IMPACT OF UNREGULATED DEVELOPMENTS IN URBAN VILLAGES OF HYDERABAD CITY ON OUTDOOR THERMAL COMFORT

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Abstract

Indian Cities are transforming at a frantic pace. As cities expand, villages and rural areas on the periphery become an integral part of the city fabric. Unregulated Developments are often a byproduct of urban villages formed by this frantic pace of development, especially in developing countries. Urban villages have some statutory provisions decentralized from the central city planning agencies that are often exploited. There is a morphological divergence in this transition resulting in unstructured and possibly unregulated development; the impact of which is not often delineated. This is further complicated by the disconnect between urban climate and urban planning. The morphological characteristics of the development have an impact on the outdoor thermal comfort that has a significant impact on the health and well being of the people. This study is focused on Hyderabad; the fourth most populous city in India that is rapidly expanding due to the advent of the IT industry. Presently, there are 175 urban villages in the Hyderabad metropolitan area. This paper evaluates the case of two urban villages Nizampet Village and Pragathi Nagar. Nizampet Village is an extreme case of exploitation of the urban village provisions leading to unregulated development while Pragathi Nagar has a stricter implementation. This presents an interesting case to study the impact of unregulated developments associated with the urban villages in Hyderabad city on outdoor thermal comfort while exploring the effect of morphological parameters like orientation, vegetation.

Keywords Outdoor Thermal comfort, ENVI-met, Urban Villages, Urbanization, Unregulated development

Introduction

Urban areas occupy less than two percent of the Earth's land surface but house 50 percent of the world's population. By 2030, urban areas will hold 60% of the world's population (United Nations, 2014). Cities are point sources of pollution. They are responsible for 50-70% of Greenhouse gas emissions (Oke et al, 2017). This haphazard urbanization has led to climatic variations in the cities which harms the health and comfort of the citizens. Changes like exacerbation of heatwaves

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increase in temperature and air pollution and reduction in air movement are observed. These, in turn, affect the thermal comfort and energy efficiency of the city. It has been observed that every 0.03°c rise in temperature the number of polluted days may increase by 10% (Akbari, 2005). Hence, it is important to understand the impact of urbanization. Over the last couple of decades, urbanization trends in India have accelerated to increase the total urban population of India. Indian urban population is estimated to be at 460 million people which is 33.6% of the total population (Census of India, 2011). By 2050, India is projected to add 404 million urban dwellers. This has resulted in a construction boom in the country along with associated energy consumption. It has been shown that the annual growth rate of energy consumption in India is above 8% (Ministry of Urban Development Government of India, 2010). It suffices to say that urban areas in India have been exponentially growing.

Another cause exacerbating the impact of urbanization is the lack of understanding of its relation with urban climate. There is an inherent gap between urban planning and urban climate knowledge. Existing development controls are often not informed by urban climate knowledge. On the other hand, urban climate knowledge is not quantified in terms of morphological parameters; thus making it difficult to be incorporated into the planning process. Local climate zone classification introduced by Stewart and Oke has been adopted by researchers to bridge the gap (Stewart et al 2012) (Kotharkar et al, 2016) (Perera et al, 2018). This paper throws light into this gap between urban planning and urban climate knowledge.

Urban Villages:

Urban villages are byproducts of rapid urbanization in India due to which the expanding cities sprawl eventually engulf the villages in tertiary areas. This phenomenon is common in bigger cities in India such as National Capital Region Delhi, Mumbai, Hyderabad, and Bangalore. As new developments move out of the downtown or CBD areas; often urban villages fall close to these developments. For example, In Hyderabad where Information Technology (IT) related developments were started in the periphery areas of the city. So, urban villages are prone to exploitation because of the sudden increase in Land prices and demand for residential areas to cater to the nearby institutional developments. Some of the urban villages have seen a population growth of 700% in a decade. Typically, urban villages have some statutory powers before they are transitioned and annexed into the central planning body. In this transition period driven by economics, unregulated developments are a very common scenario. For the context of this study, unregulated development refers to areas where developmental controls have been violated. It is imperative to understand the urbanization patterns of the Urban Villages and its impact on the urban climate. As these are nascent developments, there is a greater possibility of intervention. Due to the complexity of the definition of urban villages, in this paper gram panchayats located in or in close vicinity of urban areas are considered as Urban Villages (UV's).

