Air Ventilation Assessment System for High Density Planning and Design

Edward Ng

Department of Architecture, Chinese University of Hong Kong, Shatin, NT, Hong Kong

ABSTRACT: In 2003, Hong Kong was hit by Severe Acute Respiratory Syndrome (SARS) from which many people died. The Hong Kong Government subsequently set up a Team Clean Committee to investigate possible infectious disease prevention measures and policies. One of the general feelings was that SARS should be taken as a wake up call to critically examine the city for healthy living. Team Clean then charged the task to the Planning Department, HKSAR. It initiated a study titled: “Feasibility Study for Establishment of Air Ventilation Assessment (AVA) System”. In 2003, the research contract was entrusted to Professor Edward Ng of Department of Architecture, CUHK. Over the next two and a half years, a number of studies were conducted. The study eventually led to a methodology of Air Ventilation Assessment (AVA). Unlike many countries with guidelines for dealing with strong wind conditions, AVA is a guideline for weak wind conditions specifically designed to deal with congested urban conditions. The AVA system basically establishes a method for project developers to objectively assess their designs. The Government of Hong Kong has adopted the system and will require all major development projects to undertake the assessment. The first test case has been a 328 hectare old-airport site in the city centre. The scientific and implementation processes leading to the AVA system is reported in this paper.

Keywords: planning, high density city, thermal comfort, ventilation

1. INTRODUCTION

More than 20 cities in the world are “mega” – they have more than 10 million inhabitants. High density city design is a topical issue. There is a need to deal with the scarcity of land, to design for a viable public transport system, and to re-build the community of our inner cities. High density living is increasing an issue that planners have to confront with. Hong Kong is a high density city with a population of 8 millions living in a piece of land of 100 square kilometres. The urban density of Hong Kong is close to 60,000 persons per square kilometre. The site development density is 3000 persons per hectare. (Figure 1)

Figure 1: A typical skyline of Hong Kong.

The recent unfortunate events of Severe Acute Respiratory Syndrome (SARS) in 2003 has brought the Government and inhabitants of Hong Kong to the realization that a “quality” built environment should be an aim for Hong Kong to become a city that we can proudly call home. Gradation of development height profiles; provision of breezeways; layout planning and disposition of building blocks to allow for more open spaces; greater building setbacks to facilitate air movement; reduction of development intensity; increase open space provisions especially in older districts; and more greenery, are coined as measures in the Team Clean Report 2003 to improve our built environment. The report also highlights the need to establish methods for air ventilation to guide future planning actions. [1] This paper summarises the research findings, and reports the Air Ventilation Assessment (AVA) Method that is now adopted in Hong Kong to guide developments. The research works were commissioned to researchers at Department of Architecture, Chinese University of Hong Kong in October 2003.

2. STUDY METHODOLOGY

“Find the problem, else one risks solving the wrong one”. This was the opening sentence of Prof Mat Santamouris when he was invited to be an expert reviewer during the early stages of the study. The following methodology was adopted.

(A) A desk top study of related works and study examples around the world – not just scientific investigations, but also policy measures..
(B) A review to understand the current urban conditions of Hong Kong, and to identify issues and problems.

(C) Explore the possibility to establish performance criteria needed for considering the impact of development on wind environment.
(D) Define the critical issues and to explore the feasibility to develop a practical and cost effective assessment methodology.
(E) Examine the practicality of an effective implementation mechanism, and to develop a methodology.
(F) Establish principles and good practice for the use of professionals and practitioners in the shaping of the built environment for better wind environment.

