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GIS-based surface roughness evaluation in the urban planning system to improve the wind environment – A study in Wuhan, China



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ABSTRACT

Due to the rapid urbanisation, the urban environment has been changed and deteriorated. One of reasons is lack of consideration and implementation of climatic and environmental information in urban planning. Thus, there is a need to develop a systematic method for city planners and policy-makers to make scientific and evidence-based decisions in the urban climatic and environmental field. Taking Wuhan as an example, this study aims to provide a practical framework to identify planning goals and guidelines for master and district planning, based on the results of roughness modelling. Both meteorological information and 3D urban morphology data were simplified and integrated in a Geographical Information System (GIS) to provide the detailed information of the urban permeability distribution. Based on this spatial distribution information, both master and district planning goals for better urban wind environment can be particularly identified and corresponding planning strategies can be established. With this spatial urban permeability information and the joint effort from local town plans and policy-makers of the Planning Bureau of Government, urban planning strategies for different spatial scales and districts can well cooperate with each other and be interwoven into the whole urban planning process.

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1. Background

In the last 20 years, major cities in China have undergone rapid urbanisation. Wu Han, with an area of some 8500 km² and a population of over 10 million, is located inland and west of Shanghai. It is one of the mega cities in China and is the country's high speed rail hub. In the summer months, Wu Han is hot; the average daytime temperature of the city is around 33 degrees Celsius. The city planners of Wu Han have been postulating the idea of urban air paths for a number of years for the making of their master plan. This study to better identify and quantify the wind path idea was commissioned by the City Planning Bureau of the Wu Han City Government in 2012. The study intended to provide evidence based knowledge for Wu Han's planners.

2. Literature review

The public concern on good quality of living environment has kept on rise in the world. German and Japan lead pioneering work in the field of urban climatic application into the urban planning (Ren et al., 2011). German cities have protected their urban environment carefully in the local development since the 1950s. Stuttgart Municipal Government pays its continuing effort to upgrade the air quality of Stuttgart. One of their useful measures is the air path development (Baumueller et al., 2009). In this plan, scientists, urban planners and local governors work together to evaluate the air-flow distribution patterns, to detect the possible air paths which can bring the fresh air from the surrounding hillsides to the downtown areas of Stuttgart, and to control the urban development carefully and strategically. The relevant plan actions have played an important role on mitigating urban heat island and improving air quality.

Japan researchers and government has paid their high attention on the wind environment since the 1990s. Tokyo Metropolitan Government including eight main counties finished a study on air path in 2007. In the report, it collected the relevant wind information for planners, like wind rose information, annual and seasonal prevailing wind information, land-sea breezes system, and also provided the detailed plan of developing air paths in Tokyo Metropolitan areas (Architectural Institute of Japan, 2008).

Hong Kong is one of most high-dense and populated city in the world. Natural ventilation in urban planning is a big challenge to local planners and governors. Recently "Wall-buildings" have been constructed. They highly affect local air circulation. Thus, local researchers and governors has worked together to develop a wind information layer for planning use based on the available meteorological records, CFD simulations and expert evaluation (Ng, 2012). This layer has been used by the Planning Department of Hong Kong Government to guide the new town plan and urban renewal.

3. Objectives

The study of outdoor natural ventilation often requires large-scale aerodynamics modelling. Both physical modelling (wind tunnel) and numerical modelling can provide data regarding the airflow within the urban canopy layer. However, conducting these modelling tests for a particular urban planning exercise is expensive and time consuming. Modelling results cannot keep up with the quick planning processes, as such, Ng et al. (2011) opines that a methodology that uses a rougher understanding of the urban morphological implication to the urban wind environment can be more useful to planners. Given the growing concerns related to the way urban environment is evaluated and air paths are detected in order to fit the requirements of practical urban planning, this study aims to:

- introduce the morphological method to model urban surface roughness and evaluate urban permeability;
- analyse urban permeability to detect potential air paths to improve urban performance in outdoor natural ventilation;
- highlight the implementation of modelling results in urban planning practices and interweave the modelling results into different urban planning stages and scales, such as the master and district planning.

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