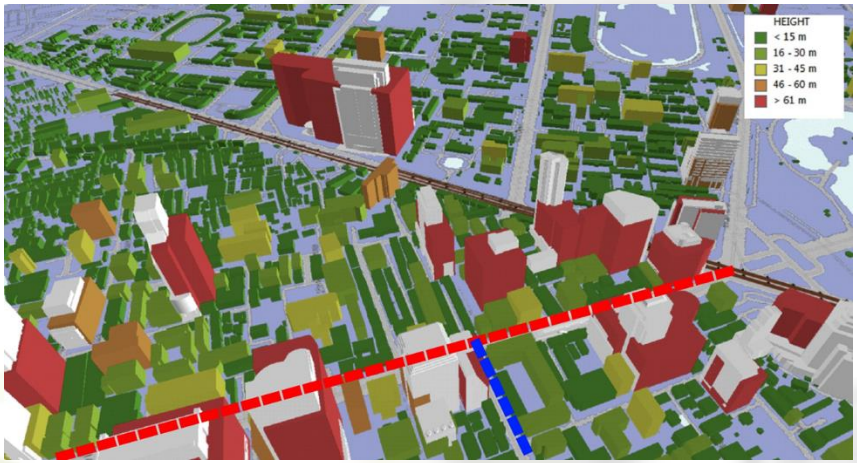
# Urban geometry and wind simulation studies for comfort in Bangkok street canyon

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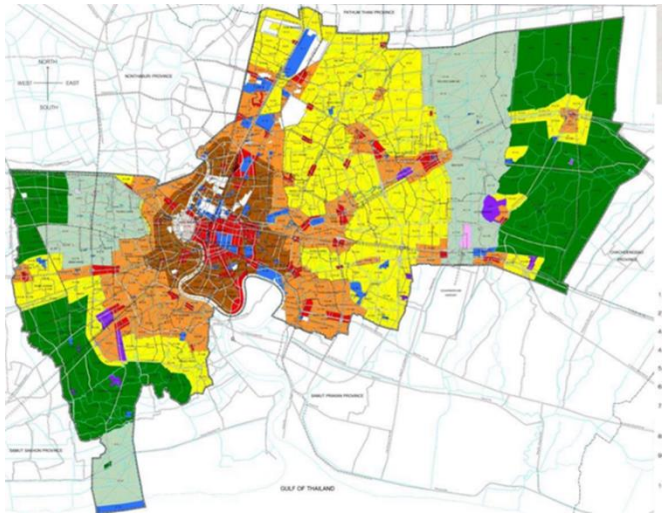
- Diurnal temperature range: minimum 22.5$^{o}$C-26.9$^{o}$C and maximum 32.1$^{o}$C-36.3$^{o}$C.
- A mean annual temperature is 27.8$^{o}$C and a mean annual RH is 79.9%.
- The minimum RH is 74% in January and the maximum RH is 85% in September.
- moderate wind speed at 1.7 m/s.



