

Microclimate and Crowd Motion as Decision-making Tools for Urban Planning and Design

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ABSTRACT

Given the flourish of urban construction projects in China in recent years, the Urban Heat Island (UHI) phenomenon is a pressing concern for urban planners and designers. Traditional heat island detection and microclimate tools require software and lengthy run time, both of which are not suitable for the early stages of urban planning and masterplans. For planners interested in producing measurable heat-resilient designs, there is an urgent need for tools that are easily operable and scaled for multi-hectare designs. Therefore, this research combines microclimate and crowd motion software to test it on a neighborhood-sized project located in Foshan, China. Through ENVI-met and Arup's interactive planning tool called Pocket City, planners are able to map the impacts of heat and its influence on pedestrian behaviors on site. The results show that unless public spaces are well shaded during the morning and midday hours, visitor retention rate is low and key commercial spots stand to suffer financial loss. The key significance of this study is finding quantitative and visual methods that improves urban planning techniques, increase consideration for pedestrian comfort, and add value to the quality of designs through technology.

KEYWORDS

Urban Planning, Urban Heat Island, Microclimate, ENVI-met, Pocket City

INTRODUCTION

Around half of the world's population lives in urban areas, and according to the United Nations Population Fund, the number will increase to 5 billion people by 2030 (Anon. A). The Urban Heat Island (UHI) phenomenon is a relevant and urgent problem cities of all sizes and scale face, regardless of location. Heat island is defined as the rise in temperature of any man-made area, resulting in warm 'islands' that retain heat compared to the surrounding landscape. Various academic studies have verified that heat islands are caused by the progressive replacement of natural surfaces by built surfaces, and through a complex interaction between thermal, environmental and other contributors (Hamilton et al. 2013).

In Mainland China, the impact and scale of new construction projects readily affects the microclimate of cities. Given the availability of developable land, demand for new housing, rapid inflation in housing prices, and increased transportation mobility of residents, suburbs and second/third tier cities face unprecedented construction in a short period of time. An extreme case in Hunan Province documented the construction of a

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30-storey hotel in just 15 days, or 360 hours. It is entirely possible for new neighborhoods and entire cities to exist in a year.

Accordingly, construction spending in China was US\$1.8 trillion in 2013, making it the largest market in the world, surpassing both United States and Japan combined (Davis Langdon 2014). The Guangdong Province in Southern China is an example of the breakneck speed of development, where the increase of new workers and residents, favorable development policies, and construction of new metro lines linking the Pearl Delta Region greatly increased the demand for housing and facilities.

The rapid speed from design to construction is both an opportunity and increased professional responsibility for urban planners, who must respond to the project time frame yet produce sustainable designs that benefit the future residents. However, traditional planning is largely qualitative and value based; plans are exchanged from calculation, diagrams, models, and renderings before handover to designers and architects.

There is a lack of quantitative and illustrative measurement in the quality of the site plan, of whether the placement of buildings, roads, public spaces, and ecological features create a comfortable and user-friendly environment. Most market models are not appropriate for urban planning scale and often require longer amount of time than planning projects allow.

The objective of this study is to propose a quantitative process that maps the microclimate of a large neighborhood (above 100 hectares), evaluate for heat-trapping design features, determine the comfort level of public spaces, and simulate pedestrian movement based on thermal comfort. The goal is to create a planning process based on technology that quickly and comprehensively evaluates design plans, meet the demands of the client, and most importantly design a neighborhood that maximizes the comfort of where people will ultimately live and work.

RESEARCH METHODS

The research takes a new neighborhood in Southern China and tests for microclimate impacts using the Predicted Mean Vote (PMV) index through ENVI-met (version 3.1) microclimate model. PMV results will then be combined with Pocket City to track pedestrian moments through the site based on thermal properties.

