Performance Based Planning for High Density Urban Habitation

Jin-yeu Tsou, Selina Lam, He Jie and Xue Yucai
The Chinese University of Hong Kong, Hong Kong
jinyeutsou@cuhk.edu.hk - selinalam@cuhk.edu.hk
hejie@cuhk.edu.hk - xueyucai@cuhk.edu.hk

In Hong Kong, about 22% of the total territory's area can be classified as built-up area and potential development area. Only 6% of this area is allocated to district and local open space for the 6.8 million populations, i.e. 2m^2 per person. Sensible planning of the limited area to enhance the livability and environmental quality hence become a challenging issue for quality urban living of the mass population. However, considering the dynamic relationship of the different performance criteria in the hyper-dense urban environment, one needs to assess various environmental criteria to carry out a balanced planning. Meanwhile, effective tools to evaluate and manage the inter-relationship of these criteria, or indexes for integrated issues indication are not readily available that a reasonable planning is not always easy to achieve. In this paper, the „openness ratio" concept is introduced for open space planning to provide an integrated index for early stage of planning and design. The new index is expected to provide a comprehensive rating system in considering the environmental performance of open area. It helps to highlight the potential problems in planning or site layout and support the integrated thinking of the four key components: visual sensitivity, urban wind, urban noise and solar heat gain. The concept has shown to be feasible on simple massing study which is applicable in the preliminary planning stage.

Keywords: *Design process; performance simulation; design methodology; urban planning.*

Introduction

In Hong Kong, about 22% of the total territory's area can be classified as built-up area and potential development area. Only 6% of this area is allocated to district and local open space for the 6.8 million populations, i.e. 2m^2 per person. Sensible planning and design of the limited area to enhance the livability and environmental quality hence become a very challenging issue for quality urban living of the mass population. However, considering the dynamic relationship of the different performance criteria in the hyper-dense urban environment, one needs to assess various environmental criteria to carry out a balanced planning. Meanwhile, effective tools to evaluate and manage the inter-relationship of these criteria, or indexes for integrated issues indication are not readily available that a reasonable planning is not always easy to achieve. In this aspect, the current approach has been mainly based on intuition with very limited supports in terms of technical know-how and scientific evidence. Planners and designers tend to follow paradigms that have evolved through experience with similar projects. Because of the complex interdependencies of environmental design strategies and building control systems, deviations from the established paradigm are very difficult to be predicted.

Since year 1995, the research team at the Chinese University of Hong Kong has been carrying out research projects on urban housing, built environment and performance-based planning and design. We have successfully developed the geographical information system to support the visual resources management for urban visual sustainability; daylighting simulation to evaluate the shading condition, solar access, illumination and lumination, and glare assessment; computational fluid dynamics simulation to assess airflow pattern and pollution problem in the urban environment; and acoustics simulation for assessing the urban acoustical quality. With these studies, the research team has accumulated field data, understanding and simulation capability regarding integrated environmental planning and design in Hong Kong high density urban context.

Meanwhile, considering the current practice of open space design, it has been recognized that planners and designers tend to focus on administrative issues of budgetary metrics or planning code rather than the humanity and livability aspects, such as environmental issues and the social economical behavior associated with the high density urban living. The attention has been put on urban form and its formation, the massing, infrastructure and zoning, that the implementation of urban void or open space to improve the physiological and environmental aspect of high density urban living has been neglected. However, with the outbreak of infectious disease in 2003, the healthy living environment, which was not valued by the conformed mode of practice, has been much emphasized.

The openness ratio concept

Traditionally, the focus of the new urban development is on the physical components that evaluation is on its physical size satisfying the basic infrastructure support. With the urge for healthy living environment, demand raised for planners and architects to consider our future urban living environment by addressing the sustainable issue from both environmental and social-economical aspect. In this aspect, focusing on the urban form might not be able to provide sufficient information on the urban environment, particularly for urban problems associate with the urban void like air and noise pollution.