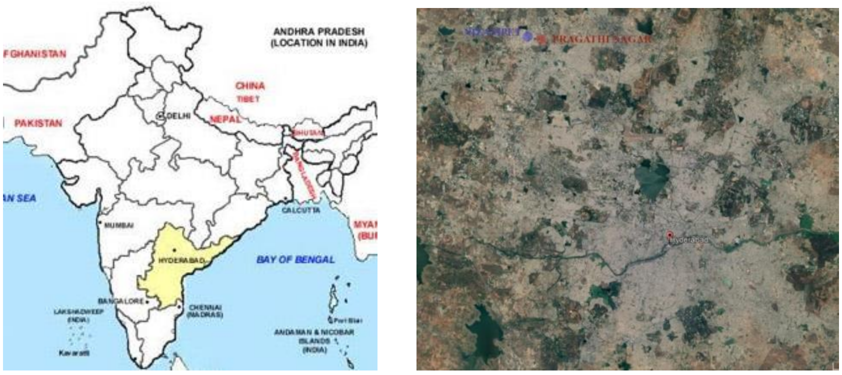

Figure 1: Location of Hyderabad in India and Location of Urban Villages understudy in Hyderabad
Source: Wikitravel, Google Maps

Background:

This study will focus on Hyderabad is the fourth most populous city in India and the capital of Telangana in the southern part of India (Fig: 1). Hyderabad is located at 17.3850° N, 78.4867° E at an elevation of 505m. The Hyderabad metropolitan area is spread over 7,257 sq km and has transformed significantly since the advent of the IT industry in the early 2000s and is considered as one of the fastest-growing cities in India. At present, there are 175 Urban Villages in the Hyderabad metropolitan area. This paper evaluates the case of two specific UV's 'Nizampet Village' (NZM) and 'Pragathi Nagar' (PN) (Fig: 2). these gram panchayats have become urban villages due to the Residential demand to cater to the IT sector developments nearby. These UV's were very recently notified in 2019 to be merged with the urban local body. But in the last decade, they have undergone a significant transformation as gram panchayats located in the urban areas. These urban villages before being annexed into the local urban bodies (HMDA in Hyderabad case) had the authority to issue permits for buildings up to G+2 floors height without any consent from the central urban body HMDA (Hyderabad Municipal Development Authority). This provision has been exploited by the real estate developers due to lack of jurisdiction of HMDA and taller buildings of G+5 floors were built by flouting the norms.

