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## The Effects of New Building Construction on Outdoor Thermal Condition and Wind flow pattern in a Tropical City

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### ABSTRACT

The urban microclimate has direct impact on thermal comfort outdoors as well as indoors. The Urban microclimate is to some extent shaped by Building Blocks, Surface Quality and Vegetation. In the tropics, heat is the dominant factor. During daytime outdoor conditions are acute due to intense solar radiations, high solar elevations, and inadequate evaporative cooling. Here addition of new building blocks can add new situation for outdoor discomfort. This study aims to find out the effects of new construction of building blocks on outdoor thermal condition and wind flow pattern that is shaped by the porosity of building blocks in a high dense tropical city like Dhaka, Bangladesh. Investigations are carried out on existing area and model areas with added building forms. Findings are focused on outdoor thermal situation and wind flow pattern during daytime in the late monsoons (September) when solar radiation and humidity is high requiring wind flow for comfort. This study has demonstrated that addition of a new tall building can offer a better outdoor thermal climate at pedestrian level but reduce wind flow to deep plot layers for less surface porosity of the building blocks in a high-density tropical city.

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## INTRODUCTION

Rapid urbanization and developments in the tropical cities like Dhaka has brought many changes to the physical environment of the city. But, Planning and designing process is not yet integrated to climatic researches. So, Dhaka being a combination of planned and organic city shows variations in its microclimatic scenario. The environmental factors such as radiation, temperature, wind speed, relative humidity, precipitation, and cloudiness are affected by the three-dimensional characteristics of urban blocks and surface materials (Ahmed, 1995). Outdoor and indoor thermal comfort is determined by these climatic factors which are shaped by urban characteristics.

The important urban design elements that affect the urban microclimate are the size of the city, orientation and width of streets, density of the built-up area, height of the buildings, and the presence of parks and other green areas (Watson, Plattus and Shibly, 2003). Building form can affect urban climate in many ways. In the case of Colombo, Sri Lanka, it was found that the wide streets with low-rise buildings and no shade trees made the outdoor conditions worse, and the most comfortable conditions were found in narrow streets with tall buildings, especially if shade trees were present (Johansson and Emmanuel, 2006). In most of the cases, outdoor thermal comfort criteria do not coincide with indoor thermal comfort criteria. Such as, tall buildings with narrow street canyon do not always allow flowing wind at deep sections. This study aims to find out the effect of construction of a new building block replacing green land. This can affect pedestrian thermal comfort due to wind flow pattern and situation can vary from primary to secondary and tertiary roads.

### Method of Study:

This research is focusing on Dhaka, Bangladesh. It is in South Asian Zone having the tropical monsoon climate. The climatic characteristic is defined as warm humid climate. Rapid urbanization especially with grid iron pattern plot layout is taking place in Dhaka city and almost all vacant green land is being occupied by tall buildings. It might be suitable situation for the first depth plot in a grid iron layout but situation might be

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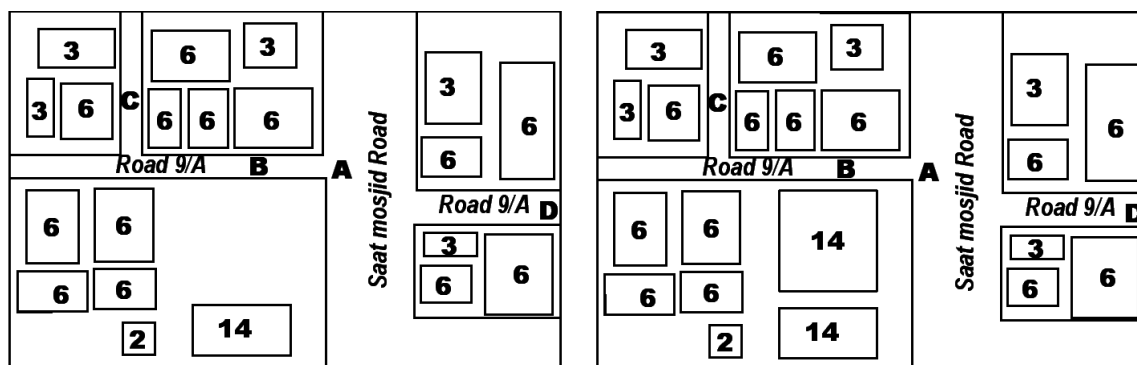
changed or Detroit in inner depth plot due to less porosity of front building. Parallel heat stress in summer is growing in Dhaka city. Thus, there is an urgent need to evaluate the effects of new building forms on the thermal climate and wind flow in the city. Dhaka is a rapid growing mega city with approximately 12.3 million people in the metropolitan area (Kakon and Mishima, 2009).