3. REVIEWS

There are a lot of scientific studies dealing with the wind environment and modelling. [2] [3] [4] It has been very quickly established that although many countries have design guidelines for gust and strong wind problems, [5] [6] few if not any of them seems to have touched on the issue of urban air stagnation and weak city air ventilation problems. Notable exceptions are studies dealing with air pollution and dispersion, [7] [8] for example Prof Chris Baker's group at Birmingham University. [9] [10] In Japan, The Tokyo Metropolitan Government has an Environmental Map so that designated areas for the implementation of measures could be identified and used as a guide for redevelopment projects. [11] (Figure 2)

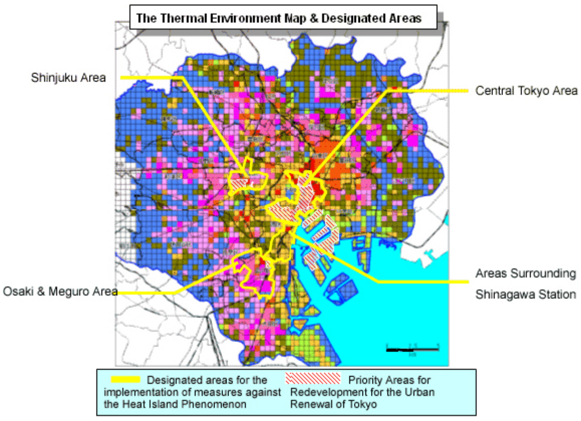

Figure 2: Tokyo Environmental Map.

In Germany, there is a requirement that developments should not worsen the climatic conditions of the site. Urban Climatic Maps have been produced. (Figure 3) They have been used to guide planning and development decisions. In the city of Kassel, the Climatic Map has been translated into a Planning Evaluation Map. This map further identifies possible action for planners. [12] [13] Using this guiding map, which has factored the dynamic characteristics of the wind movement in the city to alleviate the adverse effects of urban heat island, planners could decide if a development is blocking the wind to the city, and should the project proponent be given permission or is required to do further tests to provide justifications.

Our desktop review also identified ad-hoc studies in Hong Kong dealing with the wind environment for extreme high density conditions. A study by RWDI of Canada for a client in Hong Kong as shown in Figure 4 is an example. But in Hong Kong, weak wind studies are still rare.

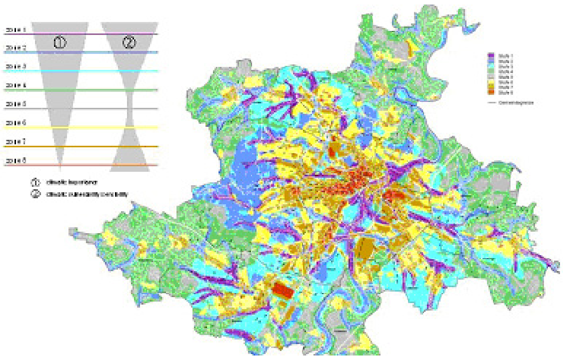

Figure 3: Planning Evaluation Map by Professor Lutz Katzschner of Kassel University.

Figure 4: A wind tunnel test of a high density estate in Hong Kong by Consultant RWDI of Canada.

4. REVIEW OF EXISTING CONDITIONS

To shorten the study period, the existing conditions in Hong Kong were evaluated based on expert qualitative evaluation. Professor Baruch Givoni, Professor Lutz Katzschner, Professor Shuzo Murakami, Professor Mat Santamouris, and Dr Wong Nyuk Hien were the five experts. With minor differences in opinion, the following key comments were received.

4.1 Breezeway / air path

As a general rule, the more air ventilation to the streets, the better it will be for these dense urban areas. The overall permeability of the district has to be increased at the ground level. This is to ensure that the prevailing wind travelling along breezeways and major roads can penetrate deep into the district. This can be achieved by proper linking of open spaces, creation of open plazas at road junctions, maintaining low-rise structures along prevailing wind direction routes, and widening of the minor roads connecting to major roads. Also avoid obstruction of the sea breeze. Any localised wind problem along the waterfront should be dealt with locally and not affect the overall air ventilation of the city.

4.2 Podium / Site Coverage

The effect of building layout (especially in terms of building site coverage) has a greater impact than that of building height on pedestrian wind environment. (Figure 5) Stepping building heights in rows would create better wind at higher levels if differences in building heights between rows are significant. The "podium" structures commonly found in Hong Kong are not desirable from the viewpoint of maximizing wind available to pedestrians. The podia with large site coverage not only block most of the wind to pedestrians (affecting comfort and air quality), but also minimize the "air volume" near the pedestrian level (affecting air quality).

Figure 5: A typical building morphology in Hong Kong: tower blocks sitting on a podium that occupies the entire site. When podiums are very close together, they significantly reduce the air space at pedestrian levels.

