (TN) and total phosphorus (TP), giving a rate of 60.2% and 82.4 % respectively. The feed was the second highest contributor, estimated 21.1% N and 9.3% P. The total inputs of nitrogen and phosphorus were 48.7 kgha-1cycle-1 and 28.96 kgha-1cycle-1 respectively. Among the inputs, only 33.4% of nitrogen and 6% of phosphorus were removed as harvested form. A large portion, 39.1% (20.6 kg ha-1cycle-1) N and 92% (26.66 kg ha-1cycle-1) P were remained in the sediments and unaccounted for. The intake of nutrients through supply water (TN 5.72 kgcl-1and TP 0.38 kgcl-1) were slightly higher than nutrient discharged (TN 5.6 kgcl-1 and TP 0.36 kgcl-1) through water outlet, which indicates the net retention of nutrients in the pond ecosystems. Therefore, the present shrimp farming practice is not loading nutrients to the wider aquatic system, rather acting as a nutrient remover from that system.

Keywords: nutrient budget; environmental capacity; shrimp culture; coastal zone; Bangladesh

Paper 61

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

A Study of Commonly Used Design Solutions for Green Roofs in Dhaka City and their Comparative Analysis

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Abstract:
Green roofs can play a significant role to reduce the urban heat island effect, reduce dependence on stormwater drainage systems, improve air quality, reduce air pollution, address recreational needs, supplement food sources and provide manifold ecological benefits in urban areas, all of which address the UN sustainable development goals 11,13 and 15. Although architects, landscape designers and building engineers have been designing and building green roofs in Dhaka, there is a dearth of evidence based research regarding the best practices of setting design parameters, available solution types and performance. Based on the descriptive survey method, this study identifies three basic types of green roofs. The common construction and use related design parameters used by the local practitioners were identified as structural load, an efficiency of drainage and damp protection, ease of installation and maintenance. The three types of green roofs are compared on the basis of their performance against these design parameters. The key findings of the study also include the potential of the use of lightweight green roof and growing media. It was concluded that further research, proper policies, and research-based development in the practice is necessary to materialize the true potential of green roofs and rooftop gardening in Dhaka which will address the UN sustainable development goals.

Keywords: Green roof, Rooftop landscape

Paper 67

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Development and Performance of Novel Graphite-starch Based Electrodes in Soil Microbial Fuel Cells

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Abstract

A novel technique of electrode fabrication was attempted to be used in a single chamber microbial fuel cell (MFC) using soil as a fuel source. Fine graphite powder was thoroughly mixed with starch as binding agent and then dried. This method of construction was inexpensive compared ***to the*** *other commercial electrodes used in soil MFC (sMFC). The electrodes had optimum surface roughness for bio-film formation and resistance in the range of 88-113* Ω*. Graphite anode was buried in substrate-mixed soil and carbon rod acted as the current collector. The performance was investigated for two different temperature conditions of 30±5°C and 10±2°C as well as for a range of external resistors from 1- 4.7 k*Ω*. In addition, effect of pH was investigated by maintaining a constant value, using a phosphate buffer solution of pH 7.12. Cells operated at a higher temperature led to a higher potential difference (p.d) whereas limiting the pH to a constant value of 7.12 decreased the current. To confirm viability of constructed graphite electrodes as both anode and cathode. sMFC was set up at ambient temperature condition for a total operational duration of 17 days (405 hours) where the open-circuit voltage (OCV) reached a maximum of 568 mV. Simultaneously, an external load of 2.2 k*Ω *was connected for a similar configuration to ensure a closed circuit p.d. In summary, the results indicate that the performance of soil MFCs for the removal of organic matter is significantly dependent on temperature, pH and external load. The inexpensive electrode materials and electrode fabrication method, and ease of fuel cell construction makes the soil MFC an attractive alternative for sustainable power generation.*

Keywords: Soil, power, electrode, microbial fuel cell

1. INTRODUCTION

The escalating energy crisis has led to the necessity of exploring renewable energy resources characterized by efficient energy transformations, as reviewed by Rabaey and Verstraete (2005). For sustainable energy production, microbial fuel cells (MFC) provide a new scope by generating electrical energy from chemical energy stored in chemical bonds of organic compound, taking advantage of the catalytic reaction of microorganisms (Allen and Bennetto, 1993). MFC is a tool in which the organic compounds are degraded in anaerobic condition by electrogenic bacteria to release a part of the energy in the form of electrons (Li, 2013). The electrons then flow to cathode through a conducting wire and are accepted by terminal electron acceptors (TEA) such as oxygen, nitrate and sulphate. TEAs form new products after gaining electrons and can diffuse out of the cell. This entire process leads to electricity generation (Logan, 2008).

Power generation in MFCs is done by using substances with abundant microorganisms as well as high organic content which includes marine sediment (Bond *et al*, 2002), sewage sludge (Zhang *et al*, 2012),

garden compost (Parot, Délia and Bergel , 2008), industrial/domestic wastewater (Rabaey and Verstraete, 2005) and animal waste (Yokoyama *et al*, 2006). In general, there is a bacterial population of approximately 10^9 cells g^{-1} of soil and organic matter content of within 100 mg g^{-1}, despite the variation between different soil types (Bot and Benites, 2005). Combined presence of bacteria and soil makes it a sustainable energy source (Deng *et al*, 2014).

During generation of current, electrogenic bacteria accumulate on the anode. The properties of anode are such that the interaction between electro active biofilm and the surface of the anode is greatly enhanced. The primary characteristics include electrical conductivity, resistance to corrosion (metal material), mechanical strength, large surface area, biocompatibility, environmentally safe and inexpensive (Guo *et al*, 2015; Mustakeem, 2015). Among carbonaceous materials, carbon mesh, carbon paper, granular activated carbon, granular graphite are typically used as anode (Rimboud *et al*, 2014; Wei, Liang and Huang, 2011). Carbon rods are quite affordable and primarily used as current collectors, however, the low surface area makes it inappropriate to be used as an anode (Jiang and Li, 2009; Liu, Ramnarayanan and Logan, 2004).

In the present study, a novel concept of electrode fabrication was aimed due to its inexpensiveness and the lack of availability of other commercial electrodes. Graphite powder was used as conductor and starch (from steamed rice) as binding agent. The hypothesis was tested by setting up soil MFCs, using carbon rods as electron collectors and the graphite-starch electrodes as anodes. Subsequently, the sMFCs were subjected to operating temperatures of 30±5°C and 10±2°C where pH was not controlled. Next, the performance was compared with a pH-controlled sMFC by using a phosphate buffer solution. In addition, it was also aimed to find out the correlation of potential difference with varied external loads in sMFCs. Eventually, the viability of constructed graphite electrodes as both a cathode and an anode was confirmed.

2. MATERIALS AND METHODS

a. Soil sample and substrate

Topsoil was collected, for its ease of availability, from a local nursery shop in Dhaka, Bangladesh. The soil sample was sieved to less than 4 mm to obtain a granular consistency and all foreign deposits were removed from the sample. The pH was determined by mixing 1 part soil with 4 parts distilled water. It was found to be equal to 7.28. A 0.2 g/mL glucose was used to serve as the carbohydrate source in this experiment. 350 g of soil was taken for each of the cells, and mixed with 90 mL of the substrate solution until the soil was saturated with the solution and obtained a mud-like consistency. For the tests conducted under controlled pH, a phosphate buffer solution having a pH of 7.12 was prepared. This included 29.6 mL of 0.2 M NaOH, 50.0 mL of potassium dihydrogen phosphate having a concentration of 0.2 M, and 20.4 mL of 0.2 g/mL substrate solution.

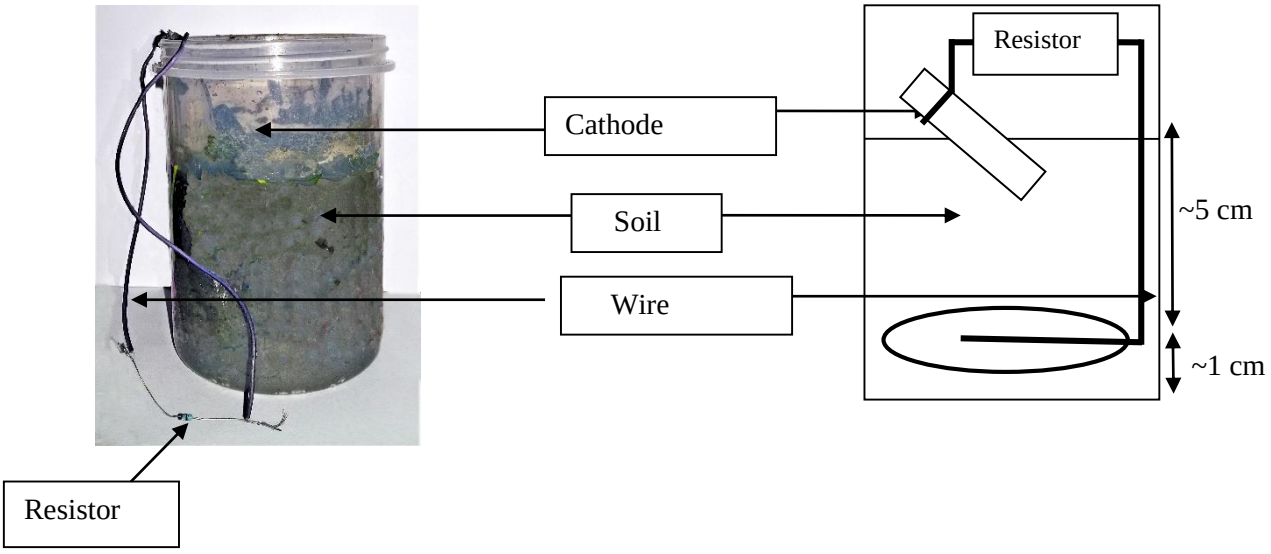
b. Electrodes

Finely divided 99.5% graphite powder was thoroughly mixed with a starch binder (steamed rice) and flattened into thin discs of 64 cm^2 area. The disc electrodes were then dried in an open flame to drive off the moisture. The anodes thus constructed had resistances that ranged from an average of 88 ohms to 113 ohms. Commercial carbon rods were used as cathodes in the experiment due to their durability and low-resistance (~5 ohms) conducive to register the current generated in the cells. Wires were attached to the anode by sealing the ends with aluminum foil and paper clips.

c. Soil MFC construction and operation

Plastic containers (9 cm diameter × 12 cm height) were filled with ~ 1 cm of the prepared mud, above which the anode was placed. The remaining mud was tightly packed on top of the anode, ensuring that no air pockets remained, to maintain an anaerobic environment next to the anode. At the top of the mud layer, part of the carbon rod was buried in the soil while the other part remained exposed to the

atmosphere. The electrodes were then connected across an external resistor, and the container was covered with a lid **(Figure 1 a and b).** After every 7 days of operation, substrate solution was added to the cells to prevent the mud from drying up. The voltage across the cells was monitored at regular intervals using a digital multimeter. Three sMFCs were constructed for three different external resistances (ER), namely 1 kΩ, 2.2 kΩ and 4.7 kΩ, to test the effect of varying ER. The effect of constant soil pH on the performance of the sMFCs was also studied for same ER arrangement. The pH was maintained at 7.12 using the buffer-substrate solution. To test for the variation between ambient (30±5 ^{o}C) and low temperature conditions (12±2 ^{o}C), two sMFCs were set up across an ER of 1 kΩ. To test the performance of the starch-based electrode as a cathode as well, two identical cells were assembled. One of them was maintained under open-circuit conditions; the other was connected across an external resistance of 2.2 kΩ.



(a) **(b)**

Figure 1 (a): sMFC closed-circuit setup (b): Schematic of the set-up

3. RESULTS AND DISCUSSION

3.1 Effect of varying external resistance (ER)

Investigation of the effect varying ER at ambient temperature conditions (30±5^{o}C) revealed that the higher the external resistance, greater the potential difference across the resistance, with the potential difference (p.d) across all the resistors rising gradually over time **(Figure 2)**. This is in accordance to results obtained by Menicucci et al., (2006), who reasoned that these observations reflected the limitations imposed on mass transfer, and on cell reaction kinetics.

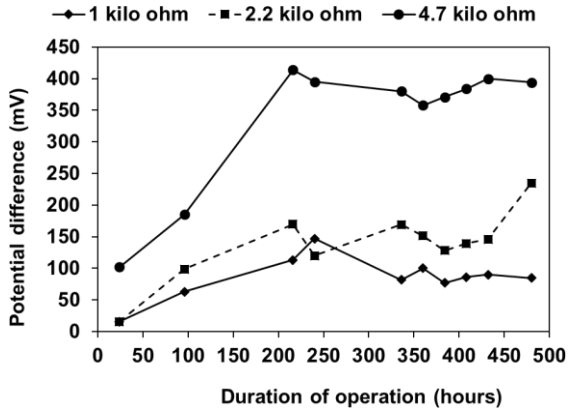


Figure 2: Effect of external load on sMFC potential difference

The initial increase in the p.d reflected the exponential growth phase of the microorganisms present. For the cells with ER 4.7 kΩ and 2.2 kΩ, the initial peak occurred after 216 h at 414 mV and 169.5 mV respectively. ER 1 kΩ had an initial peak at 147 mV, which was found after 240 h of operation. The trends were similar for both 4.7 kΩ and 1 kΩ, with an overall moderate decrease occurring after the initial peak, due to the increase in thickness of the biofilm on the anode. The curves then progressed towards a relatively constant value, which indicated that the biofilm was now stable in thickness.

3.2 Effect of temperature

Comparison between the ambient and low-temperature cells **(Figure 3)** reveals that under ambient conditions, the p.d. values were significantly higher than those obtained for the low temperature sMFC. Li et al., (2013) however obtained results that showed lower temperature MFCs had higher values of p.d. The results of this experiment thus reveal that sMFCs have a different operational behavior compared to MFCs. This might be because the low temperatures were not conducive to the growth of electrogenic bacteria existing in the soil. The sharp drop in p.d. after 48 hours of operation for the low temperature cell could be due to a sudden thermal shock encountered by the microorganisms. Extraction and analysis of the bacteria population on the anode bio film would provide further insight. The relatively moderate fluctuations for the low temperature cell compared to the ambient sMFC indicated that the bio film on the anode was more stable at low temperatures.

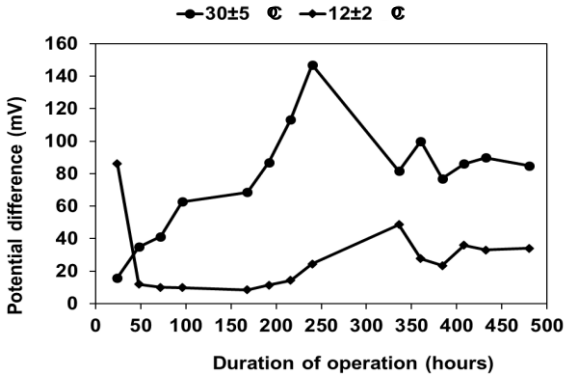


Figure 3: Effect of temperature on sMFC potential difference

3.3 Effect of constant and variable pH

When the pH was not maintained at a constant value and allowed to vary naturally due to the progress of the reaction **(Figure 4)**, the current increased to 62.8 μA after 4 days of operation and was tending towards a constant value.

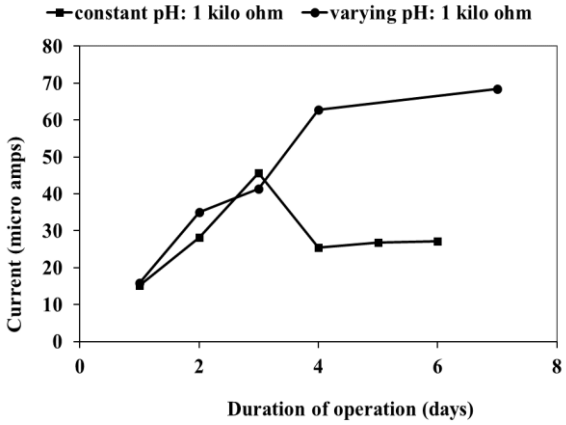


Figure 4: Effect of pH on sMFC current

The constant pH sMFC where the buffer solution was used (pH 7.12) peaked to a lower value of 45.7 μA after 3 days, which then declined sharply and reached a constant value of 27.1 μA on the sixth day. This indicated that the constant pH was not encouraging microbial growth, as it was an artificial limitation

imposed on the microorganisms.

3.4 sMFC performance validation under open- and closed-circuit conditions

Both open- and closed-circuit plots **(Figure 5)** resembled microbial growth curves, with an initial exponential phase, followed by an approximate stationary phase and a final death phase. The peak p.d for the OC curve **(Figure 5 a)** was 568 mV after 108 hours, whereas the closed-circuit p.d. reached a maximum at 6 mV after 6 hours of operation **(Figure 5 b).** Under open-circuit conditions, the p.d. values were the cell EMF values, however, when the circuit was closed, the p.d. was lower because of the potential drop across the internal resistance that comprised the soil layers and the electrodes.

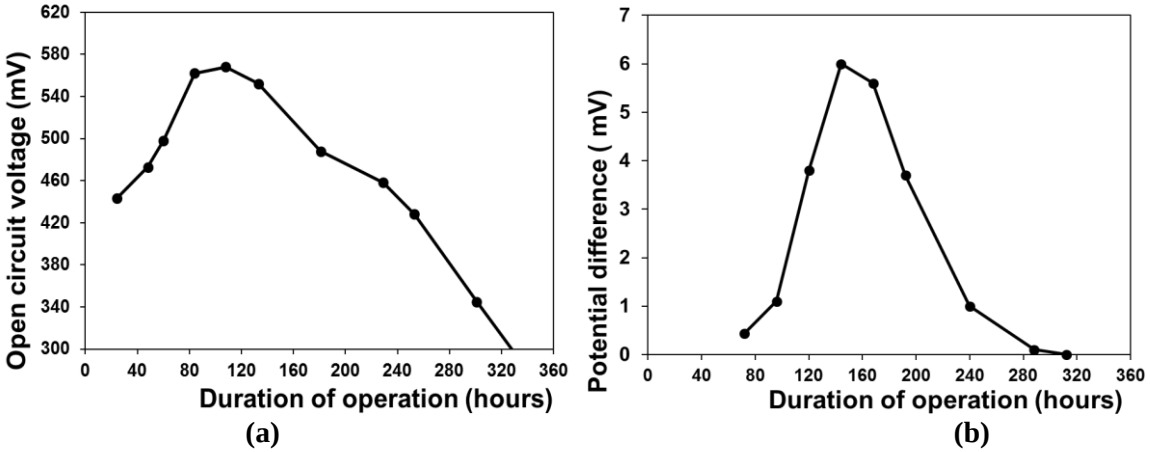


Figure 5: (a) OCV with progress of time; (b) Closed-circuit p.d with progress of time

4. CONCLUSION

This investigation successfully demonstrated the viability of novel graphite based electrodes constructed using an inexpensive binder (steamed rice) and by adopting a simple method of fabrication. It was shown that pH, temperature and external resistance greatly influenced graphite-starch anode-based sMFC's performance. Varying pH, ambient conditions and lower external resistances improved the p.d. It would have been possible to determine the relationships with the external factors conclusively if sufficient data were generated by extending the study.

ACKNOWLEDGMENTS

The authors are grateful to the Department of Chemical Engineering, Bangladesh University of Engineering and Technology for supporting the research project.