Environmental issues of open space planning are mainly created by the interactions between physical implementation (e.g. building groups) and the urban void. The environmental quality is highly related to the outcomes of these interactions. In our previous studies, the planners consider the provision of open space from the social aspect; the architects consider the provision of housing units from the social welfare and budgetary aspects. We therefore suggest a comprehensive approach for open space planning based on the urban void. Urban void induces ground activities of human and traffic. Sensible consideration of the urban void is then important to support healthy condition for human activities and urban pollution by traffic. It is expected that assessing the urban void would help to provide more detail information regarding the influences of individual environmental aspects.

Computation of the openness ratio

In assessing the urban void, the „openness ratio“ concept is implemented. The openness ratio starts

from a specific location with respect to the surrounding environment. The proportion of visible area to view range area in 360 degree from a specified view point is computed (Figure 1). Consider the magnitude of urban information to be included, Geographic Information System (GIS) which integrates the information of surrounding urban environmental features is employed for the analysis. The visibility within specified view range at individual viewpoints with respect to the 3-dimensional environment is computed. The distribution of visibility performance in the whole observing area can then be mapped by the value of openness ratio.
To include the potential application to the human perception in the physical spatial environment as for sight, hearing and skin sensation, the human visual perception is included in the simulation as to introduce the human scale. Hence, parameters reflecting the stable human visual perception, the Visual Cone (Schiffman, 1976), are introduced into the GIS-based calculation.

Accordingly the following assumptions for the calculation are made:

- Eyelevel at 1.6m.
- Vertical view angle is set at upper 35° and lower -25°.
- The azimuth angle is set at 360°.
- Grid of viewpoints at 10m separation is placed over the major open space.

Concerning the range for the openness ratio to be included, the human visual perception range is borrowed. Following Higuchi (1983), the range of view regarding vegetation sight-seeing is used and defined as:

- Foreground scene: within 360m from the viewpoint.
- Middle ground scene: beyond 360m and within 1000m from the viewpoint.

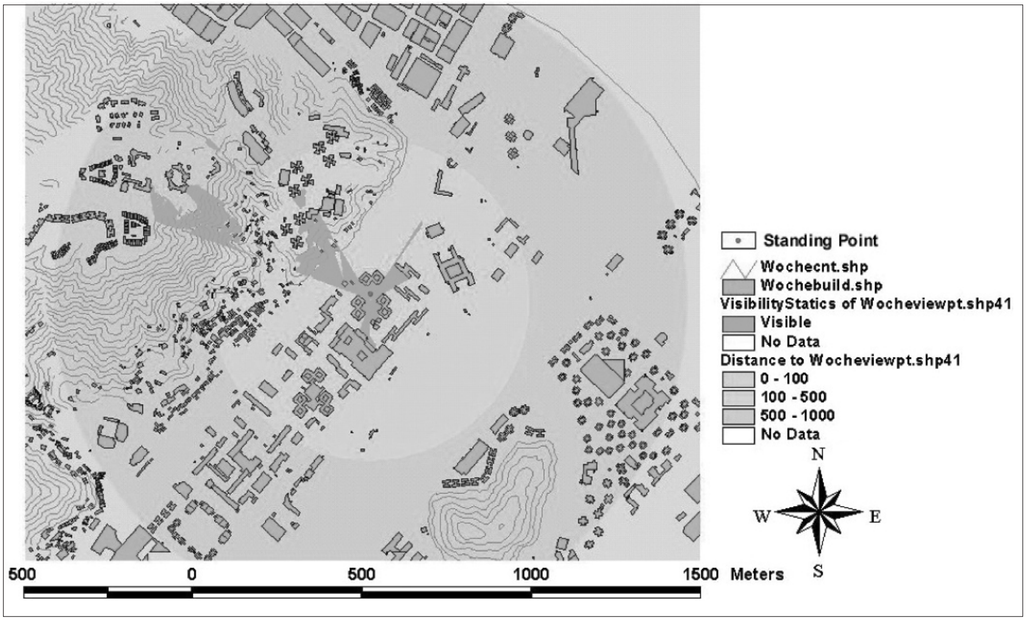

Figure 1
The ratio of the visible area to the whole view range area of a single point.