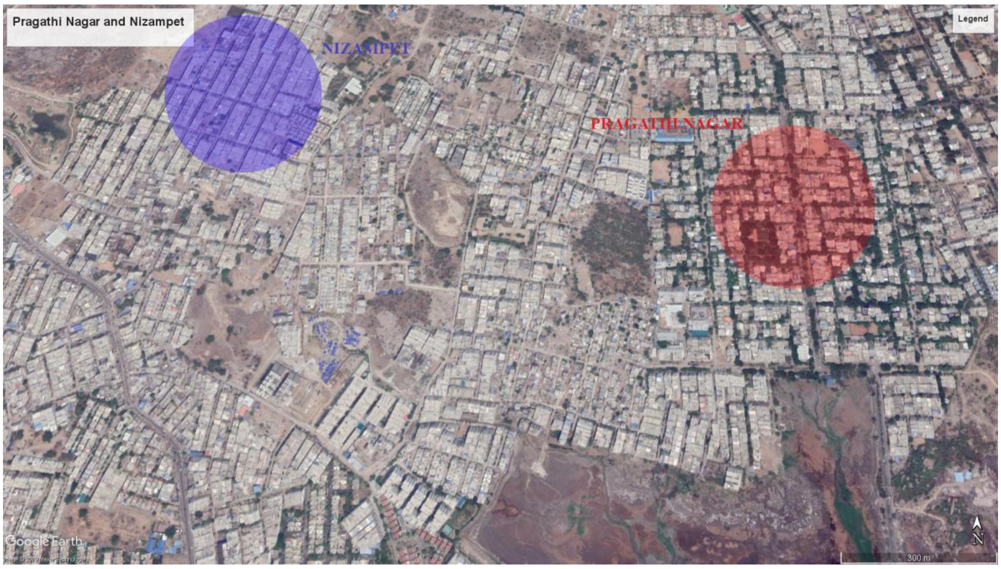

Figure 2: Location Context of Nizampet and Pragathi Nagar Urban Villages in Hyderabad
Source: Google Maps

NZM is an extreme case of exploitation of the urban village provisions while PN had a stricter implementation of the rules and hence exploited less relative to NZM. The core areas of NZM and PN are considered for the study of outdoor thermal comfort parameters. While NZM area has minimal open areas and vegetation and homogenous morphology as all buildings are of similar height (G+5). PN area has more heterogeneous morphology with higher vegetation and more open areas. Further, canyon aspect ratios are higher in NZM area when compared to PN Area; Uninterrupted and continuous Canyons are characteristic of NZM area unlike PN area (Fig: 3).

Figure 3: Site photographs of Pragathi Nagar and Nizampet Urban Villages in Hyderabad

Outdoor Thermal Comfort:

Human thermal comfort is defined as “the state of mind, which expresses satisfaction with the thermal environment” (ASHRAE, 2010). Typically, the focus of thermal comfort has been more towards indoor areas. But understanding outdoor thermal comfort has gained attention in the last decade because of the increase in thermal stress in the cities. Further, outdoor thermal conditions have a significant impact on indoor comfort (Jihad, 2016). If we consider thermal comfort in the outdoor environment, with the added complexity of the wide spatial and temporal variability of environmental conditions and the interactions between the physical environment as well as physiological and psychological mechanisms; it is very dynamic and hence challenging to quantify.

There are various indices that are considered as good indicators for outdoor thermal comfort like Universal Thermal Climate Index (UTCI), Physiological Equivalent Temperature (PET). But for this study purpose as the simulations were performed using ENVI-met Lite simulation software which gives access to only Air Temperature (Ta) and Mean Radiant Temperature (Tmrt). Tmrt and Ta were used are indicators for outdoor thermal comfort. Mean radiant temperature is defined as the ‘uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure’ (Ng, 2012) Tmrt is considered a good indicator of outdoor thermal comfort as it calculates the radiation fluxes of thermal radiant environment and also shows significant variations in a short distance which cannot be observed in Air Temperature readings. Many other thermal comfort indices use Tmrt as part of comfort models (Chen et al, 2016).

Several studies have been done to classify heat stress under Tmrt. But these studies have primarily been focused on western context. These studies have shown a correlation between mortality and Tmrt; a 5% increase in relative risk of mortality if Tmrt exceeds 55°C and 10% increase if Tmrt exceeds 59.4°C. They had classified Tmrt > 55°C as moderate heat stress and Tmrt > 60°C as severe heat stress (Thorsson, 2014) (Lau, 2015). Considering that people in Hyderabad are more resistant to thermal stress Tmrt >60 °C and < 65 °C is considered as moderate stress and Tmrt > 65 °C is considered extreme stress for study purpose.

Figure 4: Pragathi Nagar and Nizampet (250x250m) simulation Areas and Digitized Pragathi Nagar and Nizampet (250x250m) simulation Areas in Envi-met
Source: Google Maps

Methodology

Numerical simulation is the preferred method adopted in this research as they give more flexibility and versatility for the research process. Simulation is used to measure parameters concerning outdoor thermal comfort. Envi-met simulation software is widely accepted for outdoor thermal comfort scenarios in an urban setting especially at neighborhood scale for hot and dry climate scenarios. (De et al., 2017) (Johansson et al., 2014)(Middel et al., 2014)

Envi-met Setup:

