Hong Kong Housing Authority

Subsidised Sale Flats Development at Au Pui Wan Street, Fo Tan

AVA Initial Study Report

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Job number

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ARUP

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1 Introduction

1.1 Background

Ove Arup & Partners Hong Kong Ltd. (Arup) was commissioned by Hong Kong Housing Authority (HKHA) to carry out a quantitative Air Ventilation Assessment (AVA) – Initial Study for the Proposed Subsidised Sale Flats Development at Au Pui Wan Street, Fo Tan (the Development) in accordance with the "*Technical Circular No. 1/06 on Air Ventilation Assessments*" (the *Technical Circular*) jointly issued by the Housing, Planning and Lands Bureau (HPLB) and the Environment, Transport and Works Bureau (ETWB) on 19th July 2006.

The Project Site is located at Au Pui Wan Street in Fo Tan Area with an area of 0.64 hectares. The Project Site is zoned as "Residential (A)5" ("R(A)5") on the approved Sha Tin Outline Zoning Plan (OZP) No. S/ST/33. The site is currently used as a temporary public open-air carpark and a petrol filling station.

An indicated development layout plan were approved under *Proposed Amendments to the Approved Sha Tin Outline Zoning Plan No. S/ST/30*. Changes have been made to the indicative layout plan during detailed design stage. A site specific quantitative assessment on the air ventilation impact of the proposed design was required.

1.2 Objective of the Study

The objective of the study is to assess the possible air ventilation performance of the proposed subsidised sale flats development under different development scenarios with the stipulated development parameters. It is also the purpose of this study to recommend any design improvements and/or mitigation measures which may be adopted to minimize any adverse air ventilation impact.

2 Study Area

2.1 Site Characteristics

The Development is located in Sha Tin District (Area 16B) within the Fo Tan Industrial Area, it is situated on a relatively low and flat land with hilly topology to the northwest and southwest quadrants. The Development site is about 6430 square meter to the northwest of Shing Mun River Channel, southeast of the Cove Hill (about 400mPD) and west to the Fo Tan MTR Station.

The Development site is bounded by Fo Tan Road, Au Pui Wan Street, industrial clusters and a Comprehensive Development Area (CDA) area. Figure 1 indicates the location of the Development site.

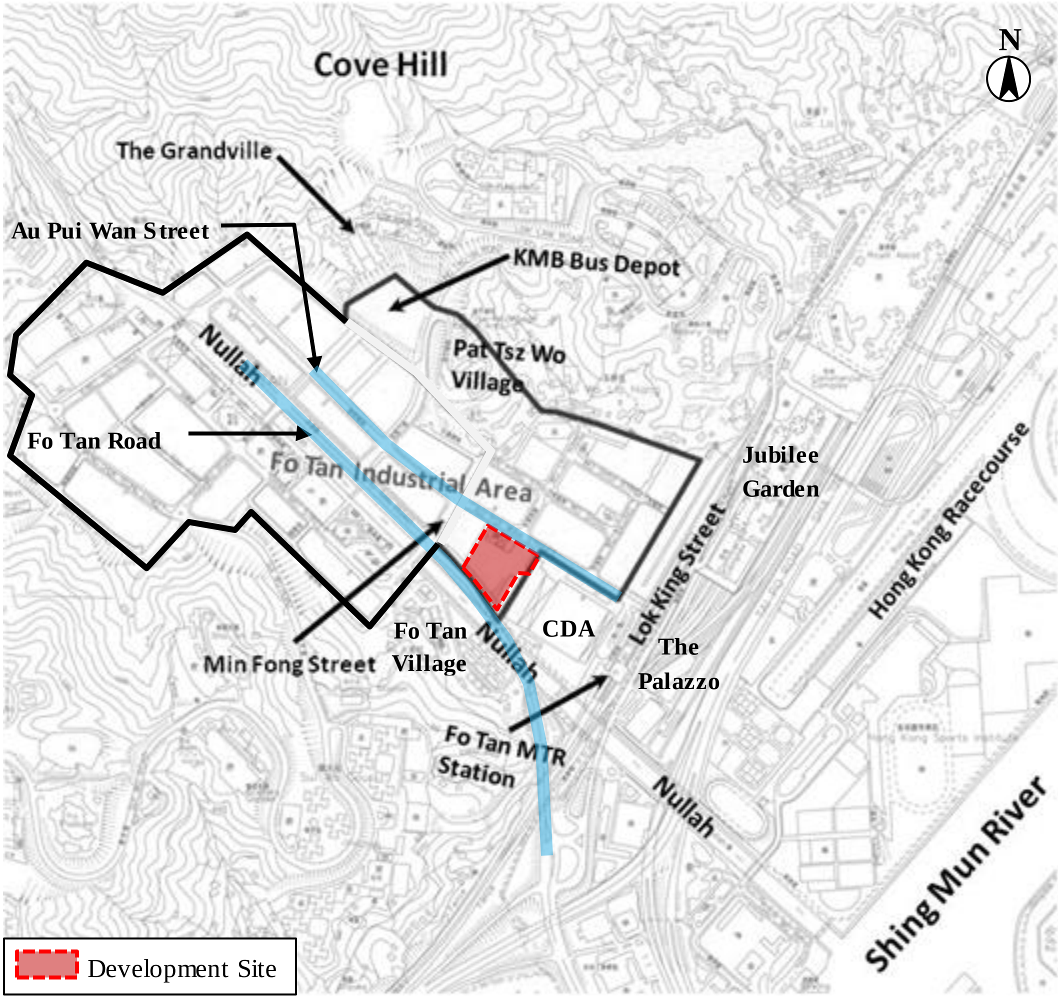


Figure 1 Site Location

The neighbourhood is mostly occupied by mid to high rise industrial buildings with extensive podium coverage. To the northeast and northwest quadrant of the Development site are dense industrial buildings with height ranging from 50mPD to 90mPD. To the southwest and south of the Development site are relatively open with Fo Tan Road and Fo Tan Village (13-24mPD). To the southeast and east of the Development site are high-rise Comprehensive Development Area (CDA) (138-163mPD) and two other high-rise residential developments, Jubilee Garden (abour 124mPD) and the Palazzo (151-157mPD). Figure 2 indicates the surrounding developments.

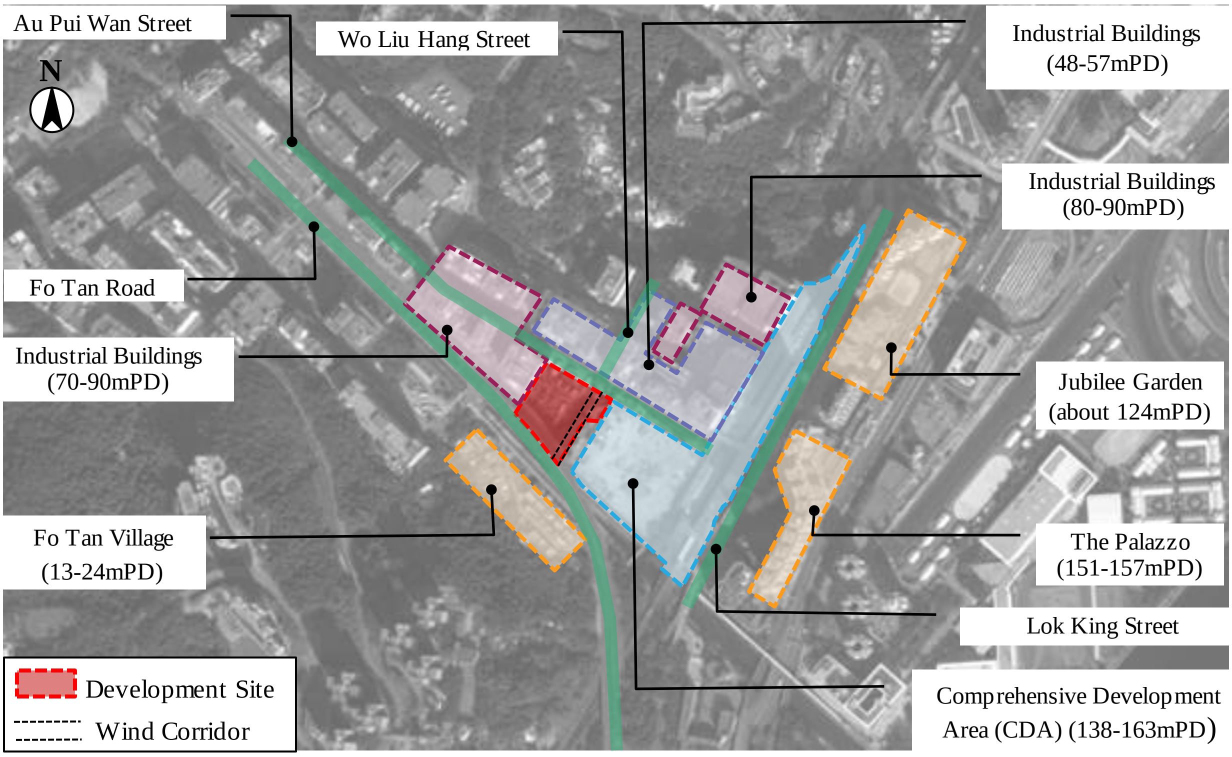
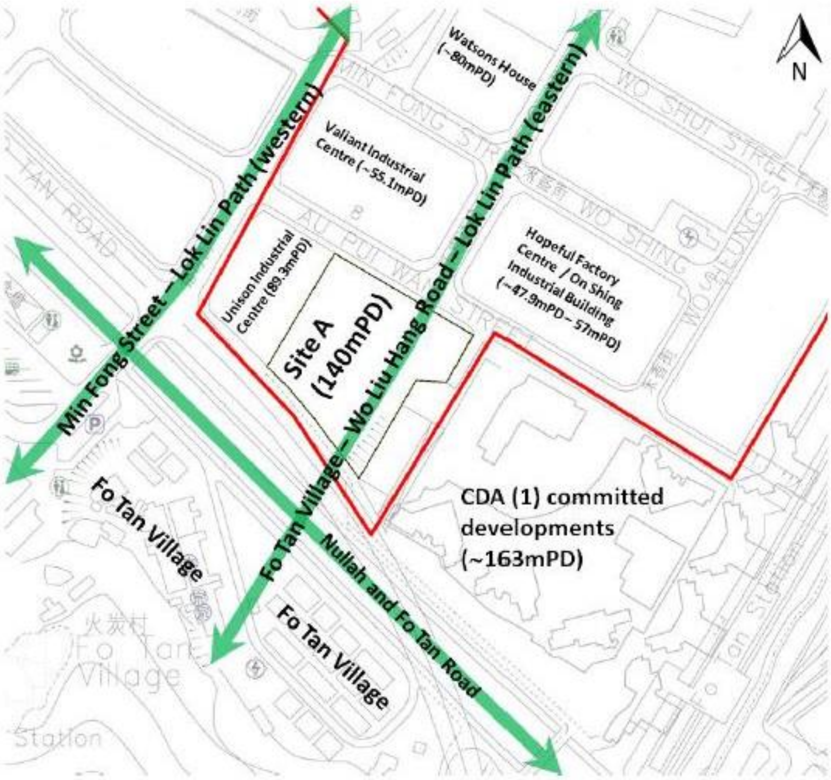


Figure 2 The Development Site and its Surrounding Developments (image source: Google Map)

According to the *Town Planning Board General Paper RNTPC Paper No. 4/15 (TPB General Paper), Proposed Amendments to the Approved Sha Tin Outline Zoning Plan No. S/ST/30*, one of the wind corridors identified, Fo Tan Village – Wo Liu Hag Street – Lok Kin Path (eastern) would run through the site to facilitate wind penetration for N and NNE wind, as shown in Figure 3 and dotted line in Figure 1.



Boundary of the Project Area (Fo Tan)

Boundary of the Site A

Major wind corridors in Fo Tan

Figure 3 Potential housing site and air path location (Source: Figure 7.2 from Appendix II of TPB General Paper RNTPC Paper No.4/15)

3 Site Wind Availability

The wind availability of the Project Site and its surrounding is an essential input for the AVA. As stipulated in the *Technical Circular*, the site wind availability would be presented by using appropriate mathematical models. Planning Department (PlanD) has set up a set of simulated meso-scale data of Regional Atmospheric Modelling System (RAMS) of the territory for AVA study, which could be downloaded at Planning Department Website[1]. Simulated RAMS data from PlanD will therefore be adopted in this AVA Study. The location of the Development falls within the location grid (x:085, y:059) in the RAMS database as indicated in Figure 4.

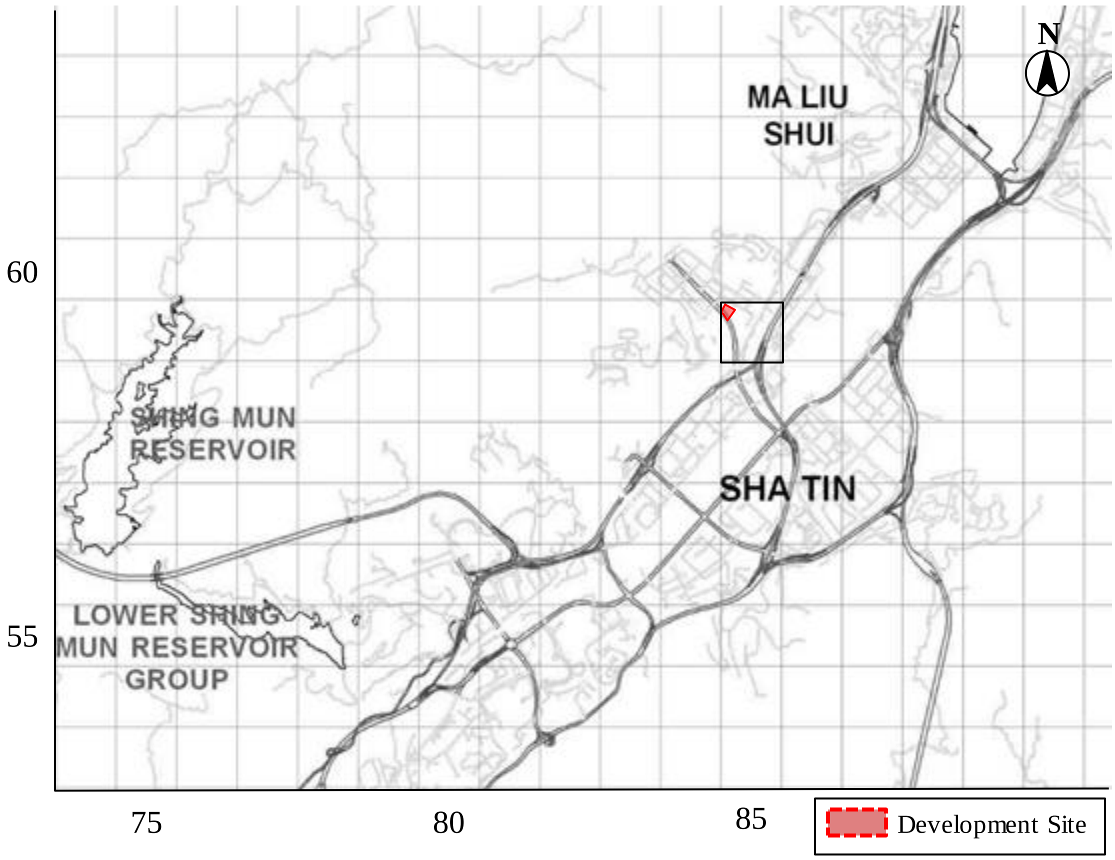


Figure 4 RAMS Grid and Location of the Development

[1] http://www.pland.gov.hk/pland_en/info_serv/site_wind/site_wind/

3.1 Wind Data

The annual and summer wind roses for the study are shown in Figure 5 and Figure 6. 500m height was selected to investigate prevailing wind conditions in this Initial Study, as it can better represent undisturbed incoming wind to the site. The simulated RAMS data shows that the majority of the wind comes from the northeast quadrant under annual wind condition while the wind mainly comes from southwest quadrant under summer wind condition.

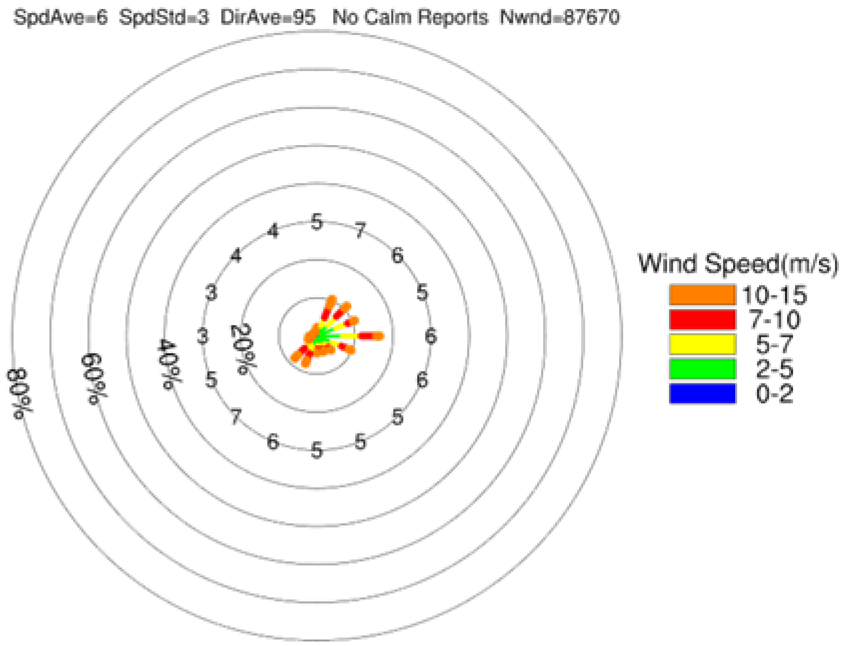


Figure 5 Wind Rose for Annual Wind Condition at 500mPD from RAMS

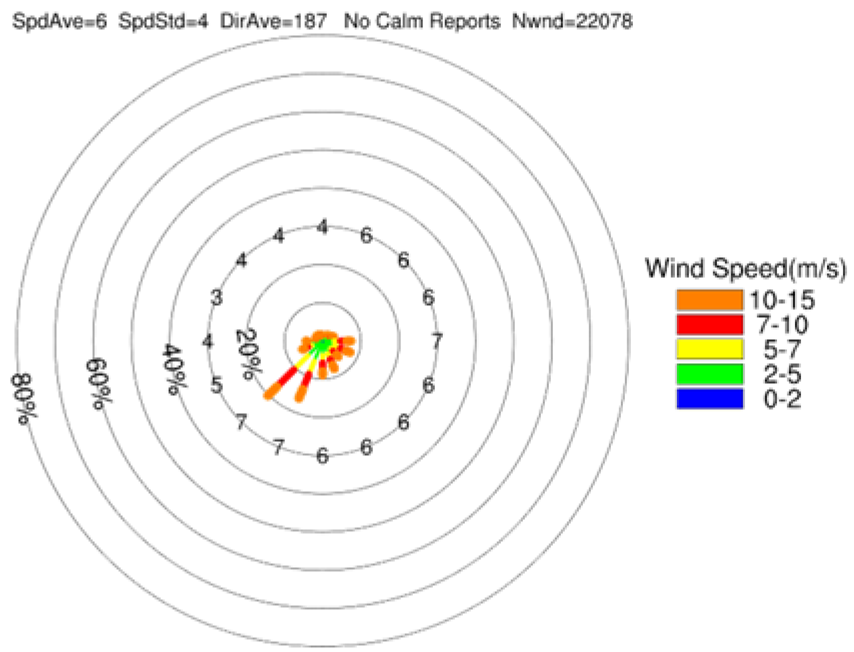


Figure 6 Wind Rose for Summer Wind Condition at 500mPD from RAMS

3.2 Wind Directions

As per the *Technical Circular*, at least 75% of the time in a typical reference year (frequency of occurrence) would be studied under both annual and summer wind condition in the Initial Study when using a Computational Fluid Dynamics (CFD) modelling technique. Since the CFD approach is adopted for the Development's AVA, this criterion together with the selected wind data are to be applied in identifying the annual and summer prevailing wind directions.

3.2.1 Annual Prevailing Wind

Eight prevailing wind directions (highlighted in red colour in Table 1) are considered in this AVA Study which covers 80.6% of the total annual wind frequency. They are north-north-easterly (10.6%), north-easterly (11.2%), east-north-easterly (10.7%), easterly (16.6%), east-south-easterly (9.8%), south-easterly (5.3%), south-south-westerly (8.0%) and south-westerly (8.4%) winds.

Table 1 Annual Wind Frequency

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Frequency	2.3%	10.6%	11.2%	10.7%	16.6%	9.8%	5.3%	4.5%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Frequency	4.6%	8.0%	8.4%	2.5%	2.1%	1.0%	1.2%	1.3%	80.6%

** The wind frequency showing in red colour represents the selected winds for the CFD simulation.*

3.2.2 Summer Prevailing Wind

Eight prevailing wind directions (highlighted in red colour in Table 2) are considered in this AVA Study which covers 81.4% of the total summer wind frequency. They are easterly (7.6%), east-south-easterly (7.9%), south-easterly (5.9%), south-south-easterly (8.0%), southerly (9.1%), south-south-westerly (16.5%), south-westerly (20.7%) and west-south-westerly (5.7%) winds.

Table 2 Summer Wind Frequency

Wind Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Frequency	1.3%	1.6%	2.2%	3.2%	7.6%	7.9%	5.9%	8.0%	
Wind Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Frequency	9.1%	16.5%	20.7%	5.7%	4.4%	1.9%	2.1%	1.8%	81.4%

** The wind frequency showing in red colour represents the recommended wind direction for the CFD simulation.*

3.3 Wind Profiles

The wind profile calculated from RAMS is adopted in this AVA study. It is recommended to extract the RAMS wind profile data from 10-500m directly as it can reflect the exact wind data. For the near ground wind speed, the power law equation was used to approximate near ground wind profile. Figure 7 indicates the data points calculated by power law from 0-10m and extracted from RAMS data for 10 – 500m height. For wind data above 500m height, the velocity is assumed to be the same as the data at 500m. These wind data will be input parameters in the CFD simulation.

The vertical discretization of the velocity profile is approximated by using an exponential law, which is a function of ground roughness and height:

$$U_z = U_G \left(\frac{z}{z_G}\right)^n$$

where U_G = reference velocity at height z_G

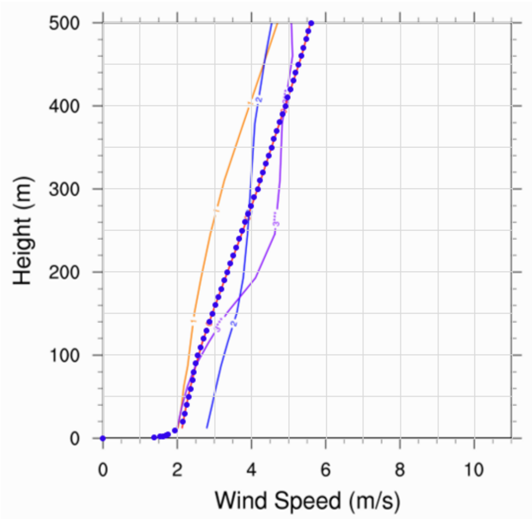
z_G = reference height

z = height above ground

U_z = velocity at height z

n = power law exponent

The power n is related to the ground roughness. A larger value of the power n represents higher roughness of the ground, i.e. dense city, while lower ground roughness was represented with smaller n value, i.e. sea surface.