Subsequent to the single view point analysis, the openness is calculated from a grid of viewpoints defined for the proposed study area. The result at each viewpoint is expressed linearly at the normal of the analysis grid that the openness ratio of all viewpoints formed a 3 dimensional „contour“. The openness ratio of the open space in a housing estate, Woche Estate, is illustrated as below as an example (Figure 2). The gradation of color illustrates the elevation range at the defined viewpoints. The lighter color indicates higher openness ratio, i.e. higher visibility, and darker color the lower. The smooth change of color indicates mild change in visibility while the sharp change indicates presence of strong visual obstacles.

Potential of using openness ratio for multi-leveled performance consideration

In order to explore the potential of using the openness ratio for multi-leveled performance consideration, the openness ratio is to be compared with assessment results of visual sensitivity, urban wind and daylighting which are common environmental concerns in urban spatial design. Meanwhile, urban acoustics, which is also a crucial consideration in urban spatial design, is not included in this paper due to the availability of data for acoustics simulation. The open space in a housing estate, Woche Estate, is used as a study case.

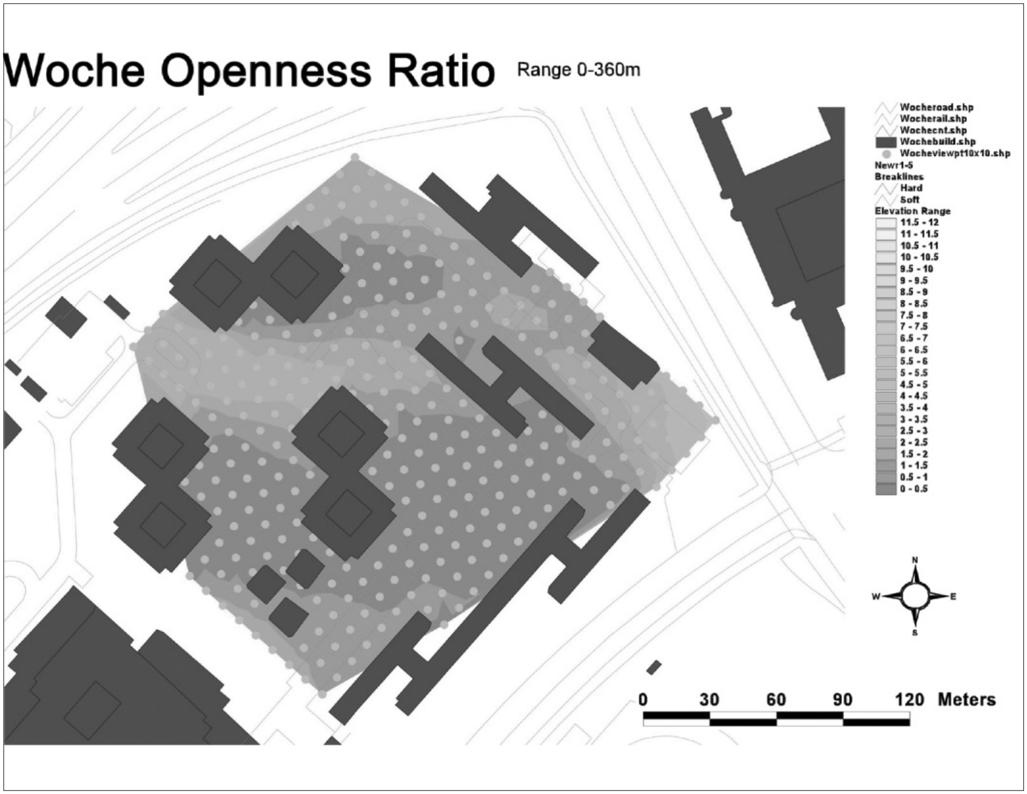

Figure 2
Visibility ratio map showing the openness ratio within 360 m.