The study is carried out in Dhanmondi area, which is one of the first planned residential communities in the city and almost grid iron patterned. The study area is shown in Fig. 1 and marked by the dotted line. The selected area is well-known as “SAAT Masjid” road around 33m wide with footpath along two sides. Commercial land use exists along both the sides of a Primary street. Secondary and tertiary roads are of around 30m width with pedestrian ways. Up to 2006, the height of buildings were limited to 6-storey in this area. So, most of the buildings are within 6-storied. But now more than 12 storied buildings are being built along the Primary road. The orientation of this canyon is  $33^\circ$  NW-SE.



**Fig. 1:** Study Area in Dhanmondi.

Investigations are carried out on existing area and model area with added building forms on the microclimate. This study was carried out for late monsoon conditions (September). During this season, the solar radiation is high ( $34^\circ\text{C}$ ) like summer, and the relative humidity in this period is about 70%, and the near-ground wind speed is about 2.0 m/s, with slight variation during the daytime (Climate Data, 2007). The microclimate was evaluated based on air temperature  $T_a$ , mean radiant temperature  $T_{mrt}$ , wind velocity  $V_s$  and relative humidity  $R_h$ . The outdoor thermal condition and wind flow pattern are compared between the existing and model area. There is a vacant corner land in the study area which is dense green now. As the primary road is presently declared as commercial zone high-rise buildings will be built according to “Imarat nirman Bidhimala 2008”. So, the effects of new Building Form on that vacant green land on Outdoor Thermal condition and on wind flow pattern towards inner section of the road in a Tropical City is investigated through site survey, and ENVI-Met software simulation with and without building. The model building was considered as similar typology as adjacent fourteen storied building. The detail plan of without and with model building is shown in figure 2 where the number shown indicate storey height. Four considered point (A,B,C,D) for data collection are also marked in plan.



**Fig. 2:** Site plan without and with model Building.

### Experimentation:

In this research field survey was carried out in Primary road (point A), secondary road (point B & D) and also in tertiary road (point C) and data on Air temperature ( $T_a$ ), Mean radiant temperature ( $T_{mrt}$ ), Air velocity  $V_s$ , Relative Humidity  $R_h$  was recorded at 2pm on 27-09-2013. The field survey was carried out by Hydro-Thermometer and Anemometer. The field survey condition was without building. At first this data was compared with the simulation result of Envi-met without model building and then compared with the simulation result of Envi-met with model building. Then from the comparison a conclusion was reached.