Envi-met is a three-dimensional model based on thermodynamics and fluid dynamics that can simulate climates in urban environments and assess the effects of atmosphere, vegetation, architecture and materials (Huttner, 2009). The Envi-met V4.4.3 Summer 19 lite version has been used for this study which allows a maximum domain size of 50x50x40 grid. For this paper, 50x50x20 domain was used and the grid dimension was 5m. This equates to a model area of 250x250x100m. In terms of Vertical grid size, the grid dimensions are to be at least twice the height of the tallest building in the model. The tallest building in the model was 20m and the vertical grid equates to 100m in the model. Google Earth imagery of the two urban villages was identified with the exact size of the model created in Envi-met. From site photographs and Google

Earth imagery, the height of the buildings and vegetation locations was identified. Using the Google Earth imagery, three-dimensional models of both the urban villages were developed (Fig: 4). The simulation process was undertaken on this model and to output Tmrt and Ta. Further receptor points are identified in the model to further analyze the changes happening at these receptor points throughout the day (Fig: 7).

Data Inputs:

Date of Simulation:

The Hottest day of May in Hyderabad (43c Maximum/30c Minimum - May 19th 2019) was considered for simulation; considering May being the hottest month. Meteorological data such as air temperature, relative humidity, and wind speed were taken for the Begumpet Airport weather station from the National Oceanic and Atmospheric Administration database (NOAA). Previous studies indicated the 2nd day of Envi-met simulation is the most accurate; so the simulation was done for 3 days from May 18th morning 7 am to May 21st, 7 am. The results from May 19th, 7 am to May 20th, 7 am were considered for analysis.

Input Data:

Predominant construction material in both urban villages is hollow concrete blocks for walls and reinforced cement slabs for roofs. Hence these materials were considered for the whole model. The main vegetation parameters in Envi-met include the vegetation type, canopy type, and height. Vegetation in Hyderabad is typically evergreen or semi-deciduous. For the simulation, a semi-deciduous tree of high Leaf area density was considered and the canopy type and height were approximated based on on-site observation. In terms of morphology, the PN area has mix of 6 floors and 3 floors buildings with open areas and vegetation whereas the NZM area is nearly devoid of vegetation and almost all the buildings are 6 floors high.

Limitations:

The Simulation is performed for the hottest day identified in May. For a comprehensive characterization, a behavior of outer thermal comfort indices throughout the year needs to be performed. Any vegetation below the height of 5m has been not included as part of the simulation environment. Further Vegetation has been generalized as semi-deciduous due to lack of evergreen vegetation availability in the simulation library. Built and surface materials have been generalized for ease of the study. For higher accuracy, forcing of meteorological data into the simulation model needs to be done. This requires the collection of meteorological data at multiple heights for the stipulated simulation period. Finally, Tmrt and Ta were used as n indicator for thermal comfort due to software limitations. Thermal comfort indices like PET and UTCI will be adopted along with Tmrt in future studies.

Analysis

Air temperature (Ta) was compared at both Nizampet and Pragathi Nagar during the day at 2hr intervals from 10 am to 6 pm. Whereas Mean Radiant Temperature (Tmrt) was considered from 10 am to 4 pm. Tmrt becomes minimal from around 6 pm; hence it was not considered at that time