0: 22.5°-112.4°

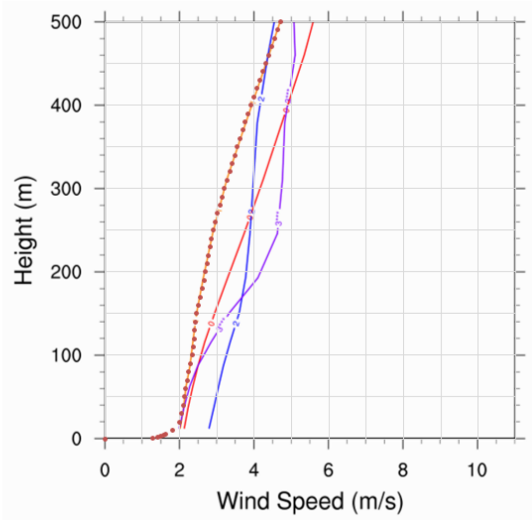
1: 112.5°-202.4°

2: 202.5°-292.4°

3: 292.5°-22.4°

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profile from 22.5°–112.4°



0: 22.5°-112.4°

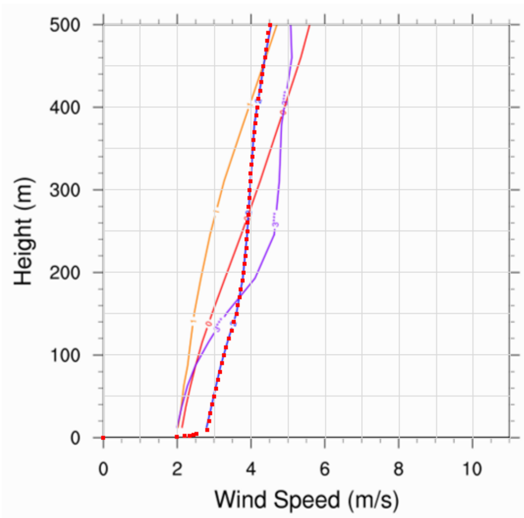
1: 112.5°-202.4°

2: 202.5°-292.4°

3: 292.5°-22.4°

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profile from 112.5°–202.4°



0: 22.5°-112.4°

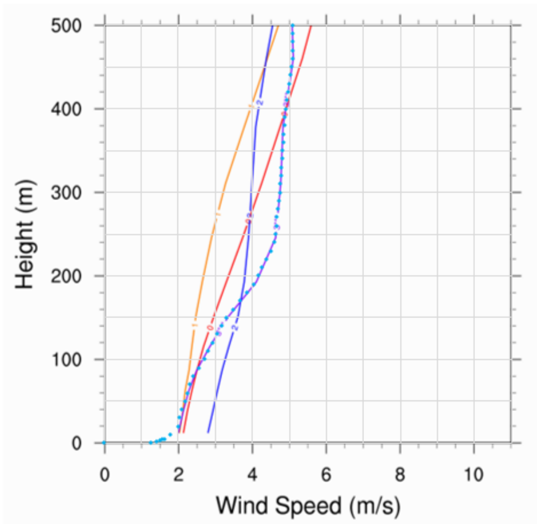
1: 112.5°-202.4°

2: 202.5°-292.4°

3: 292.5°-22.4°

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profile from 202.5°–292.4°



0: 22.5°-112.4°

1: 112.5°-202.4°

2: 202.5°-292.4°

3: 292.5°-22.4°

***: <10% total sample size in 2009, i.e. number of samples < 876

Simulated wind profile from 292.5°–22.5°

Figure 7 Wind Profile from RAMS (x:085, y:059)

4 Design Schemes for Comparison

Two schemes are analysed and compared in this AVA Initial Study, namely the Baseline Scheme and the Proposed Scheme.

4.1 Baseline Scheme: OZP – Indicative Scheme

The Baseline Scheme was extracted from the *Proposed Amendments to the Approved Sha Tin Outline Zoning Plan* from *TPB General Paper*. The Baseline Scheme consists of 2 building blocks of building height 135.7mPD and 138.7mPD respectively. The scheme follows the statutory requirement for not excedding the maximum building height of 140mPD and a maximum plot ratio of 6.

As proposed in *TPB General Paper*, the Development would have a building setback of about 20m from Fo Tan Road to its southwest and about10m setback from its western boundary to allow buffer distance with Fo Tan Road and adjacent industrial buildings.

A wind corridor in the form of non-building area (NBA) with a minimum width of 15m is generally aligned with Wo Liu Hang Street, at the eastern portion of the Development site along northeast-southwest direction, to maintain the ventilation through Wo Liu Hang Street and Fo Tan Road to Fo Tan Village. However, the exact location of the wind corridor would be subject to the detailed layout of the proposed development.

Figure 8 Master Layout Plan of Baseline Scheme (image source: Town Planning Board RNTPC Paper No. 4/15)

4.1.1 3D model of Baseline Scheme

Four different views of the 3D models of the Baseline Scheme in this AVA Initial Study are shown below.

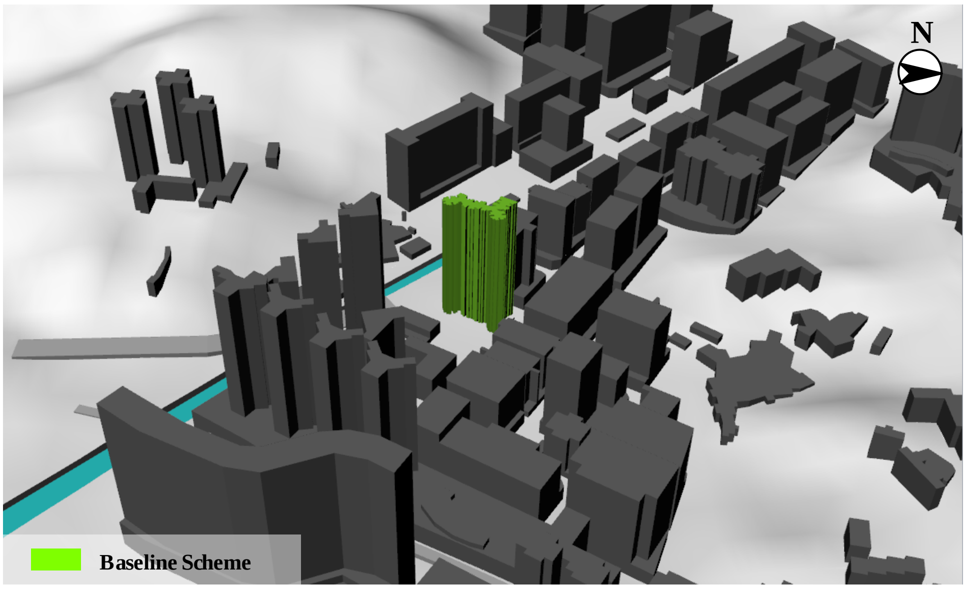


Figure 9 Easterly View of Baseline Scheme

Figure 10 Southerly View of Baseline Scheme

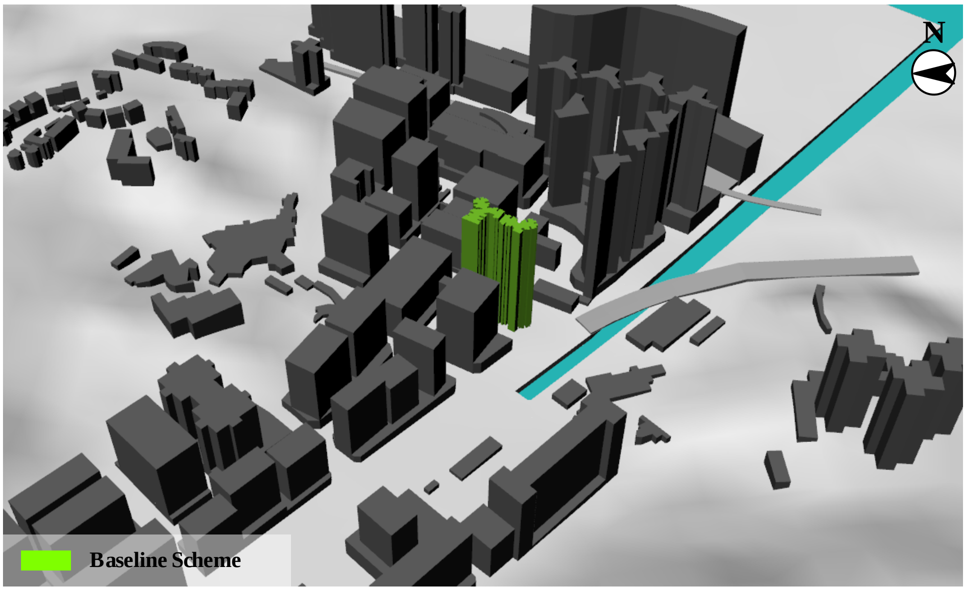


Figure 11 Westerly View of Baseline Scheme

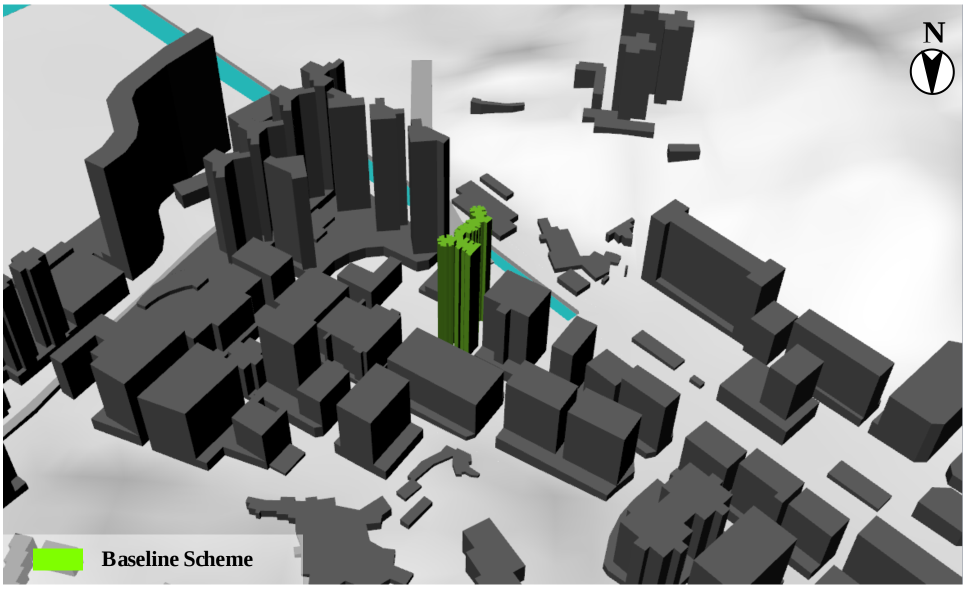


Figure 12 Northerly View of Baseline Scheme

4.2 Proposed Scheme

The Proposed Scheme consists of 1 building block of 140mPD. The Proposed Scheme preserved the 15m wind corridor in the form of NBA from the Baseline Scheme but slightly shifted toward southeast by 5m. The Proposed Scheme also maintained the 10m setback from adjacent industrial building and about 20m setback from Fo Tan Road for buffering purpose. Furthermore, the Proposed Scheme further provides a setback of about 20m from the northeast site boundary to facilitate wind penetrations.

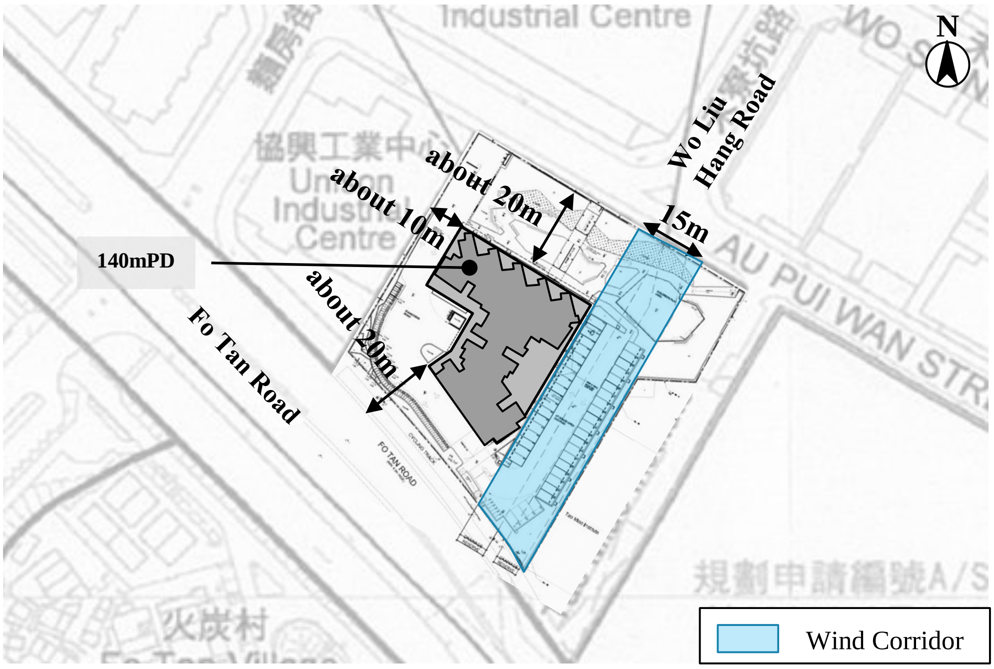


Figure 13 Master Layout Plan of Proposed Scheme

4.2.1 3D model of Proposed Scheme

Four different views of the 3D models of the proposed scheme in this AVA Initial Study are shown below.

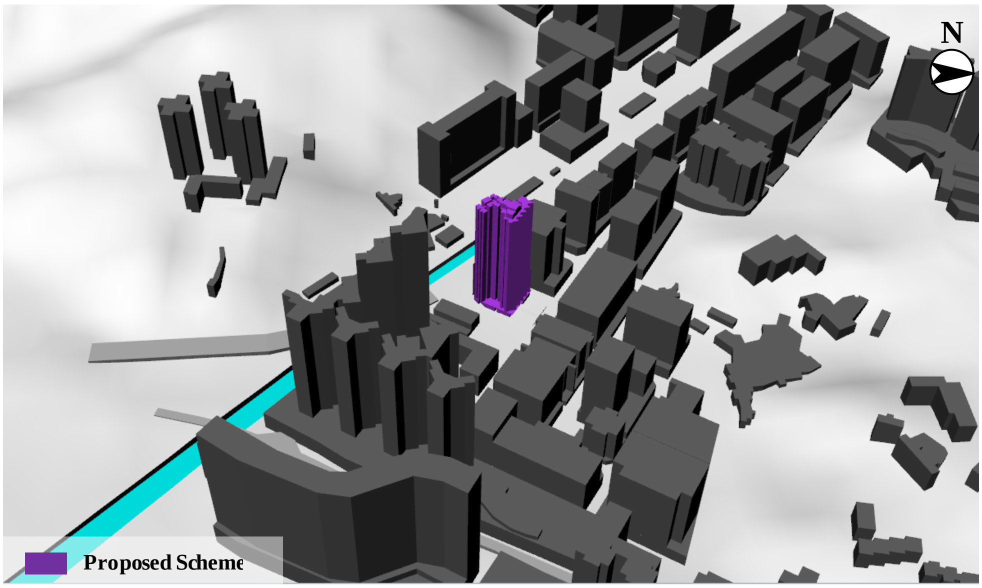


Figure 14 Easterly View of Proposed Scheme

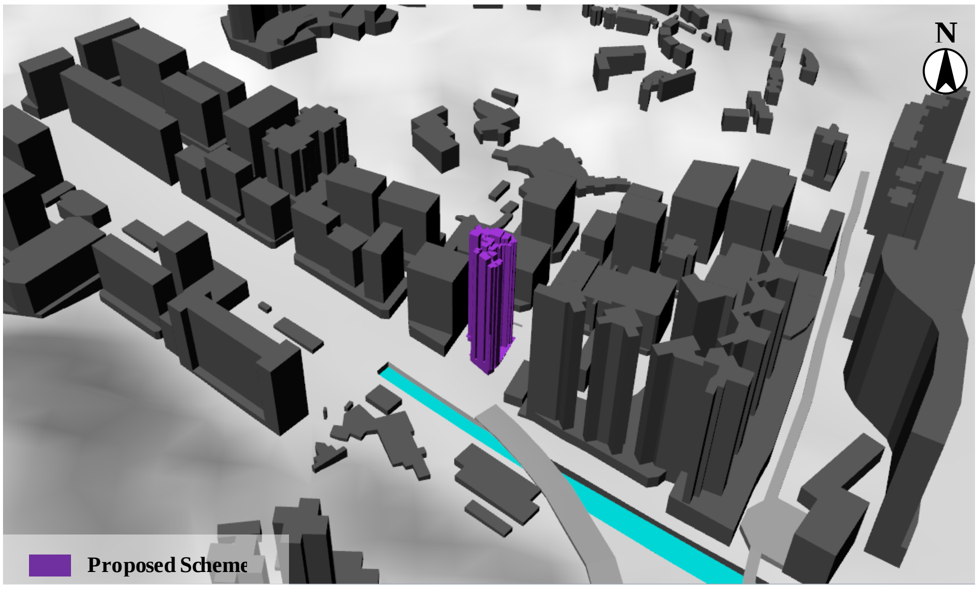


Figure 15 Southerly View of Proposed Scheme

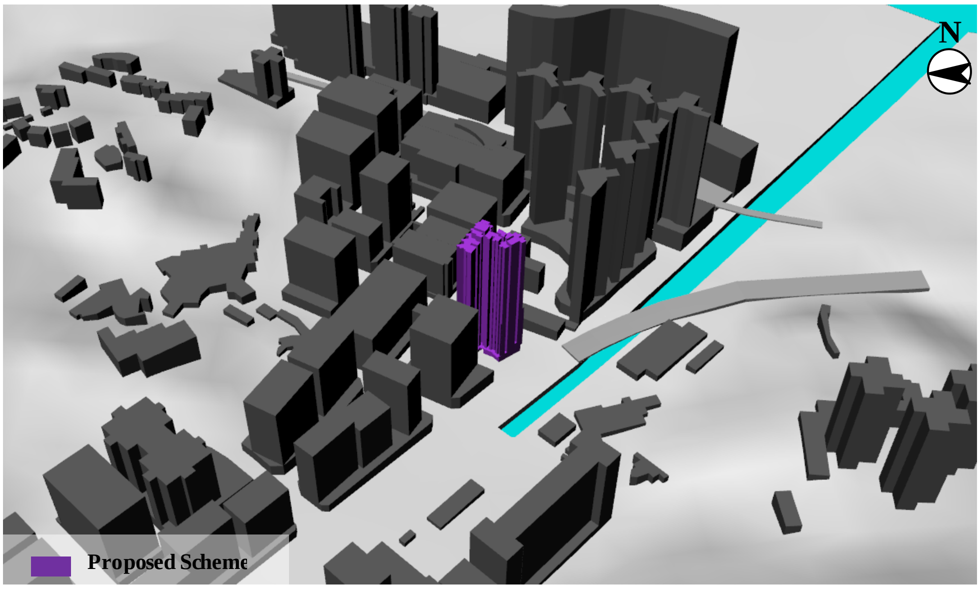


Figure 16 Westerly View of Proposed Scheme

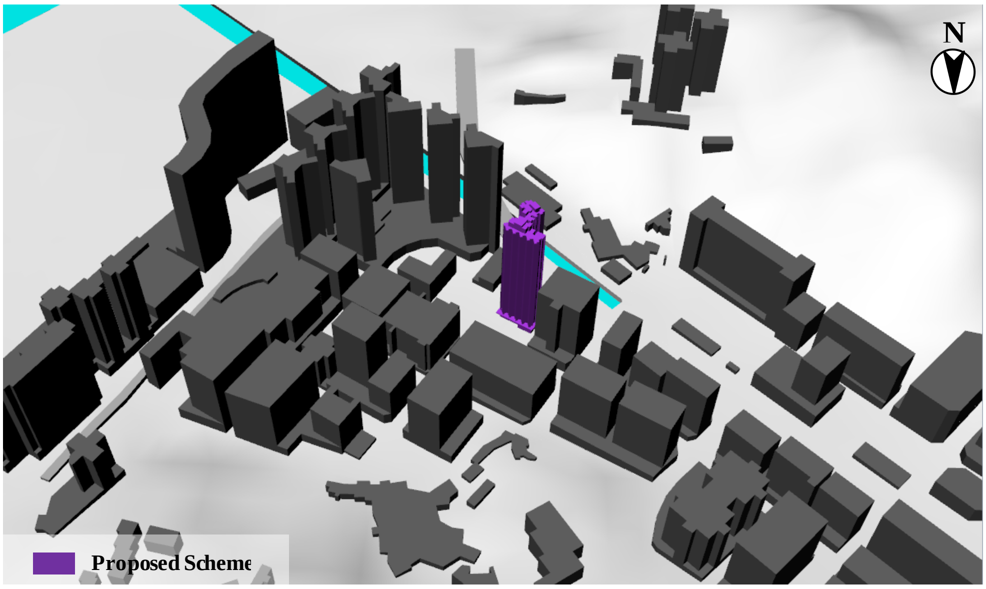


Figure 17 Northerly View of Proposed Scheme

5 Methodology

5.1 Assessment and Surrounding Areas

With reference to the *Technical Circular*, the areas of evaluation and assessment should include all area within the project area, as well as a belt up to 1H, where H is the height of the tallest building of the Proposed Development, around the site boundary.

With the maximum building height being 140mPD in the Development, the Assessment Area and the Surrounding Area span 140m(1H) and 280m(2H) away from the site boundary of the Development respectively. However, considering the complexity of the urban hub, the Surrounding Area are suggested to be enlarged in the AVA Initial Study, so that the 2H surrounding area would be extended beyond 280m to include adequate detail of the built environment. The Assessment Area and the Surrounding Area are indicated in Figure 18. The computational domain will be about 3400m (L) x 3800m (W) x 2300m (H).

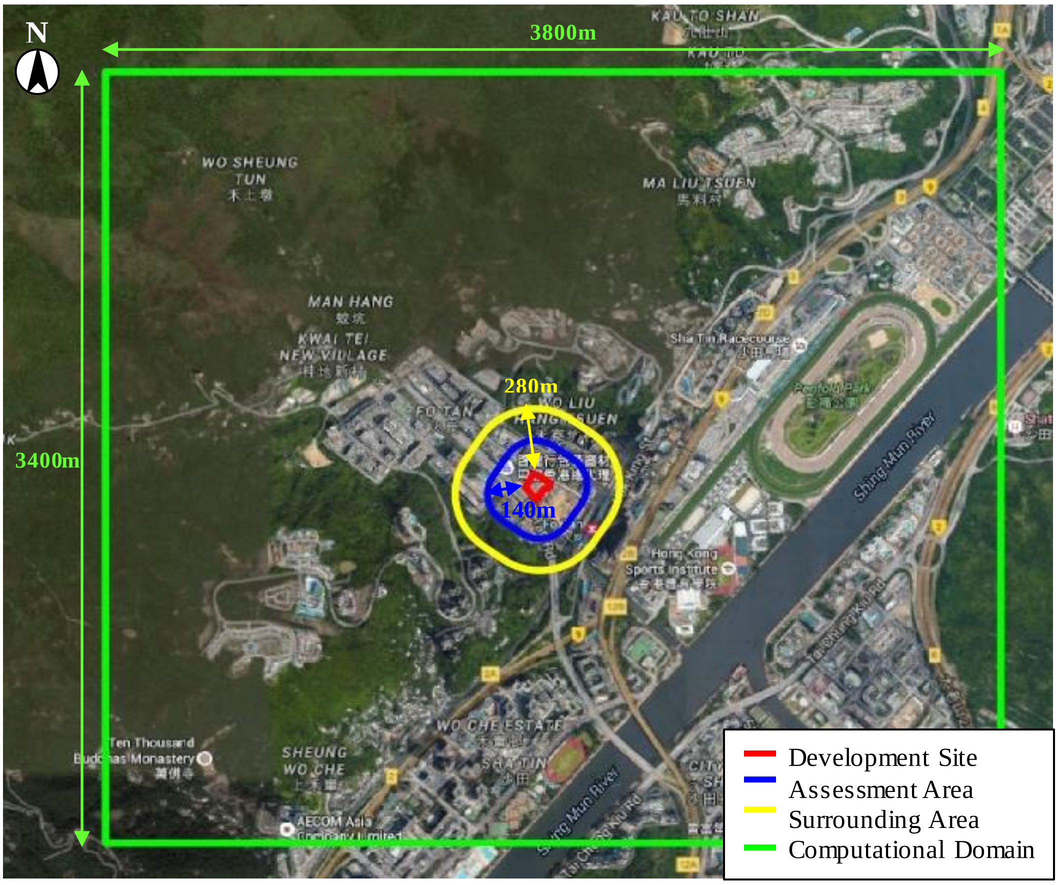


Figure 18 Project Area, Assessment Area, Surrounding Area and Computational Domain for the Study

5.2 Comprehensive Development Area (CDA)

Within the proposed Assessment Area, a planned Comprehensive Development Area (Planning Application No. A/ST/658-1, approved on 17/6/2011) at Fo Tan MTR Station will also be included. The CDA is located to the immediate southeast of the Development with 8 blocks of residential buildings with maximum building height of about 163mPD and a proposed Primary School (School) with a building height of no more than 8-storeys. These high-rise buildings are expected to create sheltering effect to the developments in the southeast.