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Paper 70

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Compactness of Neighborhood Spatial Structure: A Case Study of Selected Neighborhoods of DNCC and DSCC Area

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Abstract

*The popularization of sustainable development has contributed to the promotion of the urban compactness idea. Since the 1990s, research has generally led to the advocacy of cities that are spatially compact, with a mix of uses. Dhaka has been dealing with some burning issues mainly related to land use management, which gives rise to the shortage of livable space along with environmental degradation and economic instability. Sustainable land use management requires proper study of existing spatial structures. Majority of the previous research focused on indicators that measured compactness or the sprawling nature of urban area at City or Metropolitan scale. This research has quantified neighborhood level spatial structures to study the compactness of the development. For measuring the spatial distribution of the development, the study has taken five variables- density in terms of floor use, residential to employment ratio, the percentage of the built-up area by buildings, the degree of equal distribution measured by Gini Coefficient, and the degree of clustering measured by Moran's I Coefficient. In the case of spatial structure, the Gini represents the degree to which the distribution of the development is concentrated or dispersed over the urban area while Moran's I will measure the degree of clustering or the three-dimensional pattern of the development. Each of the studied neighborhoods (ward) has been divided into 100*100 square grid cells which defines the sub-area for analysis, where each grid cell contains the information of total floor space available for residential and employment use used as a proxy variable of the population. The study found that residential spaces in the wards have more even distribution, with more continuous or random scattering behavior, while employment spaces are clustered in a few sub areas producing monocentric urban form in Neighborhood scale. The study focused mainly on two wards, similar study covering all the wards would give the spatial structure of the whole city, which will be the ultimate need of the policymakers or planners to prepare better land use control plans as well as land use development plans.*

Keywords: Spatial Structure, Sustainability, Density, Evenness, Clustering

1. INTRODUCTION

As per the UN Sustainable Development Goal 11, it suggests that cities and communities should be inclusive, safe, resilient and sustainable. For which, the target has been set as the development of an integrated and sustainable human settlement planning and management by 2030 for sustainable urbanization. For many planners and scholars, compactness is the crucial typology to be implemented to achieve sustainability. For example, Dumreicher et al. (2000) argue that a sustainable city should be compact, dense, diverse, and highly integrated. Sustainability in urban spatial structure has been a key concern of policymakers for the last few decades (Rahman, 2012). The understanding of city structures is important for efficient management and development of a city and it is obvious that the development of a city is closely associated with its structure. The degree of spatial concentration of urban population and employment are the factors to know how a city is structured (Anas et al., 1998). Compactness is one of the most accepted, widely used and most promising options toward the idea of sustainable urban spatial

structure (Islam et al., 2009). The concept of compactness in city development incorporates higher density, centralized activities, and a good mix of different land uses in built structures. As Dhaka city is distinctive in all its existing urban dynamics, an appropriate measure needs to be developed which would help understand its urban form. Because far less knowledge exists on urban form at the neighborhood level than at metropolitan and intermediate geographical levels, this research primarily focuses on neighborhood spatial structure. Urban spatial structure is defined as the physical characteristics that makes up built-up areas, including the shape, size, density, and configuration of settlements (Williams, 2014). Brotchie et al., (1985) expressed it as "the pattern of residential and non-residential urban activities and their interactions as expressed by the built environment which accommodates them". Spatial Structure can be viewed from aggregate and disaggregate standpoints. To date, significant numbers of studies have been conducted to find out the measures and indices of quantifying spatial structure. Bertaud (2001) measured the spatial distribution of the population and trip pattern of the people for characterizing the spatial structure of the city. Galster et al. (2001) proposed eight distinct dimensions focusing on spatial geometry: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity. Ewing et al. (2002) developed sprawl indices using four indicators of urban form: residential density; neighborhood mix of homes, jobs, and services; the strength of activity centers and downtowns; accessibility of the street network. Tsai (2005) developed four quantitative variables to measure the dimensions of urban form at the metropolitan level: size (population), density, the degree of equal distribution (Gini coefficient) and degree of clustering (Moran coefficient). Islam et al. (2009) determined the urban form of Dhaka City from sustainability perspective by determining the average land consumption per capita, average distance per capita to the CBD, density profile, dispersion index, eccentricity index, land price index, land use index, relative entropy, Gini and Moran Coefficient. Kashem et al. (2009) studied the urban form of Rajshahi Metropolitan using few static indicators like spatial distribution and pattern of spatial development using Gini Index and Moran's *I*, while Rahman (2012) studied the same for Chittagong and Sylhet Metropolitan with an additional entropy index variable. Measuring compactness or sustainability of urban form is the key research topic developed by most of the studies. Urban development in the form of compact development has long been in the focus of the sustainable urban form debate. The relationship between compact development and sustainability has been questioned (Breheny, 1995, 1997; Thomas & Cousins, 1996) as well as opposed (Gordon and Richardson, 1997). Nevertheless, the supporters of compact development as a more sustainable urban form are many (McLaren, 1992) and to them, the concept of the Compact City is the most promising option to achieve this goal.

The nature of the spatial development measured by density, built-up land, the ratio of housing to employment spaces, evenness and clustering help to get directives for compactness measure of the areas; what kind of spatial structure is more appreciable for the neighborhood to be more compact is one of the key aspect of the study. As polices of compact development suggest more concentration of residential or employment space around the transit stops along with the greater level of mixing, the study is focused on spatial development pattern at neighborhood scale. However, as the neighborhood is considered as a fixed geographic unit, the concentration of development in few sub-areas may lead to greater travel time and distance. Hence, more even distribution with a high-decentralized distribution of floor spaces inside the ward can produce greater compactness in neighborhood scale. The study would check these notions from a more disaggregate level study of spatial structure indicators.

2. DATA AND METHODS

Depending on the relevant context of the studies, urban form measurements at the city (aggregate) scale and the neighborhood (disaggregate) scale are available. However, this study has considered the neighborhood scale and has taken two representative neighborhoods-one is DNCC Ward-13 (Mirpur) and other is DSCC Ward 13 (New Paltan). These two wards are representative as they are selected in terms of spatial location, socioeconomic characteristics of the neighborhood, and the street layout pattern of the area. The basic data required for the study were collected from the Detail Area Plan 2015 database. This study focuses on GIS datasets of all the buildings of the neighborhoods, which had the information of building's nature and the type of structure, locality name, floor-wise use of structure, year of establishment, holding number with spatial location and shape of buildings recorded as a polygon shapefile. Square grids (100m*100m) over the neighborhood's boundary defines the subarea of analysis.

Preparation of grids is useful to avoid the disproportionate division of sub-areas that occurs if administrative units are considered. Here, the studied neighborhoods are of different sizes and shapes, so calculating the indicators of the spatial structure need to be in a proportionate way. The Polygon Structure shapefile from DAP 2015 included numerous floor uses. From these uses, six major uses were created which were- Residential, Commercial, Industrial, Institutional, Recreational, and Mixed Use. The newly reclassified categories Polygon Structure shape file included- Structures with use of service activities like banks, hospitals, public office buildings, cinema halls, hotels are treated as commercial. Structures with use of all religious activities like mosques, temples, and other local religious institutes, hotels, community centers, educational institutes are considered institutional. Structures with residential, industrial, and mixed uses remain the same. Here, mixed-use spaces have been divided equally to residential and employment floor use. All the structure use except residential uses were added up and termed as employment use in the study. The total floor space for each category of the polygon shapefile was calculated by multiplying the floor area with the total number of floors. Final grid was produced with adequate information for calculating Gini and Moran coefficient. The Gini index is used to measure the inequality of the distribution by the following formula -

$$Gini = \frac{\sum_{i=1}^{N}(X_i - Y_i)}{2} \quad (1)$$

Here, N = the number of sub-areas i.e. each of the grid cell of (100*100m) is considered as sub area, Xi = Proportion of land area in sub-area i, Yi = Proportion of residential or employment space in sub-area i, Gini index varies between 0 and 1; whereas 0, means even distribution and, 1 means maximum discrepancy in distribution. The background calculation for the Moran's I is given below

$$I = \frac{N\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij}(X_i - X)(X_j - X)}{(\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij}))(X_i - \bar{X})^2} \quad (2)$$

Here, N is the number of sub-areas; Xi is the floor space in sub-area i, X j is the floor space in sub-area j, X bar is the average floor space and Wij is the relative weights between sub-area i and j. Zone of Indifference has been used where the features within the distance band or threshold distance are included in analyses for the target feature. For the selection of the distance band, an Incremental Spatial Autocorrelation was performed which produced a summary of Global Moran's *I* by distance.

3. RESULTS AND DISCUSSION

Density affects sustainability through differences in the consumption of energy; materials; and land for housing, transportation, and urban infrastructure (Walker and Rees, 1997). High density and integrated land use not only conserves resources but also provide for compactness, which encourages social interaction. Density can give an aggregate measure of spatial structure. Population density is a popular measure of urban density calculation, but this study focused on floor space density of an area, which will help to understand the intensity of building use. As the floors used by the users may not necessarily include the actual residents of the ward, hence average of day and night time population has been taken for gross density calculation in terms of floor use. As per the Private Residential Land Development Rules (2004) suggest 350 (person per acre) as gross density for residential development, it can be said that both the study area has a greater intensity of floor use, as her an acre of floor space accommodates nearly 550 people in both the neighborhoods (Table-1). Hence, both the neighborhood is compact in terms of floor use.

Measures	Neighborhood	
	Mirpur	**Paltan**
Grid Area (Acres)	714.13	392.90
Ground Coverage by Structures(Acres)	299.52	110.33
Percentage of Developed Area by Structures (%)	41.94	28.08
Density (Population Per Acre Floor Space)	525	541
Total Residential Floor Space (Acres)	619.63	289.18
Total Employment Floor Space (Acres)	79.40	242.36
Ratio of Residential to Employment Floor Space	7.80	1.19

Table 1: Comparison of floor space information of the two study areas

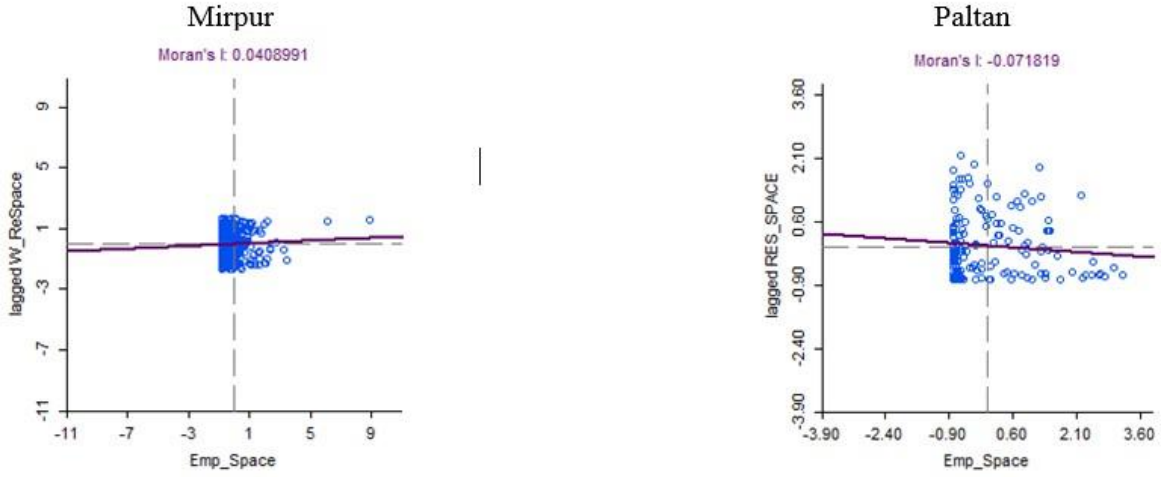
The study used building footprint area for measuring the developed land in each grid cell. By summation of structure area for all the cells of a particular neighborhood, it can be seen that Mirpur area has around 42% of its land covered by buildings while Paltan area has 28% in use (Table-1). As highly sealed areas would increase the temperature of urban areas, the city would face the Urban Heat Island (UHI) effect more acutely. Besides, the increased sealed surface would decrease the percolation rate, which would affect the stormwater drainage. Hence, it can be said that the neighborhood of Paltan is more compact hence sustainable as it has a lower percentage of built-up land by buildings. Besides, Paltan area is more balanced in terms of space distribution than Mirpur area, as for Mirpur the ratio of residential to employment space is higher on a greater margin than Paltan. This ratio value defines the degree of job-housing balance in the neighborhood scale. From the lower value of employment space of Mirpur area, it can be perceived that the distribution of commercial, institutional or industrial facilities is not adequate for being an area to be compact with a different use. Greater imbalances would lead to increased rate of driving, congestion, and air pollution as per the literature suggests. For a sustainable neighborhood, there should be proper mixing of different types of compatible land use. As the sustainability of a compact neighborhood depends on the balance between residential and employment spaces, proper land use distribution for meeting the biocapacity is necessary in this regard. Besides, for the ecological sustainability of an area, there is a certain percentage of land required for ecological purposes i.e. cropland, grazing land, forestland, fishing grounds etc. The higher amount of hard surfaces will lead to less amount of porous land available for maintaining the bio-capacity of an area. The study has used only building footprint areas and no other land use like roads, water bodies, and open spaces. The developable land area along with information of land consumption for other uses like roads, open spaces, water bodies etc. of these two neighborhoods would give a clearer picture of land consumption of the areas, which would help to measure the sustainability. Likewise, neighborhood density is linked to energy consumption. Newman and Kenworthy (1989) found a strong inverse relationship between urban density and energy consumption. As the density of the two neighborhood is comparatively high, it is expected that the energy consumption of the areas would be less than those areas where density is lower.

For being a compact neighborhood, residential and employment spaces should be evenly distributed, as it would increase the accessibility of the service facilities of that area. Besides, the even distribution of residential and employment space would increase the diversity of a neighborhood, which would ultimately increase the sustainability of the area. This study used the Gini coefficient for measuring the evenness of development of residential and employment spaces of the neighborhood. From residential Gini coefficient values, Mirpur shows more even distribution (Gini coefficient of .129) than Paltan Area does (Gini coefficient of .318). The lower value of Residential Gini for Mirpur area can be explained from the predominant residential floor space value of the areas as stated earlier. A similar scenario can be seen from the employment Gini values of the two area where Paltan (Gini coefficient of .572) has a more uneven distribution of employment spaces than Mirpur area (Gini coefficient of .207). The higher value of employment Gini coefficient indicates that the distribution of employment spaces in the wards is more uneven than the residential areas. In Metropolitan scale Kashem (2010), Rahman (2012), Israt et al. (2009) showed that the larger the metropolitan is, the higher the uneven distribution of land-use. However, the notion is not true for neighborhood scale. This uneven distribution may be the result of several reasons. Zoning regulation, distribution of community facilities and utilities, amount of space dedicated to roads, the presence of open space and water bodies of the area etc. need to be studied to understand the reason for such distribution. However, such study is outside the scope of this research. One of the key aspects of the Gini coefficient is that it cannot describe the spatial relationship of high-density sub-areas. Hence, it fails to explain whether studied geographical unit (i.e. neighborhood) is

monocentric, polycentric, or decentralized. Therefore, the degree of clustering of the development needs to be studied to measure the extent to which high-density areas are clustered or randomly distributed. The inequality of distribution reckoned by the Gini index is well complemented by the Moran's I index in this regard.

The Moran coefficients for residential and employment land-uses in Mirpur is 0.01 and -0.002 respectively. Higher Moran values for residential spaces indicate that the residential spaces are more concentrated and continuous than the employment spaces. However, Paltan has a higher Moran value for both uses (residential use: 0.229 and employment use: 0.328) than Mirpur. High positive values of Moran coefficient confirm that the tendency of the sub-areas (100m * 100m) with high attribute value (residential space or employment space) to be located near one another and low attribute values to be located near one another. In other words, both residential and employment land-uses are concentrated and clustered in few areas.
It further indicates that both the residential and employment space arrangements tend to be monocentric in nature, displaying high degrees of spatial autocorrelation. It, therefore, leads to the finding that neighborhood of Paltan area is more monocentric than Mirpur.

So far, the analysis considered two variables (e.g. Gini coefficient and Moran' I) separately. However, to get a clear idea about the pattern and distribution of residential and employment spaces over the study areas, multivariate analysis linking the two variables have been done. While univariate Moran's I show the clustering of one land use variable, the bivariate analysis shows the influence of one land use over the other. Here, employment floor space of each neighborhood is compared with the predefined weighted value for the residential spaces. The Bivariate Moran's I is positive when similar values (both high and low) of both the land uses i.e. the residential and the employment are located in close proximity to each other. The Bivariate Moran's I is negative when the opposite occurs i.e. low values of one land use category tend to be close to the high value of another category.



(a) (b)

Figure 1: Bivariate Relationship between the Employment and Residential Space of two Neighborhoods: (a) Mirpur (DNCC 13) and (b) Paltan (DSCC 13)

In Figure-1, the scatter plot shows the original values of original variables (employment floor space) on the horizontal axis and spatial lag of the variable (residential floor space) on the vertical axis. The slope of the regression line is Moran's I. Scatter plot matrix has been prepared to visualize the relationship between the two variables. Moran values for univariate analysis differs from that of the bivariate analysis as univariate analysis deals with single-use; there are high chances that these would be found more clustered or dispersed than the case when two uses are considered.

Variation of bivariate Moran's I is supported by the Bivariate Lisa Cluster map, which visually shows the

pattern of distribution (Figure- 2). For the ward of Mirpur (DNCC 13), the Bivariate Moran's I coefficient is 0.0408 which means there is a very low tendency of locating similar land use values in close proximity. For the ward of Paltan (DSCC 13), the Bivariate Moran's I coefficient is -0.0718 which indicates that there is a negative tendency of the similar land use values of both categories to be in close proximity. Moran coefficient suggests that in the Mirpur neighborhood, the high value of residential space is in close proximity to high value of employment space and vice versa. Whereas, in Paltan opposite scenario can be observed where the high value of residential space is associated with the low value of employment space and hence, resulted in negative Moran coefficient value. For both the cases, the neighborhoods are monocentric and have spatial segregation of concentration of the residential and employment floor spaces.

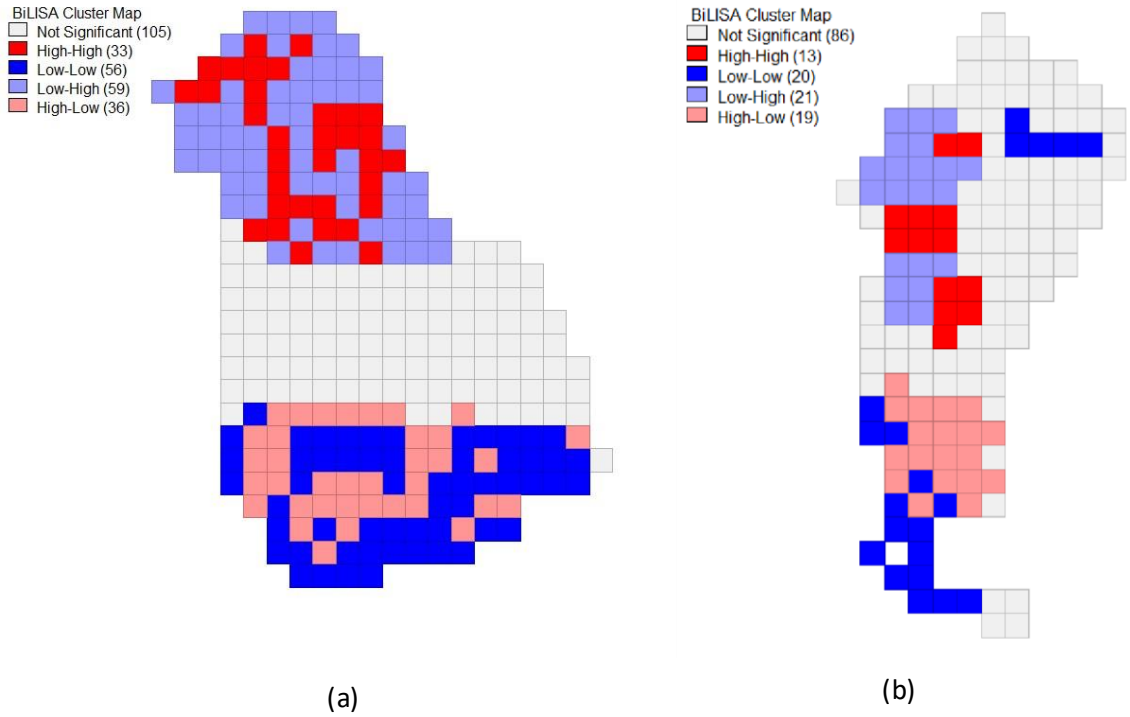


Figure 2: Bivariate Cluster Map considering Residential and Employment Space: (a) Mirpur (DNCC 13) and (b) Paltan (DSCC 13)

Reducing the need for travel is on the agenda of achieving sustainable urban form. Works of literature of neo-traditional planning and the "new urbanism" often argue that car use will decline in the neighborhoods designed with high enough densities and by closely grouping some commercial and residential developments. This monocentric form of development in both neighborhoods would create an imbalance, which would create greater travel time and distance for the residents of the neighborhoods to meet the trip requirements for both work and non-work purpose. Sustainability would be ensured if the number and length of trips by modes of transportation can be reduced which would minimize greenhouse gas emissions.