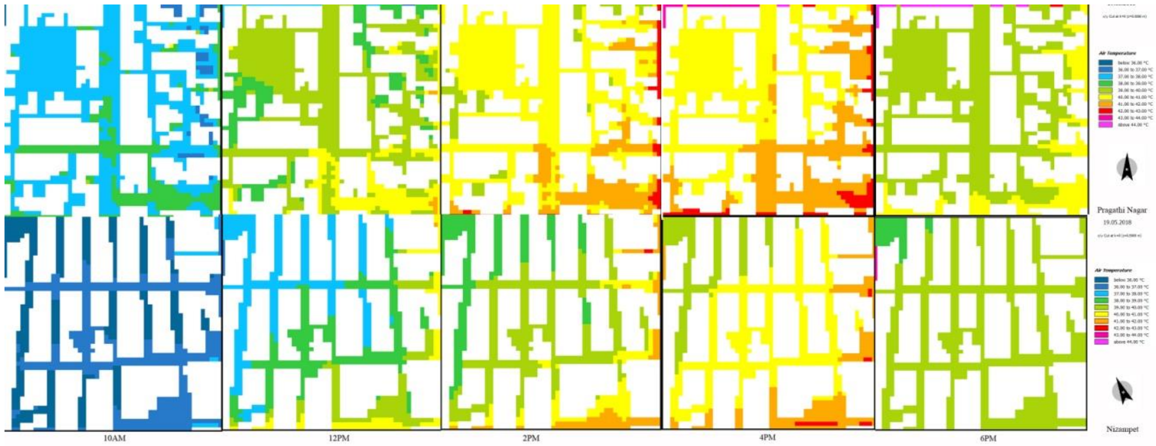

Figure 5: Air Temperature in Pragathi Nagar and Nizampet at 10 am, 12 pm, 2 pm, 4 pm, 6 pm

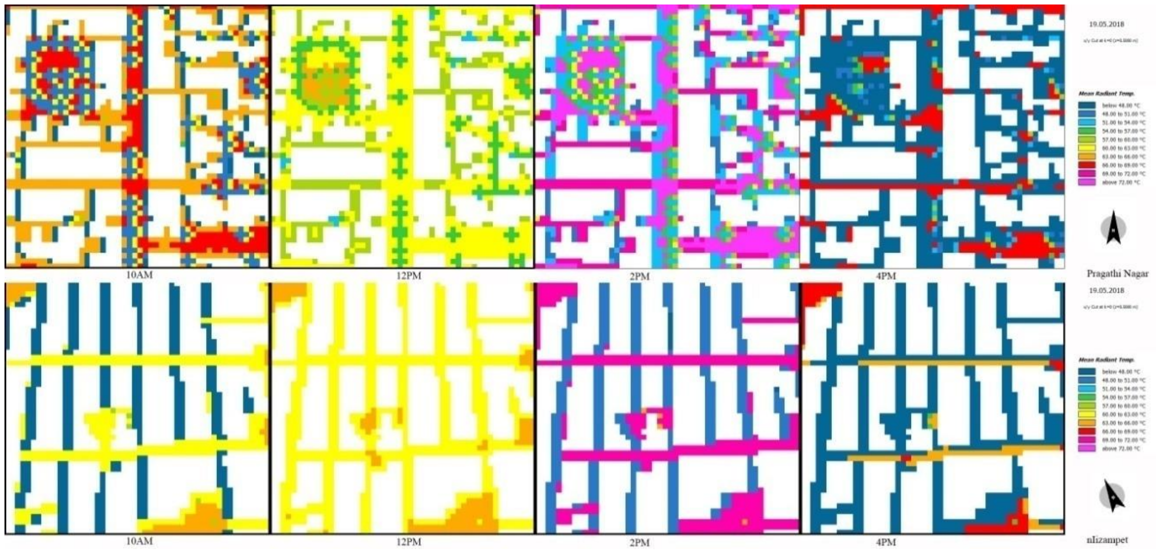

Figure 6: Mean Radiant Temperature in Pragathi Nagar & Nizampet at 10 am, 12 pm, 2 pm, 4 pm, 6 pm

The Ta in the NZM area reaches its peak between 2 pm and 4 pm while the PN area also exhibits a similar pattern. But, Ta rises faster in PN Area due to more presence of open areas and heterogeneous morphology. There is a significant difference in Ta between the NZM and PN areas; consistently the PN area exhibit higher Ta. The differences between the two neighbourhoods in terms of Ta vary between 1 to 2^{o}C and the difference is highest at 10 am at 2^{o}C. There is no evident behaviour concerning orientation and vegetation. Further, a higher Ta difference of 3^{o}C between maximum and minimum is observed in the NZM area when compared to the 2^{o}C in PN area (Fig: 5).