Site

The project site is 166 hectares and is situated in Foshan, the hinterland of the Pearl River Delta. Foshan has a mild climate with humid and hot summers of up to 36 degrees Celsius. All simulations are based on a typical warm summer day in August 2013, with data from the public U.S. Department of Energy website (Anon. B). The project scope involves a new mixed-use community with offices, retail centers, residential, central park, museum, and metro station (Figure 1). Green space requirements in Linyue are based on city planning code, and features 40% or approximately 425,000 square meters of trees, grass, water features, residential parks, and greenbelts. Areas surrounding the site consists of rural farmland with the nearby commercial centers approximately 3 kilometers away.

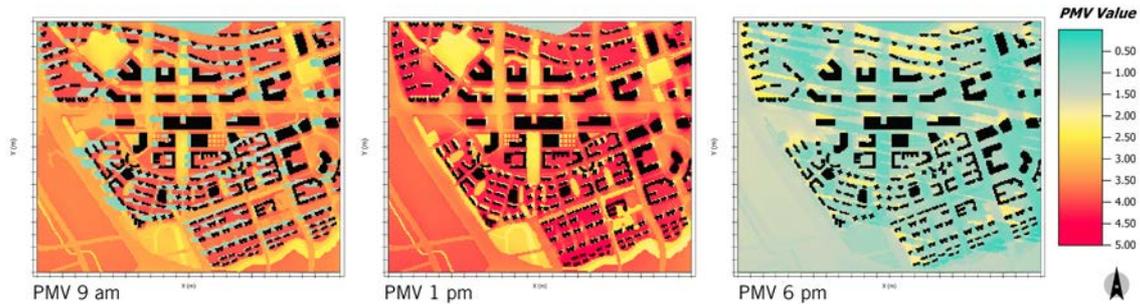


Figure 3. Pedestrian Decisions Influenced by PMV

By lunchtime, the overall PMV of the site has increased from +3.5 (hot) to +4 (very hot) and above. Most roadways have a PMV of +3 or above, which makes commuting and waiting for public transport without proper cover uncomfortable along the routes. Many inner neighbourhoods surpassed +4, an uncomfortable thermal sensation that can turn into heat exhaustion. As the sun changes position midday, tall buildings have lost most of their shading. Instead, cooling has been replaced by green areas and water bodies, which at 1 pm have the lowest PMV values throughout the site. Even small residential parks show a clear reduction in PMV. The rectangular plaza with a +2.5 PMV in the centre provides a heat refuge to lunchtime workers in the area, with a difference of +1.5 to +2 PMV lower than its immediate surroundings. With further green cover, public seating areas, dining, retail, and play space, the plaza has long term potential for leisure and commercial attraction.

At 6 pm, the thermal level of the site is between a comfortable +0.5 to +1.5 PMV. Major roads and dense residential neighbourhoods that were previously above +3 to +4 are at +1 PMV or below. The original hypothesis stipulated that Linyue retains heat well into the night due to impermeable surfaces of concrete and asphalt. According to the ENVI-met results, Linyue adequately cooled down early into the evening. When retested at 9 pm the results show only slightly lower numbers as PMV stabilizes for the rest of the night. In terms of design, it is best to concentrate resources and means for morning and lunchtime hours when PMV is at its highest.

Pedestrian Choices Based on Their Environments

A portion of Linyue TOD is tested for crowd behaviour (Figure 4). Linyue East has approximately 40% of green space calculated into the design, including a combination of water bodies, green cover, and trees. Four thousand pedestrians are dispersed from the metro station exit, and programmed to walk towards primary destinations (office buildings with commercial retail), secondary destinations (basic office buildings and museum), and residential buildings for one hour at 1 pm

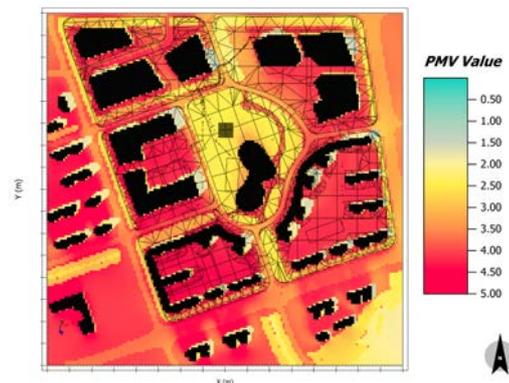


Figure 4. Linyue East PMV 1 pm

(Figure 5). Pedestrians must obey basic traffic laws such as traffic lights and crosswalks.