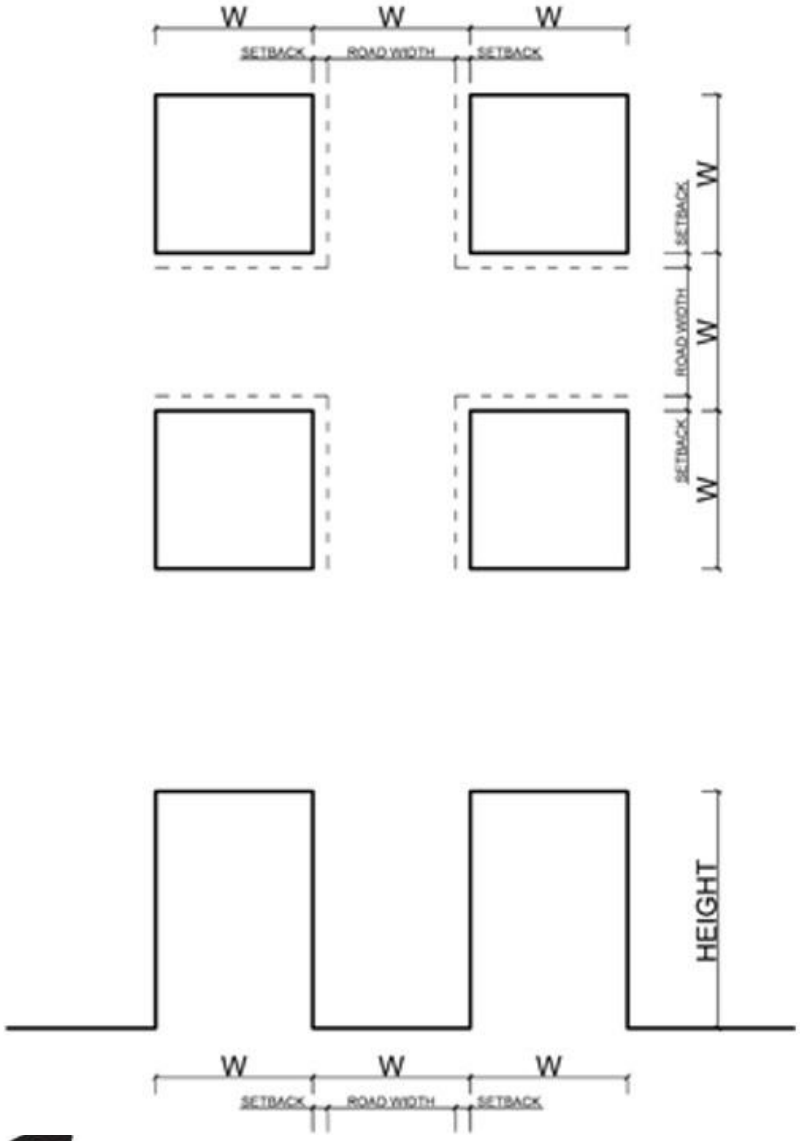
# Bangkok

The overheating conditions in urban areas of Bangkok are affected by the lack of airflow to enhance outdoor thermal comfort and air pollution dispersion. Therefore, the study is an attempt to investigate effect of height-to-width (H/W) ratio on airflow at pedestrian level in the street canyon.

# Study Methods

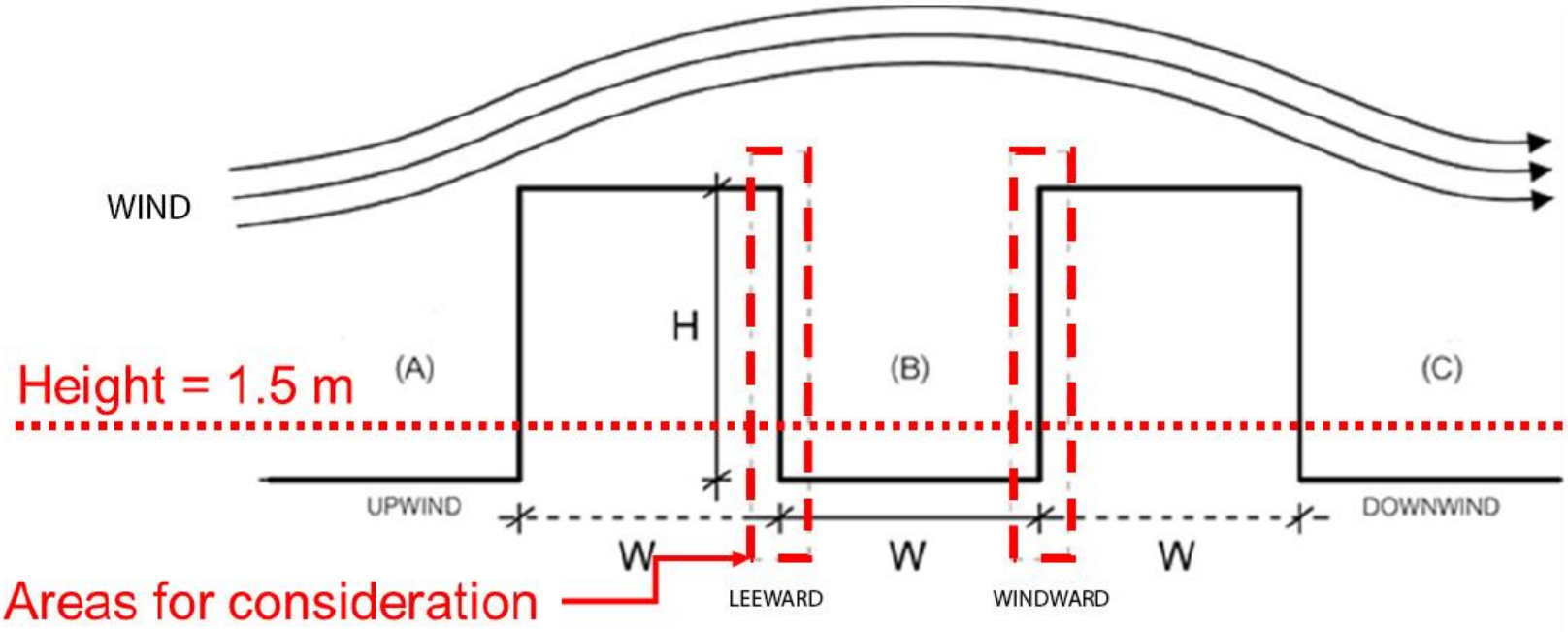
The research adopts CFD method to study urban airflow conditions influenced by H/W ratios or aspect ratios ranging from 0.1 to 2 as the maximum permitted by Thai regulation. Road widths are 12, 18, 24, 34, 64, and 94 meters, respectively. Building heights are calculated according to the relationship between H/W ratios and road widths. There are 95 simulation cases possible for the specified range of H/W ratios.