4.3 Building Disposition

Figure 6: Tall buildings too closely pack together creating an 'effective' wind block to the city behind.

Proper orientation and layout of the buildings with adequate gaps between buildings are needed. (Figure 6) Stagger the arrangement of the blocks such that the blocks behind are able to receive the wind penetrating through the gaps between the blocks in the front row. In case of a new town, to avoid obstruction of the sea breeze, the axis of the buildings should be parallel to the prevailing wind. In order to maximize the wind availability to pedestrians, towers should preferably abut the podium edge that faces the main pedestrian area/street so as to enable most of the downwash wind to reach the street level.

4.4 Building Heights

Vary the heights of the blocks with decreasing heights towards the direction where the prevailing wind comes from. If not, it is better to have varying heights rather than similar / uniform height. Given the extremely high density of the urban fabric and narrow streets, a probable strategy for improving the air ventilation is by varying building heights for diverting winds to the lower levels. Nonetheless, assessment will be required to further quantify the actual performance of such potential in view of the common deep urban canyon situations in Hong Kong.

4.1 Building permeability

The provision of permeability / gap nearer to the pedestrian level is far more important than that at high levels. Create permeability in the housing blocks. Try to create voids at ground level to improve ventilation for pedestrians. This will improve not only the air movement at the ground level (thus improving the pedestrian comfort), but also help to remove the pollutants and heat generated at ground level. The channelling effect created by the void also helps to improve the ventilation performance for those residential units at the lower floors. Creation of openings in the building blocks to increase their permeability may be combined with appropriate wing walls that will contribute to pressure differences across the building facades and thus will permit the air to flow through the openings of the buildings. The wing walls have to be designed according to the known standards. For very deep canyons or very tall building blocks, mid-level permeability may be required to improve the ventilation performance for those occupants situated at mid-floors.

4.5 More the Better

It was in general opined that unlike most cities in the world, wind gust may not be a problem in most cases. On the contrary, wind stagnation and blockage is a main problem. And for the tropical climatic conditions of Hong Kong where wind in the summer is a welcoming quantity, it was opined unanimously that "more the better" should be the guiding spirit. That is to say, designs and developments should focus on not blocking the incoming wind, as well as minimise the stagnant zones at the pedestrian levels.

5. CRITERIA

Givoni has conducted researches on outdoor comfort in two very different locations, both, like Hong Kong, are hot and humid in the summer: Japan and Israel, based on his findings, he developed formulas to predict the thermal sensation of people outdoors as a function of air temperature, solar radiation, and wind speed. According to the results of both studies, relative humidity RH has been shown to have statistically insignificant effect on comfort perception. [14] [15] Based on his formulas and the meteorological data of Hong Kong, a comfort outdoor temperature chart for urban Hong Kong was developed (Figure 7). The x-axis of the chart is outdoor air temperature and y-axis is the level of solar radiation. The shaded area represents the neutral comfort region which could be obtained by a proper combination of air temperature, solar radiation and wind speed. The chart provides a rough guide to the kind of wind environment that is desirable in Hong Kong. For example, a people in shade, given high summer air temperature of 28 degree C, a gentle wind of 1.0-1.5 m/s is optimum.

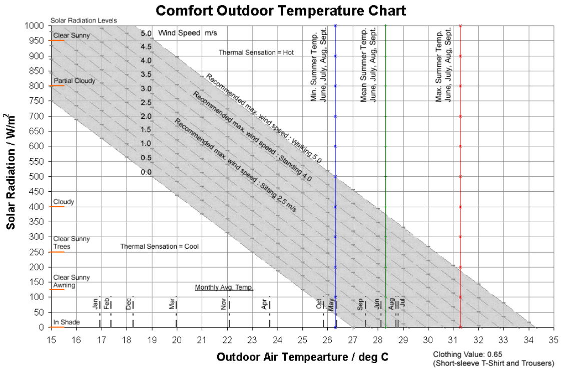

Figure 7: Comfort chart based on researches of Professor B Givoni and Hong Kong meteorological data.