Visual sensitivity

For the visual sensitivity comparison, as simulation is based on the same GIS data and computation algorithm, comparison is made with on-site panoramic photos instead of simulation results. 19 viewpoints are selected for the comparison and further analysis is to be compared with viewshed analysis of individual viewpoints. Generally, the simulated openness ratio agrees with the real site condition in the sense that area of high openness ratio leads to higher visibility of distant scenes. However, at some points, like viewpoint O in the basketball court, the actual visibility is much deviated from the simulated value that limited natural landscape could be seen (Figure 3).

Analyzing the viewshed of viewpoint O (Figure 4), it can be seen that large portion of the visible area at viewpoint O covers the race course and the river which leads to the high openness ratio. In reality, vision to the racecourse is blocked by small urban elements like vegetation and traffic. With difficulties in representing details of urban features, they were not included in the computational model. On the other hand, the river is located at a lower level that the comparatively small level difference is ignored in the computational model of the openness ratio.

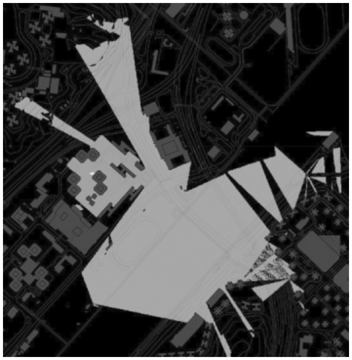

Figure 3
Woche viewpoint O site photo.
Figure 4 Visibility map from viewpoint O.

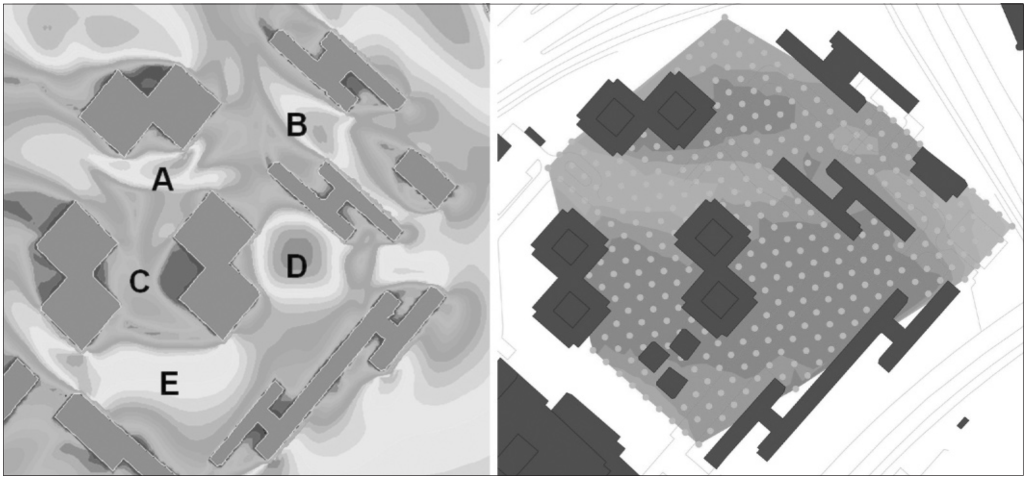

Figure 5
Speed contour at 1.5m level (right) and the openness ratio (left).

Thus, the lacked details account for the deviation in visibility between the analysis result and human perception on real sites.

Urban wind

As for the urban wind, the urban wind condition at the site is simulated by Fluent with incoming wind setting referencing the Hong Kong Observatory data. The speed contour at 1.5m from ground is extracted to be compared with the openness ratio (Figure 5). In general, the speed contour shows a more dynamic pattern than the openness ratio. When being viewed carefully, it could be found in both cases, the peripheral area enjoys higher values. Special attention is then paid to the internal areas where they are surrounded by buildings. Area A and B have comparatively higher wind speed and higher openness ratio. Similarly, area C has lower wind speed and the corresponding openness ratio is also low. Area D and E contribute to the more controversial zone.