| | Road width | | | | | |
|---|---|---|---|---|---|---|
| | 12 | 18 | 24 | 34 | 64 | 94 |
| H/W | Building height | | | | | |
| 0.1 | - | - | - | - | 6.4 | 9.4 |
| 0.2 | - | - | - | 6.8 | 12.8 | 18.8 |
| 0.3 | - | - | 7.2 | 10.2 | 19.2 | 28.2 |
| 0.4 | - | 7.2 | 9.6 | 13.6 | 25.6 | 37.6 |
| 0.5 | 6 | 9 | 12 | 17 | 32 | 47 |
| 0.6 | 7.2 | 10.8 | 14.4 | 20.4 | 38.4 | 56.4 |
| 0.7 | 8.4 | 12.6 | 16.8 | 23.8 | 44.8 | 65.8 |
| 0.8 | 9.6 | 14.4 | 19.2 | 27.2 | 51.2 | 75.2 |
| 0.9 | 10.8 | 16.2 | 21.6 | 30.6 | 57.6 | 84.6 |
| 1 | 12 | 18 | 24 | 34 | 64 | 94 |
| 1.1 | 13.2 | 19.8 | 26.4 | 37.4 | 70.4 | - |
| 1.2 | 14.4 | 21.6 | 28.8 | 40.8 | 76.8 | - |
| 1.3 | 15.6 | 23.4 | 31.2 | 44.2 | 83.2 | - |
| 1.4 | 16.8 | 25.2 | 33.6 | 47.6 | 89.6 | - |
| 1.5 | 18 | 27 | 36 | 51 | 96 | - |
| 1.6 | 19.2 | 28.8 | 38.4 | 54.4 | - | - |
| 1.7 | 20.4 | 30.6 | 40.8 | 57.8 | - | - |
| 1.8 | 21.6 | 32.4 | 43.2 | 61.2 | - | - |
| 1.9 | 22.8 | 34.2 | 45.6 | 64.6 | - | - |
| 2 | 24 | 36 | 48 | 68 | - | - |



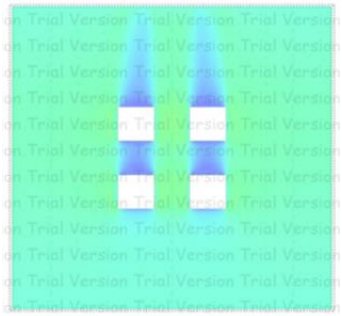
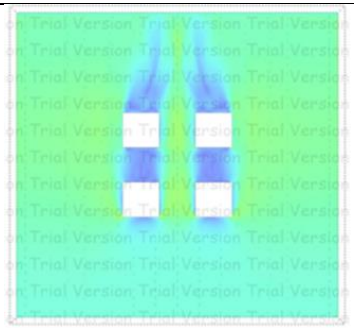
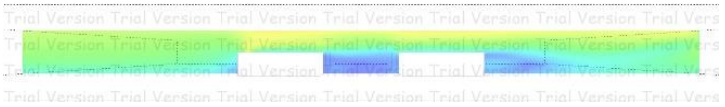
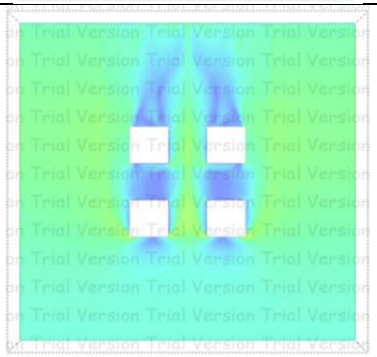

Where
H = Building height
W = Distance between two opposite buildings
RW = Actual road width

The commercial CFD simulation program, DesignBuilder is employed for calculation. The numerical models are uniform regardless of the effect of building's length and width. Domain size is 1000 m × 1000 m. All buildings are square shape and areas considered are at intersection providing identical street canyons on the direction parallel and perpendicular to prevailing wind.