Based on an examination of wind data in the urban areas of Hong Kong, a mean roof top (approximately 50m above ground) wind of some 2.5 m/s could be expected. As such, one immediately sees the need for the planning of the city to optimise this wind availability so that at pedestrian level of 2m above ground, wind can be available..

6. AIR VENTILATION ASSESSMENT (AVA)

A key objective of the study is not scientific, but to try to find an objective protocol and methodology to guide planning practice. Planners have control of a number of design parameters. For example, site coverage, building bulk, building alignment and deposition and so on. Fundamentally, it is important to ensure that buildings and their planning do not block the ambient mechanical wind. Locallised thermal wind is therefore a relatively minor consideration from a practical planning point of view.

Wind Velocity Ratio (VR) is used as an indicator. V_∞ is the wind velocity at the top of the wind boundary layer not affected by the ground roughness, buildings and local site features (typically assumed to be a certain height above the roof tops of the city centre and is site dependent). Vp is the wind velocity at the pedestrian level (2m above ground) after taking into account the effects of buildings. (see diagram below) V_p / V_∞ is the Wind Velocity Ratio (VR_w) that indicates how much of the wind availability of a location could be experienced and enjoyed by pedestrians on ground taking into account the surrounding buildings. As VR_w is solely affected by the buildings of the location, it is a simple indicator one might use to assess the effects of proposals. The higher the value of VR_w, the lesser the impact of buildings on wind availability. (Figure 8 and 9)

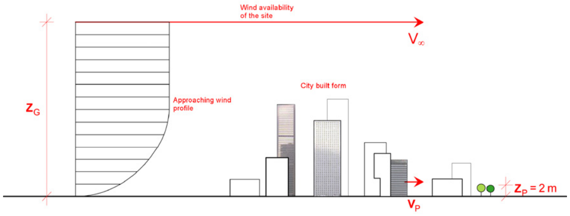

Figure 8: The concept of VR. Using VR, it is possible to factor the effects of developments to the wind environment.

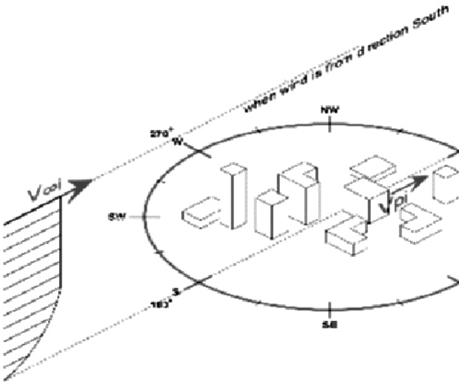

Figure 9: 16 directions are factored. The VR of each direction will then be factored with wind coming from that direction.

Based on VR as an indicator, the methodology of the assessment procedures and scope needs to be identified. The assessment area, the surrounding area, the location of test points and the definition of site wind availability need to be specified. (Figure 10)

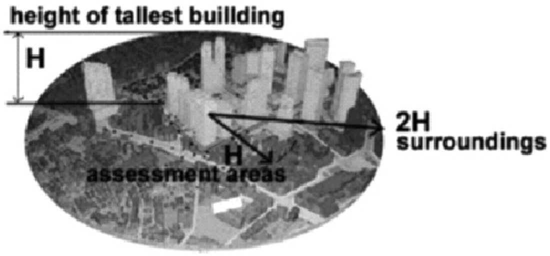

Figure 10: The assessment area and the surrounding area defined by the height of buildings on site.

Although CFD could be used for some urban wind studies, the study concluded the use of wind tunnel as a more reliable tool. Wind tunnel work procedure is robust and is known to give reliable results for wind studies for structure and for pedestrian wind studies. [5] [6]

Once VR of the tests points are measured inside a wind tunnel, project proponents are required to report 2 key ratios to represent their designs.

Along the boundary of the site, a number of perimeter test points is planted. They could be about 10 to 50 metres apart, depending on the site condition, surrounding the test site and are evenly distributed. Test points must be planted at the junctions of all roads leading to the test site, at corners, as well as at the main entrances of the test site. This set of test points is known as Perimeter Test Points. They will later provide data to calculate the Site Spatial Average Wind Velocity Ratio (SVR_w). This gives a hint of how the development proposal impacts the wind environment of its immediate vicinity.