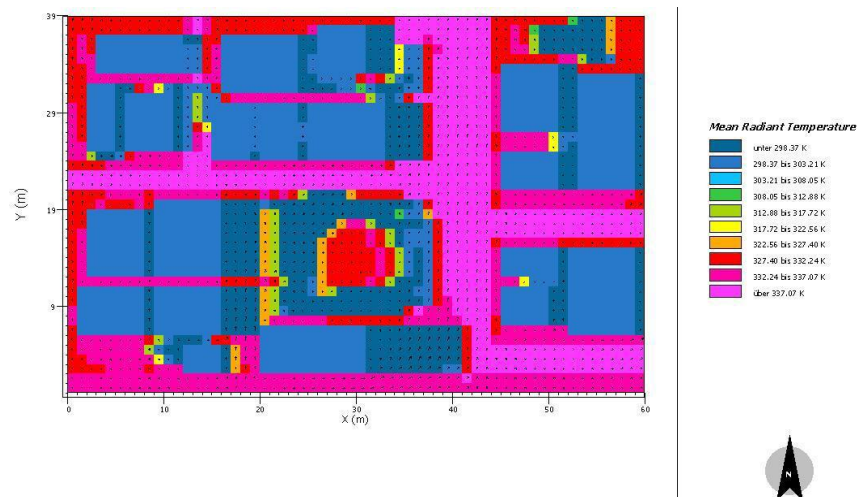
The present and future microclimate is evaluated by using a two-dimensional numerical model ENVI-met (Bruse and Fleer, 1998, Bruse, 2008). It simulates the microclimatic changes within urban environments in a high spatial and temporal resolution. This model calculates all important meteorological parameters such as the solar radiation, air temperature, relative humidity, wind speed, as well as mean radiant temperature and so on. Mean radiant temperature is the key variable for evaluating thermal sensation outdoors during the daylight hours. It has been confirmed that human comfort indexes such as PMV (predicted mean vote) and PET (physiological equivalent temperature) are strongly dependent on  $T_{mrt}$  (Matzarakis, Mayer and Rutz, 2002, Kakon and Mishima, 2009). The basic input parameters for simulation are shown in Table 1. Further, the results of air temperature in the present existing area obtained from the field measurements and numerical simulation show good agreement.

**Table 1:** Basic Input parameters for simulation.

Location	Dhaka Bangladesh, 23.24°N, 90.23°E 8.8asl
Simulation Day	Late monsoon, 27th September
Simulation Duration	From 10 am to 4 pm (6 hrs)
Spatial Resolution	60X39X20 grid size 4X4X1.5
Wind Speed and Direction	3m/s from 180° S
Initial Atmosphere tem	20° C (293k)
Relative Humidity	50%

## RESULT AND DISCUSSION

The microclimate is investigated mostly on the pedestrian ways as the assessment of thermal comfort at these positions is most important for the pedestrians. 4 different points at different roads are taken along the pedestrian ways. Parameters are evaluated at a height of 1.5 m above ground as this height is representative for the comfort assessment for a standing person. All the simulation results without and with model building is given in fig 3 and fig 4 respectively. The result is shown both in plan and in section. Then the microclimatic parameters comparative analyses of field survey and simulation results are shown in Table 2.