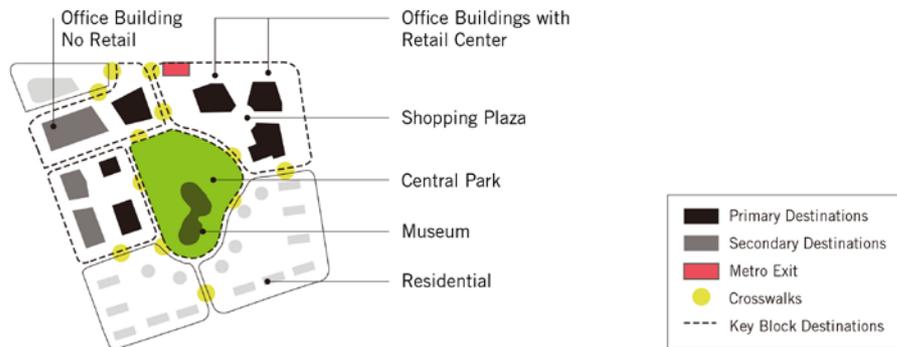


Figure 5. Destination Indicator

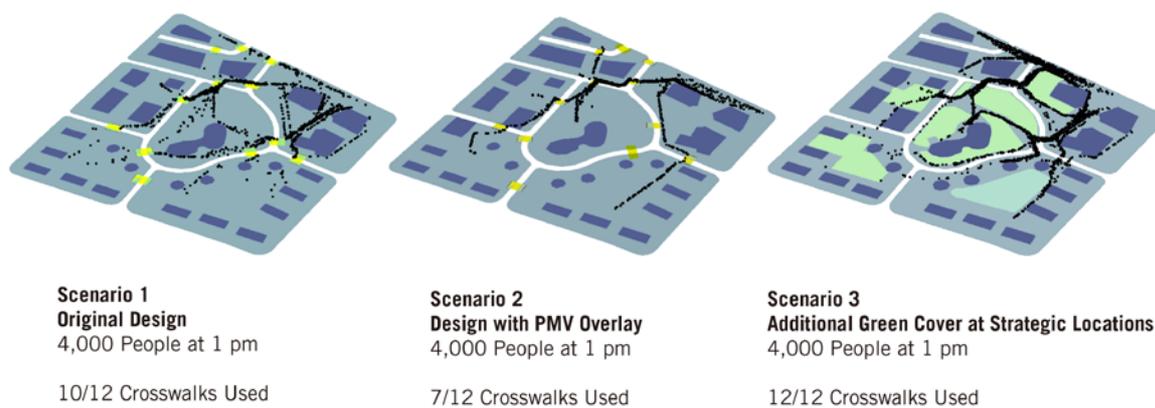


Figure 6. Pedestrian Decisions Influenced by the Thermal Comfort

Three scenarios are used to test for pedestrian movements throughout the site, including original design without consideration to PMV, design with PMV overlay, and design with improved green cover.

In the first scenario, pedestrians walked around without concern for their thermal comfort. As shown in Figure 6 “Original Design”, walking patterns are loosely dispersed from the metro station, with most pedestrians walking in and around the primary and secondary locations. The shopping plaza received a sizable number of visitors, as well as the central park and museum area. Out of 12 crosswalks, ten are utilized by pedestrians throughout the site.

However, in a real environment pedestrian actions are also dictated by comfort and attractiveness of surroundings. Urban planners need to know whether the space is inviting to visitors or causing the opposite effect. In the second scenario with PMV overlay, the results indicate that under an uncomfortably warm environment people take the shortest paths to their destinations with minimum roving. Out of 12 crosswalks, only seven are utilized. The termination points are clear, and the lack of pedestrians on the surface level indicates that people directly went indoors. In addition, the pedestrian walking patterns are notably more linear, indicating that people sought out cool points such as along buildings for shade, under tall trees, or near pocket parks. The core shopping plaza is poorly utilized by pedestrians who walked around rather than through the plaza. For planning, this is an undesirable outcome if pedestrians do not meander

and take advantage of its facilities. For retail with shopping and dining nearby, this indicates lost revenue.