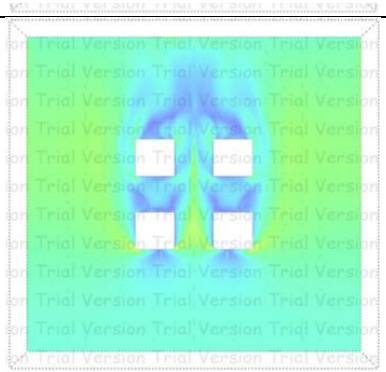
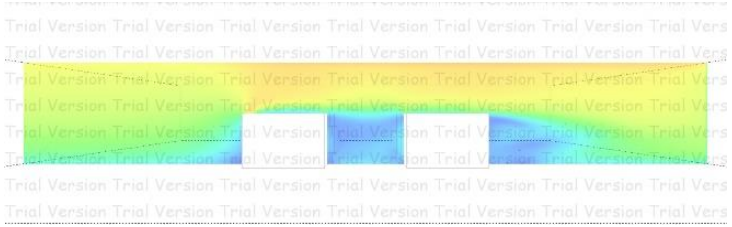
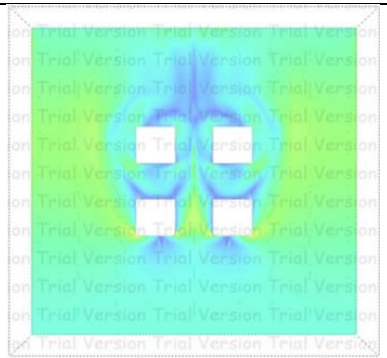
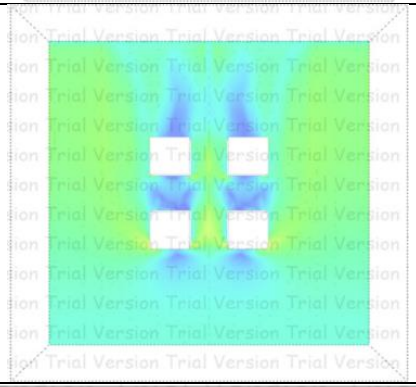



In the studies, the wind direction is set to come from the south. The reference wind velocity is 1.7 m/s as it is the average wind velocity at 10 meters above ground in Bangkok. Area for consideration on horizontal plane is 1.5 meters above ground to investigate airflow at pedestrian level while sectional area across the canyon is made vertically to investigate air velocities on leeward and windward sides.

Examples of simulation results of low (less than 0.5), medium and high values of H/W ratios (above 0.5).

| | Plan | Section |
|---|---|---|
| H/W Ratio = 0.1;<br>H = 6.4 m.;<br>W = 64 m. |  |  |
| H/W Ratio = 0.3;<br>H = 28.2 m.;<br>W = 94 m. |  |  |
| H/W Ratio = 0.5;<br>H = 47 m.;<br>W = 94 m. |  |  |

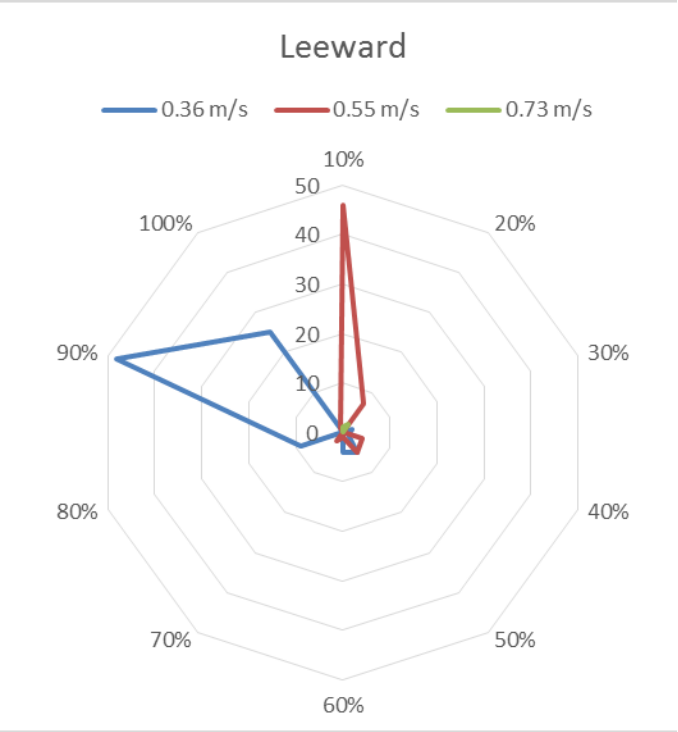
Wide roads greatly influence turbulence as shown in models with H/W ratios higher than 0.5.