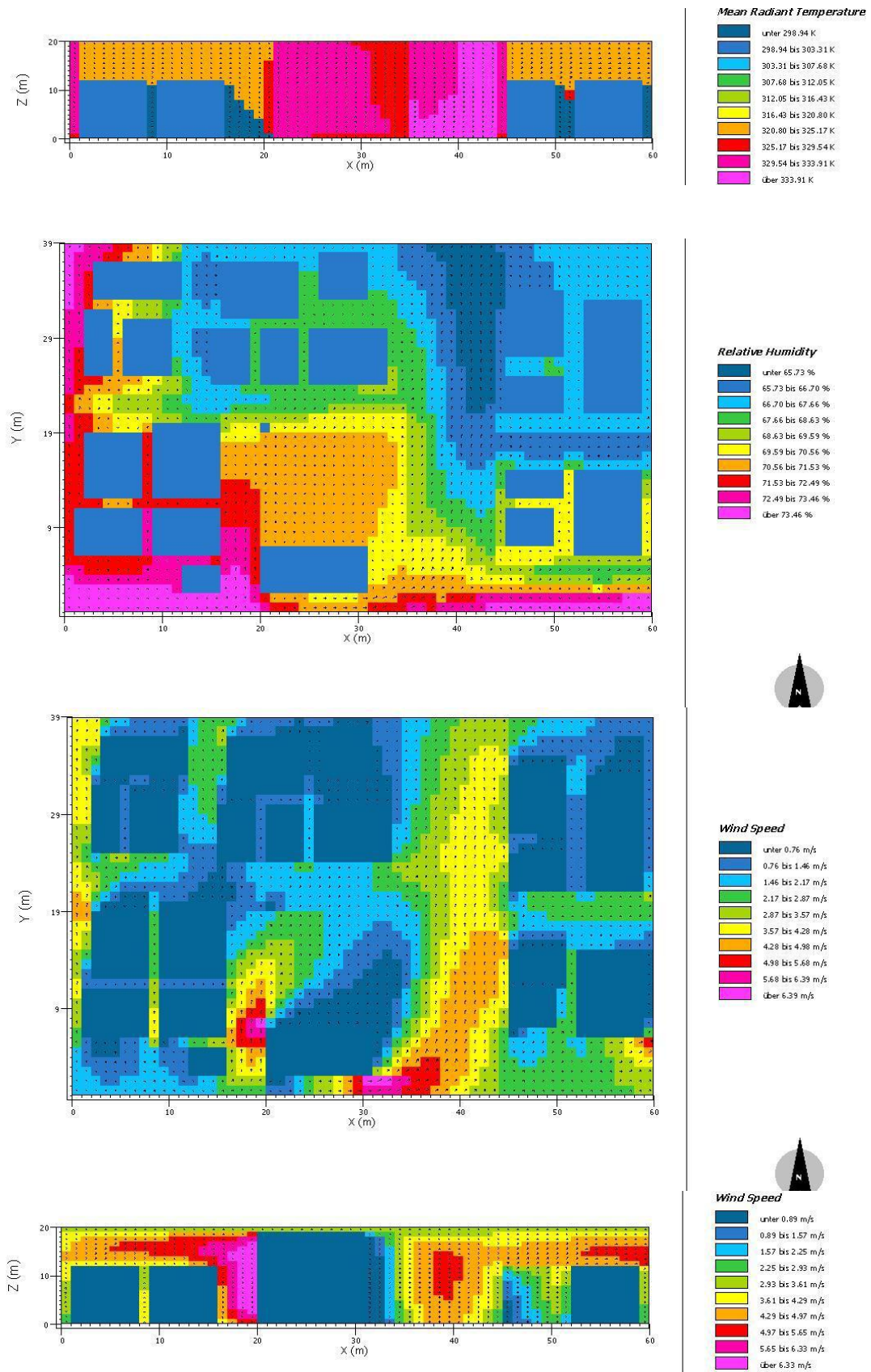
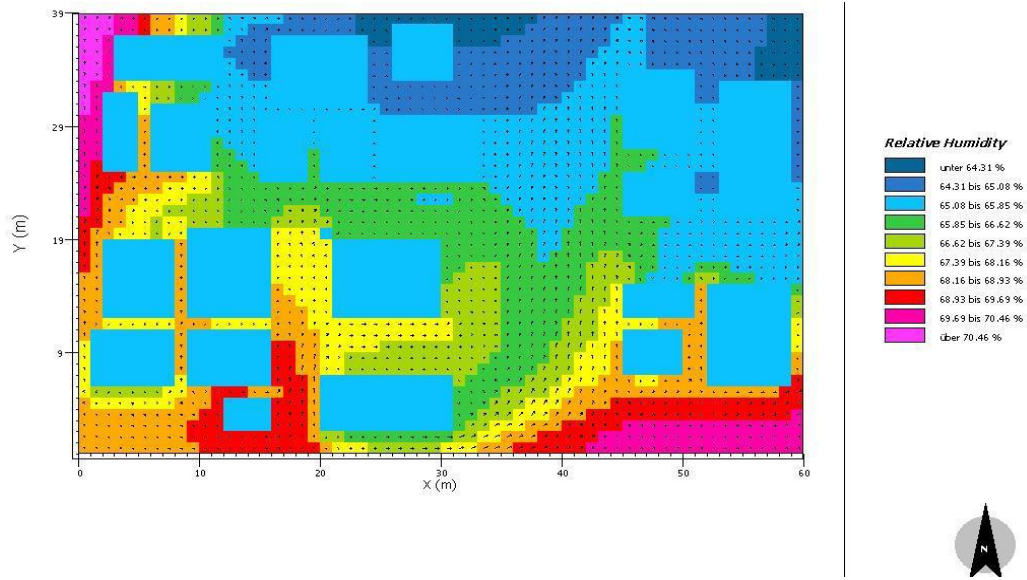
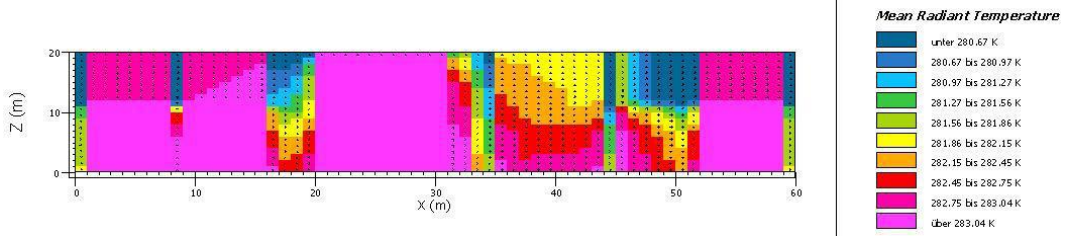