At area D, the wind speed is high while the openness ratio is low. With the arrangement of building blocks around area D, there is limited exposure to the outside and hence low openness ratio is resulted. Consider the urban wind condition, the case is more complicated as the prevailing wind condition is introduced in the simulation but not the openness ratio assessment. With the east incoming wind and the high surrounding residential blocks, high wind speed at the area is justified as area D has the east opening and strong downdraft is formed when the wind meets the high-rise building nearby.

At area E, though the pattern is similar, one would query the comparison for the simulation model is not consistent for the two simulations, three 1-storey blocks were introduced into the openness ratio calculation, but not in the airflow simulation. In fact, the sizes of the blocks are comparatively small that air could actually flow over and around the blocks. The impact of the blocks is considered to be insignificant in the airflow simulation. On the other hand, with the proximity to the neighboring high rise residential blocks, the impact of the blocks to the openness ratio is also considered to be insignificant. Hence, the difference in the simulation model in the case does not affect the comparison result.

Daylighting

Consider the daylighting condition, the solar insolation level at the site is to be compared with

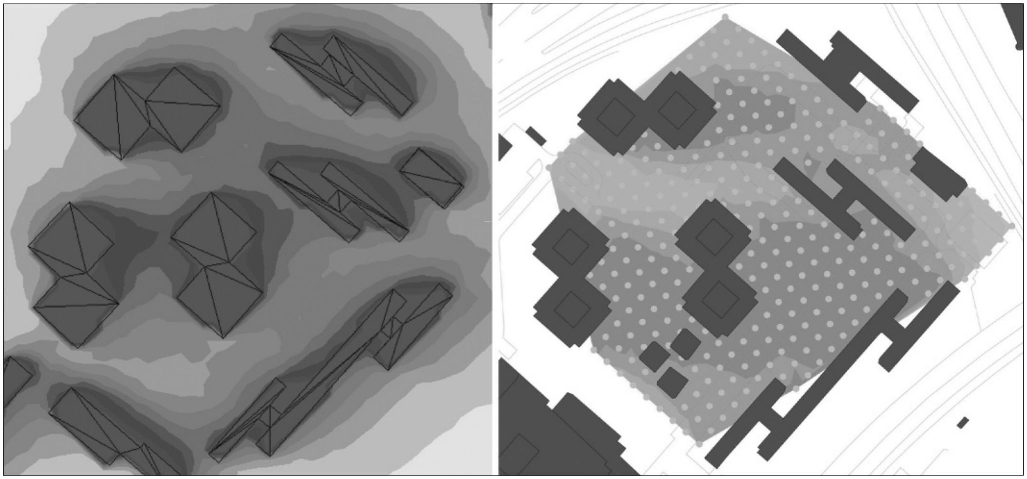

Figure 6
Insolation at 1.5m level (right) and the openness ratio (left).

the openness ratio (Figure 6). The solar insolation is the amount of incident solar radiation falling on grid points over any selected period of the year. A full year solar data is simulated with value expressed as average total daily value in Wh.

The case study has shown similar pattern of solar insolation with that of the openness ratio. At the peripheral area, both the insolation and the openness ratio value increase as retreating from the open space. In the open space between the building blocks, both the insolation and the openness ratio value decrease, but with different extent. The degradation is much more apparent for the insolation analysis than that for the openness ratio. Note has to be taken that the insolation analysis takes into account also the solar impact at position apart from the visual cone. This is the zone where solar insolation is significant. As a result, higher solar insolation at individual points is resulted. Yet, consider the locale of the sun throughout the year, not all simulation points would gain the same increase of insolation. Area closer to building blocks would have less increase due to the overshadow effect which limits the solar insolation penetration. Eventually more apparent gradation in insolation level is resulted.

Discussion

From the previous, the openness ratio could not exactly reflect the performance of every environmental aspect. However, it does offer indication regarding environmental factors which judgment should be applied.

For the visual sensitivity, with the same GIS-based dataset and computational model, the openness ratio does offer a very reliable reference for planning. However, as in the case study, special attention has to be paid to representation issues and hence leads to significant deviation. Substantial human judgment is then essential in the abstraction of computational model and the associate analysis.