In the third scenario, additional green cover are added throughout the site in active areas such as commercial or public spaces. Compared to the first two scenarios, the pedestrians disperse deeper and more diversely into the site. Twelve out of twelve crosswalks are used by pedestrians accessing the site. The presence of dots indicates that people did not disappear upon reaching their destination, but instead walked around in places that had the most shade and green space. Urban planners can use this information to strategically plant more trees and water features in the shopping plaza to further encourage pedestrian retention.

All three scenarios are lastly transferred to Pocket City, which allows a planner to zoom and observe the movement of pedestrians from any vantage point or time of the day. Figure 7 is an example of observing how people walk through the central park with PMV overlay. Designers can take advantage of this data by creating more active uses along the pedestrian paths.

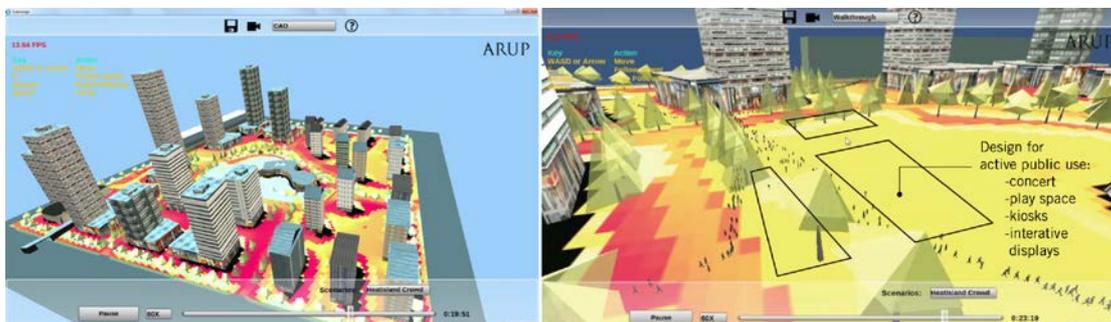


Figure 7. Pocket City Screenshot of Birdseye and Street View of Linyue East

CONCLUSION AND IMPLICATIONS

The combination of ENVI-met and Pocket City are an effective starter tool for planners seeking quantitative evaluation of pedestrian comfort and movement. Utilizing open source data, planners are thus able to review schemes in three days or less for a project of 166 hectares. By understanding the temperature and PMV of the site properties, planners have the tools to quickly assess and revise masterplans for flaws in design.

Using a 166 hectare Linyue TOD as an example, the summary concludes that the site disperses heat quickly in the evening, and more resources and heat mitigation methods are necessary between 9 am and 1 pm. Specifically, shading from its tall buildings and leafy trees, as well as a combination of water bodies and green cover are the best method to reduce the PMV of the site to a significantly more comfortable level.

The impact of thermal sensation also has a great impact on pedestrian circulation and movement throughout the site. After three rounds of testing pedestrian dispersion through Pocket City, an Arup crowd motion and simulator tool, a comfortable environment with low PMV encourages pedestrians to disperse deeper and more consistently into the site. In addition, they are more likely to use key commercial and public facilities and remain longer on site.

The measurement of pedestrian comfort is an important tool for urban planners. Although ENVI-met is a simple and limited tool at its current version, it is an effective starter tool for the early stages of design. More research is necessary to balance

accuracy of data and operation time, incorporation into the workflow of planners and designers, and the development of an effective microclimate model that can be shared with architects and building physics at later stages. The main implication of this research encourages urban planners and designers to give early considerations to the effects of microclimate, and create places that take into account heat resilience on people who will ultimately live, work, and play in the new neighbourhood.

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