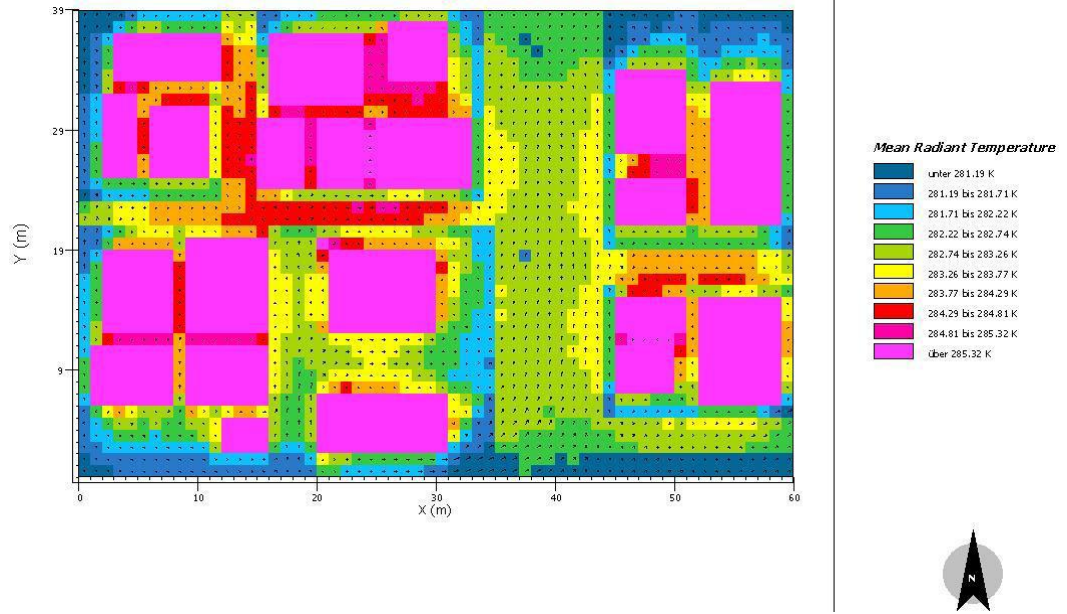
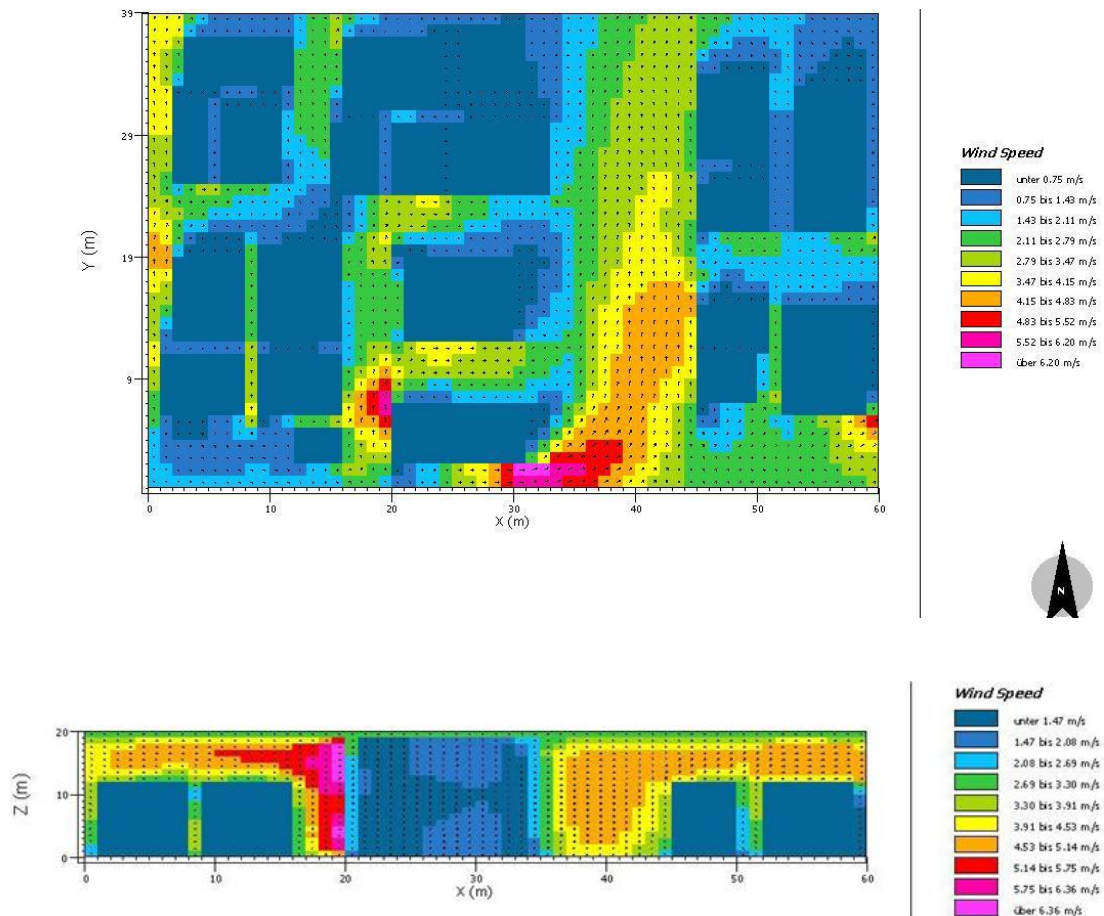