4. CONCLUSIONS

To ensure sustainability of the city, it's neighborhoods should be more compact through which sustainability would be ensured. This study depicted the scenario of only two neighborhoods, the analytical framework used in the study would help to measure and compare the urban spatial structure at the city scale in the future for effective development regulations. The study attempted to quantify the spatial structure of the city at neighborhood scale to measure the compactness in terms of its density, distribution, and clustering of development. Study results showed that floor use density is comparatively high in both the neighborhoods, of which Mirpur has a greater percentage of built-up area. Evenness of spatial distribution measured by the Gini coefficient indicates that residential spaces in the two neighborhoods are more evenly distributed than the employment spaces. Gini coefficient values for both employment and residential land-use were higher in Paltan, therefore, more unevenly distributed than in

Mirpur. While, the degree of clustering measured by Moran's coefficient suggests that the residential spaces are randomly distributed or more continuous in nature, but employment spaces are clustered in a few sub areas producing monocentric urban form. However, bivariate analysis showed positive spatial auto-correlation between residential space and employment space in Mirpur, indicating close proximity of these two land uses. According to three indicators, these two neighborhoods showed a different degree of compactness. Overall, Paltan area is compact in terms of density and balance between residential and employment spaces but Mirpur is comparatively more compact by all the three indicators except for the balance the two land uses. These three measures are under the domain of environmental sustainability as they have a direct impact on travel mode choice and travel distance of the residents, as well as on urban temperature. Further studies including indicators of environmental, social, and economic aspects of compactness should be carried out to measure the level of sustainability of the urban form.

ACKNOWLEDGEMENTS

The authors are indebted to different organizations for their support during the data collection stage. We acknowledge the data support of RAJUK and BBS. The study would not be possible without these secondary data.

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Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Geotechnical Investigations on Landslide in Rangamati by Slope Stability Analysis in Numerical Modelling

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Abstract

In rural Bangladesh, the main source of water is groundwater aquifers. The rural population has access to safe water within 150 meters of their households. However, people in these areas are still being exposed to arsenic through their water supplies, despite several government and non-government efforts to tackle this issue. The National Policy for Drinking Water Supply and Sanitation, 1998 aims to bring changes in service delivery of water by decentralization and user participation through local government and community organizations. The Bangladesh Arsenic Policy and Implementation Plan, 2004 opted piped water supply as an alternative option to provide safe water. Management of rural piped water distribution is a challenge Bangladesh has been facing for the last two decades. The water distribution system in the arsenic affected areas are suffering from a financial deficit; collected tariff can't meet the operation and maintenance costs. In this study, a survey on facility users was conducted in eleven Upazilas (sub-districts) under seven districts, namely Satkhira, B. Baria, Narail, Barguna, Dhaka, Pabna and Dinajpur. The responses from water users of eleven schemes had been taken by the household survey; conducted from January to March 2018. According to the analyzed survey results, it was found that the north and north-east districts have arsenic contamination in the shallow aquifers. It was also revealed that the southern districts in the coastal areas have deep aquifers that experience salinity intrusion. The sustainability of the distribution systems depends greatly on the resource availability for operation & maintenances, willingness to pay and the amount willing to pay. In the analysis, revenue generation, collection, and break-even connection numbers are calculated on two sets of population and households. One set of population and household was from the Bangladesh Rural Water Supply and Sanitation project survey 2014 and the other one was derived from the DHHE-JICA 2008 report of the evaluation of the performance of the village piped water supply system. Other related information was also taken from the same project for the analysis. The main purpose of this study was to identify financial challenges and review obstacles to the sustainability of rural piped water distribution systems. The findings of this study could also contribute to the policy makers and those involved in the management of the piped water system in making decisions, implementing policies and setting regulations for distribution systems.

Keywords: Landslide, Slope stability, Factor of safety, SLOPE/W, PLAXIS.

1. INTRODUCTION

Landslide is one of the most devastating natural disasters in the hilly region of Bangladesh occurring almost every year. More than 300 people were dead in Bangladesh by landslides since 2000. A total of 135 fatalities were recorded in one single event on 11 June 2008 with a repetition on 20 August 2008 adding 11 deaths in the record (Sarwar, 2008). The major landslides in Bangladesh history were (Kaptai,

1968), (Ghagra-Rangamati road, 1970), (Bandarban, 1990), (Bandarban and Chittagong, 1999), (Chittagong University campus, 2000), (Ahmed et al., 2013). But the recent incident of landslides in Rangamati, Chittagong and Bandarban, the three hilly district of Bangladesh on 12 June 2017, has forced us to rethink about our ignorance to this issue. At least 152 people were killed in total among which 110 people were reported dead in Rangamati alone (Das et al., 2017). Major natural causes that are considered in Bangladesh are steepness of slope, changes in vegetation and mostly heavy precipitation in general. Rainfall-induced landslide pose a threat to lives since they occur suddenly and travel a long distance as debris flow in high speed (Matsushi, 2006). But the causes mentioned above are mostly empirically derived and not clearly defined and examined. Devastating landslides have affected hilly regions repeatedly in recent years but no proper action has been taken regarding this issue. Despite all the loss of life and property, there have been very few landslide studies conducted in Bangladesh compared to the rest of the world. Prediction and mitigation of landslide of a natural hillslope is thus a societal demand. So, considering the facts, this study aims at geotechnical investigations based on numerical modeling on recent landslide events. This study indirectly indicates that the change in climate and weather has an adverse effect on the increased number and devastating nature of landslides. Climate change results in water level rise and irregular weather pattern and deforestation. The root of turf or plants helps in slope stability by working as nailing. Increased water level rise, groundwater table rise results in increased pore water pressure within the soil and shear strength reduction and thus the occurrence of a landslide.

2. OBJECTIVE OF THE STUDY

The main objective of the study is to prepare an informative report to understand the process and mechanism of the Rangamati Landslide. For this, the following factors will be studied –

1) To determine the minimum factor of safety for critical slip surface numerically and to compare the factor of safety before and after landslide applying limit equilibrium method.
2) To find the safety factor before and after rainfall using Finite Element Method and compare with the results from the Limit Equilibrium Method.

3. METHODOLOGY

Investigation of the landslide is a long process including various steps and techniques. There are at present several methods of stability analysis of slope which can be employed to both natural and as well as manmade slopes. For investigating landslides, any particular or combination of several methods of slope stability analysis which include both field investigations and numerical modeling can be used. The development of the process of this study and the steps are mentioned in sequential order below.

1. Site selection (site locations have been selected from Rangamati landslide areas)
2. Field investigation (geometry of slope, surrounding conditions, field reconnaissance, and subsurface soil exploration)
3. Drawing Contour Map
4. Data collection
    - SPT (in situ soil condition and soil layers)
    - Lab tests (required soil parameters)
5. Reconstruction of the slope geometry in SLOPE/W and PLAXIS
6. Comparison of the results between dry and saturated slope conditions and thus finding the triggering factors of a landslide in Rangamati region.

3.1 Site Selection and Contour map

The study area has been selected at the landslide affected hilly regions near Chittagong-Rangamati highway focusing on the recent landslide events of 2017 and 2018. The GPS location of the site is (Lat-22°37’56.24” N Lon-92°06’55.6” E)

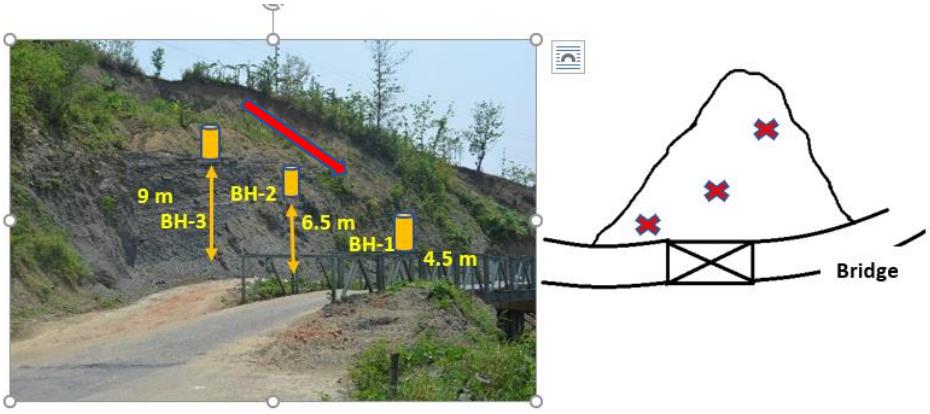


Figure 1. Selected site from field visit on April 28, 2018, with the research team.

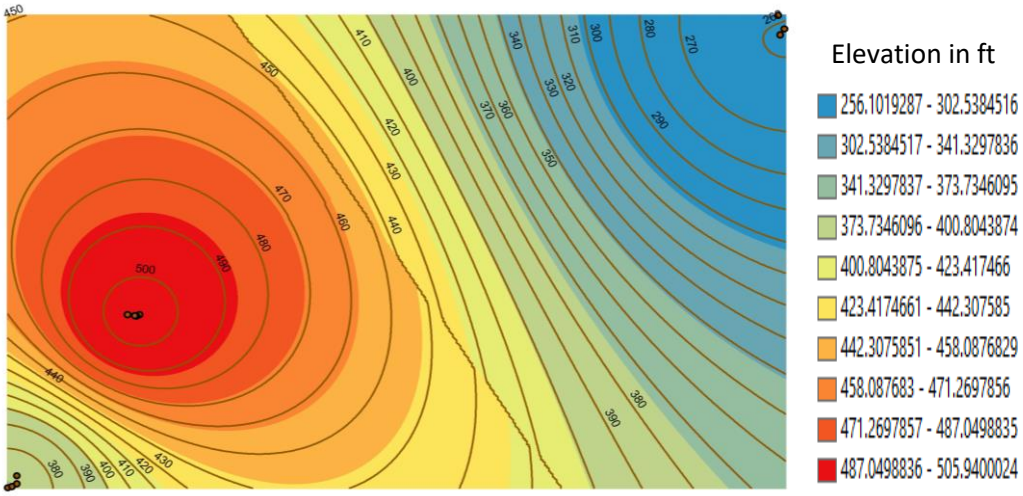


Figure 2. Contour map of the study area. The height range of the chosen site location has been shown in the contour map with 10 ft interval developed by Arc GIS.

1.2 Field Visit and Data Collection

A number of field visits were made before and during the monsoon season in the month of April and August, when the slopes are dry and when the slopes are most vulnerable to rainfall. For examination of failed slopes in situ soil condition borehole information must be obtained. Borehole information includes details of the soil layer, moisture content, standing water level. Three boreholes were done as a part of Standard Penetration Test (SPT) by the authority in association with "Dhaka Soil" by whom the data has been provided. For selected site (slope beside the bridge) three boreholes were done at ground level 4.5m, 6.5m, 9m. (Figure 1). Several basic geotechnical tests were done in the laboratory to determine the shear strength and other material properties of the soil sample collected from SPT. Material properties of soil are of great importance for numerical modeling since the main results will depend on this. Soil strength parameters are defined as Mohr-Coulomb strength parameters. From the sieve analysis (ASTM D422), hydrometer (ASTM D-421) and Atterberg limit test (ASTM D4318) soil sample are classified as silty clay. According to USCS the range of φ for silty clay will be in the range of 18° to 32°. From the direct shear test of an unsaturated soil sample, the φ value is determined 18.85° and 30.57° for the three layers of soil which fall in the range. From boreholes of different elevation, soil samples were tested and different shear strength parameters are found. From direct shear tests, cohesion (c) and angle of friction φ (phi) value are determined for each borehole sample. Borehole depth varies from 2m – 2.5m for each. Borehole couldn't be inserted in deeper depth due to the presence of bedrock. Bedrock was at a much higher elevation. Bedrock is an impenetrable layer; the software indicates that the slip surface cannot enter this material. Unit weight is another important parameter that needs to be inputted. Unit weight of soil is determined from specific gravity test. From the specific gravity test (ASTM D854).

SLOPE/W requires soil properties that satisfy the Mohr-Coulomb Criterion. Required soil properties are for the selected site is listed in Table 1.

1.3 Modelling in SLOPE/W and PLAXIS

SLOPE/W uses Limit Equilibrium Method and finds a minimum factor of safety and thus finds the failure surface. PLAXIS uses Finite Element method and shows the deformation of the slope. To recreate the field condition for both unsaturated (before failure) and saturated (after failure) soil parameters were inputted and suitable model was created.

In this study four most common LE methods have been applied for F.S calculation. They are-

1. Morgenstern- Price method

2. Bishop simplified method

3. Janbu's simplified method

4. Spencer method

Property	Symbol	Height of borehole (m)	Value (Unsaturated condition)	Value (Saturated condition)
Unit weight	γ_{sat} / γ		13.5 kN/m^3	18 kN/m^3
Cohesion	c	9	14.27 kpa	13.71 kpa
		6.5	14.27 kpa	12.02 kpa
		4.5	24.9kpa	3.36 kpa
Angle of friction	φ	9	30.57°	22.80°
		6.5	30.57°	24.41°
		4.5	18.85°	25.80°

Table 1. Material properties of the soil sample (landslide beside bridge) used in modeling

4. RESULT AND DISCUSSION

4.1 Result in Geo-SLOPE/W

Table 2 summarizes the results from 4 different Limit Equilibrium Method for low water table (before rainfall. Unsaturated condition) and high-water table (saturated condition after rainfall**).**

Method	Factor of safety Unsaturated Condition	Factor of safety for Saturated condition
Bishop	1.598	0.775
Janbu	1.485	0.629
Morgenstern Price	1.583	0.762
Spencer	1.587	0.764

Table 2. Comparison of Factor of Safety of different methods of LEM

As we know the factor of safety definition is represented in Equation (1). Factor of safety value is the ratio of available shear strength (s) in a slope to its equilibrium shear stress (τ_e).

$$F = s / \tau_e \quad (1)$$

A Factor of safety value is defined as the ratio of available shear strength (resistance force) in a slope to its equilibrium shear stress (driving force). If FOS is greater than or equal to 1.5, slope is considered to be stable. So, from the results, it is clear that after rainfall the slope becomes unstable.

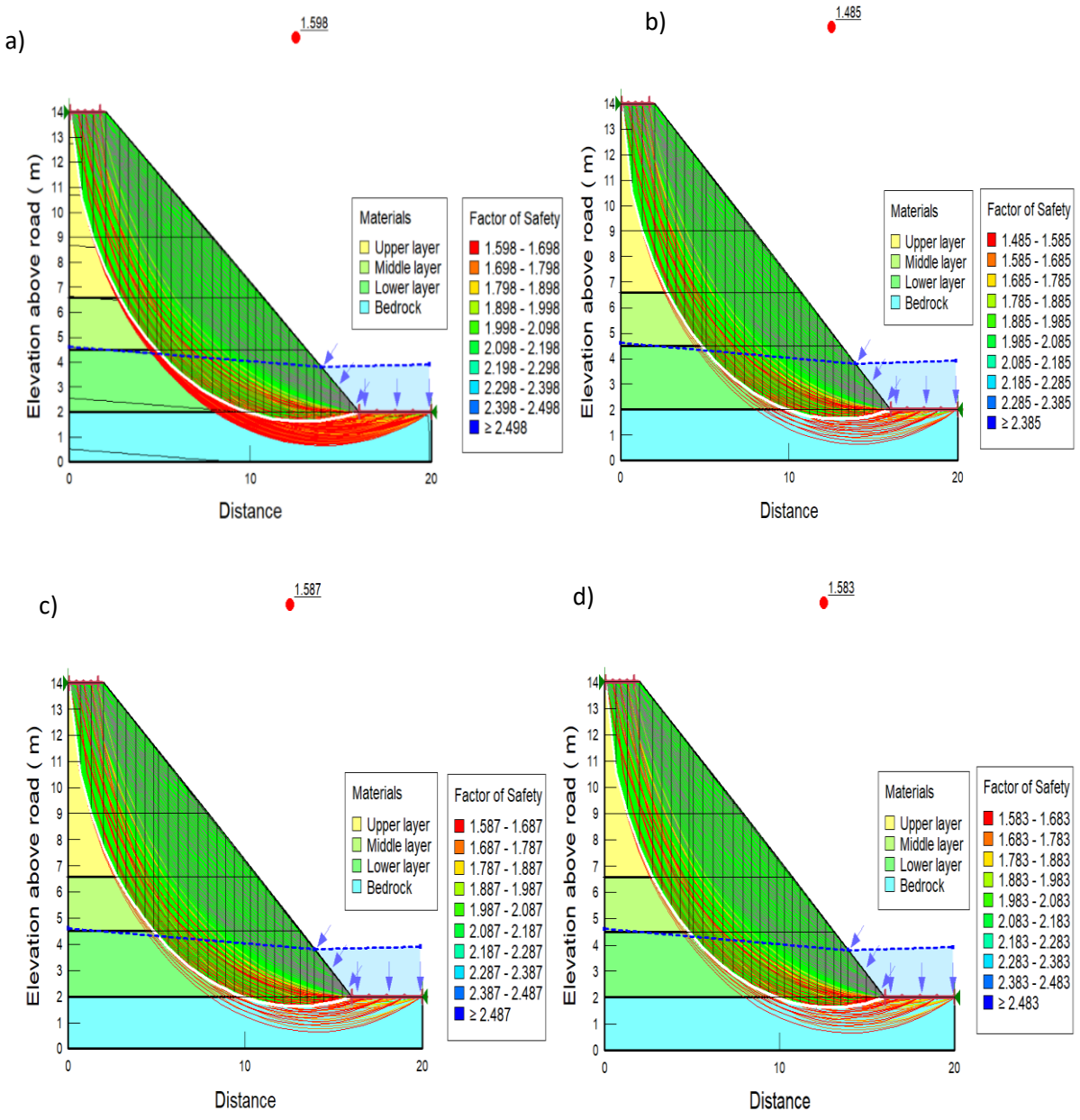


Figure 3. Factor of safety of unsaturated condition a) Bishop method b) Janbu method c) Spencer method d) Morgenstern Price method.

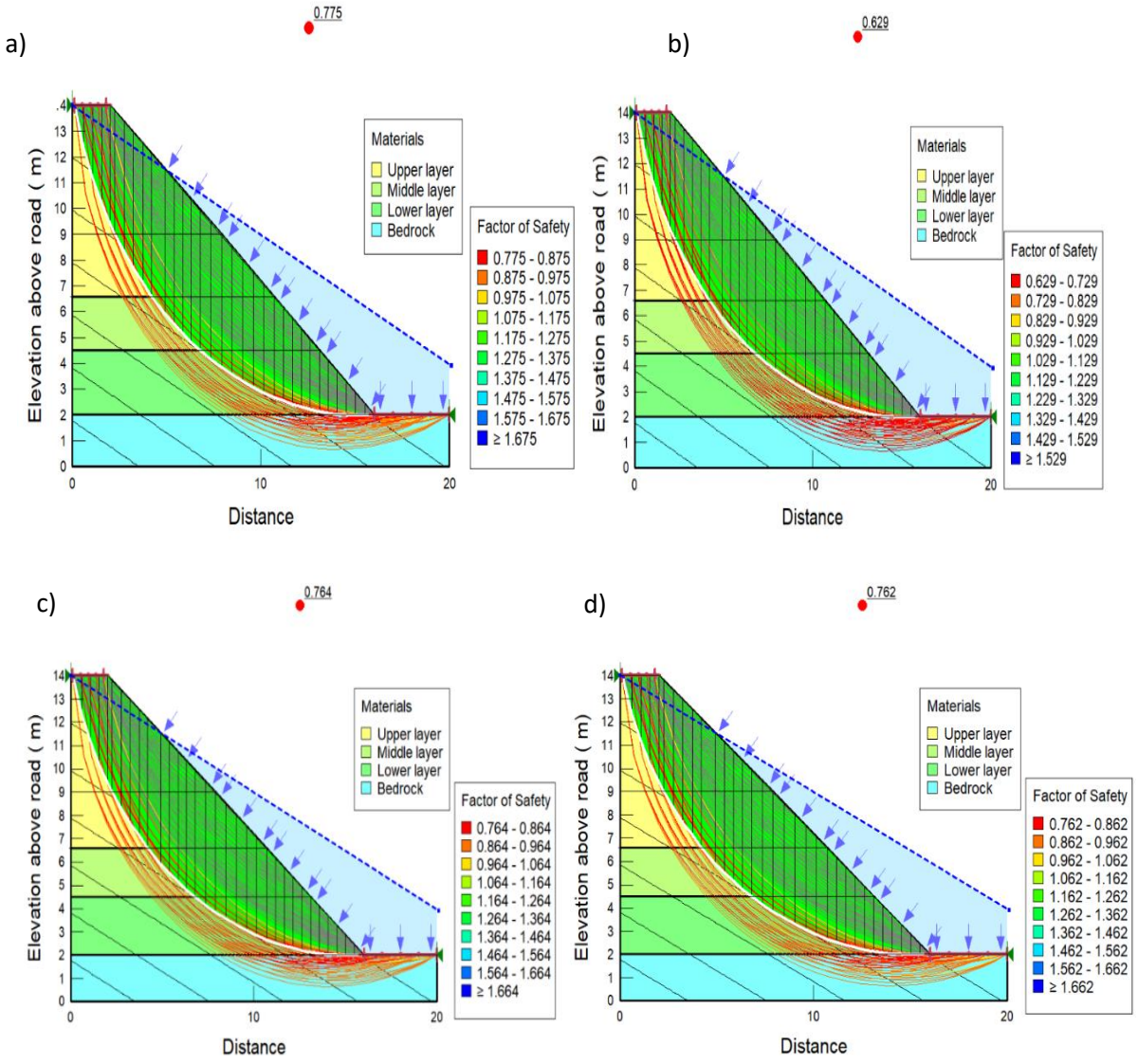


Figure 4. Factor of safety of saturated condition a) Bishop method b) Janbu method c) Spencer method d) Morgenstern Price method.