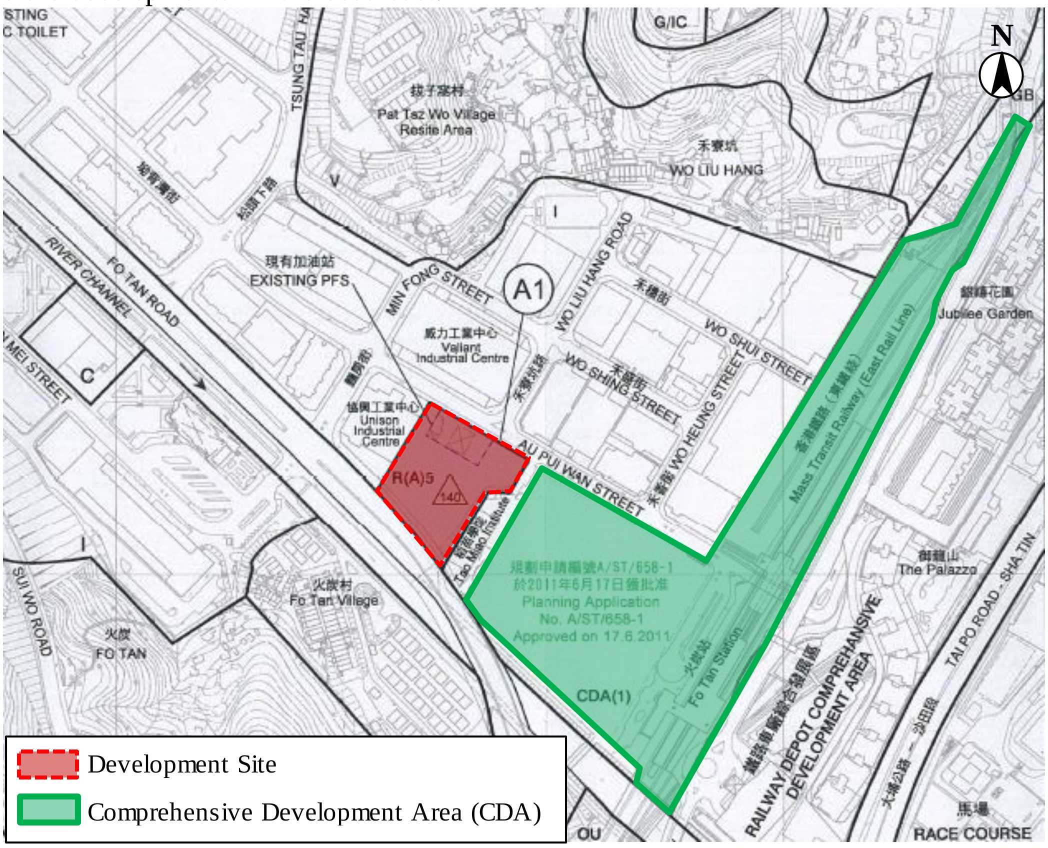


Figure 19 Location of Comprehensive Development Area (CDA)

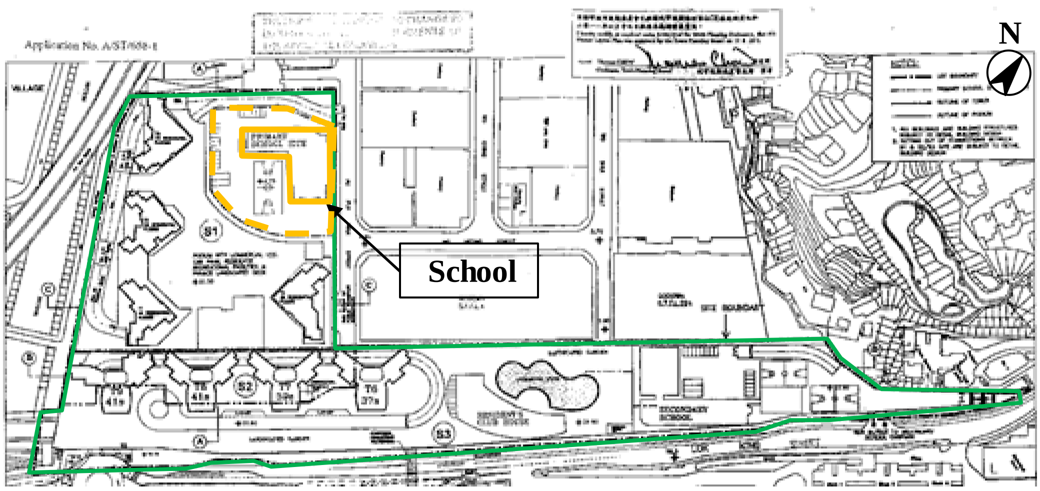


Figure 20 Master Layout Plan of the Comprehensive Development Area (CDA)

5.3 Directional Views of the 3D Domain Model

The topology characteristics and surrounding buildings are included within the computational domain. The 4 directional views of the 3D domain model are shown below.

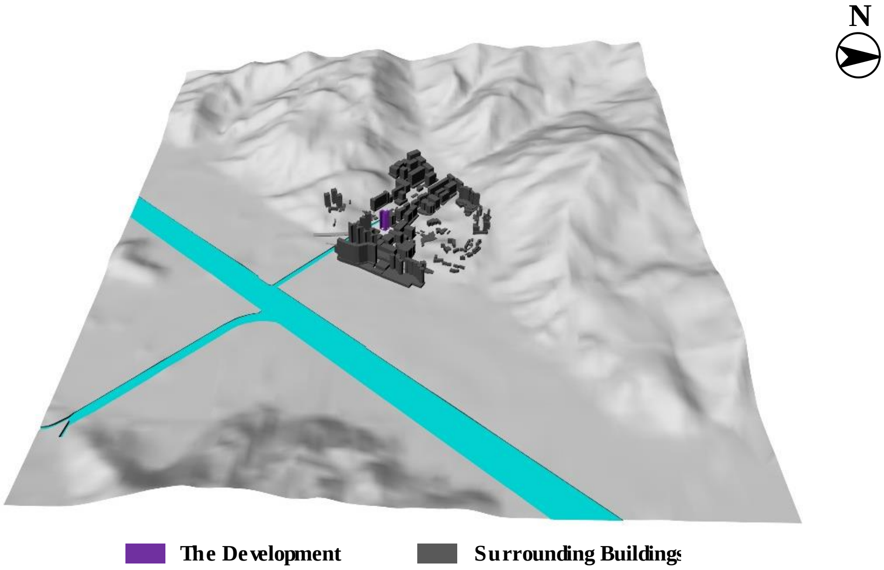


Figure 21 Easterly View of CFD Domain

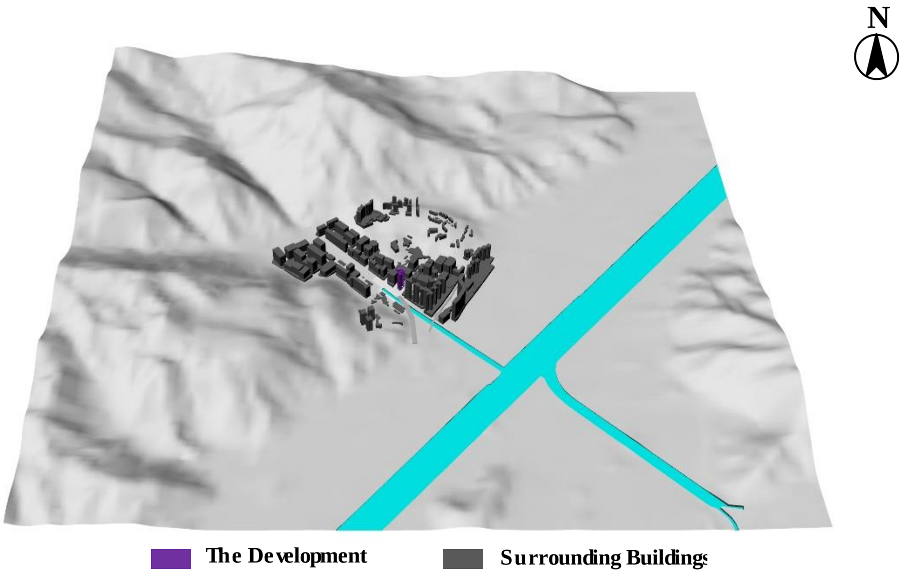


Figure 22 Southerly View of CFD Domain

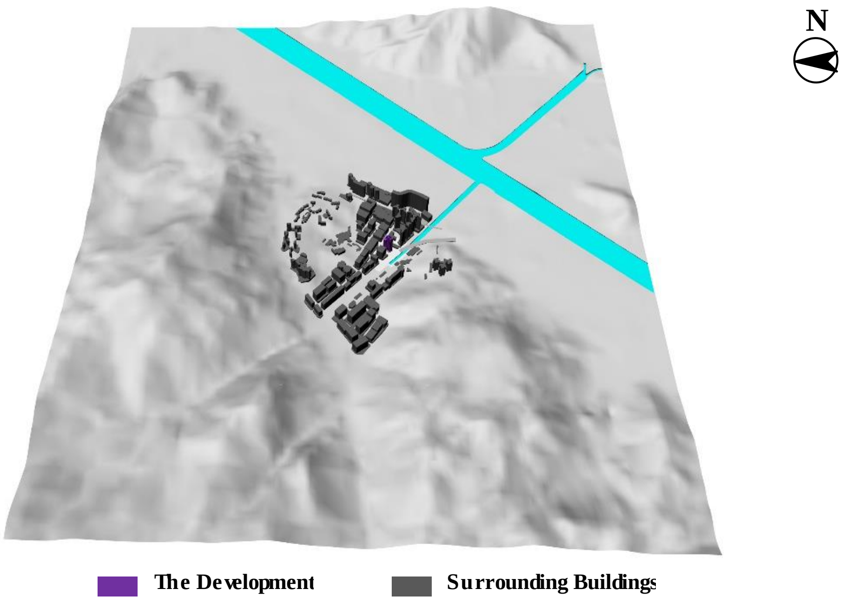


Figure 23 Westerly View of CFD Domain

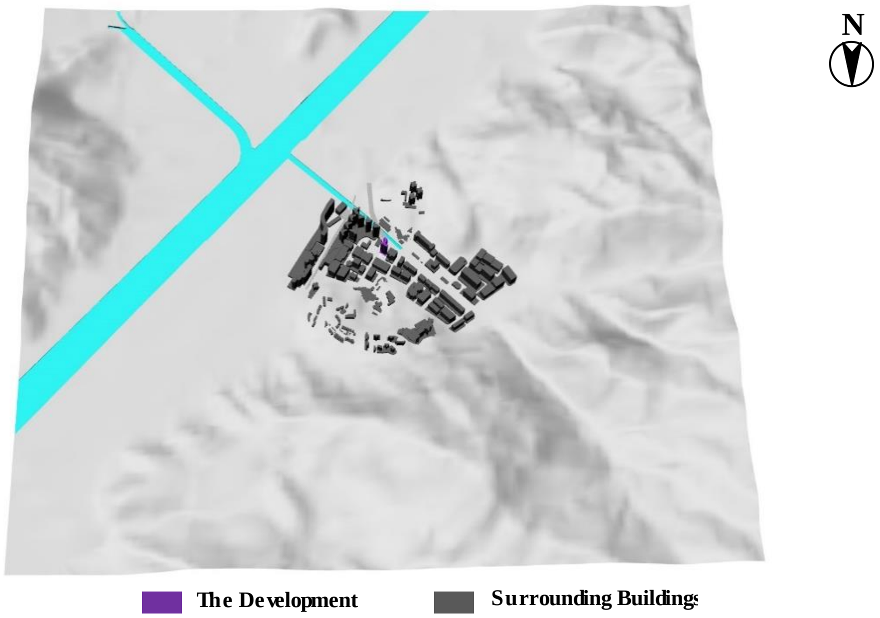


Figure 24 Northerly View of CFD Domain

5.4 Technical Details of CFD simulation

5.4.1 Assessment Tool

Computational Fluid Dynamics (CFD) technique is utilized for the AVA Initial Study. Well recognised commercial CFD packages ANSYS ICEM-CFD and STAR-CCM+ are used, where both software are widely used in the industry for AVA studies. With the use of three-dimensional CFD method, the local airflow distribution can be visualised in detail. The air velocity distribution within the flow domain, being affected by the site-specific design and the surrounding buildings, is simulated under the prevailing wind conditions in a year.

5.4.2 Mesh Setup

Body-fitted unstructured grid technique is used to fit the geometry to reflect the complexity of the development geometry. A prism layer of 3m above ground (totally 6 layers and each layer is 0.5m) is incorporated in the meshing so as to better capture the approaching wind. The expansion ratio is 1.3 while the maximum blockage ratio is 3%.

Finer grid system is applied to the most concerned area based on preliminary judgement, while coarse grid system is applied to the area of surrounding buildings for better computational performance while maintaining satisfactory result, as shown in Figure 25.

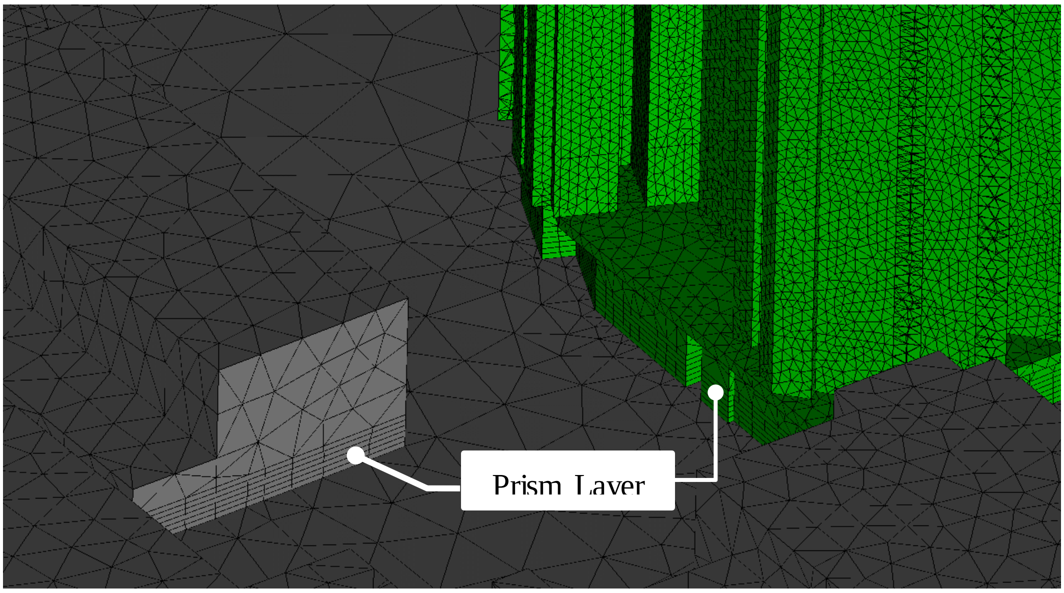


Figure 25 Prism Mesh near the Pedestrian Level

5.4.3 Turbulence Model

As highlighted in recent academic and industrial research literatures by CFD practitioners, the widely used standard k - ε turbulence model technique may not adequately model the effects of large scale turbulence around buildings and ignores the wind gusts leading to the relatively poor prediction in the recirculation regions around building. Therefore in this CFD simulation, realizable $k - \varepsilon$ turbulence modelling method is applied. This technique provides more accurate representation of the levels of turbulence that can be expected in an urban environment.

5.4.4 Calculation Method

The Segregated Flow model solves the flow equations in a segregated manner. The linkage between the momentum and continuity equations adopted the predictor-corrector approach. A collocated variable arrangement and a Rhie-and-Chow-type pressure-velocity coupling combined with a SIMPLE-type algorithm. A higher order differencing scheme is applied to discretize the governing equations. The convergence criterion is set to below $1.0E^{-4}$ on mass conservation. The calculation will repeat until the solution satisfies this convergence criterion.

The prevailing wind direction as mentioned in Section 3.2 are set to inlet boundary of the model with wind profile as detailed in Section 3.3. The downwind boundary is set to pressure with value of atmospheric pressure. The top and side boundaries are set to symmetry. In addition, to eliminate the boundary effects, the model domain is built beyond the Surrounding Area as required in the *Technical Circular*.

5.4.5 Summary

Based on previous sections, the detail parameters are summarized below.

Table 3 Detail parameters to be adopted in the CFD

	CFD Model
Model Scale	Real Scale model, 1:1 scale
Model details	Only include Topography, Buildings blocks, Streets/Highways, no landscape is included
Domain	3400m(L) x 3800m(W) x 2300m(H)
Assessment Area	≥ 1H area
Surrounding building Area	≥ 2H area
Grid Expansion Ratio	The grid should satisfy the grid resolution requirement with maximum expansion ratio = 1.3
Prismatic layer	6 layer of prismatic layers and 0.5m each (i.e. total 3m above ground)
Inflow boundary Condition	Incoming wind profile as measured from RAMS
Outflow boundary	Pressure boundary condition with dynamic pressure equal to zero
Wall boundary condition	Logarithmic law boundary
Solving algorithms	*Rhie* and *Chow* SIMPLE for momentum equation Realisable k-ε turbulence model Hybrid model for all other equations
Blockage ratio	< 3%
Convergence criteria	Below $1.0E^{-4}$

5.5 Assessment Parameters

As specified in the *Technical Circular*, the wind Velocity Ratio (VR) as proposed by the *Technical Circular* was employed to assess the ventilation performances of the Proposed Development and surrounding environment. Higher VR implies better ventilation. The calculation of VR is given by the following formula:

$$VR = \frac{V_p}{V_\infty}$$

V_∞= the wind velocity at the top of the wind boundary layer (assumed to be the mean wind speed of the approaching wind flow measured at an elevation equivalent to 500mPD in this study).

V_P = the wind velocity at the pedestrian level (2m above ground) taken into account the effects of buildings.

The higher the value of VR, the less is the impact due to buildings on wind availability.

The Average VR is defined as the weighted average VR with respect to the percentage of occurrence of all considered wind directions. This gives a general idea of the ventilation performance at the considered location at both annual and summer wind condition.

Site spatial average velocity ratio (SVR) and a Local spatial average velocity ratio (LVR) should be determined.

Table 4 Terminology of the AVA Initial Study

Terminology	Description
Velocity Ratio (VR)	The velocity ratio (VR) represents the ratio of the air velocity at the measurement position to the value at the reference points.
Site spatial average velocity ratio (SVR)	The SVR represent the average VR of all perimeter test points at the site boundary which identified in the report.
Local spatial average velocity ratio (LVR)	The LVR represent the average VR of all points, i.e. perimeter and overall test points at the site boundary which identified in the report.

5.6 Test Point Location

As per the *Technical Circular*, three types of test points – perimeter test points, overall test points and special test points are adopted to assess the ventilation performance. The allocation of these test points will be distributed evenly within the assessment area as stated in the *Technical Circular*.

5.6.1 Perimeter Test Points

A total number of 34 perimeter test points (**Red spots**), namely P Points, are positioned at interval of around 10m along the Development site boundary in accordance with the *Technical Circular*. Upon the proposed assessment area, the locations of perimeter test points are shown in Figure 26.

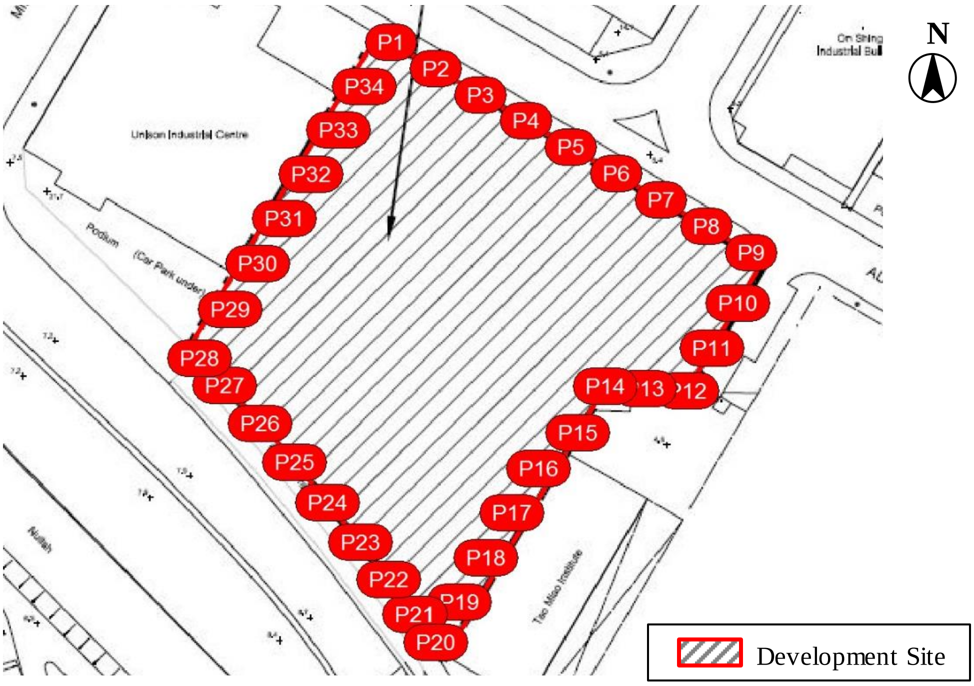


Figure 26 Location of Perimeter Test Points

5.6.2 Overall Test Points

A total number of 74 overall test points (**Black spots**), namely O Points, are evenly distributed in open areas within the assessment area, such as the streets and places where pedestrians are frequently accessed. The locations of overall test points are shown in Figure 27.