Fig. 3: Simulation without Building.





**Fig. 4:** Simulation with Buildings.

**Table 2:** Comparison between field survey and Simulation.

Location	Microclimate Parameters	Field Survey without building	Simulation without building	Simulation with Building
A	Tmrt (°C)	34	34	32
	Rh %	59	68	66
	Wind Speed m/s	1.1	3.57	2.29
B	Tmrt (°C)	32.7	32	33
	Rh %	59	70	66
	Wind Speed m/s	.1	2.17	2
C	Tmrt (°C)	32.1	32	34.8
	Rh %	61	67	65
	Wind Speed m/s	.1	2.17	2
D	Tmrt (°C)	33.4	33	34
	Rh %	51	67	65
	Wind Speed m/s	.7	2.87	2

Though the above data analysis show a little deviation between field survey and simulation, some of the previous researches show good similarities between field survey and simulation of envimat (Kakon and Mishima, 2009). If we compare the two situations one is with building and another without building we can come up to this conclusion that construction of a new high-rise building will reduce temperature in primary road but increase in secondary and tertiary roads. Again it will reduce overall humidity and will create a wind loop in front of the tall building and reduce inner section wind speed. Though it is comfortable for pedestrian of the primary road but it is suffocating for the pedestrian of secondary and tertiary road. This situation can be improved by allowing wind flow to the inner depth of block. The high-rise building with perforation like porous skin or wind court can act to flow wind behind the building. But that would necessitate further study.

#### **Conclusion:**

So, this research may come up with this conclusion that construction of a new high-rise building can improve the outdoor thermal comfort in the primary road pedestrian level but degrade the condition in secondary and tertiary road. The limitation of this research was that it did not analyze PET. To analyze PET we

had to use RAYMAN software. So, there is an option to research it further with PET analysis. May be the analysis can give a new window.

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