4.1 Result in PLAXIS

A similar profile was drawn in PLAXIS as SLOPE/W. After analysis, it is seen that when the water table rises overall deformation becomes much larger indicating slope failure.

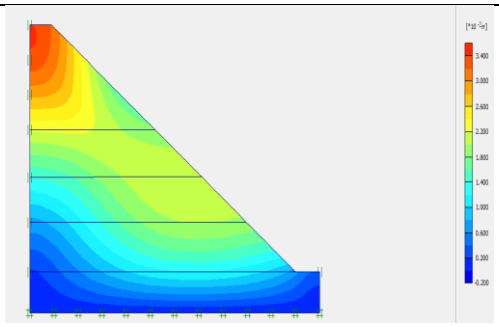
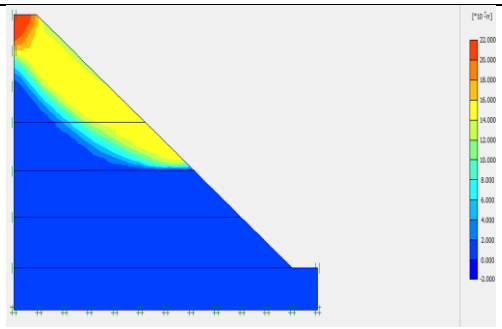
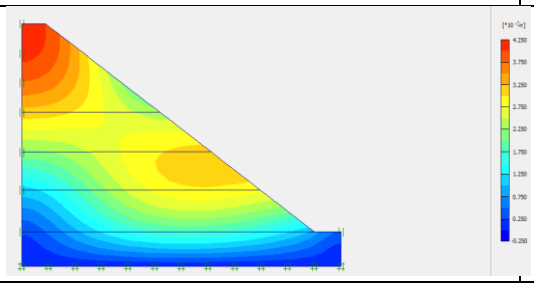
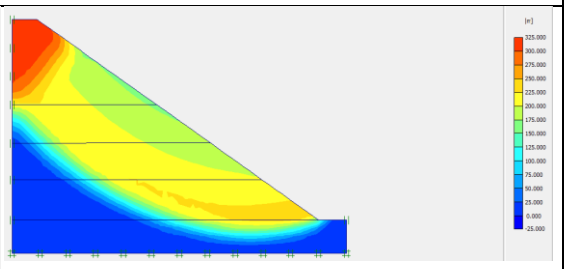
WT condition	Plastic Analysis (Existing condition)	φ-c reduction (Failure condition)
Low		
High		

Figure 5. Total Displacement of the slope at high water table and low water table.

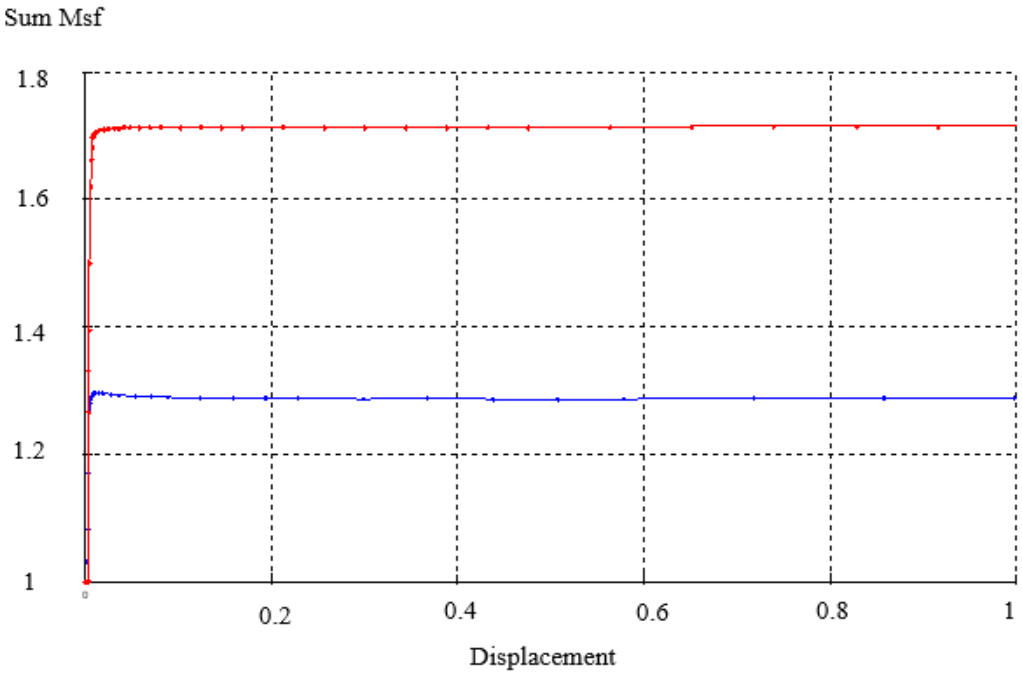


Figure 6. Displacement (m) vs $\sum MSF$ curve, low WT (red) high WT (blue)

The WT is initially considered at the low level and the water pressure is generated. Staged construction is applied to activate different soil layers, increasing the WT to a high level and activating sliding planes. Deformation analysis in a staged construction gives the number of deformations generated in the model. After the plastic calculation, safety or stability analysis is carried out employing the φ - c reduction method to calculate a global safety factor. The total displacement of the slope in two stages are shown in Fig 5. After stage construction total deformation U (in m) vs $\sum MSF$ curve is plotted for the 3 points selected along the inclined plane (top, center, bottom). From that curve (Figure .6) safety factor is obtained as 1.713 for low water table and 1.287 for the high water table. For the saturated condition result value of the safety factor is lower than 1.5 reflecting the unstable condition of the slope. From the PLAXIS analysis, the huge difference in deformed mass after rainfall indicates the rainfall working as a triggering factor for the landslide. A comparison between factor of safety result obtained from SLOPE/W and PLAXIS is shown in Table 3.

Method	Sub Method	Factor of safety Unsaturated Condition	Factor of safety for saturated condition
Limit Equilibrium Method	Bishop	1.598	0.775
	Janbu	1.485	0.629
	Morgenstern Price	1.583	0.762
	Spencer	1.587	0.764
Finite Element Method		1.713	1.287

Table 3. Comparison between factor of safety result obtained from SLOPE/W and PLAXIS

5. CONCLUSION

The obtained value of factor of safety result implies that the slope is not at all stable and needs sufficient protective measures to stabilize the slope. Based on the geotechnical study it is clear that the soil is having very low shear parameters. The increased pore pressure couldn't be balanced, causing the collapse of hills. The results of landslide investigations have practical applications to society via the avoidance, prevention, and mitigation of landslides hazard and risks. The knowledge of factors which had an influence on the landslide process may prevent a similar disaster in the future and can be applied in development strategies in the future. Among the factors affecting landslide worldwide some factors are based on regional soil conditions or environmental factors. The study was aimed at highlighting those special factors that may occur for the geological conditions of Bangladesh such as geochemistry of soil conditions.

ACKNOWLEDGMENTS

We acknowledge Colonel Md. Masudur Rahman and Assistant Professor Naveel Islam, MIST.

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Paper 82

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Sustainable Development of Roof Harvested Rainwater for Domestic Use and Urban Agriculture in Developed and Developing Nations: Economic and Feasibility Analysis

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Abstract

Access to clean water is a worldwide issue, in Bangladesh arsenic is a well-known major issue. Trying to filter contaminated ground water from shallow aquifers has failed with costly results. Starting with cleaner harvested rainwater shows promise as an alternative source of water for drinking, cooking, and household crop production. Simple filters have been developed for the household use which at first showed promise of arsenic removal but later proved ineffective in the field. Rainwater harvesting avoids the issue altogether and has been practiced extensively in Australia with great success despite it being a very dry continent. The main barriers to effective implementation are knowledge of system costs and expected reliability. This research addresses both these issues by developing an analysis method for system performance analysis and life cycle cost analysis to encourage good economic decisions. Rainwater harvesting shows great potential to bring benefits to households worldwide, as crops grown domestically tend to benefit the family unit directly as they are consumed by the growers themselves and in developing countries particularly this brings increased nutrition and health.

Keywords: Rainwater tank, rainwater harvesting, economic analysis, roof area, tank size.

1. BACKGROUND

This year marks the 50th anniversary of man setting foot on the moon on 16 July 1969, 11:32 pm GMT+10, yet the sustainable development goals published by the UN highlight that there are many people in developing countries that lack sufficient nutrition and access to clean water to this day. It is a disgrace to societies the world over that this technological achievement has not been matched with simple provision for one's neighbors. Both rainwater harvesting from rooftops and urban agriculture are ancient practices which have gained a high level of modern interest. In developing countries, urban agriculture supplies important nutrition and income to many families. In 2003, a simple filter was developed that could remove arsenic from contaminated water (Ngai et al. 2006), promising results from lab experiments showed that it could remove 90% of the arsenic content. Afterwards, installation of the filters began. However, after trials in Nicaragua, Trustees (2013) concluded that the filters "do not yet provide a sustainable and effective long-term solution" so they abandoned their use and sought clean water sources. 5000 Kanchan arsenic filter units (Ngai et al. 2006) were installed in Nepal in 2007, and a survey in 2012

found that less than half of the household filters were effective (Singh et al. 2014).

Arsenic is not only a problem in drinking water, it is also taken up by crops, particularly rice. The fact that arsenic has neither smell nor taste makes it a "monster", presenting a real and grave danger where one can easily be drinking water with high levels of arsenic without noticing. The resulting arsenicosis often has a negative socio-economic effect, with the individuals being abandoned by society (Rahman et al. 2018). This alone makes roof rainwater harvesting an important alternative source of water for drinking and cooking. Rainwater harvesting is being practiced extensively in Australia, which is a very dry continent to meet water shortages, and also in rural areas where there is a lack of access to water and in cases where bore water is unsuitable. Rainwater harvesting is a simpler process in comparison to hand pumps which often fail as has been the African experience (Parry-Jones et al. 2001). Research shows that rainwater harvesting could be a viable alternative especially when used in conjunction with urban agriculture (Stout et al. 2017).

One of the biggest hindrances to installation is the cost, therefore a thorough system performance and life cycle cost analysis is necessary to make good economic decisions. Roebuck et al. (2012) states that oversimplified approaches to analysis of RWH systems often leads to an underestimation of costs and call for detailed analysis. Victoria, one of Australia's states, instigated the "Water Smart Gardens and Homes Rebate Scheme" encouraging homeowners to use rainwater in their gardens. The scheme offered a government rebate for installing a rainwater tank. This was proven to be quite successful in Gato-Trinidad et al. (2014) report that the scheme would pay back itself within 1-12 yrs for the government and 12-47 years for the individual. They note that choosing the right tank size will affect the payback period considerably. Other authors however would question any analysis that presents a payback period (Roebuck et al. 2011). This kind of discrepancy in the literature is common place and emphasizes the need for a rigorous economic analysis. This paper presents a methodology on life cycle costing of rainwater harvesting systems with respect to their reliability and capacity to produce crops and results. The aim is that results can be put into a context that promotes realistic implementation of rainwater harvesting systems in developing countries where they can be beneficial.

2. DATA AND METHODS

The main elements of the methods used in this research are:

- Australian Standard 4536 Life cycle costing
- Yield after spillage rainwater harvesting system analysis
- FORTRAN for the data analysis
- R SCRIPT for data preparation and presentation
- Daily Rainfall data from BOM
- Garden size

Economic analysis of Rainwater harvesting systems often neglects a number of costs, so a vigorous costing methodology based on the Australian Standard of Life Cycle Costing (AS 4536) is used to analyse the system, it incorporates 4 cost/benefit stages, namely (A) Acquisition (B) Use and Maintenance Support (C) Renewal and Adaption (D) Disposal and results which include economic measures such as the net present value, benefit cost ratio and payback period. Inflation and interest rates are also incorporated and analysis is done using the present value system. Costs within the Use and Maintenance support section are often neglected, such as replacement costs and repair costs.

The primary benefit is from the value of water saved. Where the system allows crops to be grown which otherwise could not be, this is also included as a benefit. The quantity of water saved is determined using a yield after spillage analysis of daily rainfall data usually acquired from the bureau of meteorology. The model has been built in Fortran using R-script for data preparation and analysis. Details of the considerations made in the development of the model can be found in Amos et al. (2016) and Amos et al. (2018).

3. RESULTS AND DISCUSSION

Population growth and increasing levels of urbanisation all over the world has increased concerns over food and water security in developing and developed countries alike. Developing and developed countries are failing to meet the sustainable development goal 3 health and wellbeing, and Goal 11 Cleaner and sustainable cities. Goals 2 and 6, Food and water security, are a particular problem for many developing countries. Rainwater harvesting and urban agriculture can contribute to all of these goals if instigated in a scientific manner. Provisional results in Table 1 show the potential monthly water savings in an arid region of Australia with a mean annual rainfall of only 292mm. This still provided an average annual yield of 21kL which equates to over 50L/day. As can be seen in Table 1 the yield is not consistent, it varies from month to month. The lowest yield shown is for August at 650L, which still equates to over 20L/day. However, the values are averaged over the whole data set and so in any one given year lower or higher monthly yields will be expected. Nevertheless, results indicate that if the water was used as a drinking water supply alone, even in this dry arid region of Australia it could supply a reasonable amount of water.

Table 1. Rainwater tank performance summary

Station number:	***BOM Australia 013017***							
Tank size (kL):	***3000***							
Roof area (sqm):	***200***							
Month:	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***		
Mean Monthly Rain (mm)	***31.53***	***43.55***	***35.9***	***17.98***	***21.02***	***18.54***		
Rainwater tank yield (kL):	***2.56***	***2.4***	***2.16***	***1.31***	***1.73***	***1.6***		
Month:	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***	***mean***	***Total***
Mean Monthly Rain (mm)	***11***	***9.72***	***10.43***	***15.92***	***28.79***	***47.44***		***291.83***
Rainwater tank yield (kL):	***1.13***	***0.65***	***0.98***	***1.27***	***2.16***	***3.05***	***1.76***	***21.11***

If this is the case in Australia, it indicates that there is a potential in Bangladesh where there is a much higher rainfall. The main issues will be if enough water can be supplied or stored over the dry periods. However, it may be worth considering that reducing arsenic contaminated water intake for even only those parts of the year where there is abundant rainfall water available will still be beneficial in reducing the annual arsenic intake. Obviously the preference would be to eliminate the intake all together, but possibilities must be weighed against socioeconomic realities. In India low cost reverse osmosis (RO) water filters, also supported by the Tata Indian car company, are becoming popular although they may not be the ultimate solution (Annala et al. 2018). Frugal innovation plays an important role in development. Indeed, innovation also has the potential to reduce rainwater harvesting costs (Melville-Shreeve et al. 2014). Rainwater harvesting has a high potential to provide clean water as most of the pollution occurs during runoff. Filtration therefore may be more effective.

Figure 1 shows results from the analysis of two scenarios for tanks of 1 to 7 kL (m^3) and for 2, 4 and 6 occupants. A typical installation in Australia involving a toilet, laundry and garden installation with pumps and plumbing and an acceptable installation in Kenya where water is moved manually rather than by plumbing and pumps. The savings from 20L jerry cans in Kenya is where the user, due to failure of the mains supply system, often has to purchase water from street vendors at elevated prices. As can be seen from the results, the Kenyan installation has a higher benefit cost ratio (BCR). In fact, the BCR for the Kenyan scenario was even higher when the garden use was not included due to a higher reliability and consequently higher savings from avoiding purchases from street water vendors. This could be managed somehow by either installing larger tanks or managing water use to avoid the vendor purchases and still keep the benefits from garden use. The hedonic price, a measure of prestige in owning a RWH tank and the resultant increase in real estate value in the Australian market was

found by Zhang et al. (2015) to make installation beneficial to the homeowners, results from the analysis in this study confirmed this using their estimated hedonic value of $18000. Results show that analysis of RWH systems is highly situation specific.

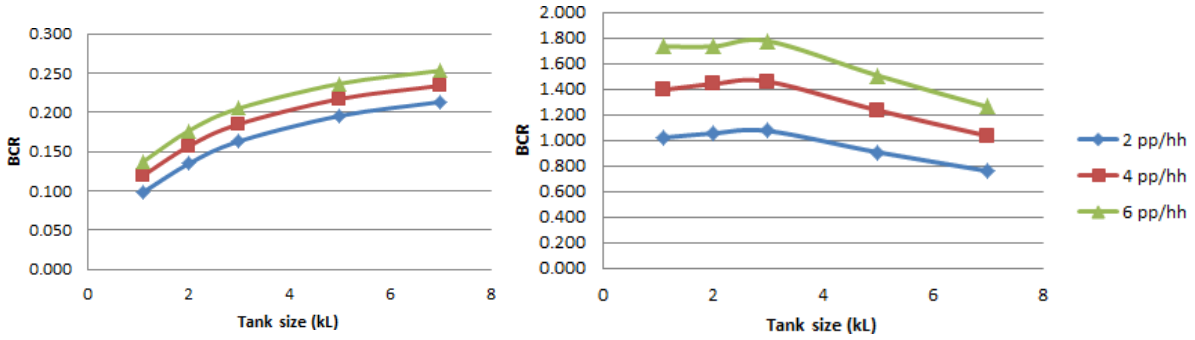

Figure 1 BCR against tank size for 2-6 occupants, laundry, toilet and garden installation with plumbing and pump (Left-Australia) and without plus 20L jerry can savings (Right-Kenya)

One aspect that the analysis neglected was benefits from food production which could change the analysis considerably, particularly in the Kenyan scenario where there is a limited water supply. Domestic agriculture is often practiced as a frugal innovation in itself, rainwater harvesting has the potential to increase crop production and increase household nutrition and possibly contribute to household income from crop sales. On a suburb scale this may also increasing the variety of vegetables available increasing nutrition in a given area and avoiding the urban desert scenario which has become an increasing problem in America (Beaulac et al. 2009).

CONCLUSION

Rainwater harvesting shows great potential to bring benefits to households worldwide, supplementing water supply and producing crops in both developing and developed countries. Rainwater harvesting could potentially reduce the arsenic intake of people exposed to arsenic contaminated water. Crops grown domestically tend to benefit the family unit as they are consumed by them, in developed countries this brings satisfaction and in developing countries particularly, this increases nutrition and health. In this way the combined use of rainwater harvesting and urban agriculture can contribute to at least 4 of the sustainable development goals, namely, Goals 2 Zero hunger, Goal 3 health and wellbeing, Goal 6 sustainable management of water and sanitation for all, and Goal 11 Cleaner and sustainable cities. Results show that the economics of rainwater harvesting systems are highly situation specific and may vary from nation to nation showing the need for a rigorous analysis. The situation in Bangladesh should be investigated and compared to issues in Australia and Kenya.

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Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Environmental Pollution of Present Chinese Industrial Revolution and Its Impact on Surrounding Countries

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Abstract

Industrial development has transformed China from an agriculture-based country to a modern high-tech economy. China is contributing in almost every sector to increase its economic growth and to make it more competitive. Production in almost every sector in China is increasing in recent days, like textile, steel, machinery etc. But this high rate of production is causing a huge problem to its surrounding countries. Coal is the main source of fossil fuel in China and it's the main reason behind the production of the huge amount of SO2, CO2, NOx etc. gases. Most of the rivers in south-east Asia is originated from Himalayan area and eventually, they end in the Indian ocean or Bay of Bengal crossing the border of countries like India, Bangladesh, Nepal, Bhutan etc. So, industrial discharges from textile industries of China are responsible for the ecological disaster in these countries. Surrounding countries are suffering from almost every type of environmental pollution, like water pollution, air pollution, marine pollution etc. The contribution of Chinese companies is also negative. Illegal trade by these companies causing the destruction of forest and other natural resources in surrounding countries. Formulation of different treaties by international organizations is forcing China to decrease its pollution rate. Although they have achieved some success, results should be found in the long run. Technical support from developed countries can play a key role in achieving its target. More dependence on renewable energy sources is the only solution at present. In the global age of industrial development, each country is not any more separated from the other. Formulation of different treaties at the international arena is necessary to bringing all these countries close to each other.