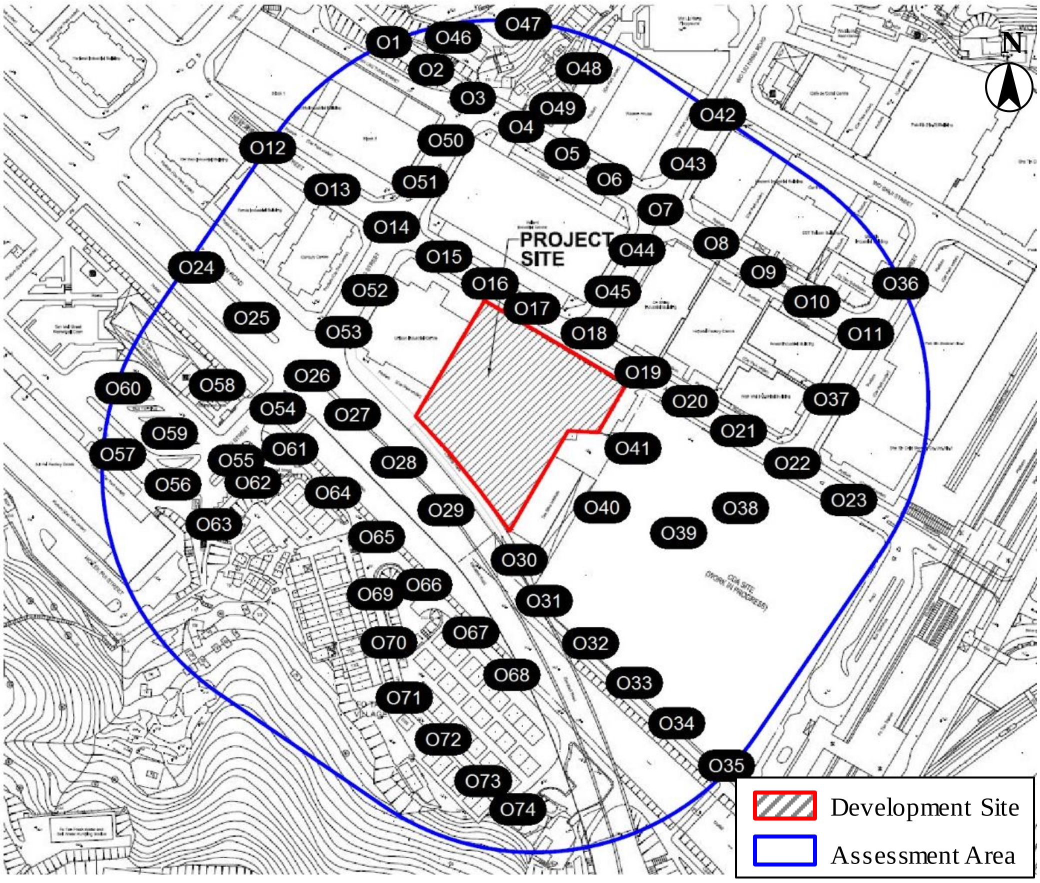


Figure 27 Location of Overall Test Points

5.6.3 Special Test Points

5 special test points (**Blue spots**), namely S Points, are evenly distributed along the centre of the non-building area (NBA) which is in alignment with the major wind corridor, Wo Liu Hang Street, in order to assess the performance of the preserved NBA in the Baseline and Proposed Scheme. The locations of special test points are shown in Figure 28.

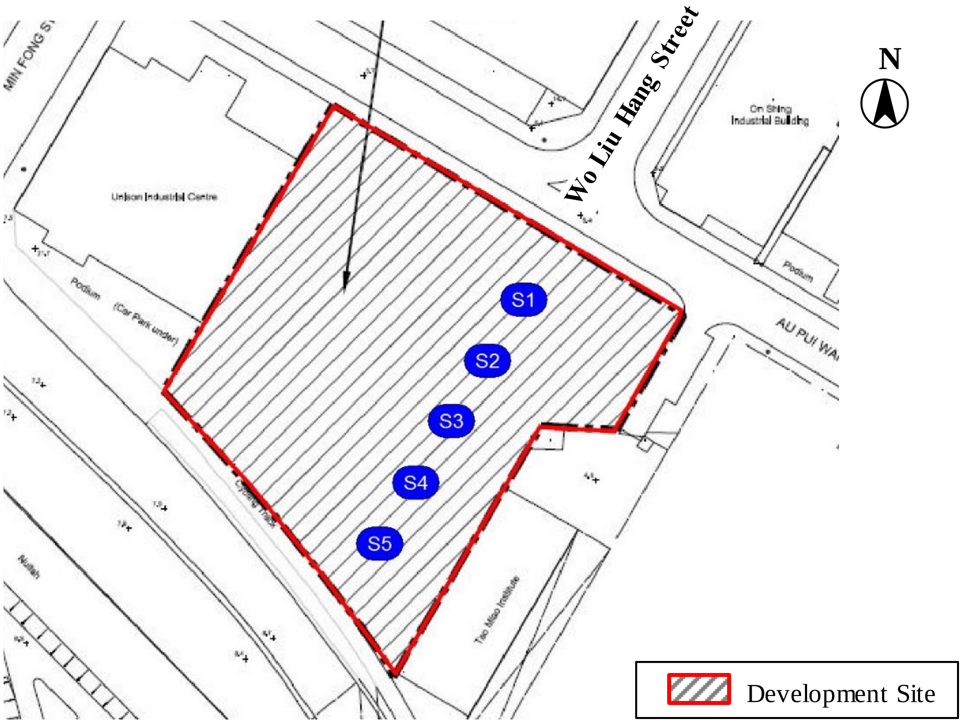


Figure 28 Location of Special Test Points

5.7 Focus Areas

Within the proposed Assessment Area, a total of 15 focus areas are identified in Figure 28. The associated test points for each focus area are tabulated in Table 4.

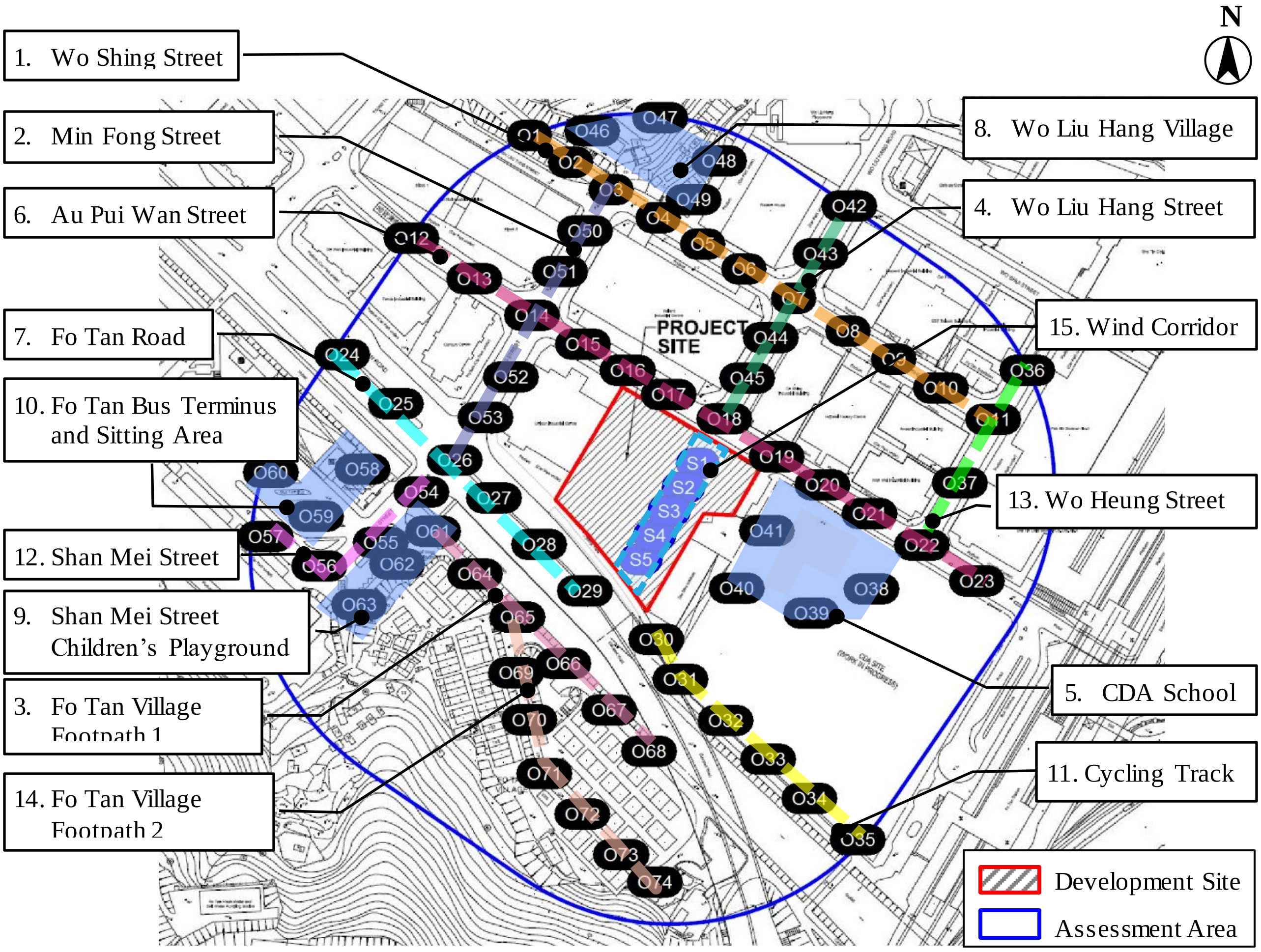


Figure 29 Focus Area with Associate Test Points in Assessment Area

Table 5 Focus Area and Corresponding Test Points

	Focus Area	Test Points
1	Wo Shing Street	O1 - O11
2	Au Pui Wan Street	O12 - O23
3	Fo Tan Road	O24 - O29
4	Cycling Track	O30 - O35
5	Wo Heung Street	O11, O22, O36 - O37
6	CDA School	O38-O41
7	Wo Liu Hang Street	O7, O18, O42 - O45
8	Wo Liu Hang Village	O46 - O49
9	Min Fong Street	O3, O14, O26, O50 - O53
10	Shan Mei Street	O54 - O57
11	Bus Terminus and Sitting Area	O58 - O60
12	Shan Mei Street's Children Playground	O61 - O63
13	Fo Tan Village Footpath 1	O61, O64 - O68
14	Fo Tan Village Footpath 2	O65 - O74
15	Non-Building Area (NBA)	S1 - S5

6 Results and Discussion

Quantitative assessment has been conducted to compare the wind performance between Baseline Scheme and Proposed Scheme using CFD. This section would discuss the wind performance within the assessment area. The directional contour plots and vector plots are given in Appendix B and Appendix C of this report.

6.1 Overall Ventilation Performance

6.1.1 Annual Condition

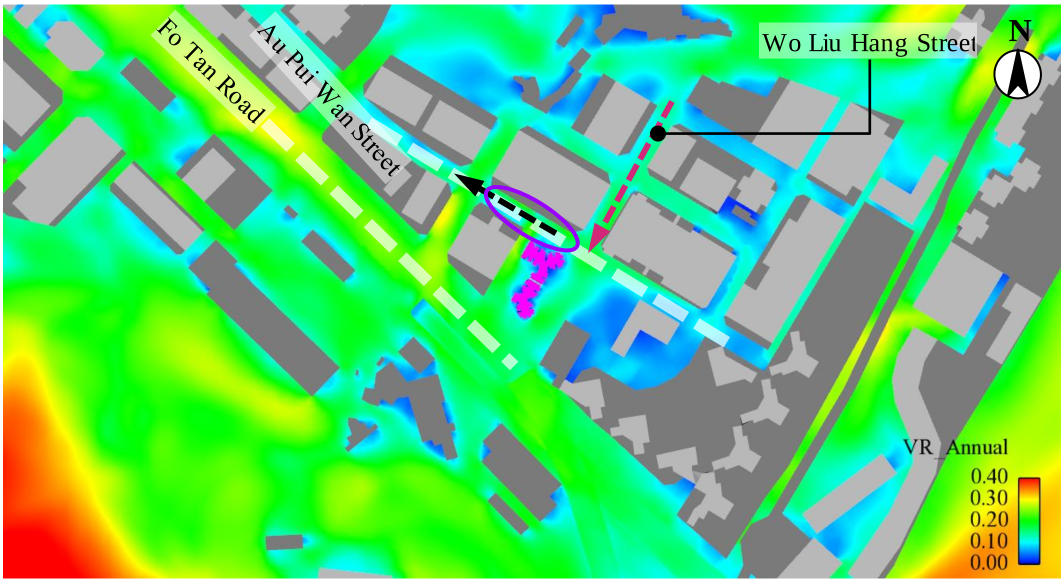


Figure 30 Average annual VR contour plots for Baseline Scheme

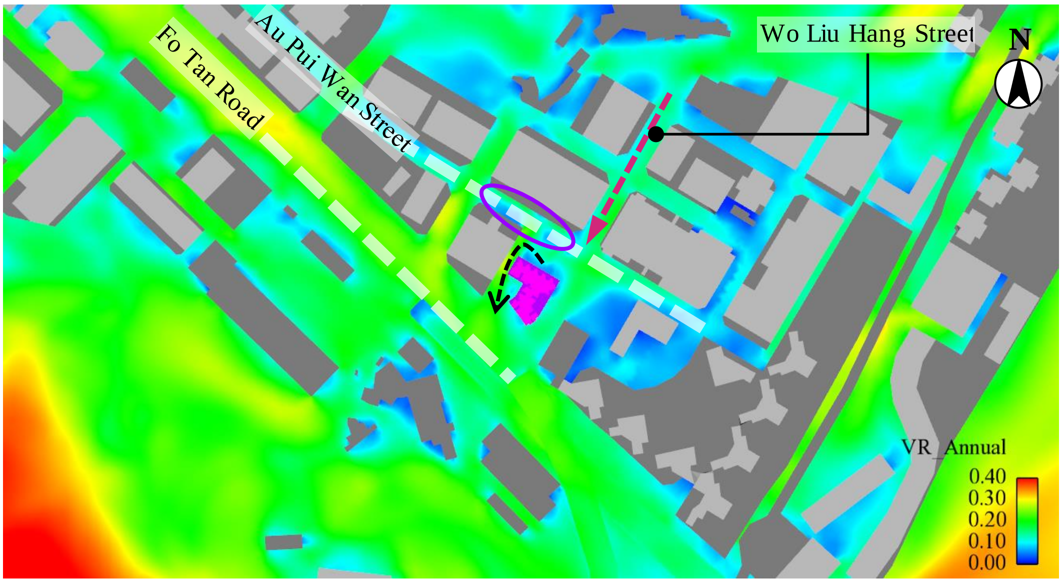


Figure 31 Average annual VR contour plots for Proposed Scheme

For the Annual condition, eight wind directions were selected, accumulating to 80.6% in occurrence of frequency. The integrated effect of these wind directions indicates the overall ventilation performance. The major prevailing winds under annual wind condition come from north-east quadrant. The above contour plots show that:

- The overall ventilation performance among Baseline and Proposed Scheme are similar under annual condition.
- The north-easterly prevailing wind would enter the assessment area mainly through Wo Liu Hang Street, shown as pink arrow in Figure 30 and Figure 31.
- The dense and high-rise building clusters to the northeast of the Development would shield the north-easterly prevailing wind entering the assessment area.
- The north-east facing façade of Baseline Scheme would capture the high and mid-level wind from north-east quadrant and downwash to the pedestrian level of Au Pui Wan Street at close proximity to the Development site, shown as black arrow in Figure 30. Hence, slightly higher VR were observed at some portion of Au Pui Wan Street (purple circled area in Figure 30 and Figure 31) under Baseline Scheme as compared to Proposed Scheme.
- Similarly, the north-east facing façade of the Proposed Scheme would also help to capture the high and mid-level wind from north-east quadrant and downwash to the pedestrian level. The 20m building setback from Au Pui Wan Street in the Proposed Scheme would facilitate the downwash wind to reach the open space at immediate north and east to the proposed building.
- The wind will then be diverted through the building separation towards the leeward side subsequently, shown as black arrow in Figure 31. The VR at Fo Tan Road were found to be slightly higher under Proposed Scheme.
- The impact of shifting of wind corridor would be not significant as both schemes achieve similar VR along the wind corridor within Development site.

The SVR and LVR are summarized in table below.

Table 6 SVR and LVR under Annual Condition

	Baseline Scheme	Proposed Scheme
SVR	0.12	0.13
LVR	0.12	0.12

Under annual condition, Proposed Scheme achieved a slightly higher SVR than Baseline Scheme. This suggested that the Proposed Scheme would achieve a slightly better ventilation performance at the immediate surroundings of the Development as compared to Baseline Scheme.

Meanwhile, Proposed Scheme achieved the same LVR as compared with Baseline Scheme, the result suggested that the ventilation performance at the local surrounding area of the Development under both the Proposed and Baseline Scheme would be similar.

Detailed discussion is presented in the Direction Analysis in Section 6.2.

6.1.2 Summer Condition

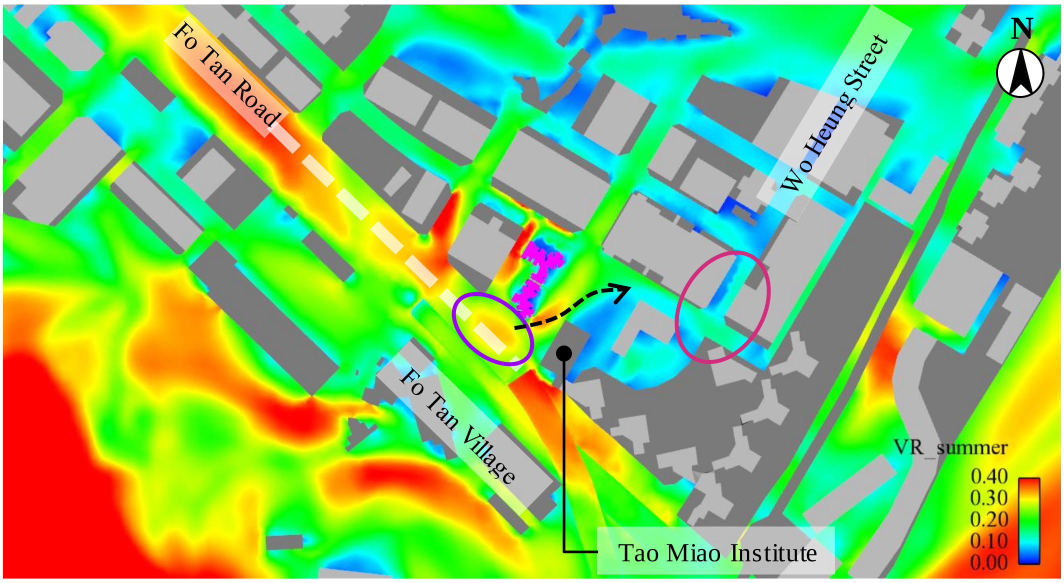


Figure 32 Average summer VR contour plots for Baseline Scheme

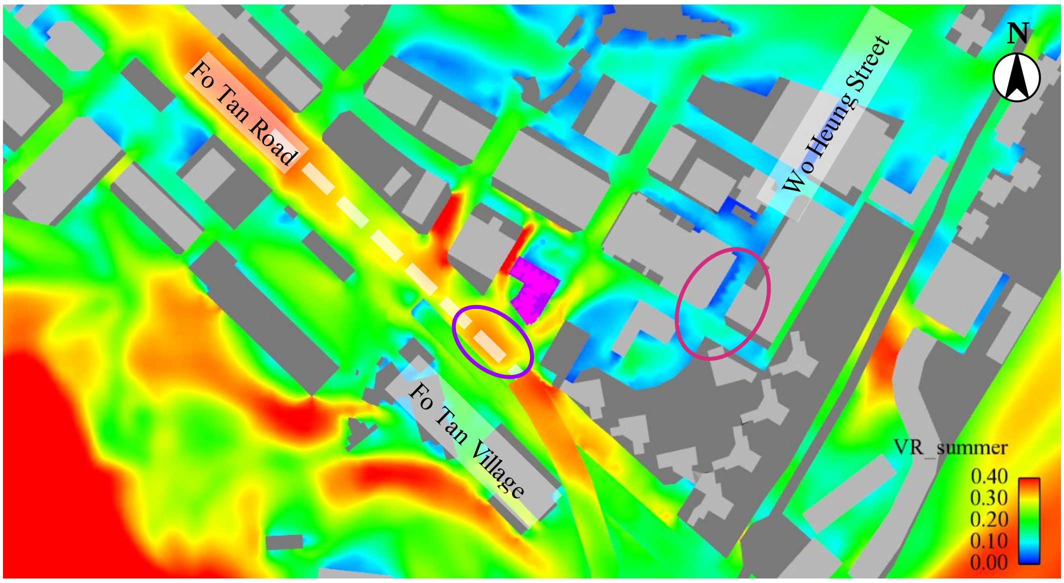


Figure 33 Average summer VR contour plots for Proposed Scheme

For the summer condition, eight wind directions were chosen, accumulating to 81.4% in occurrence of frequency. The integration of the effect of these wind directions indicates the overall ventilation performance. During the summer, pervading winds are dominated by SSW (16.5%) and SW (20.7%) direction. The above contour plots show that:

- The overall ventilation performance between Baseline Scheme and Proposed Scheme are similar under summer condition.
- The relatively open space and low-rise village clusters to the southwest of the Development would allow the south-westerly wind to skim over and enter the assessment area.
- The more extensive south-west facing façade under Proposed Scheme would capture more high and mid-level south-west wind and divert it to the pedestrian level of Fo Tan Road. Some portion of Fo Tan Road (purple circle in Figure 32 and Figure 33) showed a higher VR under Proposed Scheme as compared to Baseline Scheme.
- On the other hand, under Baseline Scheme, instead of being downwashed, some of the south-west quadrant wind would continue to travel across the NBA and low-rise Tao Miao Institute, shown as black arrow in Figure 32. Thus, slightly higher VR can be observed around the NBA, eastern part of Au Pui Wan Street and Wo Heung Street under Baseline Scheme as compared to Proposed Scheme, shown as pink circled area in Figure 32 and Figure 33.
- The overall impact of shifting of wind corridor would be not significant as both schemes achieve similar VR along the wind corridor within Development site.

The SVR and LVR are summarized in table below.

Table 7 SVR and LVR under Summer Condition

	Baseline Scenario	Proposed Scenario
SVR	0.19	0.21
LVR	0.17	0.18

Under summer condition, Proposed Scheme achieved a slightly higher SVR than Baseline Scheme, which suggested that the Proposed Scheme achieved a slightly better ventilation performance at the immediate surroundings of the Development site as compared to Baseline Scheme.

Meanwhile, the Proposed Scheme achieved a slightly higher LVR value than Baseline Scheme. This suggested that the overall ventilation performance at the local surrounding area of the Proposed Scheme would be slightly better than the Baseline Scheme.

Detailed discussion is presented in the Direction Analysis in Section 6.2.

6.2 Directional Analysis

6.2.1 NNE Wind

The incoming wind would enter the site along Wo Liu Hang Street and Au Pui Wan Street, show as pink Arrow in Figure 34 and Figure 35. As several industrial buildings with bulky building layout are located to the northeast of site, some of the incoming wind would be shielded by these buildings at the upwind location, which would dominate the wind environment within the assessment area.

Under Baseline Scheme, wind shadow would be casted by the proposed development to the southwest of the proposed building. The approaching wind along Au Pui Wan Street would be downwashed towards the pedestrian level and travel along Au Pui Wan Street, show as black arrow in Figure 34. The VR at Au Pui Wan Street would be slightly higher.