Similarly, Tmrt in the NZM area at 10 am and 4 pm is lower compared to the PN area by 3-6^{o}C; but around noon, Tmrt in the PN area is lower especially the areas adjoining the vegetation by 3-6^{o}C. In the NZM area predominantly there are only 2 different Tmrt readings usually dictated by orientation while in the PN area there is more variability in readings. There is more evidence of the orientation of streets and vegetation having an influence on Tmrt. This is evident throughout the day except for noon (12 pm measurement) when the sun is completely overhead and thus nullifying the impact of the orientation of streets. Vegetation still shows an impact on reducing the Tmrt at noon. These influences area more pronounced in terms of street orientation impact in the NZM and vegetation impact in the PN area. The impact of N-S oriented streets when compared to E-W oriented streets in the NZM area is significant and difference ranges between 15-24^{o}C. (Fig: 6) In the PN area, due to vegetation and heterogeneous morphology, the MRT varies a lot and the difference range between 15-21 °C. The highest Tmrt was typically found in the open spaces while the lowest under vegetation. Either extreme heat or moderate heat stress is observed in the PN area throughout the day but it is primarily around open areas. Areas around vegetation never experienced extreme or even moderate heat stress In the NZM area extreme stress is observed only in E-W oriented streets at 2pm; otherwise moderate stress is observed throughout the day depending on the orientation of the streets.

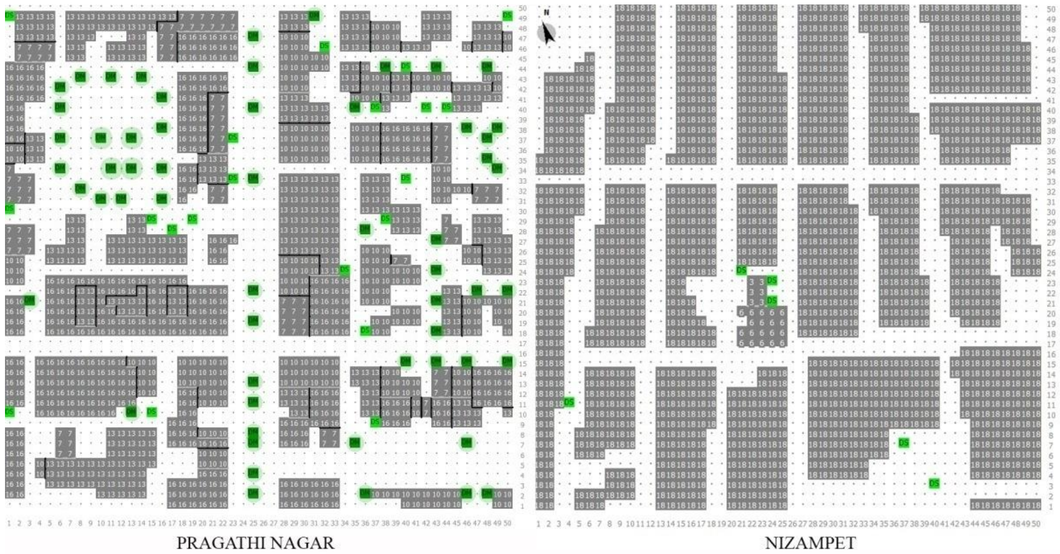

Figure 7: Receptor points considered for further Analysis

Further to highlight the differences due to vegetation and orientation, receptor points were considered in both the areas (Fig: 7). Orientation impact is evaluated in the NZM area and vegetation impact in the PN area. Point A is on a street along N-S orientation while point B is along E-W orientation in the NZM area (Fig: 8). Between Point A and B, the difference ranges between 0-24°C. The difference was very minimal at 12 pm and the highest at 4 pm. Further receptor points were considered where Point C is under vegetation and Point D is in open area in PN Area. The difference in Tmrt at Point C and Point D varies between 7.5 -24°C (Fig: 9).