Keywords: Biofuel, Marine, Renewable, Topsoil, Global Warming.

1. INTRODUCTION

Industrial pollution in present-day China has become a common concern from environmental

perspectives not only within China but also to the international community. Surrounding countries like India, Bangladesh, Mongolia, and European Union have become heavily affected by the air pollution caused by Chinese industries. According to the report of World Health Organization (WHO) seven out of ten, the world's most polluted cities in the world are in China (Miles, 2018). Huge dependence of Chinese industries on coal combustion is responsible for the high rate of CO2 generation, which eventually contributes to global warming. Industrial discharges from textile industries of China are responsible for the ecological disaster in these countries. Chinese dependence on coal is not showing any sign of reduction, but it will continue to increase in future. According to the World Energy Outlook 2017, Chinese power generation sources in 2016 were 58% coal, 20% hydro, 9% wind, 5% solar, 4% gas, 2% nuclear, 1% oil, and 1% bio-energy (Iea, 2018). This high coal consumption of Chinese industries is a major concern in surrounding countries because it is not only responsible for the deteriorating condition of air quality in surrounding countries, other areas of the environment like water are also affected by the pollution. The Chinese government is more concern regarding air and water pollution within their country compared to the global generation of CO2. They sometimes watch different initiatives taken by international organizations as an attempt by the developed countries to control their economic growth. International coordination and at the same time the development of technology is the only solution at present condition.

2. CHINA AND ITS GEOGRAPHY

China is the most populous country in the world and it is located in East Asia. It has a population of 1.35 billion. China stretches some 5,026 sq. km across the East Asian landmass. China is bordered by the sea in the east, with the East China Sea, Korea Bay, Yellow Sea, South China Sea, and bordered by landmasses on its 3 other sides, from North Korea to Vietnam (Rowley and Cooke, 2010). The total landscape of China is composed of five homogenous physical macro-region. These are Eastern China (subdivided into the northeast plain, north plain, and southern hills), Xinjiang-Mongolia, and the Tibetan-highlands.

Figure 1. China in the World Map

3. INDUSTRIAL SECTORS OF CHINA

China is the second largest economy in the world and one of the most industrialized country in the

world. China was a major leader in science and technology in ancient history until the Ming Dynasty. The invention of different ancient industrial products like, pottery, gunpowder etc. all came from ancient China (Ducksters, 2018). Modern industrial development was mainly started in China after 1949 (Toru, 2006). Efforts were made to organize science and technology based on the model of the Soviet Union, in which scientific research was a part of central planning. Foundation of much of the modern-day steel, iron and machinery industries were initiated under the First Five-Year Plan initiated around 1953–57. Soviet assistance played a key step during this period to achieve the targets of the five-year plan and major technological development (Countrystudies, 2018). A major problem faced by the Chinese industrial sector was during the Cultural Revolution period 1966–76 (Deng, 2000). In 1967 output fell, and it remained below the 1966 level in 1968. Production recovered in 1969 and grew by 18 percent in 1970. With the resumption of growth and the beginning of the Fourth Five-Year Plan (1971–75), output grew by over 10 percent in 1971 and 1972 and by 13 percent in 1973. A wide-ranging program of investment in plants and equipment, including foreign imports, raised industrial capacity (Wikipedia, 2018). After Mao's death in 1976, science and technology were taken as the main tool of development in China and Soviet constant collaboration continuously helped to achieve different targets of industrial development (Alphahistory, 2018). Present day modern industrial China is the result of different initiatives taken by the Chinese Communist Party after that period.

China is the largest producer of steel in the world. China has an industrial production rate of 567 million tons (the year 2009) of steel and it is half of the total production in the world (Tang, 2010). These huge amounts of steel are mainly utilized to meet industrial development in different sectors, like machinery building, construction, and infrastructure etc. sectors. China also successfully exports steel in different countries meeting their internal demand. The United States of America and other countries in the world is highly dependent on the production of Chinese steel industries. China is one of the world leaders in the textile industry. It has a long and rich history in the production of silk, best fiber and cotton (Flannery, 2013).

China is not so developed in automobiles like other industrialized countries like Japan or Germany. They are continuously trying to develop their technical issues to do well in the future. Development of the automobile sector was mainly started after 1949 because they were not successful to keep pace with other countries (Zhaotao, 2015). Production level was quite low in the 70s and even 80s. China is also investing in the railroad industry and civil aviation sector to get more world market in the future. Civil aircraft and aircraft engines were produced in large plants located primarily in Shanghai, Xi'an, Harbin, and Shenyang. Medium-sized factories produced the necessary test equipment, components, avionics, and accessories. China is also making continuous progress in the case of other industries like tourism, luxury goods, telecommunication etc. Providing importance on more than one sector to cope with the modern challenge is the key feature behind China's success in the industrial sector (Sturgeon and Biesebroeck, 2010).

4. MAJOR SOURCES OF ENERGY IN CHINA

The central government of China is the main responsible body for controlling major sources of energy management. Although China is one of the biggest consumers of the world's energy sources, its per capita consumption is much lower compared to other countries of the developed world.
China is mainly dependent on coal, oil, natural gas and nuclear energy for the consumption of energy. China is also making progress in the case of renewable energy production. China is the second largest producer of solar energy after Germany. China is the largest producer of coal in the world. It produces 1.95 trillion kilowatt-hours per year electricity from the combustion of coal. As of the end of 2006,

total coal reserve of China is 52 billion tons of lignite quality coal as of 2006 (Sourcewatch, 2018). Coal is also used for other purposes in China like industrial combustion, domestic use etc. Combustion of coal in China is the major concern to the international community and within China itself for its massive impact in air pollution. China consumes 10% of the global oil consul oil consumption, which is equal to 4855 Twh (in 2009). Although China was one of the largest producers of oil during the 1990s, it has increased its oil import in recent days. In 2006, it imported 47% of its total oil consumption. China announced on June 20, 2008 plans to raise petrol, diesel, and aviation kerosene prices. This decision appeared to reflect a need to reduce the unsustainably high level of subsidies these fuels attract, given the global trend in the price of oil. China is the world's seventh largest producer of natural gas, which is equal to 1,015 TWh in 2009 that was 3% of the world supply (IBP, 2015). Natural gas is utilized in almost all heavy industry in China. They are continuously searching for new sources of natural gas in the South China Sea.

China is desperately searching for other alternatives sources like solar energy, Wind, Biomass etc. China's Renewable Energy law is among the most aggressive in the world. China is one of the world leaders of solar energy production. China produces 30% of the world's solar photovoltaics (PV) (Ariel, 2009). The Chinese government is continuously taking initiatives to develop a new advanced model of the thin solar panel by its companies to solve the electricity problem. Six biggest companies of China have a combined value of 15 billion of US dollar.

China has the environmental resources to produce a huge amount of wind power and it is already the fourth largest producer of wind power in the world. The Chinese government has identified wind power as one of the main resources of economic growth. It has a future target of producing 25 GW of wind power within 2015 (Dvorak, 2015). The Chinese government also encourages foreign companies to invest in its wind power sector. Chinese solar sector also has some controversies, like China is a large producer of polysilicon, for use in first generation solar cells around the world. This product has an environmentally problematic by-product silicon tetrachloride. Cost of processing this material is very high. China is the third largest producer of ethanol-based biofuels and they are taking continuous steps to increase its production. Biomass or bio-fuel industry also has some negative sides; an increased number of farmers in the country has started to consider them in the process of "farming oil" production. Despite these issues, many experts from the World Economic Outlook and the International Monetary Fund think there would be increasing competition worldwide between biofuels and food consumption for agricultural products and that competition likely would continue to result in increases in prices of crops (Frankhaugwitz, 2018). China had a hydropower production capacity of 10 GW in 2010. Dams have been constructed on nearly all its major rivers. Projects like Gansu Dang River Hydropower Project was registered as a Clean Development Mechanism (CDM) project in accordance with the requirements of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Nasaw and Weaver, 2009).

5. POLLUTION FROM CHINESE INDUSTRIES

Huge energy consumption from Chinese industries is responsible for the production of harmful industrial discharge like CO2, SO2, PMx, toxic water etc. All these substances are playing the key role behind the deteriorating health condition in China and surrounding areas. The number of cars in China is also increasing in recent days, because of industrial development and increase in the per capita income of Chinese people.

Air pollution from Chinese industries has become a major concern for the whole world in recent days. China is a country, which lacks the availability of oil and other natural resources, but has a huge

stockpile of coal. Dependence of the Chinese industries on this coal is the main problem behind the air quality degradation in recent days (Ye, 2018). A huge amount of SO2, CO2 generated from the Chinese industries are not only deteriorating the condition of Chinese industries but also causing a huge problem for its surrounding countries. "Asian Brown Cloud" has become a topic of recent public attention in recent days. It is a layer of air pollutants recently covered parts of Indian Ocean, India and Pakistan was the result of industrial combustion from Chinese industries. Huge public reaction in these countries against this type of contribution of Chinese industries has become a major concern. Chinese industrial pollution is not a problem for not only in its surrounding countries. Even countries like the USA located thousands of miles away are also becoming conscious regarding the level of pollution from the Chinese industries (Stromberg, 2014). Countries like the USA are suffering from the huge amount Mercury produced from Chinese industries. Serious concerns over China's contribution to Tran's boundary air pollution have become a topic of major discussion in recent days. Chinese industrial pollution is a major topic of discussion for US policymakers in recent days. Another significant major problem from the Chinese industries in recent days is Acid Rain. Acid Rain is a type of rain, which carries chemicals like SO2, NOx. These pollutants mainly create different types of materials combining with rainwater and cause Acid rain. When these raindrops fall on the ground, they cause huge damage to the building materials and human skin. A person of the surrounding countries of USA, like Bangladesh, India is mainly suffering from this problem (Economy, 2007).

Although most of the river of South-East Asia mainly originates in the Himalayan region of China, it has huge water scarcity. Lack of surface drinking water is its one of the million concerns. People are suffering from different water-borne diseases, like Cholera, typhoid etc. because of this water scarcity. Lack of access to piped water is also responsible for a major deterioration health condition in China, which is making the general people more dependent on surface water. A huge number of children less than 5 years old are suffering from diarrhea disease in China has become a major concern (Pinto et. Al., 2008). China is the home of 7% water resource in the world, but the biggest problem is that it covers 20% population of the world. Three hundred million people in the whole country suffer from lack of safe drinking water. The Chinese government must face a huge public reaction in different cases if they fail to meet the demand. Increased industrial discharge from Chinese textile and other heavy industries are only making the situation more critical, but people are heavily suffering for these reasons. In a survey conducted at 44 cities in the country, the result shows that 42 of them have the serious problem of water scarcity (Pinto et. Al., 2008).

Deforestation is a global problem because trees absorb carbon dioxide and convert it to glucose during photosynthesis. So, excessive cutting of trees and destruction natural rain forest will affect environment of the entire region. Forests are major carbon storage centers, but deforestation releases all the stored carbon back into the atmosphere. This has serious global consequences because carbon dioxide is a greenhouse gas that traps heat in the atmosphere and contributes to climate change (sciencing, 2017). The huge demand for timber in Chinese industrial is the main problem behind the scenario. Because of the Chinese Government initiative to save the remaining stock of timbers available in a natural condition in China and huge industrial demand is forcing them to look for somewhere else. Academic research and NGOs such as WWF and Global Witness have already revealed the existence of illegal trading networks in central Africa, Burma, and Russia leading directly to Chinese ports or cities. China is a also a major importer, consumer, and exporter of the world's timber. It’s own forest meet 40% need, so they have to depend on global market or on illegal trade from surrounding countries to meet their remaining demand. Chinese government has signed bilateral agreements with the US, Europe, Indonesia, and Burma to ban illegal timber import, but they have not taken any kind major initiatives (Caramel and Thibault, 2012). Timber available within the border of China are also vulnerable from this increased demand from Chinese industries. Nearly, 40%

of land in China is under the threat of soil erosion at present for this increased amount of timber destruction. The world's highest water erosion rates occur in China in the Loess Plateau, where 1.6 billion tons of topsoil is washed into the Yellow River on an annual basis (Sciencemag, 2018). According to the Schloenhardt (2008) report, “Chinese industries have even increased its impact in far Russia. 40% of its logging comes from Russia and huge percentages of these timbers are illegally imported. Once these forests are irresponsibly cut for short-term gain, these values are gone forever. China is one of the top export destinations for Russia's timber, and nearly 20-25% timber comes in an illegal way to meet the demand of huge Chinese furniture, paper, plywood products, its surrounding countries are losing their remaining forces”. Although greenhouse gas emission is an international issue, Chinese contribution to its development is quite major. China is the second largest producer of greenhouse gases and 29,888,121 thousands of tons of CO2 are emitted by Chinese industries (Lim, 2011).

Illegal wildlife trade to China has also become a major concern in recent days because animal bones and other organs are used for scientific research and in traditional Chinese medicine, practiced by qualified doctors at certain hospitals in China. According to an International Fund for Animal Welfare (IFAW) report the operation in the spring of 2012 resulted in the confiscation of more than 130,000 wild animals and animal products, the shutdown of 7,155 high-street shops and 628 online stores, and the removal of illegal online trade information in China (IFAW, 2019). Recently, Chinese government have taken some major initiatives to stop illegal animal trade. In 2017, China, the world’s largest ivory market, has banned all domestic ivory sales (Southerland, 2019). Initiatives like this are required to stop illegal animal trade throughout the region

6. POLICIES TAKEN BY THE CHINESE GOVERNMENT

Environmental issues have already become a huge issue of public thinking in recent days in China. Day by day, public consideration of the air and water pollution is increasing. To counter the situation and provide a possible solution, the Chinese government had also taken some necessary measures. Because of huge lobbying by the industrial sectors these initiatives are facing difficulty in implementation. Under China's Air Pollution Action Plan of September 2013, the Chinese Government has issued a "Five-Year Plan on Air Pollution Prevention and Control in Key Regions" to mitigate air pollution problem in the area. The plan covers 3 key regions (Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta) and 10 city clusters, involving 19 provincial level jurisdictions and 117 cities (Sun et.al., 2015). These plans have been mainly taken to reduce emission from Chinese industries.

Increase the level of energy saving is one of the main targets of the Chinese government for the future. Because of the lack of oil and gas availability, Chinese industries are under the continuous threat of lack of energy supply. Policies for Energy Saving: The Chinese government has set a target of reducing energy consumption for every 10,000 Yuan (1,298 U.S. dollars) of GDP by 20 percent by 2010, while pollutant discharge should drop by 10 percent (Luan, 2007). As a result of this initiative dependence on the energy and at the same time level of environmental pollution both will decrease. Acid rain and air pollution both are directly correlated with this. So, this is a major issue of focus for the Chinese government at present. Policies for environment protection by regulation and economic incentives to reduce the amount of sulfur dioxide emitted from the burning of coal in the factories, the Chinese government has imposed heavy penalties to such emissions and encouraged the building of equipment to capture sulfur dioxide (Chow, 2010).

7. POSSIBLE RESPONSES FROM NEIGHBORHOOD COUNTRIES

Although it is very difficult to counter the major threat posed by one of the fastest growing country and major superpower China for its surrounding developing countries, their combined initiatives can achieve some success. Surrounding developing countries like India, Bangladesh, Nepal, Mongolia, and Myanmar etc. can formulate different treaties among each other and then take the agreement to the Chinese government and UN. Initiatives taken by multiple countries instead of the single initiative must be more appealing to the international arena. Neighboring countries can also claim compensation from the Chinese government, because of the harm they cause to their environment through UN (Tang, 2010).

Border control is one of the main ways of achieving success in the present world. Countries like India and China have already achieved some success in going through some bilateral agreements in case of Tiger protection. Different types of endangered species in this region especially the Royal Bengal Tiger is under the threat of extinction, because of illegal trade in the border. The operation in the spring of 2012 by the Chinese Government resulted in the confiscation of more than 130,000 wild animals and animal products, the shutdown of 7,155 high-street shops and 628 online stores, and the removal of illegal online trade information (Ifaw, 2018). In September 2011, during the visit of Indian Prime Minister Manmohan Singh, Indo-Bangladesh pact for Sunderban Tiger protection was signed by West Bengal chief minister Mamta Banerjee and Bangladesh. Controlling the illegal trading of timber also necessary in the present scenario. According to the International Non-Government Organization Global Witness, for example, Chinese companies are carrying out large-scale, unregulated logging and mining operations in Myanmar: "Large parts of forest along the China-Myanmar border have been destroyed, forcing logging companies to move even deeper into Myanmar's forests in their search for timber. When China failed to take action in the case of Burma, the Myanmar government arrested more than 400 mainland workers and put them in jail for eight months until June 2006, when Beijing and Rangoon reached an agreement (Economy, 2007).

8. CONCLUSION

In the global age of industrial development, each country is not any more separated from the other. Formulation of different treaties at the international arena to bringing all these countries close to each other is necessary. Countries like China face huge internal development and industrilisation demand, but at the same time, it lacks necessary fossil fuel to achieve that target. Development in the renewable energy sector is still not satisfactory to change the present condition. So, level of environmental destructive steps taken by different companies in different cases is not only causing a problem for its own people, but also to the surrounding countries. The Chinese government, in different cases, is showing lack of interest to take the necessary steps to solve the problem. Only international collaboration among surrounding countries and technological development can solve the problem. Developed countries also required coming forward to provide more technical support to China for developing green energy sources.

ACKNOWLEDGMENTS

We I would like to express my special thanks of gratitude to supervisors, Dr. Gary Reiners, College of Design, Iowa State University who gave me the golden opportunity to do this wonderful project on the impact assessment of present Chinese industrial revolution on the surrounding environment during my Master's studies. I would also like to acknowledge with much appreciation the crucial role of

research staffs of the Iowa State University, who gave me necessary guidelines in all stages of the project. A special thanks go to my teammate, Jared Taylor, who helped me in several stages of the project.

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Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Sustainability of Carsharing Service in Dhaka: A Case Study on Uber Users

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Abstract

Sustainability of transport system depends on a range of services and impacts produced by transport which can be indicated by several factors like mode choice, affordability, equity, accessibility, pollution, safety, and efficiency. To address the increasing congestion problem and demand for mobility, car sharing services have been introduced to urban areas to focus sustainability. Uber is a ridesharing service catered for an easy, comfortable, and convenient urban travel experience. It was launched in Dhaka in 2016. As a new alternative mode is available to the city dwellers, many of them are using it. The study intended to identify the Uber users as well as to understand their usage pattern and preferences from a sustainability perspective. For this study data was collected through in-person questionnaire survey of Uber users at several potential points of users by random sampling method. The study has used descriptive approaches to investigate the issues. Results show that Uber is mostly used by the people of middle to high income, younger age group, due to its better accessibility and safety. However, due to the higher fare structure, low to middle income people can not avail this service which is a negative point for Uber as far as sustainability is concerned. Uber trips are found most likely to be shifted from CNG and Taxi. Uber has no impact to change private car ownership status and car use. In some cases, Uber has diverted trips from non-motorized modes. It is clear from the observation of this study that Uber is providing service to a particular segment of the population with less sustainability concern of urban transport in Dhaka.

Keywords: Uber, Carsharing, Sustainability, Accessibility.