Under Proposed Scheme, some of the incoming wind would also be downwashed by the north-east facing facade. Due to the additional setback of 20m provided by landscape garden in the north-east of the Study Site. The approaching wind along Au Pui Wan Street as well as the downwashed wind would travel through the building separation between the proposed Development and Unison Industrial Center, to ventilate the leeward side of the Development, show as black arrow in Figure 35. Higher VR would be observed along the Fo Tan Road. Both the Baseline and Proposed Scheme achieve similar ventilation performance along the NBA within the Development Site.

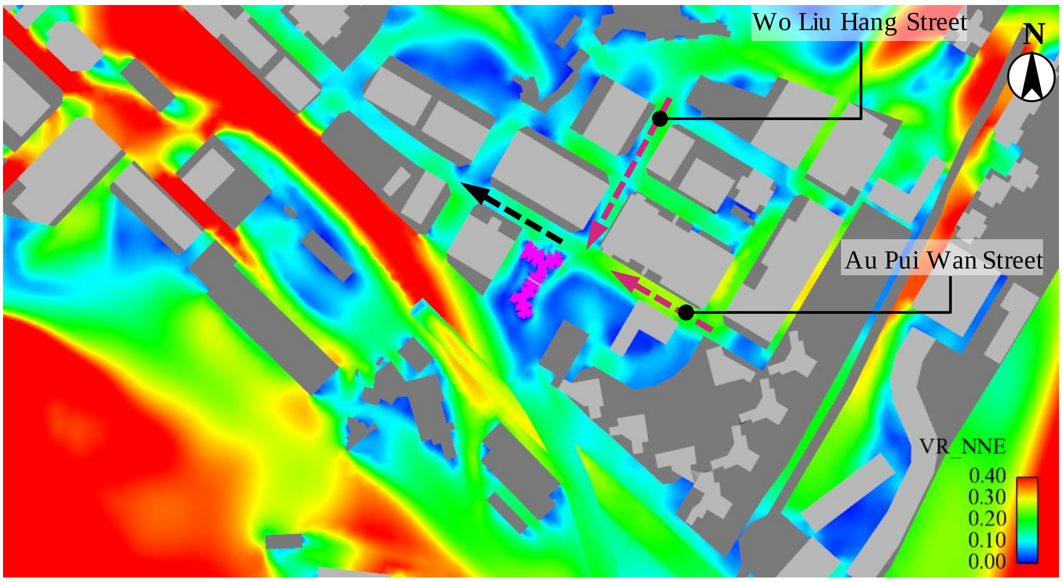


Figure 34 VR contour plot for Baseline Scheme under NNE Wind

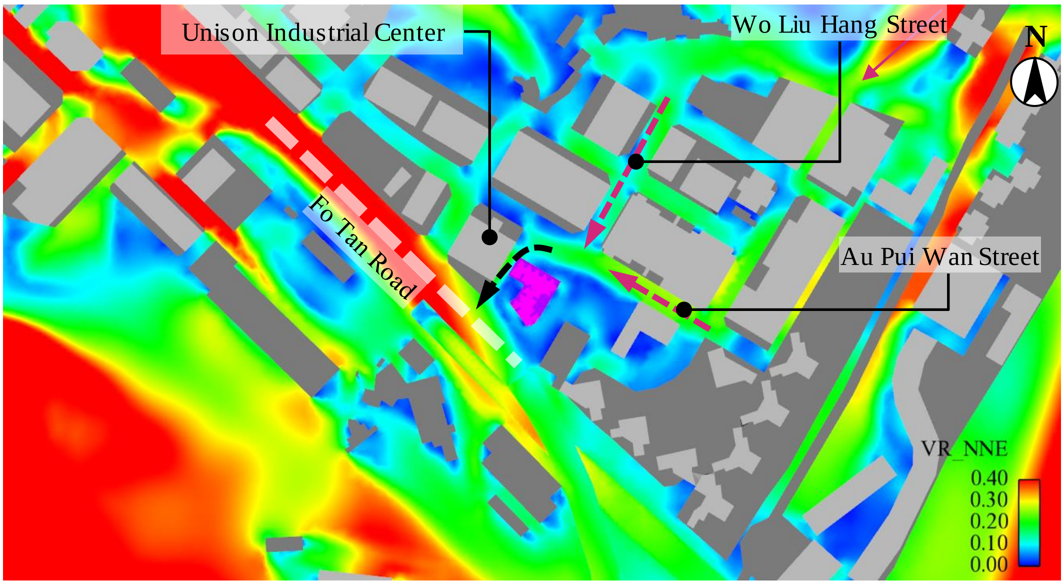


Figure 35 VR contour plot for Proposed Scheme under NNE Wind

6.2.2 NE Wind

Under NE wind, the incoming wind would travel along Wo Liu Hang Street and reach the Study Site, shown as pink arrow in Figure 36 and Figure 37. Due to the difference in building height between the proposed Development and industrial buildings located to its north-east across Au Pui Wan Street, downwashed effect would be observed by the north-east facing facade of the proposed Development.

Similar to NNE wind, under Baseline Scheme, the layout of the proposed building would divert the travel along both sides of Au Pui Wan Street, show as black arrows in Figure 36. Hence the VR at Au Pui Wan Street would be slightly improved. The northern part of the building in Baseline Scheme would cast some wind shadow to the leeward side of the building. Some of the NE wind would be downwashed and travelled towards Wo Liu Hang Street, where lightly higher VR were observed.

On the other hand, under the proposed scheme. Due to the setback of 20m from the Au Pui Wan Street, landscape area to the north of the proposed building would provide additional open space, which would allow the downwashed wind to reach the adjacent CDA School, shown as black arrow Figure 37. Hence, the VR at adjacent School Site and along the wind corridor within the Development Site would be slightly improved. In addition, the wind would reach the leeward side of the proposed building through the building separation between the proposed development and Unison Industrial Building, shown as blue arrow Figure 37.

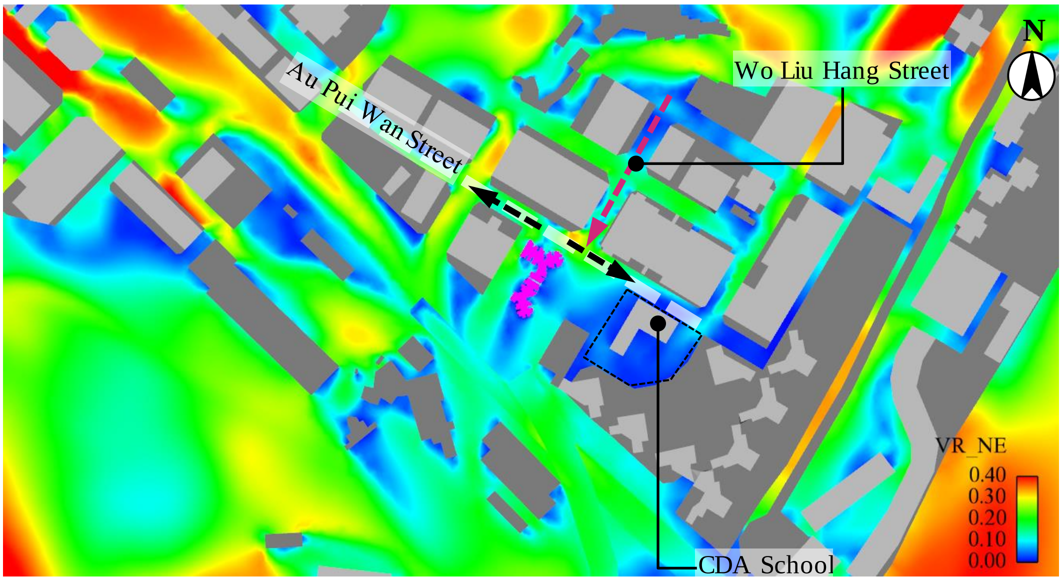


Figure 36 VR contour plot for Baseline Scheme under NE Wind

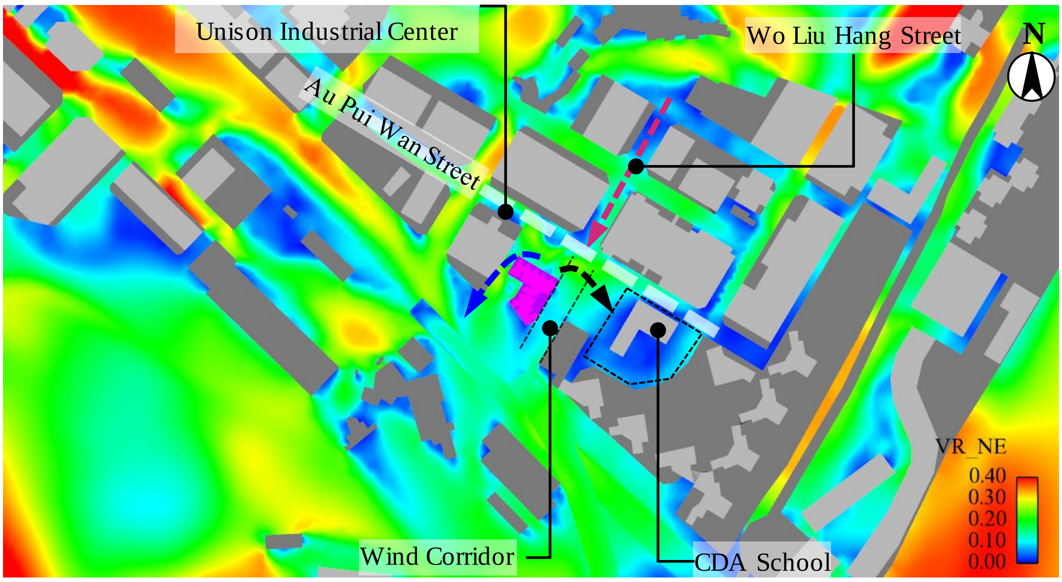


Figure 37 VR contour plot for Proposed Scheme under NE Wind

6.2.3 ENE Wind

Under ENE Wind, the densely occupied industrial building located at the upwind location would shield some of the incoming wind and dominate the wind environment in surrounding areas. The overall ventilation performance would be similar for both Baseline and Propose Scheme.

The facade facing ENE direction would be longer under Baseline Scheme, the incoming ENE wind would be downwashed to ventilate the pedestrian level in the eastern part of the Study Site, shown as purple circled area in Figure 38. The wind would then travel towards the Fo Tan Village Footpath and Au Pui Wan Street. Hence, the VR for these areas would be slightly higher. Meanwhile, the larger frontage area facing ENE direction would result in a larger wake zone in the leeward side of the proposed development.

On the other hand, the 20m setback from Au Pui Wan Street would allow the wind to travel towards the building separation between the proposed Development and Unison Industrial Centre, shown as blue arrow in Figure 39. Together with the smaller wake zone created by the proposed development, the VR at Fo Tan Road, Shan Mei Street Children's Playground (black dotted area in Figure 38 and Figure 39) would be slightly higher comparing to Baseline Scheme.

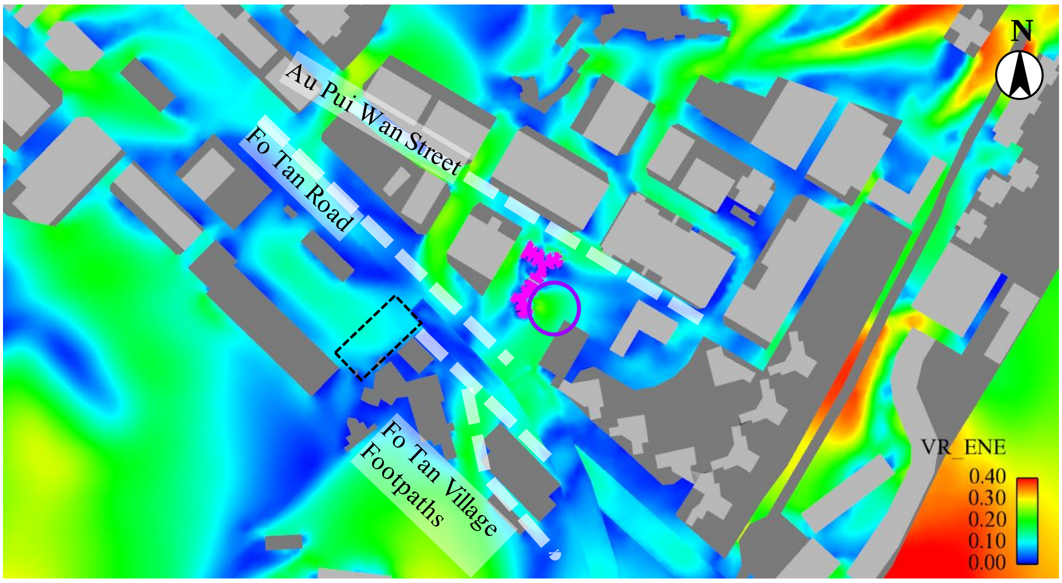


Figure 38 VR contour plot for Baseline Scheme under ENE Wind

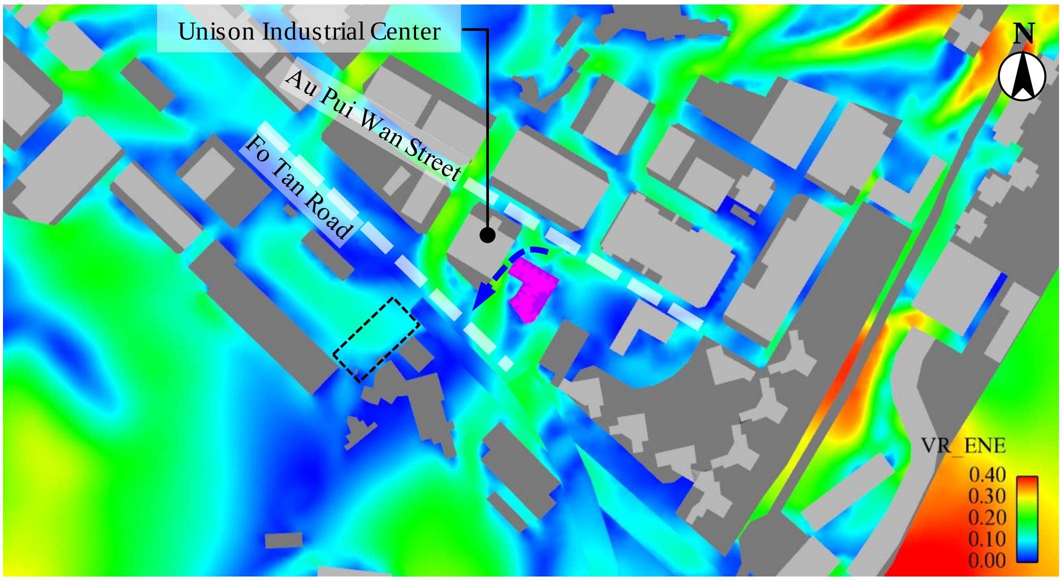


Figure 39 VR contour plot for Proposed Scheme under ENE Wind

6.2.4 E Wind

Under E wind, the incoming wind would be shielded by the surrounding buildings, mostly due to the committed CDA site adjacent to the Development site, which would result in a generally calm wind environment in the Development site and its surrounding area. The road networks within the surrounding areas would divert the incoming E wind to reach the assessment area from north-east direction and the hilly range to the southwest of the site would divert the incoming wind to travel along south-east direction, shown as pink arrows in Figure 40 and Figure 41.

Similar to NE and ENE wind directions, the incoming wind would be downwahsed to ventilate western part of Au Pui Wan Street under Baseline Scheme, shown as purple circled area in Figure 40.

On the other hand, under Proposed Scheme, due to the 20m setback from Au Pui Wan Street, the downwashed wind would ventilate the Landscape Garden within the Study Site, the open space between the proposed Development and adjacent CDA School and the eastern part of Au Pui Wan Street, shown as purple area in Figure 41. The shift of wind corridor result in insignificant impact on the ventilation performance under E wind direction.

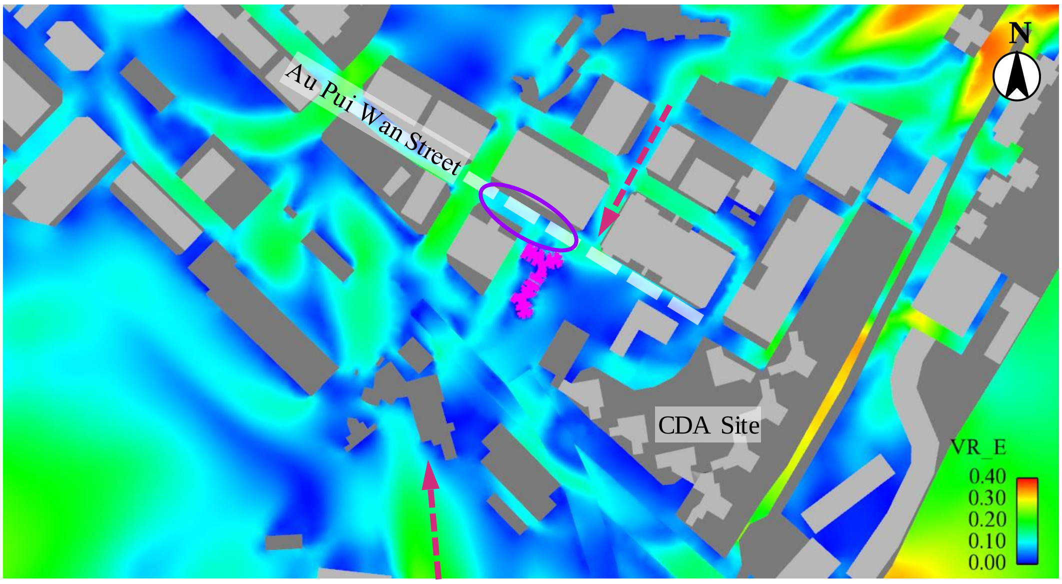


Figure 40 VR contour plot for Baseline Scheme under E Wind

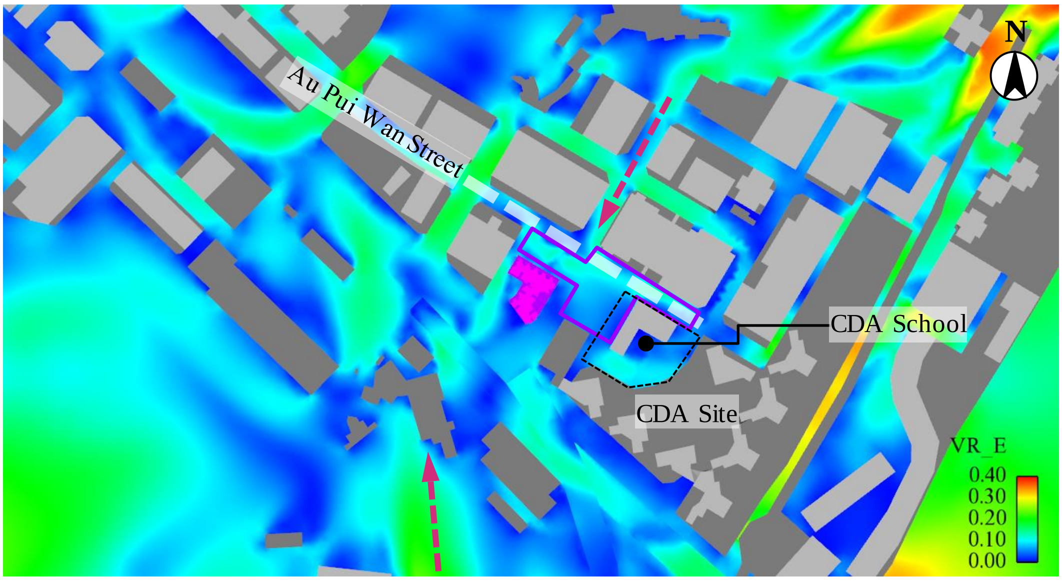


Figure 41 VR contour plot for Proposed Scheme under E Wind

6.2.5 ESE/SE Wind

Under ESE wind, most of the incoming wind would be shielded by the high-rise buildings in adjacent CDA site, which would dominate the wind environment in the surrounding area. The overall ventilation performance would be similar for both Baseline and Proposed Scheme while the VR near the proposed development would be slightly affected.

Under Baseline Scheme, due to the wider building separation between Tao Miao Institute and proposed development, the wind coming from Fo Tan Road (shown as pink arrow in Figure 42 and Figure 43) would enter the site through the NBA with some acceleration when travelling around the building corner, shown as black arrow in Figure 42.

On contrary, under Proposed Scheme, more wind would travel along the building separation along the western site boundary, shown as black arrow in Figure 43. Hence, the VR at the building separation between Unison Industrial Building and proposed Development would be slightly higher. Similar ventilation performance were observed under both Baseline and Proposed Scheme.

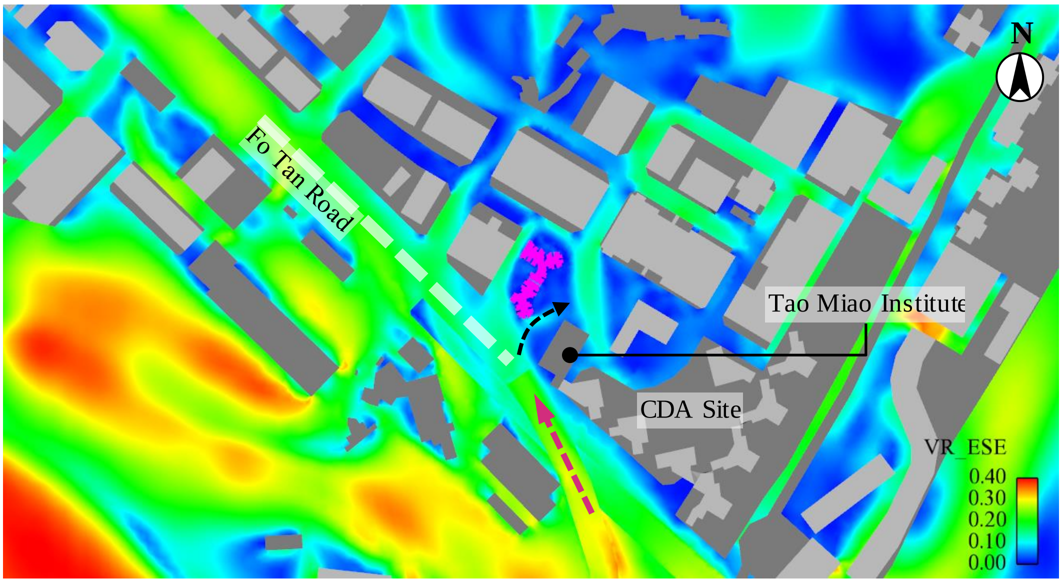


Figure 42 VR contour plot for Baseline Scheme under ESE Wind

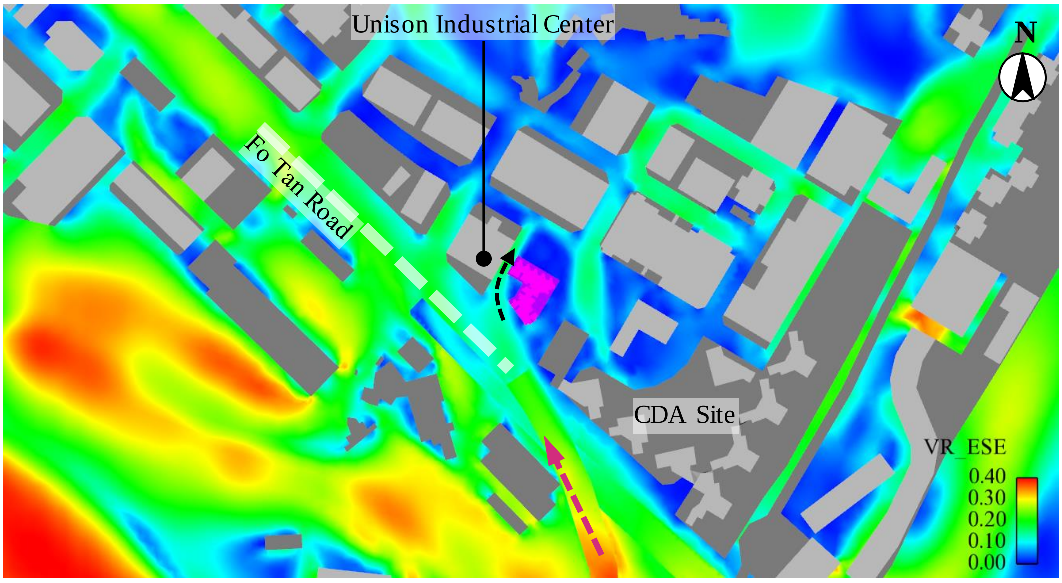


Figure 43 VR contour plot for Proposed Scheme under ESE Wind

6.2.6 SSE Wind

The incoming wind would travel along Min Fong Street, Fo Tan Road and through some of the building separation in adjacent CDA Site and building separation between the Unison Industrial Center and proposed development, shown as blue arrows in Figure 44 and Figure 45. The stream of air entering the Au Pui Wan Street would be diverted sideways by the Valiant Industrial Centre, shown as black arrows in Figure 44 and Figure 45.

