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# A Study of Thermal Performance in University Campuses in Urban Context of Dhaka City

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#### Abstract

Higher education in Bangladesh is growing. Around 3.2million students are enrolled in tertiary level education in the country. Dhaka is the center of this growth. There are around 08 public and 50 private universities operating Dhaka. Among these universities public universities have campuses and most of the private universities don't have permanent campuses. But as per Private University Act-1992, these private universities are bound to set up permanent campuses. Some of these universities have already set up a permanent campus in and around Dhaka city, others are in the process of establishing new campuses. Under such circumstances, it is necessary to study the thermal comfort parameters of the students pursuing educations as well as a sustainable environment in these built campus spaces in the context of the hot humid compact urban context of Dhaka. So that knowledge from these studies can be utilized to achieve healthy as well as a sustainable environment in Dhaka. This paper focuses on thermal comfort parameters in open spaces in terms of wind velocity, ambient air temperature, and relative humidity in the university campus in Dhaka. Three universities are studied, one is Govt and the other two are private Universities. It is found from the research that university campuses with large trees and green courtyards contribute to the significant reduction of air temperature in in Dhaka. The literature reviewed and the results are discussed.

Keyword: Sustainability, Campus design, Thermal comfort, Pavement material, Outdoor spaces, Landscaping, Tropical climate.

#### 1. Introduction

Campus built environment has a great influence on a student's health and ability to learn. A well-designed campus can foster the learning environment, alleviate stress and healing mental health. But a well-designed campus comprises many aspects, one of them is a good thermal environment. A good or healthy thermal environment can provide comfort in indoor and outdoor. In this paper, outdoor thermal parameters analyzed for outdoor activity. Outdoor activity on campus is very important since it provides vital space for group learning, discussion, activities, sport, and cultural programs. But unfortunately, nowadays this vital space is neglected in our country and educational institutions are becoming more and more introverted and interior classroom oriented. But in higher education sector the University Grant Commission are pushing private universities to have a permanent campus within five years of it establishment (Private University Act-1992). As an impact of this law several private universities have already set up permanent campus in and around Dhaka. Rest of the universities are also pursuing to establish a permanent campus. Since the weather of Bangladesh is hot humid, the thermal comfort in outdoor spaces is an issue to be critically handled. Culturally we have many programs and festivals which are held outdoors such as Pohela Boishakh. Higher educational institutions hold such programs on their campus where lots of students participate. But unfortunately, many new campuses do not address thermal comfort as a serious issue. Most of them have hard surfaces, no shading, and plantations, which result in uncomfortable and unbearable conditions for the students and participants in outdoors. Over sweating, dehydration and heat stroke occur often, people die each year. So, a good campus with well designed, ventilated and shaded outdoor is a must in our context. For this purpose, this study is focused on a comparative thermal parameters study of three distinct campuses in Dhaka.

# 2. Methodology

The structure of this paper based on a literature review and field survey. Six papers have been reviewed related to campus design and outdoor thermal comfort study. The field survey was done on three different Universities, among them two are private university and one is a public university. Among the studied university campuses, private university campuses are relatively new. These private universities are constructed between the 1990s and 2000s while the studied public university was built around the 1960s in Dhaka.



Figure 1. Research methodology (Developed by Author).

#### 3. Literature Review

The literature review is carried on selected six papers from the Elsevier website. Out of these six papers five papers on thermal comfort-related study, another paper is on healthy campus open space design by (Lau, Gou, & Liu, 2014). Out of the five thermal comfort-related papers, one paper is on the thermal performance of courtyards in Malaysia by (Ghaffarianhoseini, Berardi, & Ghaffarianhoseini, 2015), another paper is on the influence of pavement materials on pedestrian thermal comfort by (Djekic, Djukic, Vukmirovic, Djekic, & Dinic Brankovic, 2018), other paper is on thermal comfort in a campus in the subtropical region by (Zhao, Zhou, Li, He, & Chen, 2016), other paper is on thermal comfort in sunlight, building shade and pergola shade by (Watanabe, Nagano, Ishii, & Horikoshi, 2014) and finally thermal study of pedestrian selecting a shaded area in the humid subtropical area by (Watanabe & Ishii, 2016). The reviews of these papers are provided below.