1. INTRODUCTION

Sustainable development focuses on meeting the needs of the present without compromising the ability of future generations to meet their own needs and is measured according to social, environmental, and economic dimensions (CEE, 2009). The adoption of the United Nations 2030 Development Agenda considering 17 Sustainable Development Goals in 2015 has provided a new impetus to address the sustainability of transport systems and urban areas across the world. Sustainability of transport system depends on a range of services and impacts produced by transport which can be indicated by mode choice, use, affordability, equity, accessibility, energy efficiency, pollution, safety, security, public health, efficiency and integrity (Litman, 2018). Sustainability in transport has been emphasized on the goals of ensuring healthy lives and promoting well-being for all at all ages, ensuring access to affordable, reliable, sustainable and modern energy for all, making cities and human settlements inclusive, safe, resilient and sustainable and ensuring sustainable consumption and production patterns. According to European Council of Ministers of Transport (2004), a sustainable transportation system is one that allows the basic access needs in a safe and consistent manner considering human and ecosystem health with equity within and between generations. Sustainable transportation mode also should be affordable, operate efficiently and support a vibrant economy. From the environmental perspective, it should limit emission; minimize consumption of non-renewable resources; the use of land and the production of noise (CST 2005, as quoted by Littman 2016). Several strategies can be followed to bring sustainability in transportation system like avoiding the need to travel, reducing the total distances travelled or emission intensity of transport modes, encouraging people to use eco-friendly modes etc. The choice of walking, cycling, other non-motorized modes, public transport, carsharing can drive the system towards sustainability (GNBF, 2010).

Carsharing services allow individuals to gain the benefits of a private vehicle without costs and responsibilities of vehicle ownership as well as reduce the use of private vehicles which can assist to lessen the emission level. Due to the widespread adoption of smartphone embedded with GPS, combined with the availability of digital road maps, the use of ridesharing services is enhancing (Clewlow and Mishra, 2017). Around 0.4 million individuals share nearly 11,700 vehicles as part of organized carsharing services over the world (Shaheen and Cohen, 2008). It has been found that the worldwide number of carsharing members will continue to grow from 2.3 million in 2013 to more than 12 million by 2020 (Degirmenci and Breitner, 2014). It can contribute to diminish the use of private cars and to minimize the level of greenhouse gas emission which can help to attain the goals of sustainability.

Uber is a carsharing service where a smartphone application was designed to connect passengers and drivers by means of the internet to generate trips for making urban travelling easier (Nistal and Regidor, 2016). The main goal of Uber is to make the cities more accessible by reducing congestion and pollution through encouraging carsharing as well as providing a convenient mode of transport for the users (Dong et al., 2014). Carsharing is a very recent phenomenon in Dhaka and was launched on 22 November, 2016 through Uber service (bdnews24.com, 2017). According to a report by Uber, Dhaka has a lack of parking spaces and car users face difficulties for that; to mitigate their sufferings and to reduce per capita car ownership Uber has been introduced in Dhaka; now around 0.55 million people are using this service (personal communication with T. Ahmed, February 13, 2018). UberX, UberPREMIER, and UberMOTO these three options are now available in Dhaka and provide services within Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) area (bdnews24.com, 2017). It has expanded services due to its benefit, popularity and increasing demand for it; for that reason, some other similar services were also introduced with time.

In Dhaka city, more than 45% of the total trips are generated by motorized vehicles like car, motorcycle, taxi, mini bus, truck etc. (Rahman and Shafiq, 2009). After the introduction of ridesharing services, there is a possibility of changing the share of motorized trips and the questions may arise regarding the sustainability of this system. Sustainability of that service may depend on the use pattern, overall benefit from this service and users' perception regarding use of such service. This paper seeks to identify the users of Uber in Dhaka including their use pattern as well as to understand the factors influencing the choice of such service. Issues and concerns pertaining to ride are also further identified and discussed. The paper also attempts to evaluate how these modes contribute to the promotion of sustainable transportation that has been discussed on further sections of this paper.

2. METHODOLOGY

The research has used primary data collected by in-person questionnaire survey of users. At 95% confidence level and 5% margin of error, the sample size for in-person questionnaire survey was calculated to be 384. As no previous information or database of Uber users including their locational distribution is available, potential location of users was needed to be identified through Uber app tracking by the authors. And it has been assumed that where the density of Uber car is high there the density of users and travel demand of Uber are also high. To identify the Uber hotspot, data were collected for three points of time (9:00 am, 5:00 pm and 8:00 pm) in a single day for a week in the month of January, 2018. Data were collected through setting the origin of the trip at different locations of Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC). When the origin points were fixed in the app, the density of Uber cars around one to three kilometers radius from the origin point was shown at Uber app which was further recorded. Thus the potential points (Uber hotspots) for the survey were identified through summarizing the recorded data. Among 43 points, 12 points were selected as potential points where the average number of Uber cars was the highest on recording times. Among the 12 points, six points are located within DNCC and the rest six points are from DSCC. From Dhaka North City Corporation, Mirpur, Shaymoli, Karwan Bazar, Gulshan, Uttara, and Dhanmondi were selected. And Lalbagh, Siddeswari, Motijheel, Khilgaon, Kamalapur and Dhaka University areas were chosen from Dhaka South City Corporation. To ensure that the total sample size is equally distributed among all study areas, 32 respondents were surveyed from each area through random sampling. Here it is notable that in person questionnaire survey was used because it allows data collection in a single interview with respondents and less time is required to collect the whole information. Due to time constraints and the unwillingness of people, the collection of all trip information has become impossible. That is why the trip information of one month by Uber was collected. Due to the presence of some missing data and outliers, information of 379 users was kept for analysis. The paper has used descriptive approaches to investigate the collected information of different variables to fulfill the objectives and further the results were assembled with the essence of sustainability.

3. RESULTS AND DISCUSSION

The profile of users including their use and perception has been comprehended from the available data and the sustainability of their use was further judged using these contexts. According to an interview of an Uber official, the users of Uber are increasing with time and it became almost double within one year, but no information had been provided about which socio-economic groups mainly use Uber. That information is important to get an idea about sustainability socially and economically. Moreover,

users' perception, their understanding, use pattern can help to investigate the sustainability environmentally.

3.1 User Group of Uber

Out of the total number of respondents 64% has come from the age group of 18 to 33 years which indicates that people of younger ages mainly opt to use such ridesharing services in Dhaka. Average monthly household income of Uber users was found BDT 76,604 though among the users it deviates highly. Moreover, according to users' opinion, they need to pay BDT 35 to BDT 45 per kilometer in Uber trips. From these pieces of information, it has been revealed that Uber service in Dhaka does not facilitate all social and economic groups equally and low to middle income people could not avail this service usually. In a social and economic perspective of sustainability, this situation cannot be equitable.

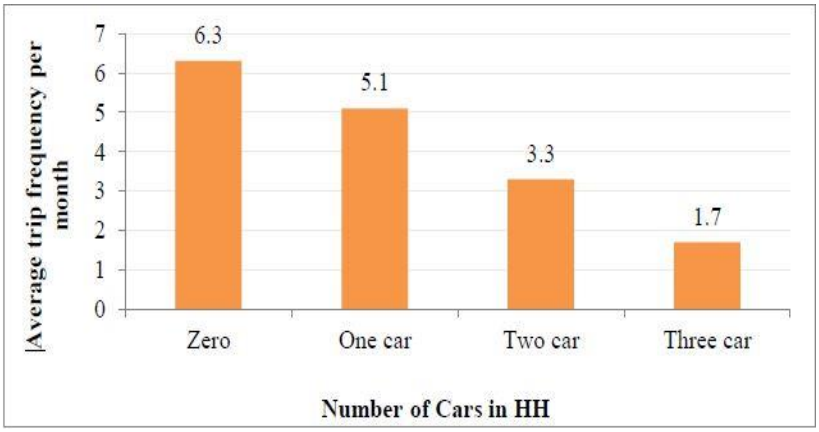

Figure 8: Car ownership of different income group

Almost two-thirds of the users has no private car (65%) and the use of Uber decreases with the increase of the number of cars in household (Figure 1) which denotes that Uber trips may increase car use among the city dwellers. It can be the contributor to increase motorized trips that is not apposite to bring sustainability in the transportation system.

3.2. Use Pattern of Uber

Sustainability of a carsharing program may depend on the extent of sharing tendency of users and change of private vehicle use. In which, degree of car-sharing happening can be defined from the number of co-trip makers of trips. Generally, Uber car has the capacity to carry three co-trip makers with user; but according to condition and wish or demand of users it may vary. At Uber trips, friends, colleagues and family members have been found as co-trip makers and among them, friends and family members are co-trip makers at 53% trip. Due to the social context of Bangladesh sometimes users ride alone rather sharing a trip with unacquainted persons; so ultimate goal of carsharing for sustainability is not maintained. Carsharing tendency changes in accordance with the trip purpose and it is higher for non-work trips. Most of the trips made by Uber are single purpose trips and 52% trips are generated only for shopping and recreational purpose.

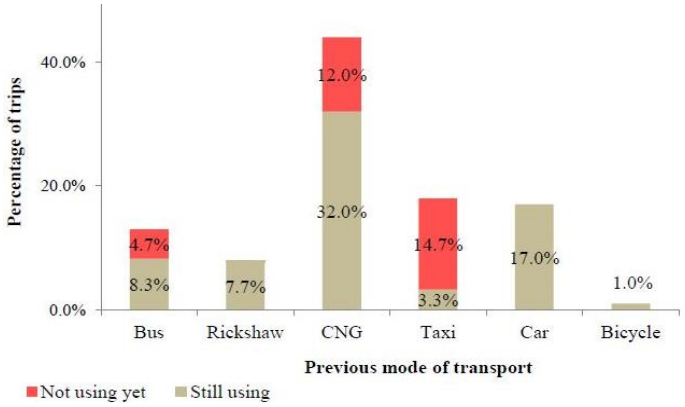

Figure 9: Previously used modes for Uber trips

Uber trips have been shifted from other modes generally and 44% trips are diverted from CNGs and 18% from taxis (Figure 2). But here it is notable that most of the trips (14.7%) which have been shifted from taxi are not made by it at all now. The trips which have been switched from private cars are not permanent shift; such users use Uber occasionally instead of a private car. Most of the users have no concern about reducing greenhouse gas emission; they like to ride with Uber to avoid the hassle of parking or to get relief from various driving problems or in the situation of breaking down of the car. So it can be stated that Uber has no impact to change car ownership status. Around 9% trips have been permuted from non-motorized modes like rickshaw; bicycle etc. though their shift is not inalterable. Howbeit Uber has grasped the trips from non-motorized to motorized to some extent which may be urged the system towards unsustainability from an environmental perspective.

3.3. Factors Influencing Uber Trips

In accordance with users' opinion, the reasons behind preferring Uber instead of other modes are mainly easy accessibility, safety, technological nature, and reliability.

Table 10: Factor influencing to choose Uber

Factors behind choosing Uber instead of other modes	% of response
Safety	47.5
Fast service and reliable	34.8
Comfort	36.4
Easy accessibility	57.7
Technology based mode; so no cost negotiation with drivers	43.7
Avoiding hassle of parking and driving	5.7
Emergency trips	4.3

These are shown in Table 1 where easy accessibility appears to be the top reason for preference of Uber and around 58% user accord with that. To get a safe ride and to avoid the negotiation with drivers attract many users to use Uber. Moreover, the users who own private vehicles use Uber to get relief from parking and driving; so it can be stated that Uber can reduce the need for self-driving.

3.4. Evaluation of Uber Service with Respect to Sustainability

The Uber service in Dhaka can be evaluated from the perspective of sustainable transport. In this case, sustainability is discussed in terms of reliability, safety, affordability, traffic congestion reduction and trend of motorization. It has been revealed that users are satisfied with this service in terms of reliability as they need a shorter waiting time than other modes. However, there are reported that sometimes drivers of these services refuse to book passengers during the rush period, particularly at the time of congestion.

According to users, Uber provides secured and safe service; especially the feedback of female users was very positive in this regard. But a few cases of threats to the safety and security of passengers have been reported- like drivers take advantage during peak hours by charging more fare illegally, sometimes drivers ask about destinations with reluctance to go there although it has been preset through Uber app, sometimes GPS system of Uber does not work or denote fake location.

The fare structure of Uber in Dhaka may not be supportive for the users of all socio-economic classes. That is why low to middle income people cannot ride with this service. Due to the presence of surge pricing option, fares can spike drastically during peak periods and inclement weather. This pricing mechanism puts passengers to expend more fare during congestion periods. 83% users have claimed about that.

Theoretically, Uber should have reduced the need of self-driving to some extent or encourage sharing ride with others going in the same direction. But from the information of the number of co-trip makers using Uber service, it is notable that carsharing in Dhaka still does not address the issue of extensive utilization of low occupancy vehicles which could be identified as one of the root causes of congestion in urban centers. Without the intervention of proper carpooling concept and change of social context, it may not be possible for Dhaka.

From Figure 2 it has been found that most of the Uber trips have been diverted from CNG, taxi and private car. Users who have shifted their trips from private car to car-sharing are still using private cars, they cannot be supportive to the sustainability of the transport system. The trips which have been shifted from CNG and taxi are mainly for users' comfort. In some cases, Uber has shifted trips from public bus, rickshaw and bicycle which are known as sustainable modes of transport. Due to diversion from such non-motorized trips to motorized trips it may increase emission level which is unsustainable in the context of environment and public health. Therefore, it can be stated that car-sharing program of Dhaka has less concern for sustainability rather its function is mainly running to support current transportation scenario.

4. CONCLUSION

Although it has been established in this study that apps-based transportation services provide attractive alternatives to ride, it is also clear that most users are those who mainly used CNGs, taxis or other public transport modes rather than private vehicles. Such condition may not be the contributor to achieve sustainable transport in terms of emission reduction, congestion reduction and assurance of public health. Car-sharing service in Dhaka does not serve all social class equitably; due to high fare structures, such service is in out of affordability of all income groups. Besides due to social context users do not like to share trips with obscure passengers; so overall carsharing could not support efficient, integrated and sustainable transportation system of Dhaka. To encourage people for sharing cars with others, minimum occupancy level of carsharing vehicles can be set and the fare structures

need to be fixed considering users' requirement and affordability with adequate rules and regulation. In overall government intervention including the incorporation of users' interest at regulation of ridesharing is necessary to protect the rights and well-being of commuters which can be helpful to lead the transportation system of Dhaka towards sustainability.

ACKNOWLEDGMENTS

The authors would like to acknowledge the Department of Urban and Regional Planning, BUET to give the opportunity to conduct the research. The authors express their heartiest gratitude to the survey respondents and Uber officials; without their cooperation, it would be impossible to conduct the research.

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Paper 89

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Challenges Faced in Preparing Sustainability Reporting: Emphasis on Commercial Banks Reporting Pattern in Bangladesh

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Abstract:

This is an exploratory paper with the objective of investigating the degree of environmental responsibility maintained by the commercial banks of Bangladesh, and to evaluate the need to enhance responsibility towards the environment by such banks. Corporate social duty is somewhat related with "sustainability reporting". Environmental sustainability is the core of socio-economic development. It is termed as one of most the crucial phenomena around the world. Since Bangladesh is extremely vulnerable towards environmental changes, it is under serious threat of having its economic achievements reversed. At the same time, reasons behind the banks' demotivation for contributing to corporate social duty should be examined carefully. In this paper, we have chosen nine leading private banks of Bangladesh and on average fifteen years data summing up to 134 firm years. Content analysis has been done in order to find out the total words disclosed. Three dimension of Sustainability reporting has been identified. The strategy includes examining and checking of the yearly reports of these banks to watch the acts of CSR (Corporate Social Responsibility) detailing. The findings suggest that banks of Bangladesh face challenges in maintaining a sustainability performance on the three dimensions, respectively and that sustainability reporting integration remains a distant aspiration.

Keywords: sustainability reporting; nature; environmental responsibilities; socio-economic impact

INVITED

Paper 90

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

Removal of chromium from tannery effluents using egg and snail shells

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Abstract

Presence of chromium, which is toxic, non-biodegradable and having a long natural life, in the industrial wastewater discharge can cause serious health hazard in an ecologically sustainable environment. The leather tanning industry in Bangladesh discharges such wastewater without treatment. There are some current traditional processes used to control chromium level in effluent discharged into the natural environment, but those processes also produce harmful by-products and consume energy thus need improvement for the sustainable world of the future. This paper presents the development of an innovative chromium reduction process using one of the residential wastes, such as eggshell, as the raw material. This process has been proved to produce the chromium reduction efficiency very close to currently used commercial $CaCO_3$ process. The experiment was done on tannery effluent by precipitation method to remove chromium. For comparative analysis, in addition to eggshell, snail shell and commercial $CaCO_3$ were also used as precipitant. Chromium concentration was measured using Atomic Absorption Spectrophotometer (AAS) and found to be decreased at least 99% for egg and snail shells which were better than commercial $CaCO_3$. Moreover, the precipitate occurred here was further treated with concentrated H_2SO_4 to form a by-product solution of basic chromium sulfate, which could again be as tanning liquor resulting a chemical recycling process that reduces the net waste to the environment. Considering the efficacy of this new precipitation process in the light of net waste to the environment, it appears to be a better substitute of the conventional method. Nevertheless, a full study of net cost, energy, climate and environmental impact of this process and the baseline conventional process remains a further study for future.

Keywords: Tannery effluent, egg and snail shells, chromium, waste material, precipitation

1. INTRODUCTION

Industrial wastes are the main sources of all pollutants and its on-site treatment before discharge into the sewage system is the major concern for reducing the pollution problem. The rapid industrialization has both direct and indirect adverse effects on the environment. The rate of effluent, as well as contamination, is increasing with increasing unbalanced industrialization, Sarker et al (2016). Bangladesh has now more than 30,000 industrial units and out of them only 10% of industries discharge treated effluent and the rest of the industries discharge effluent in the river without any treatment which contaminates surrounding channel, agricultural fields, irrigation fields, surface water and finally introduced into the food chain, Roy et al (2014).

Among all industries, the tannery industry is ranked as having the highest pollutant producer in different operations and processing purpose. All the tannery industries in Bangladesh are mainly concentrated in the Hazaribagh area of Dhaka city. More than 200 tannery industries are in the Hazaribagh area and about 90% of them are engaged in chrome tanning operation, Chowdhury et al (2013). During chrome tanning and re-tanning operation, 60-70% of chromium has been used to bind with hide and skin and other 30-40% of excess unused chromium is discharged into the final effluent, Chowdhury et al (2013), Abdulla, Hafez et al (2002). According to literature survey, it has been found that the concentration of Cr ion in untreated tanning wastewater varies from 1300 to 8000 ppm depending on the adopted operational procedure, Hafez et al (2002), Chaudry (1998). Where it has been proven that the tolerable limit of chromium ion from the discharge of effluents into water bodies should be within the range of 0.05-10 ppm, Bosnic (2000).

Different physio-chemical processes have been developed for the treatment of tannery effluents. Among them chemical oxidation, chemical precipitation, ion exchange, solvent extraction, filtration, adsorption, coagulation-flocculation, ultra-filtration, reverse osmosis and membrane filtration are most available methods, Amokrane et al (1997), Song, Ates et al (1997), Krishanamoorthi et al (2008), Hawley et al (2004), Chang (2001), Mohan et al (2006). Besides this, some of them are not that much effective and sometimes seeking high cost. Concerning all that matters, we have developed a very cost effective effluent precipitation process where the main ingredient is eggshell that can be easily found from the house, restaurant, bakeries, hotel etc. Thus, a revolutionary effort to environmental safety, eggshell has been investigated for removal of chromium and reuse of chromium.

2. MATERIAL AND METHODS

2.1 Preparation of eggshell

Eggshell was collected from various areas of Bangladesh. Then the sample was washed to remove impurity and interference material such as organics and salts, then the sample was rinsed with deionized water. After filtration with 0.45 μm membrane filter, the sample was dried for 24 h at 100°C in an oven. Afterward, the sample was passed through a grinder machine and the calcination operation was done in a furnace at 800°C for 2 h. Then, the calcined sample was soaked overnight. The filtrate was then kept in the oven at 105°C to obtain pure CaO after undergoing filtration, Park et al (2007).

2.2 Preparation of Snail Shell

Snail shell was collected from two districts namely Naogaon and Rajshahi. The tissue portions were removed by boiling in water which was followed by rinsing with deionized water. The shells were then dried naturally for 2 days and kept in the oven for 50°C for the next 2 days for complete drying. The sample was passed through a grinder machine and the calcination operation was done in a furnace at 800°C for 2 h. Then, the calcined sample was soaked overnight. The filtrate was then kept in the oven at 105°C to get pure CaO after undergoing filtration, Park et al (2007), Hossain (2013).

2.3 Sampling

Chrome tanning wastewater was collected from three different industries namely Samina, Ruma and Chowdhury tannery limited using acid-washed polypropylene bottles to avoid unpredictable changes in characteristic as per standard procedures, Apha (1998). These industries are located at Hazaribagh, Dhaka. The sample was analyzed to measure chromium content, p^H, turbidity, conductivity, and TDS which are considered very important parameters of wastewater, Apha (1995).