Under Baseline Scheme, the air stream from building separation within the adjacent CDA site would meet the diverted air stream from Valiant Industrial Centre, where counter flow would occur, highlighted in purple circled area in Figure 44. Hence, relatively VR would be observed around Tao Miao Institute and CDA School.

Under Proposed Scheme, the stream of air through the building separation within CDA site would be diverted by the industrial buildings along Au Pui Wan Street (shown as pink arrow in Figure 45), which would slightly enhance the VR at the CDA School and the north-eastern corner of the Study Site. In addition, due to the slightly longer facade length along Fo Tan Road under Proposed Scheme, more wind would be diverted towards Min Fong Road hence the slightly higher VR were observed.

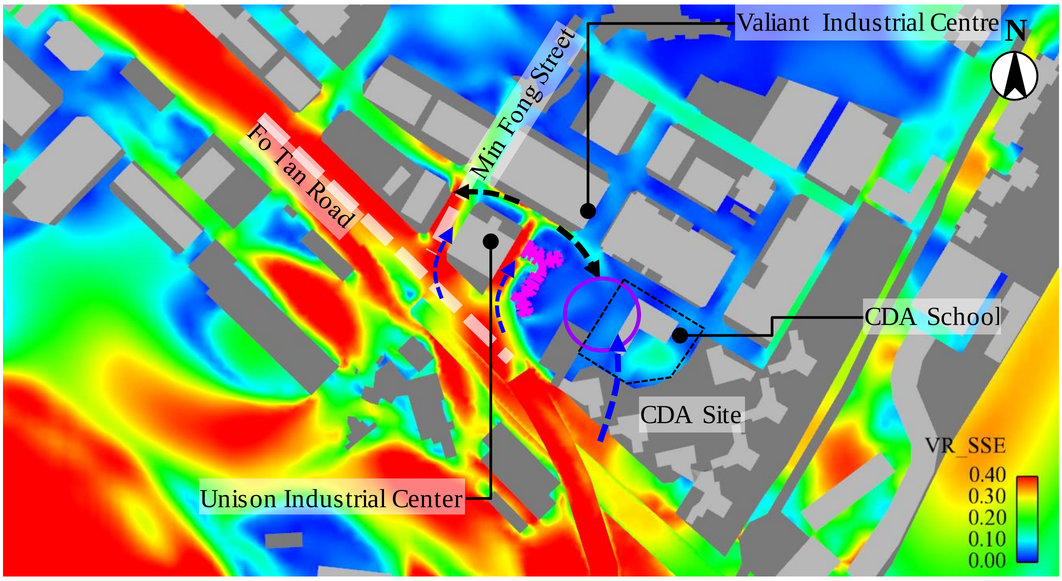


Figure 44 VR contour plot for Baseline Scheme under SSE Wind

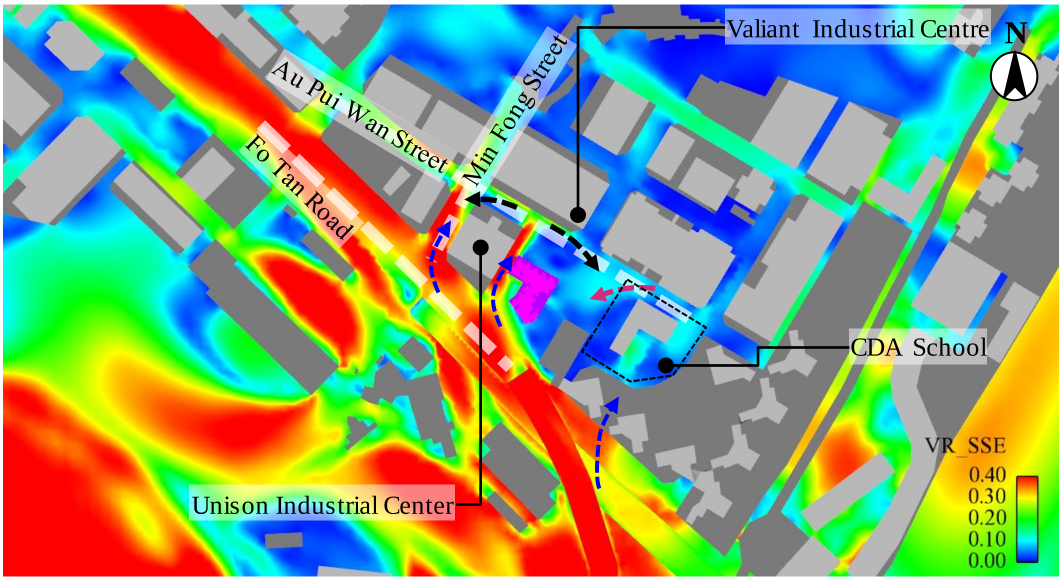


Figure 45 VR contour plot for Proposed Scheme under SSE Wind

6.2.7 S/SSW Wind

The incoming south wind would skim over the low-rise village building to the south of the study site. The overall ventilation performance would be similar under both Baseline and Proposed Scheme with some difference at localized areas.

Due to the shift of NBA, the proposed wind would be diverted towards the CDA School in Proposed Scheme, shown as blue arrow in Figure 47. Hence the VR at adjacent CDA School and eastern part of Au Pui Wan Street would be slightly higher. In addition, due to the setback of 20m from Au Pui Wan Street, the air stream entered the site from the building separation along the western site boundary would travel along Wo Liu Hang Street (shown as black arrow in in Figure 47), where slightly higher VR were observed.

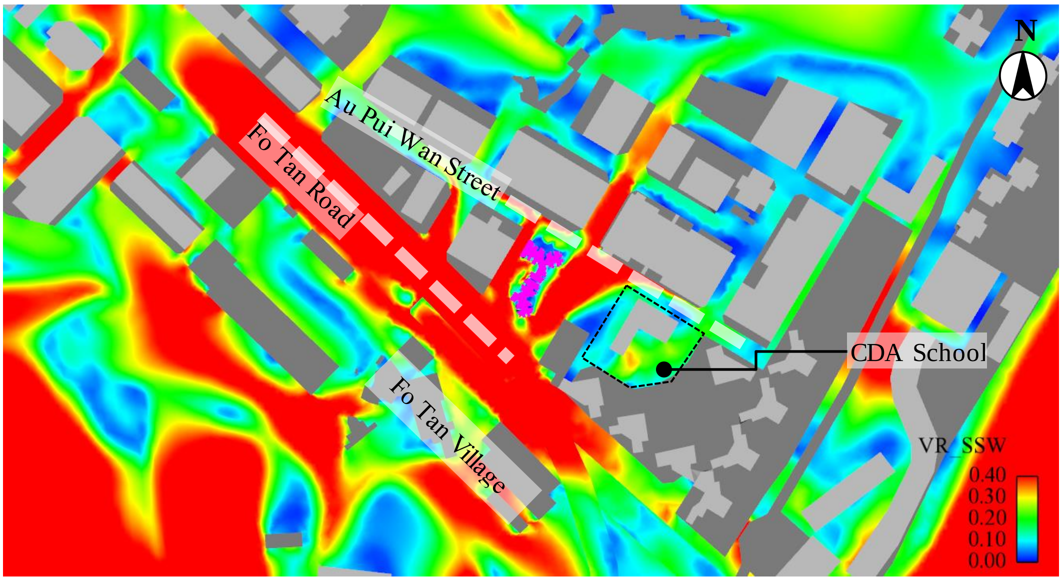


Figure 46 VR contour plot for Baseline Scheme under SSW Wind

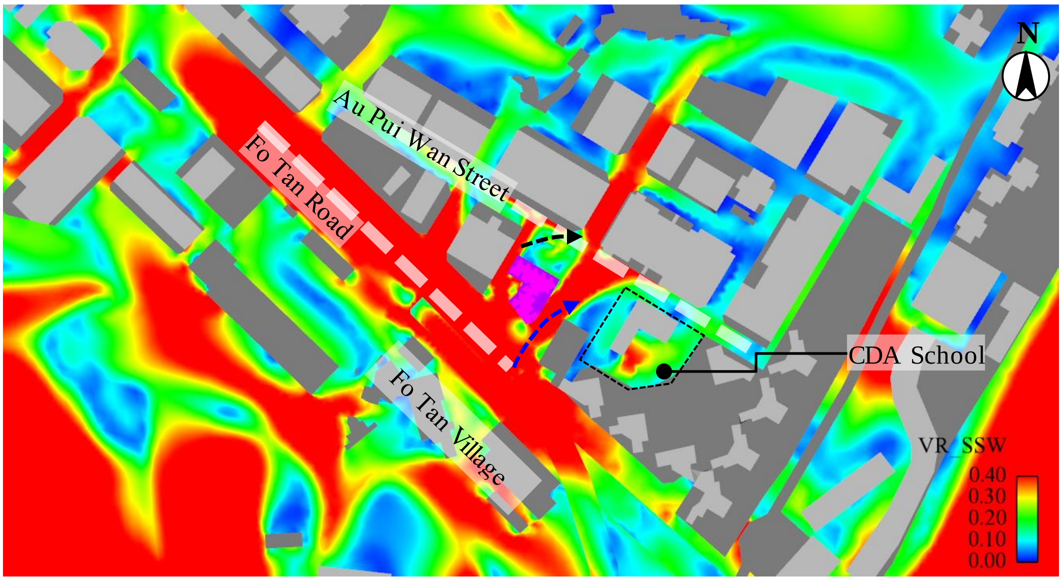


Figure 47 VR contour plot for Proposed Scheme under SSW Wind

6.2.8 SW/WSW Wind

The incoming wind would be reach the proposed development and downwashed by the south-west facing facade towards the pedestrian level.

As the south-west facing facade would be slightly larger in Proposed Scheme, more wind would reach the pedestrian level, shown as purple circled area in Figure 49. The downwashed wind would then be diverted towards Fo Tan Raod, Au Pui Wan Street and CDA school site through the building separation, where slightly higher VR at Fo Tan Road and around Fo Tan Village were observed.

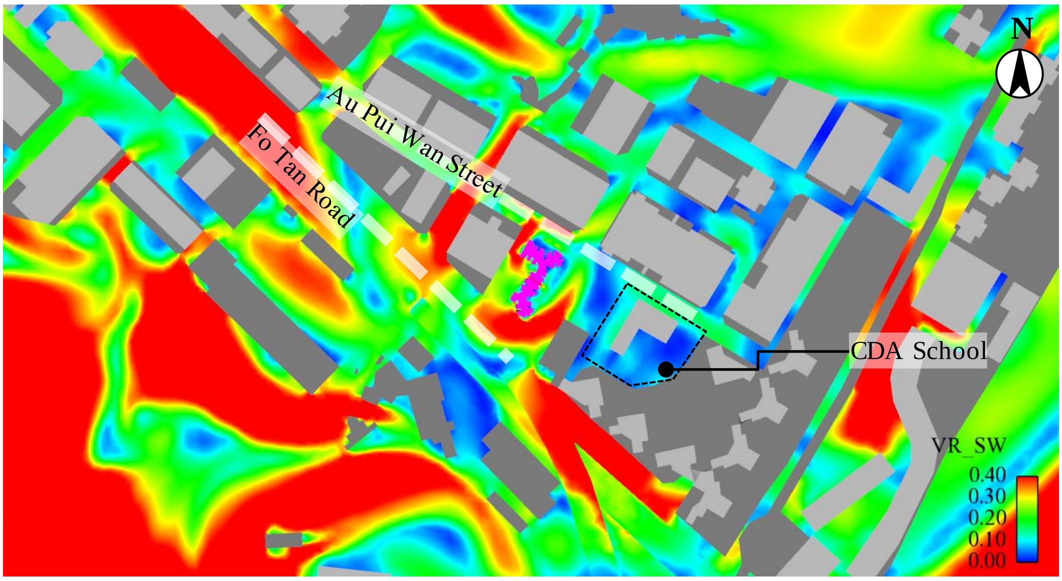


Figure 48 VR contour plot for Baseline Scheme under SW Wind

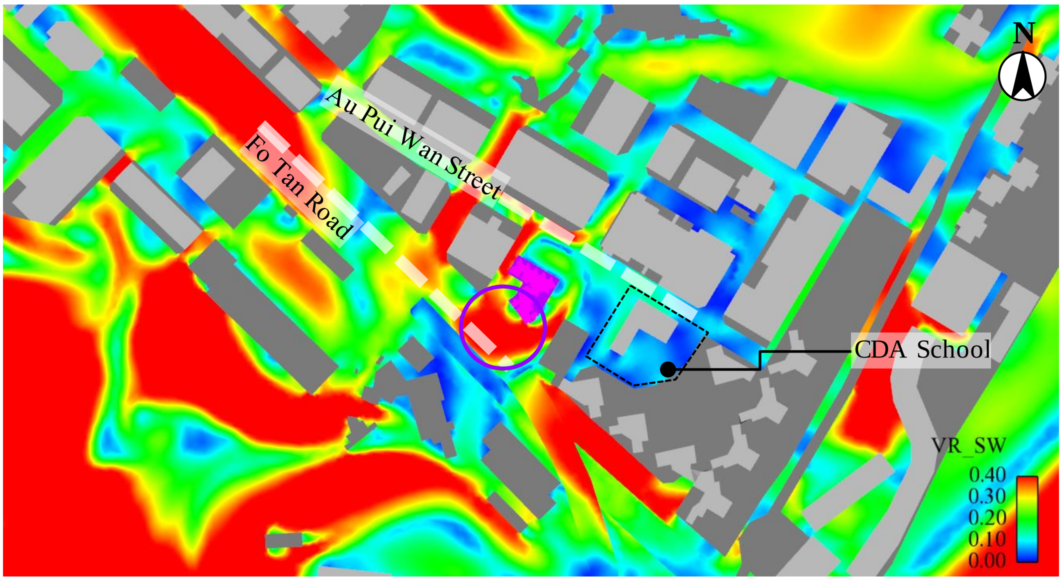


Figure 49 VR contour plot for Proposed Scheme under SW Wind

6.3 Focus Area

Various Focus Areas with frequent pedestrian access and within major activity zones were defined, as shown in Section 5.7. Detailed VR of each test points shown in Appendix A.

The average VR for the Focus Areas under annual and summer conditions respectively are presented below.

Table 8 Focus Area Results under Annual Condition

		Annual Condition		Summer Condition	
Focus Areas		Baseline Scheme	Proposed Scheme	Baseline Scheme	Proposed Scheme
1	Wo Shing Street	0.09	0.09	0.09	0.09
2	Au Pui Wan Street	0.10	0.09	0.12	0.13
3	Fo Tan Road	0.18	0.19	0.25	0.26
4	Cycling Track	0.13	0.13	0.24	0.24
5	Wo Heung Street	0.08	0.07	0.09	0.08
6	School	0.06	0.06	0.08	0.08
7	Wo Liu Hang Street	0.12	0.12	0.15	0.16
8	Wo Liu Hang Village	0.07	0.07	0.08	0.08
9	Min Fong Street	0.17	0.17	0.23	0.24
10	Shan Mei Street	0.14	0.15	0.18	0.18
11	Fo Tan Bus Terminus and Sitting Area	0.14	0.14	0.21	0.21
12	Shan Mei Street's Children Playground	0.14	0.15	0.17	0.17
13	Fo Tan Village Footpath 1	0.16	0.16	0.21	0.21
14	Fo Tan Village Footpath 2	0.15	0.14	0.19	0.20
15	Non-Building Area (NBA)	0.12	0.12	0.24	0.24

Under annual condition, the high-rise residential buildings in adjacent CDA site and various industrial buildings at upwind location would dominate the wind environment in surrounding area. Thus, most of the focus areas achieved a similar VR values indicating their ventilation performance is similar between Baseline and Proposed Scheme.

Majority of the incoming wind are from E/NE direction. The larger frontage area under northeast quadrant wind and the layout of the proposed building in Baseline Scheme, would divert the wind to travel along Au Pui Wan Street, where slightly higher VR were observed at some upwind locations such as Au Pui Wan Street and Wo Heung Street. On the other hand, the additional 20m set back from Au Pui Wan Street would divert the wind to travel through the building separations to reach the leeward side of the proposed building. Hence, slightly higher VR were observed at Fo Tan Road and Shan Mei Street. Similar VR were observed at the Non-Building Area (NBA).

Similar to annual condition, the overall ventilation performance were similar in both schemes. The majority of the summer prevailing wind are from southwest quadrants. Due to the larger frontage area facing southwest direction, more wind would be downwashed towards pedestrian level, which would then be diverted to Fo Tan Road and around Fo Tan Village at upwind area as well as towards Au Pui Wan Street and Wo Liu Hang Street at leeward side. The VR were found to be slightly higher at these areas. Similar VR were observed at the Non-Building Area (NBA).

7 Conclusion

The major findings of this study could be summarized as follows:

- Under annual condition, the Proposed Scheme achieved a slightly higher SVR, indicating that slightly better ventilation performance at immediate surroundings of the Development as compared to Baseline Scheme.
- Under annual condition, the high-rise building in the adjacent CDA site and dense industrial buildings to the northeast of the Development site would dominate the wind environment. Similar LVR were achieved for both Baseline and Proposed Scheme, indicating similar ventilation performance would be similar for both schemes.
- Under summer condition, the Proposed Scheme achieved a slightly higher SVR, indicating that slightly better ventilation performance at immediate surroundings of the Development as compared to Baseline Scheme.
- Under summer condition, due to the larger frontage area facing southwest direction under Proposed Scheme, more wind would be downwashed towards pedestrian level. Slightly higher LVR were observed in Proposed Scheme, indicating slightly better ventilation performance in local area under Proposed Scheme.
- The impact of shifting of NBA would be insignificant under both annual and summer condition.

Appendix A

Velocity Ratio Table of the Test Points

A1 Baseline Scheme

A1.1 Preliminary Test Points

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	10.6%	11.2%	10.7%	16.6%	9.8%	5.3%			8.0%	8.4%		80.6%	
Frequency Summer				7.6%	7.9%	5.9%	8.0%	9.1%	16.5%	20.7%	5.7%		81.4%
P1	0.14	0.18	0.10	0.09	0.14	0.12	0.46	0.51	0.73	0.57	0.20	0.19	0.36
P2	0.16	0.22	0.15	0.11	0.03	0.05	0.03	0.03	0.04	0.14	0.31	0.10	0.07
P3	0.10	0.06	0.03	0.05	0.01	0.01	0.01	0.12	0.24	0.20	0.37	0.07	0.12
P4	0.07	0.26	0.17	0.15	0.01	0.05	0.04	0.15	0.27	0.27	0.36	0.13	0.15
P5	0.09	0.26	0.19	0.15	0.02	0.06	0.03	0.08	0.14	0.19	0.39	0.12	0.11
P6	0.16	0.19	0.16	0.12	0.11	0.08	0.03	0.25	0.41	0.14	0.41	0.14	0.17
P7	0.17	0.18	0.14	0.10	0.15	0.10	0.02	0.31	0.54	0.20	0.41	0.15	0.21
P8	0.16	0.15	0.10	0.07	0.15	0.10	0.06	0.28	0.52	0.05	0.41	0.12	0.17
P9	0.17	0.11	0.08	0.06	0.05	0.03	0.09	0.20	0.42	0.02	0.30	0.09	0.13
P10	0.03	0.09	0.05	0.04	0.08	0.05	0.04	0.23	0.44	0.02	0.25	0.07	0.13
P11	0.06	0.06	0.05	0.03	0.13	0.08	0.04	0.12	0.22	0.06	0.22	0.06	0.09
P12	0.09	0.07	0.06	0.03	0.14	0.09	0.04	0.13	0.19	0.04	0.22	0.07	0.09
P13	0.08	0.06	0.04	0.03	0.11	0.08	0.04	0.11	0.18	0.06	0.07	0.06	0.07
P14	0.08	0.07	0.05	0.02	0.09	0.08	0.05	0.22	0.36	0.22	0.08	0.09	0.15
P15	0.05	0.07	0.08	0.03	0.06	0.06	0.05	0.29	0.43	0.48	0.41	0.11	0.23
P16	0.03	0.10	0.10	0.03	0.03	0.02	0.03	0.24	0.37	0.45	0.46	0.10	0.21
P17	0.04	0.11	0.14	0.05	0.04	0.03	0.02	0.16	0.27	0.35	0.42	0.10	0.16
P18	0.04	0.12	0.15	0.06	0.04	0.02	0.03	0.10	0.20	0.28	0.33	0.09	0.13
P19	0.04	0.13	0.16	0.07	0.04	0.01	0.04	0.09	0.17	0.23	0.24	0.09	0.11
P20	0.07	0.15	0.18	0.09	0.03	0.03	0.10	0.15	0.25	0.19	0.43	0.10	0.14
P21	0.05	0.12	0.16	0.08	0.06	0.05	0.12	0.29	0.46	0.23	0.51	0.11	0.20

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	**10.6%**	**11.2%**	**10.7%**	**16.6%**	**9.8%**	**5.3%**			**8.0%**	**8.4%**		**80.6%**	
Frequency Summer				**7.6%**	**7.9%**	**5.9%**	**8.0%**	**9.1%**	**16.5%**	**20.7%**	**5.7%**		**81.4%**
P22	0.04	0.11	0.15	0.07	0.10	0.06	0.15	0.30	0.46	0.25	0.49	0.11	0.21
P23	0.05	0.09	0.14	0.07	0.11	0.06	0.13	0.27	0.37	0.43	0.44	0.12	0.23
P24	0.01	0.03	0.11	0.07	0.13	0.14	0.28	0.27	0.40	0.47	0.32	0.12	0.25
P25	0.02	0.08	0.03	0.03	0.13	0.15	0.29	0.27	0.44	0.42	0.19	0.11	0.24
P26	0.02	0.15	0.11	0.10	0.13	0.17	0.32	0.28	0.46	0.36	0.14	0.14	0.24
P27	0.10	0.17	0.13	0.12	0.12	0.21	0.34	0.26	0.44	0.34	0.13	0.15	0.23
P28	0.10	0.18	0.14	0.10	0.10	0.19	0.30	0.22	0.40	0.35	0.12	0.14	0.22
P29	0.10	0.17	0.17	0.12	0.12	0.18	0.38	0.28	0.40	0.29	0.10	0.15	0.22
P30	0.12	0.18	0.19	0.13	0.14	0.18	0.42	0.40	0.57	0.26	0.14	0.17	0.26
P31	0.15	0.21	0.21	0.14	0.15	0.18	0.46	0.48	0.68	0.23	0.18	0.18	0.28
P32	0.15	0.23	0.22	0.15	0.16	0.17	0.46	0.47	0.66	0.30	0.15	0.19	0.29
P33	0.17	0.22	0.20	0.14	0.17	0.18	0.49	0.50	0.71	0.59	0.23	0.22	0.37
P34	0.15	0.17	0.15	0.10	0.16	0.15	0.48	0.51	0.73	0.64	0.20	0.21	0.38