- From the above papers, it is observed that human thermal comfort study is complicated and diverse. Several parameters need to be monitored to collect data for analysis such as air temperature, humidity, incident solar radiation, radiant temperature, air velocity. There are several thermal indices to evaluate human thermal comfort. While designing a courtyard for better thermal performance major focus should be given on the courtyard orientation, courtyard height, surface albedo, vegetation cover as well as trees on thermal comfort in a tropical hot humid climate, as these can influence thermal performance of a courtyard. (Ghaffarianhoseini et al., 2015)

- From the study of (Ghaffarianhoseini, Berardi, & Ghaffarianhoseini, 2015) it is observed that north-facing courtyards have better thermal performance. The height of the courtyard wall can cut shadow and thus reduce solar gain, trees can also reduce solar gain through their shade and shadow.

-Surface material, roughness, colors have a profound impact on outdoor thermal comfort on pedestrians. Grass has the least surface temperature among all surface covers so grass should be extensively used to tackle solar heat gain on pavements. While choosing pavement materials light color and reflective material should be chosen for reducing solar heat gain. (Djekic et al., 2018)

- Shading elements like trees, pergolas, building shade provide excellent refuge for a pedestrian outdoor in a hot environment. In outdoor context, the shading should be provided for pedestrian for thermal comfort such as pergola or pavilion which have better thermal performance as shown by (Watanabe et al., 2014)

-Landscaping with trees, flowers, small ponds have an impact on stress mitigation for students in urban campuses. These elements have thermal environment cooling qualities at the same time.

- The approaches for healthy campus open space design are Landscape Design, Spatial Design, and Green Design. The elements of Landscape Design are lawn, tree, colorful plants, dense planting, pond, sculpture, and fountain. The elements of Spatial Design are courtyard, window views, circulation, privacy, and engagement. The Green Campus

Design will alleviate mental stress through sensation, foci, interaction, order, direction, control, ecosystem, and physical comfort, as demonstrated by (Lau et al., 2014)

#### 4. Scope & Limitations

The scope of this study is limited to a few courtyards of some private and public universities. An extensive study of all the permanent building campuses of universities in Dhaka is out of the scope of this paper. The study is limited to observation and measurements of climatic parameters such as temperature, humidity and wind speed during the early autumn season in September 2018 on some campuses in Dhaka.

# 5. Field Study

For the purpose of field study three parameters are selected based on literature survey these are wind velocity, ambient air temperature and humidity. The field survey was conducted on three universities in Dhaka. North-south University and South-east University are the private universities and Bangladesh University of Engineering and Technology (BUET) is a public university which is established in 1960s. North-south University (NSU) is situated in a dense residential context in Bashundhara Residential Area, South-east University (SEU) is located in Tejgaon industrial area and finally, Bangladesh University of Engineering & Technology (BUET) is located in a comparatively more spacious space in Dhaka, Palashi area. Among these universities courts were selected based on shading, surface materials and student activity for thermal performance study purposes. In North-south three courts were selected, Court 01 is enclosed by north and south academic building, Court 02 is in level 01 in front of amphitheater and Court 03 is a dead-end and enclosed by auditorium and library building with shrubs. All of these courts have hard surface 2'x2' tiles as pavement material and very little shading except enclosing buildings from the south as well as little or need no tree or landscape elements such as fountains. Sky condition during the field study was cloudy with around 20-30% of cloud cover.

The court of Southeast University (SEU) is enclosed by Architecture building in north and Science academic building in the south. It's actually playfield covered with grass but on the east edge of the field, there were some trees. Three courts are selected in the (BUET) campus area. Court 01 is a densely shaded pathway for pedestrian as well as vehicle in front of Old Academic Building (OAB), Court 02 is in front of the cafeteria which is enclosed on the south by Central Auditorium and on the east by Cafeteria, Court 03 is the green field in front Architecture Dept. building which is enclosed on north and east by Architecture department and on the south by Central Library building. It has large trees on its periphery.



Figure 2. The sky condition was partially cloudy during survey.



Figure 3. NSU campus, Bashundhara Residential Area, Dhaka.



Figure 4. Court 01 of SEU campus in Tejgaon, Dhaka.



Figure 5. SEU campus in Tejgaon, Dhaka.

#### 6. Result discussions

The microclimatic differences in North south university courtyards are noticeable. The average highest temperature is recorded 37.6°C in court 03 with relatively low wind speed 1.25km/h and around 42% of humidity. As previously mentioned that the court 03 is surrounded on three sides by walls and buildings, as a result, wind speed is very low here, making this court most uncomfortable than the other two courts. The wind speed in court 02 is high since a large wind channel is created because of the large aperture in amphitheater which allows fresh southeast air to enter the campus and flow out to the north. Surface temperature in all courts of NSU is quite high because of the extensive use of hard surfaces and few shading. There is no shade except the building shade from the south which is insufficient in hot summer days.