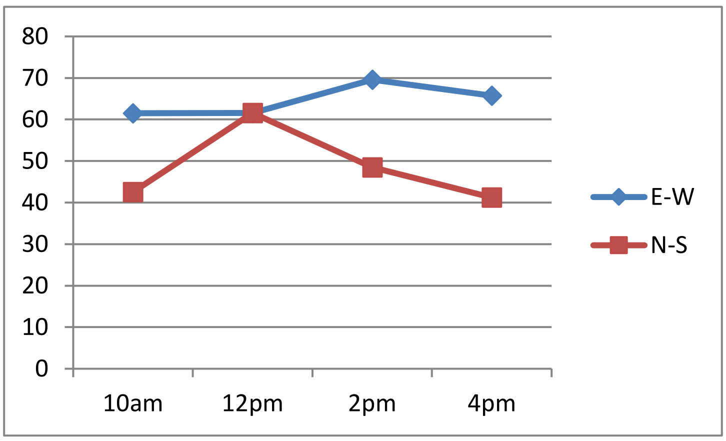

Figure 8: Tmrt difference between Receptor points A and B in the NZM area. Point A N-S orientation, Point B E-W orientation

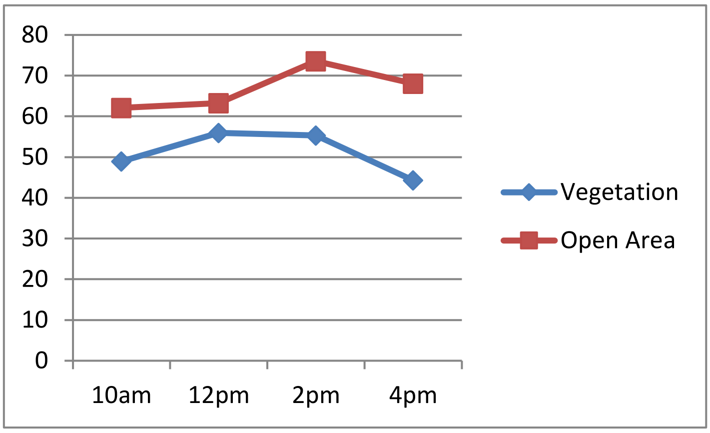

Figure 9: Tmrt difference between Receptor points A and B in the NZM area. Point C- vegetation, Point D Open

Conclusion:

Ta in the NZM corresponded to its homogenous building morphology and lack of vegetation. In the PN area due to its heterogeneous morphology and presence of vegetation, there is more variation of Ta. In terms of Tmrt, this distinction is even more pronounced as it is a more dynamic index that can capture more variation spatially compared to Ta. The Analysis reinforces the unsuitability of Ta and suitability of Tmrt as an outdoor thermal comfort indicator because of their spatial variability respectively. The difference in Tmrt between vegetation and open areas reaches as high as 21c in the PN area whereas the difference due to orientation in Tmrt at NZM ranges reaches as high as 24C. This highlights the importance of the usage of building morphology as a shading system apart from the vegetation. At noon, vegetation provides more protection from thermal stress due to the direction of the sun. In the present conditions, noontime is very uncomfortable for the NZM area due to a lack of vegetation.

The Impact of unregulated developments doesn't fit the general assumption of deteriorated outdoor thermal comfort. Accurate implementation of developmental controls will not necessarily correlate to better thermal comfort as development controls have a weak urban climate link. NZM area is better in thermal comfort in some cases by taking advantage of the mutual shading of building morphology and seldom experiences extreme heat stress. The analysis highlights the missing link between urban planning and urban climate. Several aspects that have an impact on the health and thermal comfort of people like wind movement, pollution dispersion, and Daylight availability have not been considered in the scope of the study. It is likely possible the NZM area is significantly worse off in these aspects.

Recommendations:

- Appropriate Thermal comfort Indices like Tmrt have to be adopted for outdoor thermal comfort studies. The results will vary depending upon the index adopted.
- Building orientation, canyon aspect ratio (mutual shading), vegetation and other morphological parameters have to be optimized together for the best outdoor thermal comfort scenario.

- The impact of morphological parameters on outdoor thermal comfort has to be quantified and parameterized for multiple configurations. This will enable urban planners and urban designers to integrate urban climate knowledge.
- Future research should focus further on demystifying the link between urban climate and urban planning and suitable frameworks need to be developed to link them effortlessly.

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