A1.2 Overall Test Points

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	10.6%	11.2%	10.7%	16.6%	9.8%	5.3%			8.0%	8.4%		80.6%	
Frequency Summer				7.6%	7.9%	5.9%	8.0%	9.1%	16.5%	20.7%	5.7%		81.4%
O1	0.02	0.14	0.13	0.01	0.10	0.06	0.06	0.05	0.08	0.03	0.11	0.06	0.05
O2	0.06	0.14	0.07	0.06	0.08	0.07	0.01	0.03	0.06	0.24	0.03	0.07	0.08
O3	0.10	0.17	0.07	0.11	0.06	0.05	0.13	0.24	0.14	0.22	0.19	0.09	0.13
O4	0.04	0.16	0.04	0.13	0.08	0.03	0.02	0.01	0.19	0.20	0.09	0.09	0.10
O5	0.16	0.21	0.15	0.16	0.08	0.05	0.04	0.05	0.10	0.14	0.11	0.11	0.08
O6	0.18	0.19	0.08	0.14	0.06	0.06	0.04	0.02	0.08	0.18	0.06	0.10	0.08
O7	0.11	0.17	0.05	0.11	0.08	0.07	0.04	0.17	0.38	0.13	0.20	0.11	0.14
O8	0.16	0.18	0.14	0.14	0.15	0.10	0.00	0.09	0.13	0.11	0.18	0.12	0.09
O9	0.18	0.20	0.13	0.14	0.17	0.11	0.04	0.09	0.13	0.03	0.06	0.11	0.07
O10	0.14	0.13	0.10	0.11	0.15	0.10	0.04	0.10	0.12	0.13	0.18	0.10	0.10
O11	0.21	0.05	0.07	0.07	0.08	0.07	0.04	0.07	0.04	0.15	0.15	0.07	0.07
O12	0.11	0.18	0.15	0.12	0.02	0.04	0.18	0.23	0.14	0.23	0.18	0.10	0.13
O13	0.15	0.07	0.14	0.08	0.02	0.05	0.28	0.31	0.30	0.20	0.12	0.10	0.16
O14	0.09	0.28	0.19	0.18	0.12	0.21	0.25	0.35	0.15	0.42	0.18	0.16	0.21
O15	0.11	0.14	0.10	0.09	0.01	0.03	0.08	0.13	0.14	0.07	0.24	0.07	0.08
O16	0.16	0.19	0.09	0.09	0.02	0.03	0.14	0.22	0.27	0.15	0.34	0.10	0.14
O17	0.13	0.15	0.08	0.09	0.08	0.01	0.03	0.06	0.07	0.28	0.44	0.09	0.12
O18	0.17	0.27	0.15	0.13	0.12	0.09	0.11	0.18	0.32	0.10	0.47	0.14	0.15
O19	0.24	0.16	0.13	0.10	0.04	0.02	0.03	0.25	0.47	0.09	0.22	0.12	0.15
O20	0.26	0.08	0.07	0.09	0.05	0.03	0.03	0.10	0.13	0.16	0.32	0.09	0.10
O21	0.27	0.02	0.03	0.02	0.03	0.03	0.05	0.03	0.01	0.16	0.47	0.06	0.07
O22	0.21	0.09	0.10	0.07	0.04	0.04	0.06	0.08	0.21	0.18	0.49	0.09	0.12
O23	0.05	0.03	0.05	0.06	0.02	0.06	0.05	0.06	0.06	0.13	0.35	0.04	0.08
O24	0.45	0.30	0.05	0.13	0.20	0.22	0.35	0.38	0.58	0.04	0.12	0.19	0.21

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	10.6%	11.2%	10.7%	16.6%	9.8%	5.3%			8.0%	8.4%		80.6%	
Frequency Summer				7.6%	7.9%	5.9%	8.0%	9.1%	16.5%	20.7%	5.7%		81.4%
O25	0.46	0.26	0.06	0.12	0.20	0.18	0.34	0.37	0.60	0.27	0.11	0.20	0.26
O26	0.42	0.18	0.07	0.11	0.17	0.22	0.35	0.36	0.62	0.35	0.06	0.20	0.27
O27	0.35	0.17	0.19	0.11	0.17	0.25	0.34	0.33	0.59	0.26	0.04	0.19	0.25
O28	0.25	0.15	0.06	0.09	0.11	0.29	0.41	0.29	0.54	0.31	0.10	0.16	0.25
O29	0.17	0.06	0.14	0.09	0.16	0.26	0.44	0.36	0.53	0.15	0.33	0.14	0.24
O30	0.12	0.14	0.14	0.07	0.09	0.26	0.40	0.39	0.52	0.37	0.38	0.15	0.28
O31	0.16	0.18	0.11	0.06	0.10	0.29	0.39	0.34	0.46	0.42	0.22	0.16	0.27
O32	0.10	0.10	0.02	0.04	0.11	0.31	0.39	0.29	0.39	0.49	0.36	0.13	0.27
O33	0.12	0.13	0.03	0.01	0.08	0.27	0.31	0.22	0.30	0.50	0.39	0.12	0.24
O34	0.10	0.11	0.03	0.03	0.10	0.29	0.28	0.18	0.27	0.45	0.39	0.12	0.23
O35	0.09	0.09	0.03	0.02	0.01	0.17	0.22	0.05	0.23	0.39	0.34	0.09	0.17
O36	0.18	0.15	0.04	0.02	0.14	0.10	0.04	0.09	0.11	0.07	0.13	0.08	0.07
O37	0.25	0.16	0.08	0.09	0.05	0.08	0.07	0.10	0.12	0.10	0.39	0.10	0.09
O38	0.06	0.06	0.04	0.07	0.04	0.01	0.08	0.11	0.27	0.01	0.26	0.06	0.09
O39	0.08	0.03	0.09	0.10	0.01	0.02	0.11	0.17	0.30	0.07	0.28	0.07	0.12
O40	0.10	0.05	0.04	0.06	0.09	0.04	0.06	0.10	0.12	0.05	0.14	0.06	0.07
O41	0.06	0.04	0.05	0.04	0.05	0.03	0.05	0.06	0.05	0.07	0.16	0.04	0.05
O42	0.20	0.01	0.18	0.09	0.15	0.04	0.06	0.14	0.34	0.04	0.06	0.10	0.11
O43	0.16	0.05	0.14	0.07	0.17	0.04	0.08	0.16	0.36	0.16	0.12	0.11	0.14
O44	0.15	0.16	0.12	0.14	0.10	0.08	0.06	0.23	0.45	0.19	0.24	0.14	0.18
O45	0.12	0.09	0.10	0.11	0.12	0.08	0.05	0.25	0.49	0.28	0.28	0.13	0.20
O46	0.05	0.25	0.12	0.07	0.02	0.06	0.07	0.18	0.05	0.15	0.15	0.08	0.08
O47	0.08	0.10	0.09	0.09	0.07	0.05	0.06	0.08	0.26	0.31	0.05	0.10	0.14
O48	0.06	0.08	0.11	0.02	0.04	0.04	0.02	0.04	0.07	0.03	0.05	0.04	0.03
O49	0.10	0.05	0.11	0.06	0.03	0.02	0.04	0.04	0.06	0.20	0.04	0.06	0.07
O50	0.13	0.31	0.17	0.16	0.03	0.11	0.15	0.30	0.16	0.33	0.22	0.14	0.17

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	10.6%	11.2%	10.7%	16.6%	9.8%	5.3%			8.0%	8.4%		80.6%	
Frequency Summer				7.6%	7.9%	5.9%	8.0%	9.1%	16.5%	20.7%	5.7%		81.4%
O51	0.10	0.30	0.21	0.18	0.04	0.15	0.23	0.37	0.23	0.35	0.31	0.16	0.20
O52	0.18	0.28	0.24	0.21	0.15	0.22	0.41	0.47	0.43	0.49	0.17	0.21	0.30
O53	0.08	0.25	0.22	0.19	0.16	0.24	0.41	0.43	0.58	0.42	0.07	0.20	0.30
O54	0.21	0.08	0.07	0.09	0.23	0.28	0.37	0.13	0.28	0.22	0.09	0.13	0.18
O55	0.14	0.27	0.12	0.14	0.22	0.25	0.24	0.32	0.27	0.24	0.15	0.16	0.19
O56	0.19	0.29	0.11	0.09	0.28	0.32	0.41	0.25	0.12	0.22	0.13	0.15	0.18
O57	0.25	0.15	0.08	0.04	0.28	0.25	0.40	0.18	0.18	0.22	0.12	0.13	0.17
O58	0.10	0.05	0.00	0.14	0.17	0.21	0.39	0.20	0.40	0.10	0.18	0.11	0.18
O59	0.09	0.27	0.13	0.11	0.26	0.33	0.44	0.34	0.06	0.36	0.18	0.15	0.21
O60	0.09	0.22	0.13	0.08	0.28	0.34	0.44	0.35	0.09	0.39	0.19	0.15	0.22
O61	0.26	0.14	0.09	0.04	0.22	0.22	0.29	0.26	0.55	0.24	0.23	0.16	0.23
O62	0.16	0.27	0.11	0.11	0.14	0.15	0.12	0.12	0.24	0.24	0.13	0.14	0.15
O63	0.22	0.25	0.08	0.12	0.19	0.26	0.36	0.16	0.08	0.14	0.10	0.13	0.13
O64	0.27	0.15	0.02	0.12	0.25	0.30	0.44	0.32	0.48	0.18	0.08	0.16	0.23
O65	0.33	0.16	0.06	0.09	0.26	0.30	0.40	0.23	0.49	0.02	0.13	0.15	0.19
O66	0.31	0.13	0.15	0.05	0.16	0.14	0.20	0.26	0.52	0.03	0.35	0.14	0.18
O67	0.29	0.16	0.11	0.10	0.16	0.20	0.36	0.29	0.48	0.25	0.08	0.16	0.22
O68	0.24	0.19	0.09	0.12	0.20	0.22	0.35	0.26	0.42	0.30	0.07	0.17	0.22
O69	0.23	0.15	0.13	0.03	0.25	0.29	0.40	0.28	0.27	0.07	0.21	0.13	0.17
O70	0.21	0.15	0.19	0.02	0.18	0.21	0.29	0.21	0.23	0.07	0.12	0.12	0.13
O71	0.27	0.19	0.18	0.05	0.25	0.30	0.40	0.37	0.45	0.12	0.03	0.16	0.21
O72	0.18	0.16	0.12	0.09	0.27	0.28	0.37	0.34	0.45	0.20	0.31	0.16	0.24
O73	0.17	0.17	0.11	0.11	0.27	0.31	0.38	0.26	0.30	0.27	0.29	0.16	0.23
O74	0.17	0.19	0.08	0.12	0.23	0.29	0.32	0.20	0.32	0.14	0.20	0.14	0.18

A1.3 Special Test Points

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	**10.6%**	**11.2%**	**10.7%**	**16.6%**	**9.8%**	**5.3%**			**8.0%**	**8.4%**		**80.6%**	
Frequency Summer				**7.6%**	**7.9%**	**5.9%**	**8.0%**	**9.1%**	**16.5%**	**20.7%**	**5.7%**		**81.4%**
S1	0.08	0.10	0.04	0.03	0.03	0.08	0.03	0.36	0.60	0.15	0.23	0.10	0.19
S2	0.03	0.07	0.10	0.04	0.03	0.07	0.04	0.39	0.61	0.20	0.44	0.10	0.21
S3	0.03	0.06	0.20	0.07	0.03	0.06	0.04	0.43	0.64	0.27	0.54	0.12	0.25
S4	0.07	0.11	0.21	0.08	0.11	0.07	0.07	0.44	0.63	0.45	0.57	0.16	0.29
S5	0.08	0.11	0.15	0.07	0.05	0.04	0.01	0.30	0.41	0.49	0.50	0.13	0.24

A2 Proposed Scheme

A2.1 Preliminary Test Points

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	10.6%	11.2%	10.7%	16.6%	9.8%	5.3%			8.0%	8.4%		80.6%	
Frequency Summer				7.6%	7.9%	5.9%	8.0%	9.1%	16.5%	20.7%	5.7%		81.4%
P1	0.12	0.25	0.17	0.12	0.15	0.15	0.46	0.52	0.73	0.58	0.33	0.21	0.37
P2	0.14	0.24	0.17	0.11	0.02	0.03	0.10	0.10	0.16	0.34	0.35	0.12	0.15
P3	0.16	0.23	0.17	0.13	0.02	0.03	0.04	0.08	0.21	0.04	0.43	0.11	0.09
P4	0.19	0.25	0.19	0.13	0.02	0.02	0.05	0.17	0.37	0.07	0.44	0.13	0.13
P5	0.20	0.25	0.17	0.12	0.05	0.05	0.02	0.20	0.30	0.12	0.45	0.13	0.14
P6	0.18	0.25	0.17	0.13	0.11	0.08	0.02	0.06	0.23	0.13	0.47	0.13	0.12
P7	0.18	0.22	0.15	0.11	0.16	0.10	0.08	0.27	0.56	0.12	0.48	0.15	0.20
P8	0.17	0.21	0.15	0.11	0.15	0.10	0.08	0.33	0.56	0.14	0.45	0.15	0.21
P9	0.16	0.17	0.13	0.11	0.05	0.03	0.08	0.29	0.50	0.11	0.35	0.12	0.17
P10	0.02	0.12	0.07	0.07	0.08	0.05	0.10	0.28	0.40	0.08	0.28	0.08	0.15
P11	0.04	0.10	0.06	0.07	0.12	0.08	0.10	0.17	0.21	0.03	0.29	0.07	0.10
P12	0.06	0.08	0.05	0.06	0.13	0.09	0.08	0.07	0.07	0.01	0.27	0.05	0.06
P13	0.07	0.11	0.07	0.07	0.14	0.09	0.07	0.20	0.28	0.04	0.22	0.08	0.11
P14	0.06	0.12	0.08	0.06	0.09	0.08	0.05	0.35	0.53	0.29	0.08	0.12	0.20
P15	0.07	0.08	0.06	0.04	0.06	0.06	0.03	0.25	0.38	0.32	0.23	0.10	0.18
P16	0.03	0.09	0.06	0.03	0.03	0.06	0.06	0.31	0.47	0.53	0.40	0.11	0.25
P17	0.02	0.11	0.13	0.06	0.04	0.02	0.03	0.25	0.36	0.43	0.38	0.11	0.20
P18	0.02	0.12	0.15	0.07	0.06	0.02	0.03	0.23	0.37	0.32	0.31	0.11	0.18
P19	0.02	0.12	0.16	0.08	0.05	0.01	0.05	0.12	0.22	0.17	0.17	0.08	0.11
P20	0.07	0.16	0.20	0.11	0.03	0.06	0.14	0.27	0.43	0.11	0.48	0.11	0.17
P21	0.05	0.11	0.16	0.09	0.06	0.05	0.15	0.35	0.54	0.29	0.51	0.13	0.24
P22	0.05	0.08	0.11	0.08	0.12	0.13	0.30	0.28	0.43	0.42	0.44	0.13	0.25

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	**10.6%**	**11.2%**	**10.7%**	**16.6%**	**9.8%**	**5.3%**			**8.0%**	**8.4%**		**80.6%**	
Frequency Summer				**7.6%**	**7.9%**	**5.9%**	**8.0%**	**9.1%**	**16.5%**	**20.7%**	**5.7%**		**81.4%**
P23	0.02	0.07	0.03	0.07	0.11	0.09	0.26	0.23	0.35	0.47	0.38	0.11	0.24
P24	0.03	0.08	0.06	0.05	0.10	0.11	0.24	0.16	0.31	0.44	0.25	0.10	0.21
P25	0.02	0.12	0.11	0.05	0.13	0.16	0.29	0.23	0.42	0.39	0.13	0.12	0.22
P26	0.01	0.14	0.16	0.08	0.13	0.15	0.31	0.27	0.47	0.39	0.17	0.14	0.24
P27	0.14	0.18	0.19	0.12	0.13	0.20	0.33	0.24	0.44	0.39	0.24	0.17	0.24
P28	0.13	0.22	0.21	0.10	0.07	0.15	0.22	0.20	0.40	0.49	0.39	0.17	0.25
P29	0.18	0.25	0.23	0.13	0.12	0.20	0.37	0.23	0.35	0.31	0.27	0.17	0.22
P30	0.20	0.27	0.25	0.14	0.15	0.21	0.43	0.36	0.56	0.24	0.19	0.19	0.25
P31	0.22	0.25	0.23	0.13	0.18	0.20	0.46	0.44	0.67	0.52	0.33	0.22	0.35
P32	0.22	0.18	0.17	0.10	0.19	0.19	0.49	0.51	0.76	0.68	0.43	0.22	0.41
P33	0.13	0.12	0.09	0.06	0.17	0.13	0.46	0.50	0.73	0.62	0.33	0.18	0.38
P34	0.06	0.16	0.11	0.07	0.16	0.14	0.46	0.50	0.73	0.63	0.24	0.18	0.37

A2.2 Overall Test Points

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	10.6%	11.2%	10.7%	16.6%	9.8%	5.3%			8.0%	8.4%		80.6%	
Frequency Summer				7.6%	7.9%	5.9%	8.0%	9.1%	16.5%	20.7%	5.7%		81.4%
O1	0.02	0.14	0.13	0.02	0.10	0.07	0.05	0.05	0.09	0.05	0.10	0.06	0.05
O2	0.05	0.14	0.06	0.06	0.09	0.08	0.01	0.03	0.06	0.23	0.02	0.07	0.08
O3	0.10	0.16	0.08	0.10	0.05	0.06	0.15	0.26	0.15	0.27	0.24	0.10	0.15
O4	0.04	0.16	0.04	0.11	0.07	0.08	0.03	0.03	0.14	0.13	0.03	0.08	0.08
O5	0.17	0.21	0.15	0.16	0.07	0.07	0.04	0.00	0.08	0.14	0.01	0.11	0.07
O6	0.19	0.18	0.08	0.13	0.06	0.07	0.05	0.03	0.04	0.17	0.04	0.10	0.07
O7	0.11	0.16	0.05	0.11	0.08	0.07	0.03	0.20	0.43	0.09	0.24	0.11	0.14
O8	0.16	0.17	0.14	0.14	0.15	0.10	0.02	0.12	0.22	0.06	0.20	0.12	0.10
O9	0.17	0.19	0.12	0.14	0.17	0.11	0.01	0.09	0.11	0.02	0.07	0.11	0.07
O10	0.14	0.13	0.09	0.10	0.15	0.10	0.01	0.09	0.11	0.07	0.21	0.09	0.08
O11	0.18	0.04	0.07	0.05	0.08	0.07	0.05	0.05	0.06	0.06	0.22	0.06	0.06
O12	0.12	0.14	0.14	0.10	0.03	0.04	0.23	0.22	0.12	0.21	0.16	0.09	0.12
O13	0.16	0.03	0.12	0.05	0.01	0.05	0.30	0.29	0.30	0.18	0.10	0.08	0.15
O14	0.12	0.27	0.21	0.16	0.12	0.21	0.35	0.42	0.25	0.37	0.18	0.17	0.23
O15	0.04	0.10	0.09	0.07	0.01	0.01	0.02	0.08	0.06	0.14	0.23	0.06	0.07
O16	0.13	0.21	0.13	0.10	0.06	0.08	0.26	0.29	0.37	0.34	0.40	0.14	0.22
O17	0.06	0.06	0.05	0.04	0.07	0.02	0.03	0.04	0.08	0.37	0.42	0.07	0.13
O18	0.12	0.07	0.07	0.06	0.13	0.09	0.09	0.09	0.30	0.24	0.47	0.10	0.16
O19	0.25	0.17	0.11	0.08	0.04	0.01	0.08	0.32	0.51	0.12	0.23	0.13	0.17
O20	0.26	0.15	0.12	0.13	0.05	0.03	0.09	0.17	0.08	0.14	0.31	0.10	0.10
O21	0.26	0.09	0.09	0.12	0.05	0.04	0.07	0.07	0.10	0.10	0.43	0.09	0.09
O22	0.21	0.05	0.08	0.04	0.05	0.04	0.09	0.10	0.20	0.09	0.49	0.07	0.11
O23	0.05	0.03	0.05	0.04	0.01	0.07	0.03	0.05	0.03	0.06	0.37	0.03	0.05
O24	0.45	0.29	0.09	0.13	0.20	0.23	0.34	0.37	0.59	0.13	0.11	0.20	0.23

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	**10.6%**	**11.2%**	**10.7%**	**16.6%**	**9.8%**	**5.3%**			**8.0%**	**8.4%**		**80.6%**	
Frequency Summer				**7.6%**	**7.9%**	**5.9%**	**8.0%**	**9.1%**	**16.5%**	**20.7%**	**5.7%**		**81.4%**
O25	0.46	0.28	0.06	0.12	0.20	0.17	0.33	0.36	0.60	0.19	0.11	0.20	0.24
O26	0.42	0.25	0.11	0.06	0.18	0.23	0.35	0.37	0.61	0.37	0.05	0.20	0.27
O27	0.39	0.23	0.18	0.07	0.17	0.24	0.32	0.33	0.59	0.30	0.03	0.20	0.25
O28	0.30	0.15	0.12	0.08	0.11	0.29	0.40	0.29	0.53	0.43	0.09	0.18	0.27
O29	0.22	0.12	0.09	0.08	0.15	0.27	0.44	0.33	0.51	0.40	0.30	0.16	0.28
O30	0.14	0.14	0.14	0.08	0.08	0.25	0.39	0.40	0.50	0.32	0.38	0.15	0.27
O31	0.19	0.20	0.11	0.08	0.09	0.29	0.39	0.35	0.48	0.39	0.24	0.16	0.27
O32	0.10	0.11	0.05	0.04	0.11	0.31	0.39	0.29	0.38	0.44	0.35	0.13	0.26
O33	0.13	0.13	0.03	0.01	0.08	0.27	0.31	0.22	0.29	0.47	0.38	0.12	0.23
O34	0.11	0.12	0.03	0.05	0.10	0.28	0.28	0.18	0.27	0.44	0.38	0.12	0.22
O35	0.09	0.09	0.03	0.02	0.01	0.17	0.21	0.05	0.23	0.40	0.34	0.09	0.17
O36	0.13	0.15	0.04	0.01	0.14	0.10	0.06	0.11	0.11	0.11	0.16	0.07	0.08
O37	0.25	0.13	0.05	0.07	0.05	0.06	0.07	0.07	0.11	0.04	0.31	0.08	0.07
O38	0.07	0.07	0.07	0.07	0.05	0.01	0.10	0.10	0.25	0.02	0.23	0.06	0.09
O39	0.07	0.03	0.09	0.08	0.02	0.01	0.08	0.19	0.38	0.08	0.35	0.07	0.13
O40	0.09	0.05	0.01	0.05	0.07	0.03	0.01	0.07	0.10	0.07	0.18	0.05	0.06
O41	0.04	0.05	0.02	0.04	0.04	0.03	0.01	0.08	0.12	0.09	0.16	0.04	0.06
O42	0.20	0.01	0.18	0.09	0.16	0.04	0.06	0.18	0.40	0.04	0.07	0.11	0.12
O43	0.15	0.05	0.15	0.08	0.18	0.03	0.09	0.18	0.41	0.11	0.13	0.11	0.14
O44	0.15	0.15	0.12	0.14	0.10	0.09	0.05	0.25	0.52	0.18	0.28	0.14	0.19
O45	0.11	0.12	0.10	0.12	0.12	0.09	0.06	0.25	0.53	0.25	0.32	0.13	0.21
O46	0.05	0.25	0.13	0.06	0.03	0.06	0.07	0.18	0.06	0.15	0.12	0.08	0.08
O47	0.07	0.11	0.09	0.09	0.07	0.04	0.07	0.09	0.25	0.30	0.06	0.10	0.13
O48	0.06	0.09	0.11	0.03	0.03	0.04	0.03	0.01	0.05	0.08	0.07	0.05	0.04
O49	0.10	0.03	0.11	0.06	0.02	0.02	0.04	0.03	0.07	0.23	0.04	0.06	0.08
O50	0.14	0.31	0.17	0.15	0.02	0.03	0.16	0.33	0.18	0.35	0.29	0.14	0.18