Figure 6. BUET campus, Palashi, Dhaka



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### Figure 7. Courts in BUET

The field study is done in two days 08-9-2018 and 09-9-2018. The meteorological data these days are given below **Table 1**. Meteorological Data on field survey days (source: www.timeanddate.com)

SL	Date	Time	Temperature	Humidity	Wind
1	8-9-2018	12:00-18:00	34°C	72%	3km/h
2	9-9-2018	12:00-18:00	34°C	64%	4km/h

The instruments used for measuring temperature, humidity and wind flow are borrowed from BUET and listed below. **Table 2:** Instrument specifications.

SL	Instrument Name	Information
1	SMART SENSOR AR867	Temperature and Humidity
2	EXTECH 45118	Temperature and Wind flow

# Table 3. Field study data.

![](_page_4_Figure_7.jpeg)

Table 4. Field Study Data.

![](_page_4_Figure_9.jpeg)

![](_page_4_Picture_10.jpeg)

Figure 8. Wind flow pattern in NSU campus.

The Southeast university campus has a large open grassy playfield in the center of its campus. But unfortunately, there are insufficient trees for required shades in the area for the students to stay outdoor. Air Temperature was around 36.12°C with relative humidity was 47.75 %. The air velocity in the field was quite high 9km/h in east-west and southeast direction since there was no obstruction surrounding the field. The surface temperature was high 42°C. The microclimatic character in BUET is diverse. The performances of the courts are varied. The temperature in the court 01 which is densely shaded by trees in front of Old Academic Building (OAB) is lowest 33.66 °C with little wind speed and relative humidity is around 49%, which is clearly in the comfort zone as described by (Ahmed, 2003). Court 02 has a hard surface in front of the cafeteria. The surface temperature of the court was quite high at 47.3 °C. The air temperature was 35.24 °C, the humidity was 51% with air velocity was 7.74 km/h. The prevailing wind direction was in a southeast direction.

![](_page_5_Picture_2.jpeg)

Figure 9. Wind flow pattern in SEU campus.

The air temperature in court 03 with a grass field was 36.78 °C which was high compared to court 02 with a hard surface. But the fact is that wind speed in court 03 was low 3.78 km/h comparing to 7.74 km/h in court 02 which was almost half. Wind played a strong role to cool down court 02 air temperature. The humidity in court 03 was 45%. There was no shade in court 02 and partial shade in court 03, on the other hand, court 03 was fully covered with dense tree shade. The surface temperature in court 03 was 40.5 °C.

![](_page_5_Picture_5.jpeg)

Figure 10. Prevailing wind direction in BUET campus.

# 7. Conclusions

From the above observations, it is clear that microclimatic weather is strongly influenced by local conditions. In these cases, the conditions or character played important roles are surface cover, prevailing wind directions, building shade, building orientation, tree shade. Among the studies, the court 01 in BUET has performed the best. The distinctive advantage of court 01 is that it is densely covered with large trees that is why most of the solar radiation reflected outside while making inside the tree canopy comfortably cool. The result of this study conforms to the findings by (Djekic, Djukic, Vukmirovic, Djekic, & Dinic Brankovic, 2018) on the influence of surface mater, roughness, and shading on thermal comfort of the pedestrians in open spaces. The large trees in BUET campus had contributed to a lesser temperature which supports the research done by (Sun et al., 2017) through numerical simulation on the impact of higher trees on thermal comfort in urban green spaces. The pilotis in the ground floor in Northsouth University court 01, court 02 and in BUET court 2 and court 3 enables southeastern wind flow as a result temperature reduced which is following the research done by (Xi, Li, Mochida, & Meng, 2012) in subtropical urban campus and also by (Liu, Niu, &

Xia, 2016) who found that better thermal comfort is achieved in under the elevated building in open spaces through wind simulation.

Though this study is only limited to only three campuses, a detailed study can be done on all or most of the permanent campuses in Dhaka for detail climatic study and formulation a guideline for better thermally comfortable outdoors in permanent campuses in Dhaka. From the context of rapid urban growth and the rise of permanent building campuses in and around urban centers in Bangladesh, this study is very crucial. For better academic life outdoor as well as observing rich Bengali culture we need thermally better outdoor environments and future studies can show that through rigorous researches.

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