2.4 Experimental Technique

A sample of 5 g of CaO was mixed with every 250 ml of chrome tanning wastewater and precipitation could occur at room temperature. The precipitate of chromium was found as a compact sludge and was filtered using Whatman filter paper.

$$CaO + H_2O \longrightarrow Ca^{2+} + OH^-$$

$$Ca^{2+} + OH^- + Cr^{3+} + SO_4^{2} \longrightarrow Cr(OH)_{3\,(s)} + Ca^{2+} + SO_4^{2-}$$

The precipitate was then heated at 700°C for 2 h to get rid of various organic matter residues. Later, it was mixed with H_2SO_4 in 2:3 ratio to get a further product which is chromium sulfate. The chemical reaction of a typical chrome recovery process is:

$$2Cr(OH)_{3\,(s)} + 3\,H_2SO_4 \longrightarrow Cr_2(SO_4)_{3(aq)} + 6H_2O$$

2.5 Digestion of Soil Sample

For the quantitative analysis of Cr, samples were digested following aqua regia extraction process recommended by the International Organization for Standardization (ISO), Sastre et al (2002). In this procedure, 5 ml of the sample was placed in a 250 ml pyrex digestion tube. First, the pre-digestion step was done at room temperature for 16 h with 28 ml of 37% HCl and 10 ml of 70% HNO_3 (3:1) mixture. Then, the suspension was digested at 130° C for 2 h, in a reflux condenser. The obtained suspension was then filtered through an ashless Whatman filter paper and diluted to 100 ml with 0.5 mole/l HNO_3 and stored in polyethylene bottles at 4°C before analysis.

2.6 Total Heavy Metals Concentration Measurement

After digestion, the samples were analyzed for metals Cr with a Perkin-Elmer atomic absorption spectrometer (Model-An Analyst 800, USA). Specific hollow cathode lamp was used to determination

of Cr at 357.9 nm wavelength. The instrument had a minimum detection limit of 0.10 ppm for Cr in the flame method. Samples were aspirated through nebulizer and absorbance was measured with a blank as a reference. The calibration curve was obtained using standard samples (containing 0.2, 0.5, 1.0, 2.0 and 4.0 ppm for Cr). The correlation coefficient was found to be 0.994 for Cr.

2.7 TDS, Conductivity, Ph and Turbidity Determination

The other physical parameters pH, conductivity, TDS were measured using a potentiometer (metrohon906 tornado) and the turbidity was measured using digital turbidity meter (Hach 2100Q).

3. RESULTS AND DISCUSSION

3.1 Effluent treatment egg and snail shells

The concentration of chromium in the raw wastewater of tanning process collected from Samina, Ruma and Chowdhury industries was 1721 ppm, 1103 mg/L and 1404 ppm respectively, which are too high to be discharged directly into groundwater. The wastewater from the tanning process is an important source of environmental pollution due to the presence of high concentration of contaminants like chromium and other organic compounds as well as sulfates, Song et al (2000). The optimum p^H value for precipitation of Cr (III) is 8, Patterson and Minear (1997). This study followed a simple acid-base neutralization reaction where reaction occurred between chrome liquor and CaO collected from calcined eggshell and snail shell. The end result of this reaction is the formation of insoluble $Cr(OH)_3$ as a precipitate. pH has a vast impact on this reaction as the precipitation rate was found to increase with the increase of pH and reducing the amount of chromium into a supernatant solution. Table 1 shows that Cr concentration was reduced above 99%. It should be noted that the reduction of chromium through eggshell and snail shell was a little bit higher than commercial $CaCO_3$. This may be attributed to the high surface area of egg and snail shells during preparation.

A sample of 5g of commercial $CaCO_3$ was also mixed with every 250 ml of chrome tanning liquor and thus precipitation could occur at room temperature. The precipitate of chromium was found as a compact sludge and was filtered using Whatman filter paper.

A simple acid-base reaction between chrome liquor and commercial $CaCO_3$ has also been occurred to obtain precipitation of Cr (III) at pH value ranging from 7.9-8.5 and the result of percentage of removal of chromium stands for up to 99% as illustrated by bar-chart in Figure 1. Calcined natural egg and snail shells showed excellent performance in removing toxic chromium.

Table 1: Chromium concentration of tannery effluent before and after treatments

Name of the companies	The initial concentration of chromium in ppm	Final concentration (ppm) after treating with					
		Eggshell	Chrome removal (%)	Snail shell	Chrome removal (%)	$CaCO_3$	Chrome removal (%)
Samina	1721	2	99.88	2.5	99.85	14.5	99.16
Ruma	1103	0.4	99.96	0.3	99.97	8.1	99.27
Chowdhury	1404	10	99.29	4	99.72	17	98.79

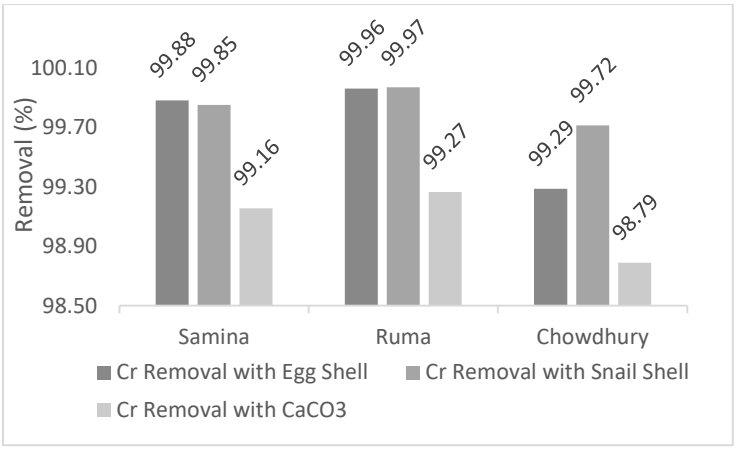

Figure 10: Percentage of Cr removal by eggshell, snail shell and $CaCO_3$ from different tannery effluents

3.2 p^H analysis

Shown in Table 2 is p^H of tannery wastewater before and after treatment. Before treatment of tannery effluent, pH of all tannery effluents was found to be very low. During chrome tanning operation in tannery industry $Cr_2(SO4)_3$ salt was used, and pH should be maintained within 3-3.5 to ensure proper chromium complexation formation between fiber and residues of the collagen, Fuck et al (2011).

Table 2: p^H of tannery wastewater before and after treatments

Name of the companies	pH prior to the treatment	pH value according to ISO [23, 24]	pH value after treatment with		
			Eggshell	Snail shell	$CaCO_3$
Samina	4.24		7.35	7.70	8.20
Ruma	3.91	6.5-8.5	7.41	7.59	8.50
Chowdhury	4.12		7.50	7.39	7.91

If these effluents directly disposed to the environment without any treatment it may be harmful to the aquatic environment**.** After treatment with eggshell, snail shell and $CaCO_3$ pH value was found to increase from 7.35 to 8.50. This is because eggshell, snail shell as well as $CaCO_3$ are basic in nature and neutralize the acidic condition of the aquatic system. It emphasized that after treatment those effluents can be discharged into the domestic sewage system because according to ISO guideline statement for batter aquatic life pH of aquatic environment should be between 6.5-8.5.

3.3 TDS analysis

As an important parameter of water quality, TDS was measured (shown in Table 3). The initial values of TDS of three industries were 6300, 6840 and 5130 ppm respectively which were very close to the *GM* Ayoub et al (2011). However, the values of TDS still lie above the permissible limit (30-380 ppm according to ISO 10500-1991), Sirohi and Tyagi (2014).

Table 3: TDS of tannery wastewater before and after treatment with percentage decreased

Name of the companies	TDS value prior to the treatment in ppm	Standard TDS value according to ISO [23, 24]	TDS value after treatment					
			Egg shell	Percentage reduced	Snail shell	Percentage reduced	$CaCO_3$	Percentage reduced
Samina	6300		1050	83.33	1124	82.16	1822	71.08
Ruma	5840	30-380	980	83.22	1054	81.95	1915	67.21
Chowdhury	5130		1110	78.36	1005	80.41	1541	69.96

Our intention was to lessen contaminants in the effluent as much as possible. It was possible to reduce TDS up to 80%. The maximum and minimum TDS value was obtained after the treatment with Eggshell and $CaCO_3$ respectively. It was observed that the eggshell and snail shell has comparatively better ability to adsorb the dissolved solid particle from the effluent than commercial $CaCO_3$.

3.4 Turbidity analysis

The turbidity of tannery wastewater was measured before and after effluent treatment. Table 4 shows that turbidity was reduced at around 80.24-85.31%, 80.31-84.67%, and 69.12-71.18% respectively by Eggshell, Snail shell, and $CaCO_3$. The significant reduction in turbidity was up to a satisfactory level.

Table 4: Turbidity of tannery wastewater before and after treatment

Name of the companies	Standard Turbidity value [27]	Turbidity value prior to the treatment (NTU)	Turbidity value after treatment with					
			Eggshell	% reduced	Snail shell	% reduced	$CaCO_3$	% reduced
Samina	10-25	3013	552	81.68	573	80.98	904	70.00
Ruma		3274	481	85.31	502	84.67	1011	69.12
Chowdhury		3047	602	80.24	600	80.31	878	71.18

Obtained results indicate that Egg and Snail shells have shown to reduce turbidity significantly due to the higher adsorption ability of those two adsorbents than $CaCO_3$. After effluent treatment turbidity value is still higher than standard permeable level 10-25 NTU, indicating that further treatment should be required before disposing of that treated effluent.

3.5 Conductivity analysis

The conductivity of tannery effluent before and after treatment was measured as shown in Table 5. The initial values of conductivity of three industries (Samina, Ruma and Chowdhury) were found to be 116.7, 125.7 and 102.7 mS/cm respectively. The conductivity value has crossed the maximum standard value set by USEPA and WHO Timpano et al (2011), Hasan et al (2012).

Table 5: Conductivity of tannery wastewater before and after treatment with percentage decreased

Name of the companies	Standard Conductivity value according to USEPA, WHO [28, 29]	Conductivity value prior to the treatment in mS/cm	Conductivity value after treatment with					
			Eggshell	% decrease	Snail shell	% decrease	$CaCO_3$	% decrease
Samina		116.7	21.1	81.92	22.3	80.89	36.5	68.72
Ruma	0.3-0.6	125.7	19.7	84.33	21.2	83.13	37.8	69.93
Chowdhury		102.7	19.8	80.72	19.9	80.62	30.9	69.91

After treatment with eggshells (snail shells) the reduction level of conductivity was found to be 80.72% (84.33%), 80.62% (83.13%) and 68.72% (69.93%) for Egg, Snail shell and $CaCO_3$ respectively.

3.6 Production of chromium sulfate

Tannery wastewater was treated with calcined egg and snail shells and after completing treatment there was found some precipitate of chromium as sludge which was further treated with sulfuric acid maintaining a certain ratio to get the new product. Finally, basic chromium sulfate was produced which is an essential product required for the chrome tanning process. Hence, it can be applied for further tanning process minimizing the cost of commercial chromium sulfate up to a certain limit and eliminate the environment pollution.

3.7 Further study on comparative sustainability impact.

Although the above results clearly demonstrate that the eggshell (and snail shell) can be used for chromium treatment of leather tannery effluent effectively and potential reduction of net waste-to-environment from residential and industrial processes, however, further study was out of scope to determine quantitative benefits of cost, energy, greenhouse gas emission (global warming potential) against the existing traditional processes. The latter study is a must to determine the full life cycle impact to the planet and sustainability of this new process.

4. CONCLUSIONS

By this research, it was demonstrated that the re-use of residential waste, such as eggshell, as raw material to treat industrial wastewater can reduce the chromium concentration in tannery effluent by 99.71 % which is much better than the current standard processes. This new treatment process will produce an overall lesser net environmental impact than that of the current processes. The net benefit is that for eggshell, TDS was significantly reduced to around 81.64 % and with snail shell, it was 81.51 % compared to 69.42 %. obtained with calcium carbonate ($CaCO_3$). The initial values of conductivity of three industries namely Samina, Ruma and Chowdhury were 116.7, 125.7 and 102.7 mS/cm respectively, indicating that conductivity value was crossed maximum standard value set by USEPA and WHO. The reduction in conductivity level by egg and snail shells significantly

outperforms $CaCO_3$. Thus, egg and snail shells can be used as a tool for combating industrial waste. It was also found that one of the by-products of this process can be chromium sulfate which can be re-feed to the tannery processing line as tannery liquor, thus reducing the net environmental waste. The further quantitative study is required to determine actual cost, energy and greenhouse gas emission per liter of effluent treated by this and conventional processes.

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INVITED
Paper 92

Proc. Of 1st International Conference on Sustainability in Natural and Built Environment (iCSNBE 2019)
19-22 Jan 2019, Dhaka, Bangladesh
ISBN: 978-0-6482681-4-7

A Real Market Property Financing Model for an Equity-Based Sustainable Banking

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Abstract

The common and immediate reaction to the use of word "sustainability" relates to the climate change and impact to the planet due consumption of resources and technologies those support the modern human lifestyle. The money market and the economic policy and methods, which are practiced in the current world order, have a strong role how the lifestyle is architected and subsequent relationship with the overall sustainability of the human society and the plant. Sustainable banking is a new dimension in the money market which primarily emphasize into investment that can assists the sustainable development activities, for commercial or individual projects, but the fundamental security for a bank in such investment is relying on the charging interest on the investment without sharing no visible risk with the client. Thus, what lagging here is, the promotion of equity in wealth between a bank and it's client. This process cannot fully guarantee achievement of the UN 2030 Agenda and the Sustainable Development Goals, SDG 1, 8, 10, 11 and 16 through this interest-based financing model. There is a great opportunity to promote sustainability goals through an equity-based consumer financing model for real-estate property. This paper will present a real market Real estate property financing model replacing the conventional interest-based model that has been proven sustainable and promoting equity among the clients of a financier and the investor alike. The model has been operational in Australia under a Cooperative Entity since 2006 with sustained and stable dividend output for the investor at the same time housing equity holder cum clients securing their share of real estate property consistently even throughout the economic recession period that occurred in Australia. From consumer point of view, the model has been satisfactory to 95% of the consumer whereas the unsatisfied consumers were only those who were not familiar with the equity-based model and measured their satisfaction against the status quo of the conventional interest-based model.

Keywords: Sustainable Investment, Equity-based lending, Real Estate Financing Model.

1. INTRODUCTION

The traditional interest-based economy is a global feature which has penetrated the human lifestyle and economic existence and is seen as a key functioning factor of economic progress of developing and developed nations alike. There are enormous debates about how and if this interest-based economy is a sustainable process for years to come. The scope of this paper does not cover any of such debates. Nevertheless, two major organic and fundamental consequences of interest-based economy to the life of human on the planet earth are, 1) growth of capitalism and 2) cumulative inflation of money value. To the author of this article, both are unsustainable in long run.

The growth of capitalism continuously increases the gap between the poor and the rich. This inequality cannot be sustainable, particularly in the modern time of technological advanced society where the difference is visible, and tensions are obvious due the inequality. Social instability and wrong political purpose of financial success of nations are common impact of this interest-based economy of this time. On the other hand, the cumulative inflation of money value keeps pressure on the people to chase the endless rise of price of commodity or assets without actually improving the real usability of the materials of life. Change of value with time of any commodity or asset due to its demand and its usability is a natural process. Whereas, interest-based economy creates an artificial value added due to the inflation, which is nothing more than degradation of value of currency, thus price of a thing is ever increasing regardless of usability or demand while it is in the market.

The alternative to interest-based economy is the equity partnership and real market trading. The people who believes in equity and trading based financial transactions, such as Muslims, it is great challenge for them to find such financial system to fulfill their need for money lending for personal asset building or business activities. It is not limited to only the believing community, rather it is a condition that the entire global economy needs to rely on equitable ownership of asset and real value aspiration of assets with demand and usability. In overcoming the challenge, several attempts have been made by the religious scholars worldwide however, it became evident that no process was able to overcome the pre-disposed traditional banking concept, process, and influence of laws of the lands. Instead, the institutions developed only contractual documents and management processes compatible to Islamic Principles whilst keeping all financial transactions and calculation exactly same as the traditional banking system. In relation to real estate property or consumer commodity finances, these processes sometimes replace the word "*interest*" with "*profit*" or "*rent*" or "*rental facility*" and so on, thus remain as pseudo approaches which have lots of deviations of opinions, blind trusts on scholar's opinion and a poorer acceptance to the people who is willing to understand the process themselves and try to relate to the real-world factors.

In all these pseudo non-interest-based finances, the customers are charged with a rental which is significantly different from the real market rent of an asset, for example, a property, or a profit which is not reflecting the profit that property would make when traded. This is purely because the pseudo non-interest-based finances just use the traditional banking interest rate as the basis of calculation of the rent or profit whilst the banking interest rate may not have direct or reasonable relationship with the real-world rental or profit potential of the property.

This paper thus presents the development of an equity-based trading model and applied for real estate asset or property and demonstrate the financial mechanism that is workable taking into considering the real-world factors. The model has been applied in Australia since 2006 under a cooperative mechanism successfully giving opportunity to the investor and the purchaser relying on real market demand based and equity sharing satisfactorily.

The Real Market Partnered (the Islamic term "*Musharaka*") (RMM) financial process presented in this article takes into consideration of the real-world market potentials of a property and take that as the prime basis of the net return potential which then used to derive the schedule of net payments by the customer truly reflecting the real market.

The Real Market Partnered (Musharaka, RMM) finance includes the following basic processes:

1. Purchase an asset (e.g. a property) with combined contribution from the financier and the financed customer.

2. Rent the property to the financed customer at an agreed rental value based on real market valuation by independent and certified valuer. The rental value can also be appreciated as the real-world appreciation of rental potential with a rental growth rate. The rental and its growth rate can be re-evaluated at a reasonable frequency as the parties find appropriate.

3. Parties agrees that the financed customer also purchases the financier's share over an agreed term period so that by the end of the term, the financed customer becomes the full owner of the property financially. Typically, the transactions occur monthly but other intervals can also be devised. This is called diminishing partnership (Musharaka) process. The financed customer also acquires the shares at a pre-agreed price per unit. The purchase price is determined by the property value growth potential as an annual growth rate which is obtained through an independent evaluation using real-world market data. Review of these growth rates (rental and price) occurs at a pre-agreed interval to reflect the real market. The real-world data represents the value of demand of that particular property in such location of such condition driven by the open market competition. One could argue that the real-world property value growth data also has indirect impact from the interest-based inflation existed in that society and that economy. It is true, but it is probably will remain in-separable until such time when the entire society is changed to the non-interest-based economy. Therefore, over years, more the non-interest-based economy will increase, more the indirect impact of inflation will reduce.

4. Parties also share reasonable and determinable costs of ownership of the property.

5. The financed customer can purchase additional shares at any time permissible by the agreement and the local law.

6. At the end of the term or when the financed customer completed purchasing all the shares from the financier, the property is handed over to the financed customer by the locally appropriate legal process and the financial contract is terminated.

7. Any dispute is managed through trust, contract and by the applicable local laws, those are not contradicting with the non-interest-based practices.

8. The ownership of the property shares are managed through the contract and through the compliance of the local legal process. For example, in Australia, the financier can either chose to secure their share by registering the property in party's legal names or through contract and mortgage, depending upon which one is appropriate in the context of financial, local law and non-interest-based process compliances. In Australian context, registering financier name will require payment of local duty (or tax) twice, therefore, the latter process is found appropriate.

In other countries, any other appropriate processes can be implemented to suit the local situations.

The above process is a simple description of the core financial process. Further details are worked out by the institutions depending upon their technical ability and compliances to local laws and applicable non-interest-based transaction principles. The financial calculation model used in the Real Market Partnered (Musharaka, RMM) finance is described below

2. FINANCIALS OF THE PROPERTY ACQUISITION BY THE PARTIES

This model is currently used by the Islamic Cooperative Finance Australia Limited (ICFAL) since 2006. The ICFAL name is mentioned throughout the article to reflect a financier.

Total Purchase Cost/Value including property price and agreed expense = P_v
Purchaser share of the property value (Purchaser Units) = M_{sh}
ICFAL share of the property value (ICFAL Units) = I_{sh}

3. PURCHASERS MONTHLY PAYMENT CALCULATION

Interval of the regular ICFAL Unit purchase by the financed customer = Monthly
Total number of payments in the Term = T

3.1. Payment for ICFAL Unit purchase by the purchaser post-acquisition:

Monthly number of ICFAL unit purchased regularly, $P = \frac{I_{sh}}{T}$

Payment, P_n, for the purchase of ICFAL Units, P, at the n^{th} month is

$$P_n = P\left(1 + \frac{g}{12}\right)^n$$

Where g is the agreed annual rate of property appreciation based on valuation report set at the time of this agreement is executed.