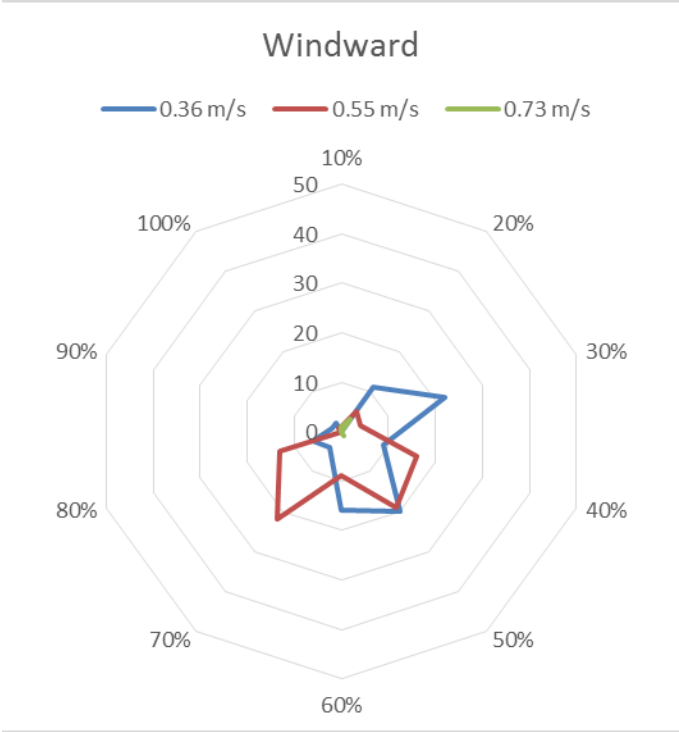
| | | |
|---|---|---|
| H/W Ratio = 0.7;<br>H = 65.8 m.;<br>W = 94 m |  |  |
| H/W Ratio = 0.9;<br>H = 84.6 m.;<br>W = 94 m |  |  |
| H/W Ratio = 1.5;<br>H = 96 m.;<br>W =64 m |  |  |

# Results

- Wind velocities at pedestrian level in the street canyon perpendicular to the prevailing wind range from 0-0.18 m/s which cause still air.
- In the canyon parallel to the prevailing wind, the velocities range from 0.73-0.91 m/s which can enable thermal comfort and enhance air pollution dispersion.
- Laminar flow occurs when building heights do not exceed 9-9.4 m (3 storeys).
- Turbulence and vortex are profound on building's edges and downwind area when H/W Ratios are not less than 0.2 and building heights are above 9-9.4 m (3 storeys).
- Turbulences are likely to occur with increasing building height in association with increasing road width.
- H/W Ratios range from 1-2 can generate turbulence for heat mitigation and air pollution dispersion. The turbulent flow can occur even when the road width is only 12 meters. However, the influences of high H/W ratio are profound when width = 34 meters.

For the road of 12, 18, 24 and 34 meter wide, airflow patterns remain the same with increasing potential of turbulence. However, in cases of road width greater than 64 meters, the pattern is different.
Wind velocities on windward side are generally higher and more distributed in the area than those on leeward side as the radar chart shows percentages of areas on leeward and windward sides with the frequencies of low, medium and high velocity occurrence.



# Conclusion

Results from the study show that medium to high H/W ratios tend to increase air velocities and create turbulence in the canyon, thus promoting cooling effect for pedestrians. Therefore, it is possible to promote high density development for Bangkok. Nonetheless, it is required to balance between high H/W ratio and road width to avoid too deep canyon that traps heat during the night. It is recommended that stagnant conditions in the canyon can be improved by providing wind channel on ground level of buildings especially those that are situated along narrow roads. The recommended H/W ratios range from 0.5-2 while road width should not be less than 12 meters and not less than 34 meters is preferable.

# Thank you