Concerning urban wind, instead of revealing the urban wind pattern at the ground level, the openness ratio rather indicates potential area with airflow in the sense that more open area is more susceptible to airflow. The actual flow rate does depend on the prevailing wind and building height which are less concerned factors in the openness ratio assessment. Prevailing wind provides direction in the openness ratio evaluation which increases its reference value. Building height, on the other hand, has more complicated effect. In the openness ratio calculation, the impact of building height diminishes as approaching to the focus of the visual cone, i.e., whether the building is 3m or 30m makes small to no difference on the openness ratio when the concerned target is close enough to the building. However, tall buildings induce downdraft which might cause discomfort or relief pollution at the urban ground level. It is then important to note the height of the building and the respective impact, particularly if it is close to the concerning point. Also, the openness ratio includes impact within the visual cone that 3D urban wind condition or turbulence effect are not likely to be predicted from the openness ratio.

Regarding daylighting, similar to the urban wind, the openness ratio cannot truly reflect the solar impact, but mainly helps to reveal the potential area with solar access. Meanwhile, it would be more useful for consideration of solar radiation and illumination, but not solar conditions like overshadowing and glare. The overshadowing concerns the dynamic locale of the sun at specific day and time where the openness ratio assessment concerns vision in 360 degree to the surrounding environment.

Conclusion

One might argue that the reference potential is debatable as the case study shown might only be a coincidence. Concerning assessments of different environmental aspects, complicated algorithms have been developed for individual criteria that they are not common and are unlikely to be shared for multiple aspects assessment. However, the study was founded with the common concept of spatial quality assessment rather than similar algorithmic expressions. In fact, consider the principal of the computation, there shows some indication of the openness ratio for multi-leveled performance consideration.

Further works

To further develop the application of the openness ratio, the research team plans to:

1. fine tune the algorithm for the openness ratio assessment; and
2. develop the indexes for integrated issues indication to facilitate multi-leveled performance consideration.

With the current algorithm, the openness ratio presents the performances of different environmental criteria in varied reference value. It is expected that fine tuning the algorithm would help to increase the reference value for the current criteria and expand the adaptability to different assessment.
On the other hand, to represent the overall reference value, a combined index which could reflect the performance of integrated issues should be developed. The performance of individual criteria should be linked with a weighted factor which highlights the sensitivity of individual criteria with respect to a concerned environment. For example, in a highly polluted area, significance of airflow concern should be reflected with a higher weighted factor.

Acknowledgements

The work described in this paper was partially supported by a grant from the Research Grant Council of the Hong Kong Special Administrative Region, China (Project No/ CUHK4282/03H).

References

Higuchi, T. 1983. The Visual and Spatial Structure of Landscapes, translated by Terry, C. Cambridge, Massachusetts: The MIT Press.

Hong Kong Special Administrative Region, Nov 2003. Hong Kong Planning Standards and Guidelines (HKPSG). Planning Department, Hong Kong.

CHOW, Benny. April 1997. Computation in daylight architecture. Proceedings of the Second Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA97). National Chiao Tung University, Taiwan.

KANG Jian, TSOU Jin-Yeu and Selina LAM. 2001. Sound Propagation in Urban Streets: Comparison Between UK and Hong Kong. Proceedings of the 8th International Congress on Sound and Vibration (ICSV 2001). Hong Kong Polytechnic University, Hong Kong.

Schiffman, R. 1976. Sensation and Perception. New York: Wiley.

Tilley, A. 1993. The Measure of Man and Woman: Human Factors in Design. New York: Whitney Library of Design.

TSOU, Jin-Yeu. 2001. Strategy on applying computational fluid dynamic for building performance evaluation, Automation in Construction 10 (3), 2001. pp. 327-335.

ZHANG, Zongyu. 2001. Web Based Public Participation in Visual Impact Assessment of Urban Landscape. Thesis of master degree, The Chinese University of Hong Kong, Hong Kong.