Profit paid to ICFAL on purchase of Unit in the n^{th} month, P_{fn}

$$P_{fn} = (P_n - P) = P\left\{\left(1 + \frac{g}{12}\right)^n - 1\right\}$$

ICFAL Unit balance after the n^{th} month, $I_{sn} = (I_{sh} - nP)$
Purchaser's Unit balance after the n^{th} month, $M_{sn} = M_{sh} + nP$

3.2. Additional share purchase by the purchaser during the term:

Payment, P_{n1} for the purchase of any ICFAL Units, P_1, at the n^{th} month is

$$P_{n1} = P_1\left(1 + \frac{g}{12}\right)^n$$

Profit paid to ICFAL on purchase of additional Unit in the n^{th} month

$$= (P_{n1} - P_1) = P_1 \left\{ \left(1 + \frac{g}{12}\right)^n - 1 \right\}$$

ICFAL Unit balance after this additional share purchase of P_1, $I_{sn} = I_{sn1} - P_1$, where I_{sn1} is the ICFAL balance of Units one-month prior to the n^{th} month.

Similarly, the purchaser's Units after the additional share purchase of P_1, $M_{sn} = M_{sn1} + P_1$, where M_{sn1} is the Purchaser's balance of Units one-month prior to the n^{th} month.

3.3. Purchaser Ijarah (Rental / Lease) Payment:

Rental Payment for ICFAL share on the n^{th} month, $R_{In} = R_n \frac{52}{12} . \frac{Isn}{Isn+Msn}$
R_n is the agreed rental per week for the property on the n^{th} month, which is calculated as

$$R_n = R_0 \left(1 + \frac{r}{12}\right)^n,$$

where R_0 is the agreed weekly rental and r is the agreed annual percent rental growth rate, set at the time of undertaking to rent the property by the purchaser or any change reviewed during the term as required to reflect market and scheduled in the financial plan. These values are determined by the independent valuation of the market. When no valuation is performed, by the agreement of the parties, the national CPI index can be taken as the basis for the rental growth rate.

3.4. Fixed cost share by ICFAL:

As per the Partnership (Musharakah) Agreement, the scheduled fixed and determinable cost items of property ownership are:

a. Council rates and charges as per the council bills
b. For strata property, the strata levy
c. Water and waste fixed service availability charges
d. Agreed property and public liability insurance (Takaful

From actual bills, the total monthly cost of ownership is determined on the n^{th} month of the term as F_n = Σ all items.

ICFAL share of the fixed cost items on n^{th} month, $F_{In} = F_n \frac{Isn}{Isn+Msn}$

ICFAL share of the fixed cost items over the entire Term, $F_{IT} = \sum_{n=1}^{T} F_{In}$.

3.5. Total Monthly Payment, P_{tn}:

Monthly payment by the purchaser on the n^{th} month of the term $P_{tn} = P_n + R_{In}$
Total monthly payment with additional share purchase on the n^{th} month, $P_{tn} = P_n + P_{n1} + R_{In}$.

3.6. Net Monthly Payment, P_{net}:

The net monthly payment after the fixed cost offset on the n^{th} month, $P_{net} = P_{tn} - F_I$

3.7. Total Payment for the entire Term, P_T:

The total payment the purchaser makes over the entire Term is calculated as below.

$P_T = \sum_{n=1}^{T} P_{tn}$, Where T is the total number of months in the entire term.

3.8. Net Payment for the entire Term, P_{Tnet}:

The net payment by the purchaser over the entire term $P_{Tnet} = P_T - F_{IT}$

4. Equivalent net rate of return (the rate, *k*) to the Financier

The equivalent net rate of return (the *rate*) is calculated as the Internal Rate of Return (IRR) based on the financier initial share (Musharaka) Unit value I_{sh} and the series of regular unequal monthly scheduled payments (rental, Musharaka unit purchase and fixed cost share offset) received from the Purchaser over the entire Term as annuity. This is then annualized to determine annualized percent rate (of return).

The actual rate depends on the actual transactions including payments for regular Share (Musharaka) Unit purchase, additional Share (Musharaka) Unit purchase, renal and the fixed cost offset during the Term. This is typically less than the scheduled rate because of reduction of ICFAL unit equity due to additional share purchase ahead of the scheduled regular purchase.

Two alternative methods are used to simplify the calculation.

4.1. Considering average net monthly payment as annuity

$$P_{av} = \frac{P_T - F_{IT}}{T}$$

$$I_{sh} = P_{av}\left[\frac{1 - \left(1 + \frac{k}{12}\right)^{-T}}{\left(\frac{k}{12}\right)}\right]$$

Where *k* is the equivalent rate per year. The value *k* is derived from iteration of the above equation using project I_{sh}, $P_{av,}$ and *T*.

This method is approximate enough when the variation of payment is low and for not additional Share (Musharaka) Unit purchase occurs. Accuracy deviates when additional unit purchase takes place.

4.2. Considering the series of regular monthly net payments as annuity

$$I_{sh} = \sum_{n=1}^{T} \frac{P_{tn} - F_{In}}{\left(1 + \frac{k}{12}\right)^{n}}$$

Where *k* is the equivalent rate per year. The value *k* is derived from iteration of the above equation using project I_{sh} and *T* values and P_{tn} is series of actual monthly total payment for n^{th} month including

regular and any additional payment for Share (Musharaka) Unit purchase and F_{In} is the share of the fixed cost refunded by ICFAL to the Purchaser.

5. EXAMPLE OF A REAL FINANCIAL PLAN

The schedule inserted in the below section is prepared with typical real values but calculated for a very short Term of 60 months.

In this example, Islamic Cooperative Finance Australia Limited (ICFAL) is used as a financier and a dummy member (the purchaser) is used for demonstration purpose only.

5.1. Input Data Block

Sample Member 92888888	Number and Name of Membership (The purchaser)
5	Term of Finance (Years), *T/12*
$250,000	Total ICFAL Contribution, I_{sh}
$100,000	Total Purchaser's Contribution, M_{sh}
1-Sep-15	Property Acquisition Settlement Date
$600.00	Administrative Fee
1	Rental and Growth Review Interval, years
Torense Title Home	Type of property
$350.00	Agreed Current Weekly Rental (R0)
1.00%	Evaluated Annual Rental Growth Rate, *r*
2.00%	Evaluated Annual Rate of Property value gain, *g*
$200.00	Evaluated Monthly fixed costs, F_n
0.00	ICFAL Share end of the term (< $0.50)

5.2. Output Data Block and the Example Financial Schedule

Financial Plan (Rental and Musharaka Unit Purchase Schedule)

ICFA Ltd	Vs.	Sample Member 92888888		
			Finance Term	**05.0 years**
			Total Cost of Acquisition of the Property:	**$350,000**
			Agreed weekly Rental to be shared by ICFAL and member	**$350**
			Monthly Payments for Rental and Musharaka Unit Purchase are varying with an average	**$4,945.9**
			First Regular Payment: **1-Oct-15** Last Regular Payment:	**1-Sep-20**
			Administrative charges to be deducted from Member's a/c with 1st regular payment.	**$600**
			Agreed Rental and Growth review interval	**1.00 years**

ICFA Returns and Members Payment Summary	
$46,752.93	ICFA Total Profit
$4,357.14	ICFA Total Fixed Cost Share, F_{IT}
$42,395.78	Total Net Profit at completion of term
$4,873.26	Average Net Monthly Payment, P_{av}
6.34%	Annualised net Rate of Return (average method - D1), *k*
6.48%	Annualised net Rate of Return (series method - D2), *k*
$296,752.93	Member's Total Payment for entire Term, P_T
$292,395.78	Member's Total Net Payment for entire Term, P_{Tnet}

Date	Member Actual payment ($P_{tn} = P + R_{ln} + P_{fn}$)	Member's purchase of Musharaka Units (P)	Share of Rental		ICFAL Profit on Musharaka Unit sell (P_{fn})	Balance of Musharaka Units		ICFAL balance unit target sell Price (a)	Member balance unit target sell Price (b)	Property Target Net Sell Price (a+b)
			ICFAL (R_{ln})	Member		ICFAL (I_{sn})	Member (M_{sn})			
1-Sep-15	Property Musharaka Settlement			-		**250,000**	**100,000**			
1-Oct-15	5257.85	4,166.67	1,084.2	433.7	6.94	245,833	104,167	246,243	104,340	350,583
1-Nov-15	5247.62	4,166.67	1,067.1	452.1	13.90	241,667	108,333	242,473	108,695	351,168
1-Dec-15	5237.38	4,166.67	1,049.8	470.6	20.87	237,500	112,500	238,689	113,063	351,753
1-Jan-16	5227.12	4,166.67	1,032.6	489.1	27.85	233,333	116,667	234,893	117,446	352,339
1-Feb-16	5216.84	4,166.67	1,015.3	507.7	34.84	229,167	120,833	231,083	121,844	352,926
1-Mar-16	5206.54	4,166.67	998.0	526.2	41.84	225,000	125,000	227,259	126,255	353,515
1-Apr-16	5196.22	4,166.67	980.7	544.8	48.85	220,833	129,167	223,423	130,681	354,104
1-May-16	5185.89	4,166.67	963.3	563.5	55.88	216,667	133,333	219,572	135,122	354,694
1-Jun-16	5175.54	4,166.67	946.0	582.1	62.92	212,500	137,500	215,709	139,576	355,285
1-Jul-16	5165.17	4,166.67	928.5	600.8	69.97	208,333	141,667	211,832	144,046	355,877
1-Aug-16	5154.78	4,166.67	911.1	619.5	77.03	204,167	145,833	207,941	148,529	356,470
1-Sep-16	5144.38	4,166.67	893.6	638.3	84.10	200,000	150,000	204,037	153,028	357,065
1-Oct-16	5133.96	4,166.67	876.1	657.1	91.19	195,833	154,167	200,119	157,541	357,660
1-Nov-16	5123.51	4,166.67	858.6	675.9	98.28	191,667	158,333	196,188	162,068	358,256
1-Dec-16	5113.06	4,166.67	841.0	694.7	105.39	187,500	162,500	192,243	166,610	358,853
1-Jan-17	5102.58	4,166.67	823.4	713.6	112.51	183,333	166,667	188,284	171,167	359,451
1-Feb-17	5092.08	4,166.67	805.8	732.5	119.64	179,167	170,833	184,311	175,739	360,050
1-Mar-17	5081.57	4,166.67	788.1	751.5	126.79	175,000	175,000	180,325	180,325	360,650
1-Apr-17	5071.04	4,166.67	770.4	770.4	133.94	170,833	179,167	176,325	184,926	361,251
1-May-17	5060.49	4,166.67	752.7	789.4	141.11	166,667	183,333	172,311	189,542	361,853
1-Jun-17	5049.92	4,166.67	735.0	808.5	148.29	162,500	187,500	168,283	194,173	362,456
1-Jul-17	5039.34	4,166.67	717.2	827.5	155.48	158,333	191,667	164,242	198,819	363,060
1-Aug-17	5028.73	4,166.67	699.4	846.6	162.68	154,167	195,833	160,186	203,480	363,666
1-Sep-17	5018.11	4,166.67	681.5	865.7	169.90	150,000	200,000	156,116	208,155	364,272
1-Oct-17	5007.47	4,166.67	663.7	884.9	177.13	145,833	204,167	152,033	212,846	364,879
1-Nov-17	4996.81	4,166.67	645.8	904.1	184.37	141,667	208,333	147,935	217,552	365,487
1-Dec-17	4986.14	4,166.67	627.9	923.3	191.62	137,500	212,500	143,823	222,273	366,096
1-Jan-18	4975.44	4,166.67	609.9	942.6	198.88	133,333	216,667	139,698	227,009	366,706
1-Feb-18	4964.73	4,166.67	591.9	961.8	206.16	129,167	220,833	135,558	231,760	367,317
1-Mar-18	4954.00	4,166.67	573.9	981.2	213.45	125,000	225,000	131,403	236,526	367,930
1-Apr-18	4943.25	4,166.67	555.8	1,000.5	220.75	120,833	229,167	127,235	241,308	368,543
1-May-18	4932.48	4,166.67	537.8	1,019.9	228.06	116,667	233,333	123,052	246,105	369,157
1-Jun-18	4921.70	4,166.67	519.6	1,039.3	235.38	112,500	237,500	118,855	250,917	369,772
1-Jul-18	4910.89	4,166.67	501.5	1,058.7	242.72	108,333	241,667	114,644	255,744	370,389
1-Aug-18	4900.07	4,166.67	483.3	1,078.2	250.07	104,167	245,833	110,418	260,587	371,006
1-Sep-18	4889.23	4,166.67	465.1	1,097.7	257.43	100,000	250,000	106,178	265,446	371,624
1-Oct-18	4878.37	4,166.67	446.9	1,117.2	264.80	95,833	254,167	101,924	270,320	372,244
1-Nov-18	4867.49	4,166.67	428.6	1,136.8	272.19	91,667	258,333	97,655	275,209	372,864
1-Dec-18	4856.59	4,166.67	410.3	1,156.4	279.59	87,500	262,500	93,371	280,114	373,485
1-Jan-19	4845.68	4,166.67	392.0	1,176.0	287.00	83,333	266,667	89,073	285,035	374,108
1-Feb-19	4834.75	4,166.67	373.7	1,195.7	294.42	79,167	270,833	84,761	289,971	374,731
1-Mar-19	4823.79	4,166.67	355.3	1,215.4	301.86	75,000	275,000	80,433	294,923	375,356
1-Apr-19	4812.82	4,166.67	336.9	1,235.1	309.30	70,833	279,167	76,092	299,890	375,982
1-May-19	4801.83	4,166.67	318.4	1,254.9	316.76	66,667	283,333	71,735	304,873	376,608
1-Jun-19	4790.83	4,166.67	299.9	1,274.7	324.24	62,500	287,500	67,364	309,872	377,236
1-Jul-19	4779.80	4,166.67	281.4	1,294.5	331.72	58,333	291,667	62,977	314,887	377,865
1-Aug-19	4768.76	4,166.67	262.9	1,314.4	339.22	54,167	295,833	58,577	319,918	378,494
1-Sep-19	4757.69	4,166.67	244.3	1,334.2	346.73	50,000	300,000	54,161	324,964	379,125
1-Oct-19	4746.61	4,166.67	225.7	1,354.2	354.25	45,833	304,167	49,730	330,027	379,757
1-Nov-19	4735.51	4,166.67	207.1	1,374.1	361.79	41,667	308,333	45,285	335,106	380,390
1-Dec-19	4724.39	4,166.67	188.4	1,394.1	369.33	37,500	312,500	40,824	340,200	381,024
1-Jan-20	4713.25	4,166.67	169.7	1,414.1	376.89	33,333	316,667	36,348	345,311	381,659
1-Feb-20	4702.10	4,166.67	151.0	1,434.2	384.47	29,167	320,833	31,858	350,437	382,295
1-Mar-20	4690.92	4,166.67	132.2	1,454.2	392.05	25,000	325,000	27,352	355,580	382,932
1-Apr-20	4679.73	4,166.67	113.4	1,474.4	399.65	20,833	329,167	22,832	360,739	383,571
1-May-20	4668.52	4,166.67	94.6	1,494.5	407.26	16,667	333,333	18,296	365,914	384,210
1-Jun-20	4657.28	4,166.67	75.7	1,514.7	414.88	12,500	337,500	13,745	371,106	384,850
1-Jul-20	4646.03	4,166.67	56.8	1,534.9	422.52	8,333	341,667	9,178	376,313	385,492
1-Aug-20	4634.76	4,166.67	37.9	1,555.1	430.17	4,167	345,833	4,597	381,537	386,134
1-Sep-20	4623.48	4,166.67	19.0	1,575.4	437.83	-	350,000	-	386,778	386,778
n/a	0.00	-	-	-	-	-	-	-	-	-
Total	**296,753**	**250,000**	**33,618**	**59,734**	**13,135**			**-**	**-**	**-**
Date	Member Actual payment (Ptn = P + Rln + Pfn)	Member's purchase of Musharaka Units (P)	Share of Rental		ICFAL Profit on Musharaka Unit sell (Pfn)	Balance of Musharaka Units		ICFAL balance unit target sell Price (a)	Member balance unit target sell Price (b)	Property Target Net Sell Price (a+b)
			CFAL(Rln)	Member		ICFAL (Isn)	Member (Msn)			

Note - 1 Unless otherwise reviewed upon request from any party after the completion of the 1st year from the Musharaka Settlment, this finacial plan will remain firm for the full term.

Note - 2 The Balance of Musharaka Units are at the original unit price. At the early termination or when purchase of additional units has to occur, the sell price of ICFAL Musharak units will be as per the column "ICFAL Units Sell Price". If a sell has to occur prior to the finance term is complete, the target sell price of the property is to be determined by the value listed as "Property Net Sell Price" after all selling expenses.

Note - 3 The purchaser agreed to purchase ICFAL Musharaka Units at nominal annual property value growth rate of 2.00%. Agreed annual average Rental growth rate is 1.00%. All the profits on unit sale and Rental to be paid to ICFAL over the entire term as scheduled without any additional unit purchase will equate to an Equavalent Annualised Rate of 6.34%.

Note - 4 An estimated average monthly fixed cost of $200.00 covering council rates, water and sewerage service and insurance will be shared in proportion to the balance of units at the middle of billing period by ICFAL. This may equate to approximately $4,357 over the entire finance period during when ICFAL share diminishes from 71.43% to 0.00%. Actual amount will differ from this estimate based on actual bills.

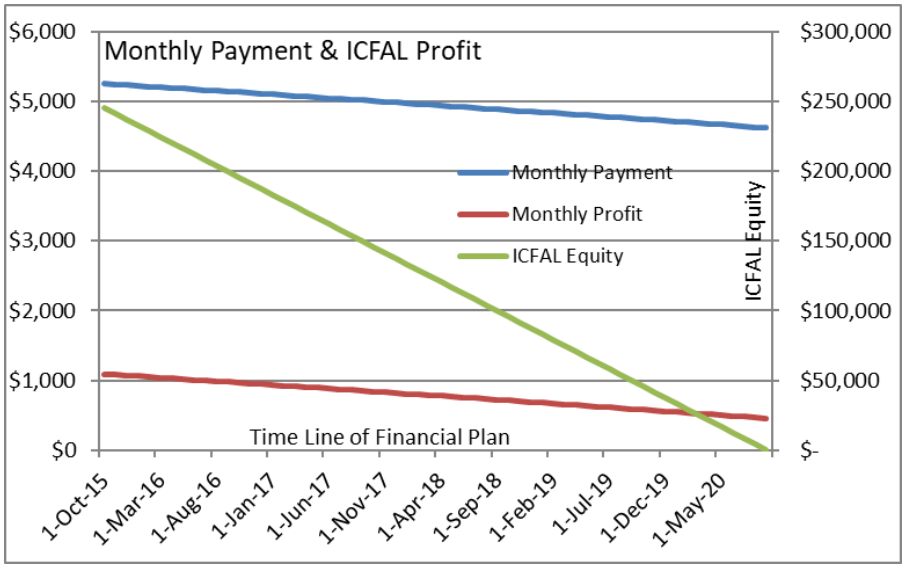

Figure 1: Demonstration of Purchaser Monthly Payment, ICFAL Profit and corresponding ICFAL equity which is diminishing. The Monthly Payment includes the price of a monthly share purchase and rental share.

6. CONCLUSION

While the economic equality is a vital principle in social stability which would bring equitable and sustainable living harmony in the global human society, the financial tools, such as the one demonstrated in this paper, is useful to achieve such equality through banking and financing process. The Real Market Partnership (Musharaka, RMM) model used the non-interested-based real market value aspiration due to demand, usability, and quality of a property. It has also used an equity model which would promote sharing risks and gains between the financier and the financed consumer, particularly for real estate property. The same model can also be applied to other activities such as business, industry, farming, and manufacturing. The equity and risk sharing would improve consumer perception of real usability and value thus will reduce speculation and uncertainty as well as improve the financier's participation of the equity thus also will avoid speculative transaction which could increase their risk of profit. This model will promote economic stability. The model used in Australia since 2006 has proven providing stable dividend (no data presented above for business sensitivity) to the investor while satisfied the purchaser (consumers) with the financial and equity gain achieved till today in Australian financial market, which had several ups and downs during the same period.

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