Test points should also be evenly distributed over the assessment area of the model. For detail study, one test point per 200 to 300 square metres of the assessment area would typically suffice, except when doing rough initial study, or when the site condition is simpler. Test points should be positioned where pedestrians can or will mostly access. This may include pavement, open spaces, piazzas, concourses and so on, but exclude back-lanes or minor alleyways. For streets, the tests point should be located on their centerlines. Some of the test points must be located at major entrances, as well as identified areas where people are known to congregate. This group of test points will be known as Overall Test Points, together with the Perimeter Test Points, will provide data to calculate the Local Spatial Average Wind Velocity Ratio (LVR_w). This gives a hint of how the development proposal impacts the wind environment of the local area.

7. IMPLEMENTATION

The idea of Urban Acupuncture was coined as a metaphor. The idea was to identify key "needle points" that are most effective. For example, for metro areas of downtown Hong Kong, it is almost impossible to re-plan. A better strategy would be to find the most effective measures, as well as the most critical sites. For example, to encourage gaps to appear, there is a proposal to allow trading of land rights with a bonus scheme.

The Hong Kong government has decided initially that all government projects of a certain characteristics to go through AVA. Some of the characteristics are:

Preparation of new town plans and major revision of such plans.

Development that deviates from the statutory development restriction(s) other than minor relaxations.

Urban renewal development that involves agglomeration of sites together with closure and building over of existing streets.

Development with shielding effect on waterfront, particularly in confined airsheds.

Large-scale development with a high density, e.g. site area over 2 hectares and an overall plot ratio of 5 or above, development with a total GFA of 100,000 sq.m. or above.

8. GUIDELINES AND PRINCIPLES

In addition to the assessment methodology, the government will also incorporate some guidelines into their Hong Kong Urban Standard and Guidelines. This document will provide some hints to designers and planners. An example is as Figure 11.

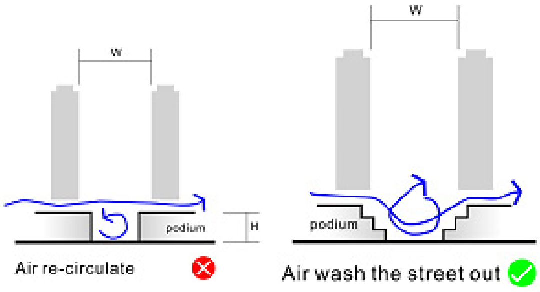

Figure 11: An example of the guideline dealing with the shape of the podium.

9. POLICIES AND THE WAY FORWARD

A joint government beaux level technical circular will be issued to head start AVA. The government has also required the planning development of the old Kai Tak airport site (400 hectares) to undertake AVA. It is the first government land trying out the new methodology. (Figure 12)

Figure 12: The Old Kai Tak site undergoing wind tunnel site wind availability tests.

Beyond the immediate policy implementation, the government is commissioning a number of further studies to advance the AVA methodology. (Figure 13) An urban climatic map of Hong Kong will be generated to strategically guide design. Professor Lutz Katzschner's team at Kassel university in Germany will help. Furthermore, a series of tests will be conducted to establish a benchmark standard for Hong Kong that is practical, reasonable and achievable. This will further the current AVA with a standard to achieve.

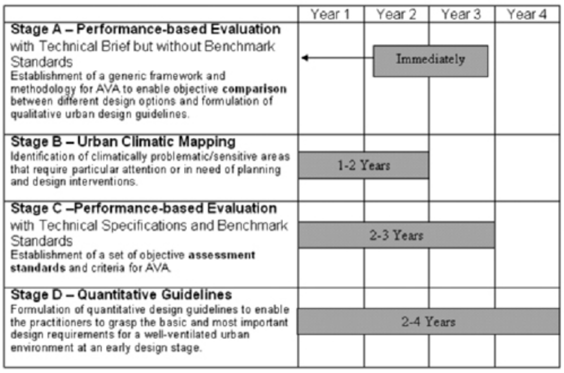

Figure 13: Further stages of AVA development.

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