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	10.6%	11.2%	10.7%	16.6%	9.8%	5.3%			8.0%	8.4%		80.6%	
Frequency Summer				7.6%	7.9%	5.9%	8.0%	9.1%	16.5%	20.7%	5.7%		81.4%
O51	0.12	0.31	0.22	0.18	0.01	0.02	0.24	0.40	0.21	0.31	0.33	0.14	0.19
O52	0.20	0.29	0.25	0.18	0.17	0.26	0.47	0.52	0.58	0.48	0.17	0.23	0.33
O53	0.11	0.25	0.22	0.16	0.16	0.26	0.44	0.46	0.62	0.40	0.09	0.20	0.31
O54	0.21	0.08	0.08	0.11	0.21	0.25	0.33	0.14	0.28	0.32	0.12	0.14	0.20
O55	0.15	0.29	0.12	0.15	0.22	0.25	0.25	0.30	0.28	0.08	0.14	0.15	0.16
O56	0.21	0.30	0.11	0.09	0.28	0.32	0.41	0.25	0.12	0.24	0.10	0.16	0.18
O57	0.26	0.15	0.08	0.03	0.28	0.25	0.40	0.18	0.18	0.25	0.11	0.13	0.18
O58	0.10	0.06	0.00	0.15	0.18	0.18	0.37	0.21	0.39	0.19	0.19	0.12	0.20
O59	0.09	0.29	0.13	0.11	0.27	0.33	0.45	0.33	0.07	0.31	0.16	0.15	0.20
O60	0.10	0.22	0.14	0.06	0.28	0.34	0.46	0.34	0.09	0.37	0.18	0.14	0.22
O61	0.23	0.21	0.10	0.05	0.21	0.22	0.30	0.29	0.50	0.26	0.10	0.16	0.22
O62	0.16	0.29	0.12	0.12	0.15	0.16	0.14	0.10	0.26	0.27	0.14	0.15	0.16
O63	0.23	0.26	0.09	0.11	0.19	0.26	0.36	0.16	0.08	0.21	0.09	0.14	0.14
O64	0.27	0.13	0.02	0.13	0.23	0.29	0.42	0.31	0.49	0.06	0.06	0.15	0.20
O65	0.32	0.15	0.02	0.11	0.26	0.30	0.40	0.23	0.49	0.11	0.13	0.16	0.21
O66	0.32	0.14	0.13	0.01	0.12	0.12	0.21	0.27	0.53	0.10	0.37	0.13	0.19
O67	0.32	0.17	0.13	0.10	0.14	0.17	0.34	0.29	0.48	0.18	0.09	0.16	0.20
O68	0.28	0.21	0.10	0.13	0.20	0.21	0.36	0.25	0.42	0.25	0.07	0.17	0.21
O69	0.19	0.13	0.08	0.06	0.25	0.29	0.40	0.27	0.27	0.10	0.20	0.12	0.17
O70	0.17	0.14	0.14	0.03	0.18	0.21	0.29	0.21	0.23	0.14	0.13	0.11	0.14
O71	0.24	0.19	0.17	0.05	0.25	0.30	0.41	0.37	0.44	0.19	0.03	0.16	0.22
O72	0.17	0.16	0.11	0.07	0.27	0.28	0.37	0.34	0.45	0.26	0.30	0.16	0.25
O73	0.16	0.17	0.11	0.10	0.27	0.31	0.38	0.26	0.30	0.30	0.29	0.16	0.23
O74	0.16	0.18	0.08	0.10	0.23	0.29	0.32	0.19	0.32	0.17	0.19	0.14	0.19

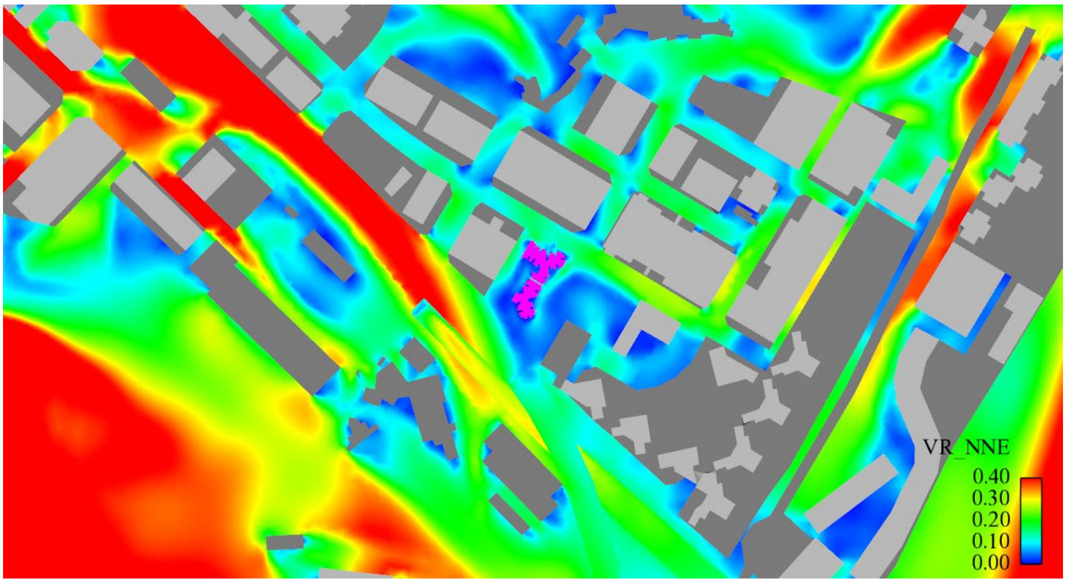
A2.3 Special Test Points

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	Annual	Summer
Frequency Annual	**10.6%**	**11.2%**	**10.7%**	**16.6%**	**9.8%**	**5.3%**			**8.0%**	**8.4%**		**80.6%**	
Frequency Summer				**7.6%**	**7.9%**	**5.9%**	**8.0%**	**9.1%**	**16.5%**	**20.7%**	**5.7%**		**81.4%**
S1	0.02	0.19	0.12	0.09	0.09	0.09	0.08	0.18	0.59	0.21	0.32	0.13	0.20
S2	0.07	0.12	0.07	0.06	0.04	0.08	0.07	0.39	0.70	0.18	0.31	0.12	0.23
S3	0.08	0.10	0.03	0.02	0.01	0.06	0.10	0.46	0.70	0.25	0.46	0.11	0.25
S4	0.08	0.09	0.10	0.04	0.05	0.07	0.04	0.43	0.66	0.32	0.55	0.12	0.26
S5	0.06	0.10	0.15	0.07	0.04	0.01	0.03	0.33	0.46	0.52	0.51	0.13	0.25

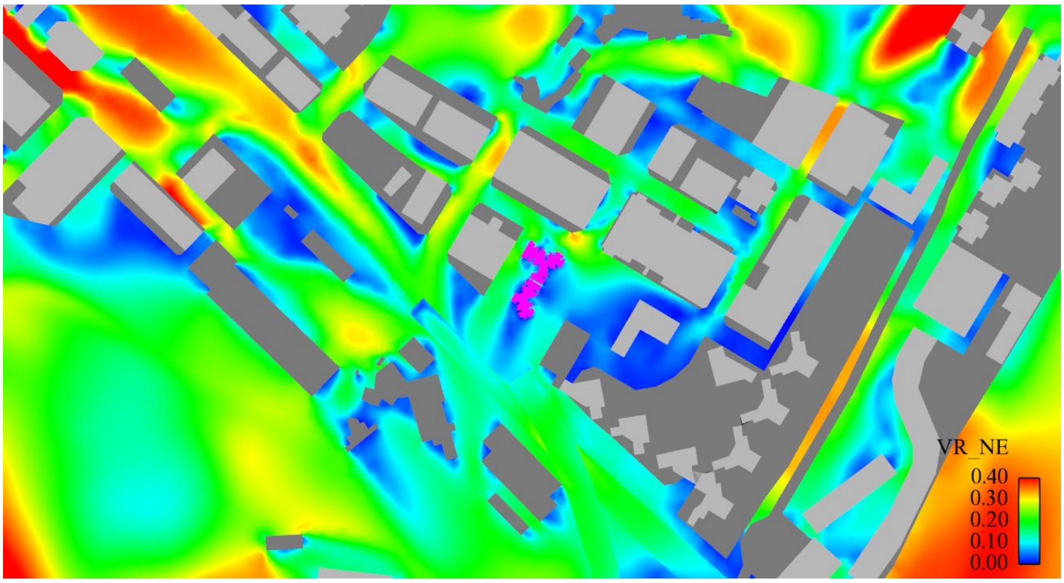
Appendix B

Directional VR Contour Plots

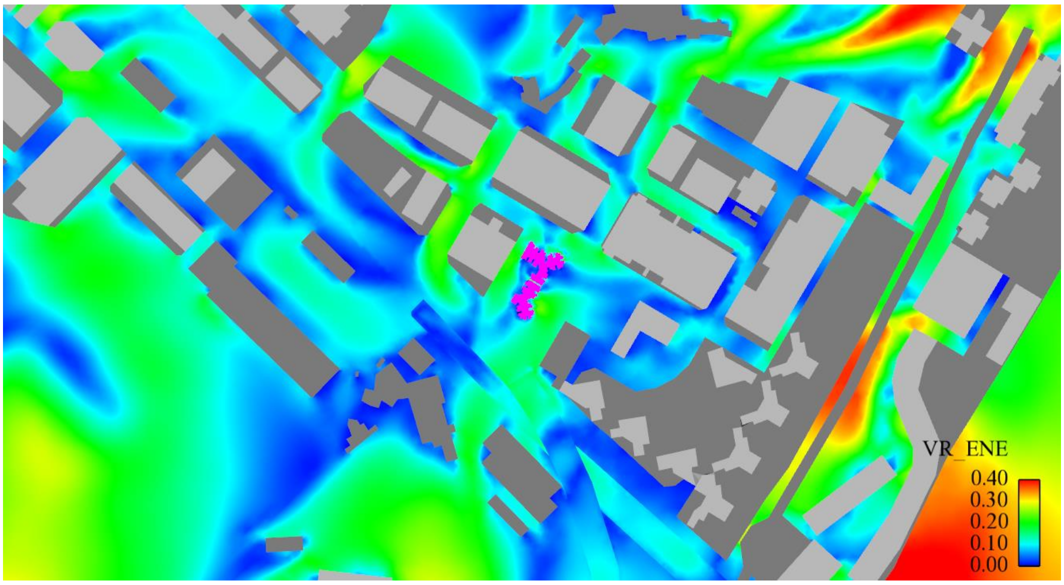
B1 Baseline Scheme



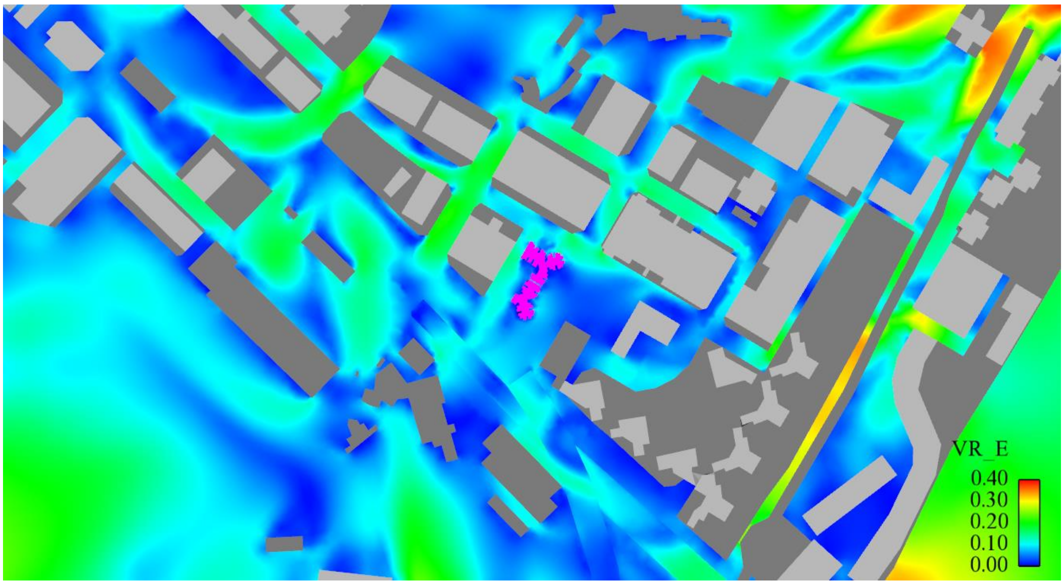
Contour Plots of Baseline Scheme under NNE Direction



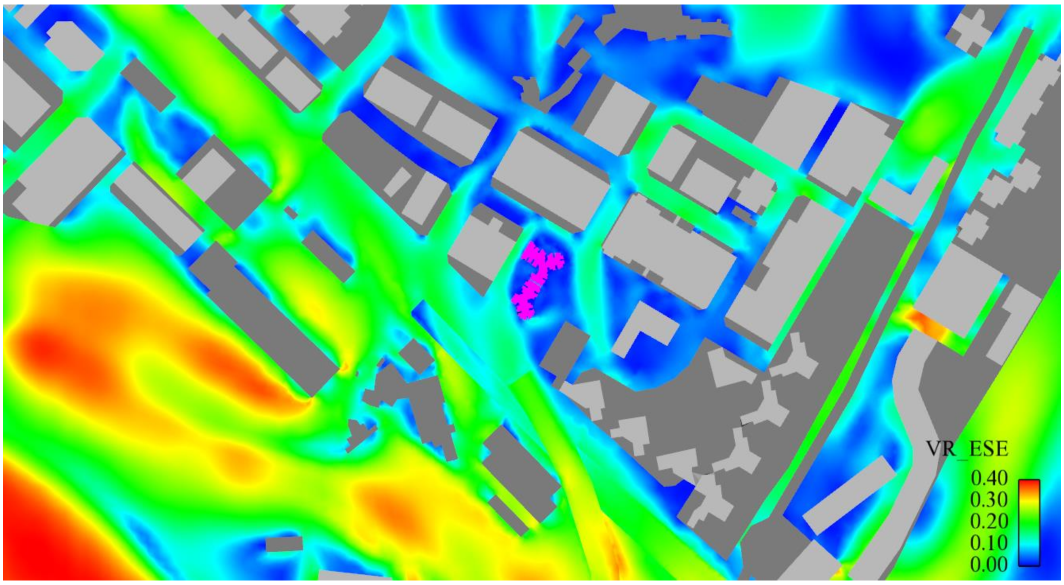
Contour Plots of Baseline Scheme under NE Direction



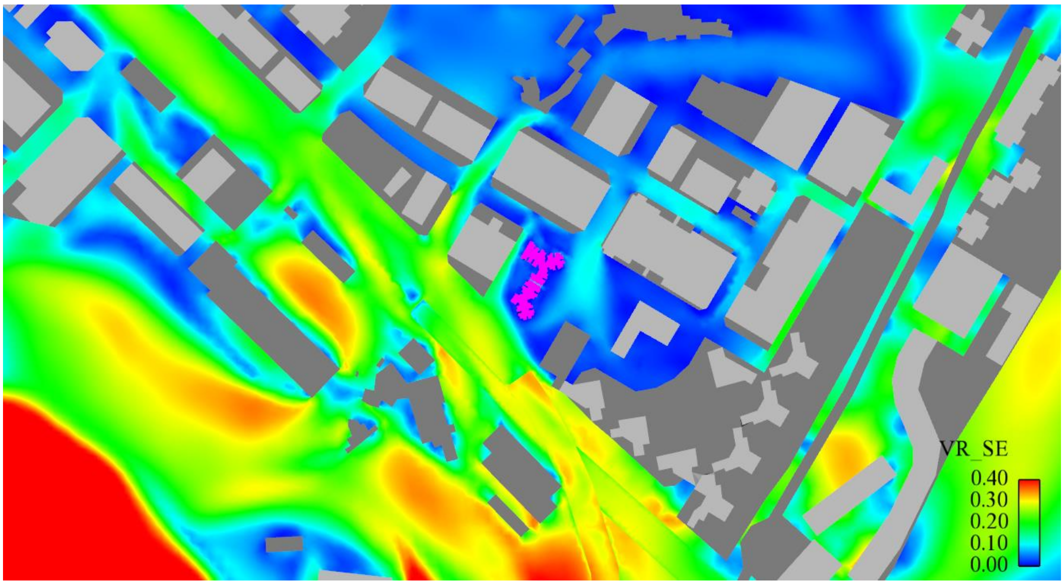
Contour Plots of Baseline Scheme under ENE Direction



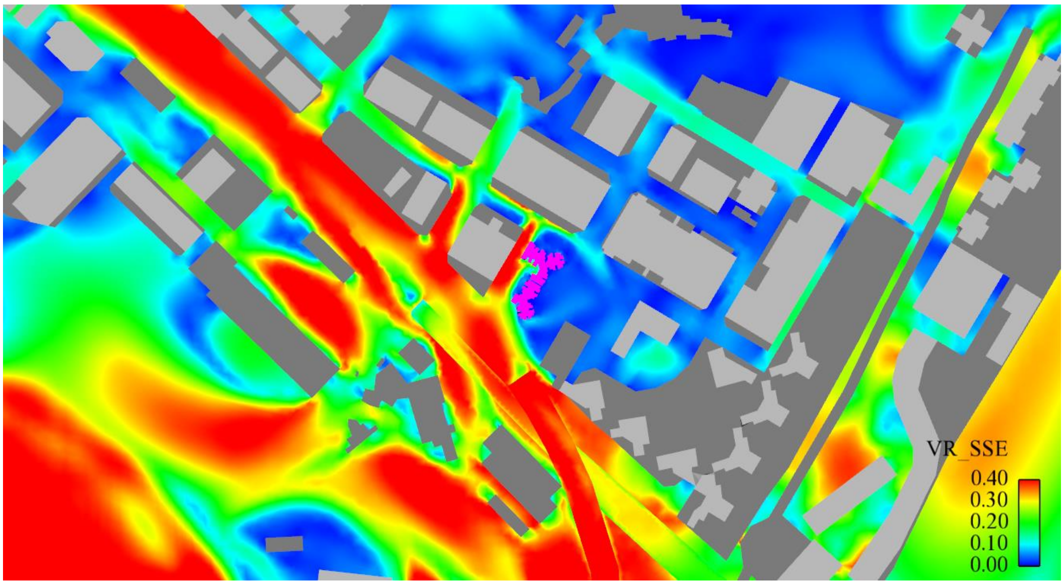
Contour Plots of Baseline Scheme under E Direction



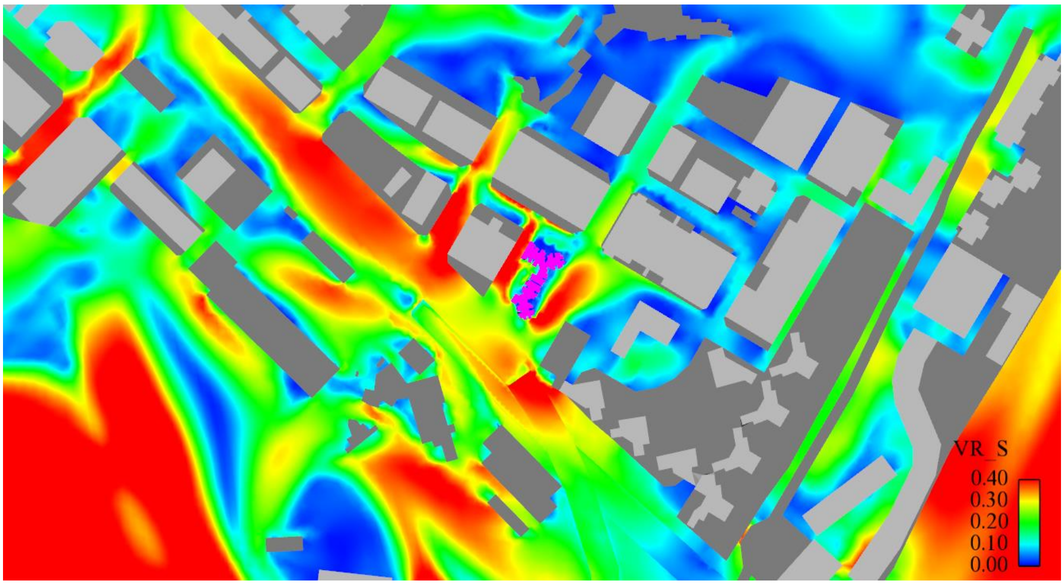
Contour Plots of Baseline Scheme under ESE Direction



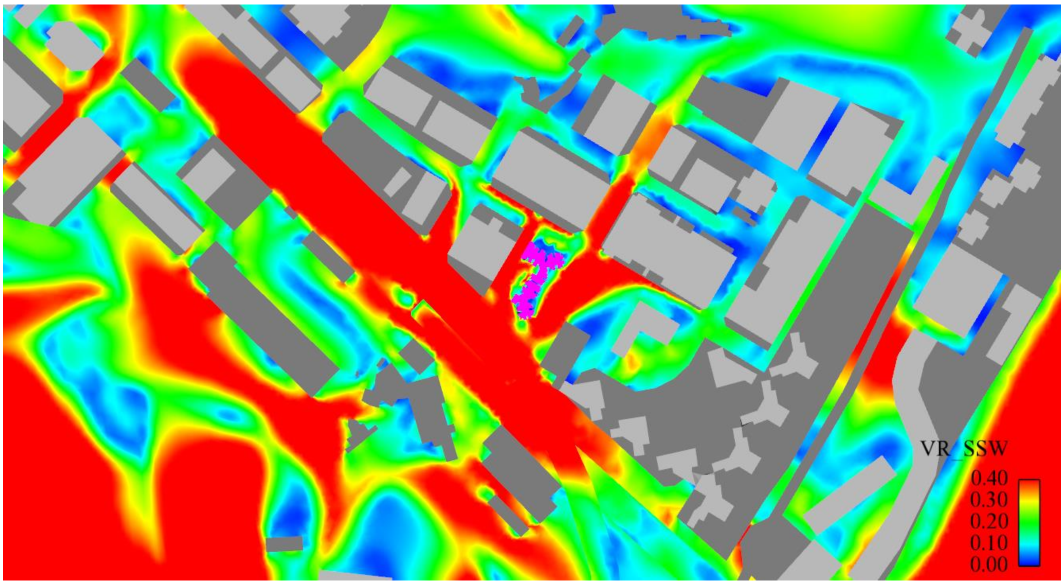
Contour Plots of Baseline Scheme under SE Direction



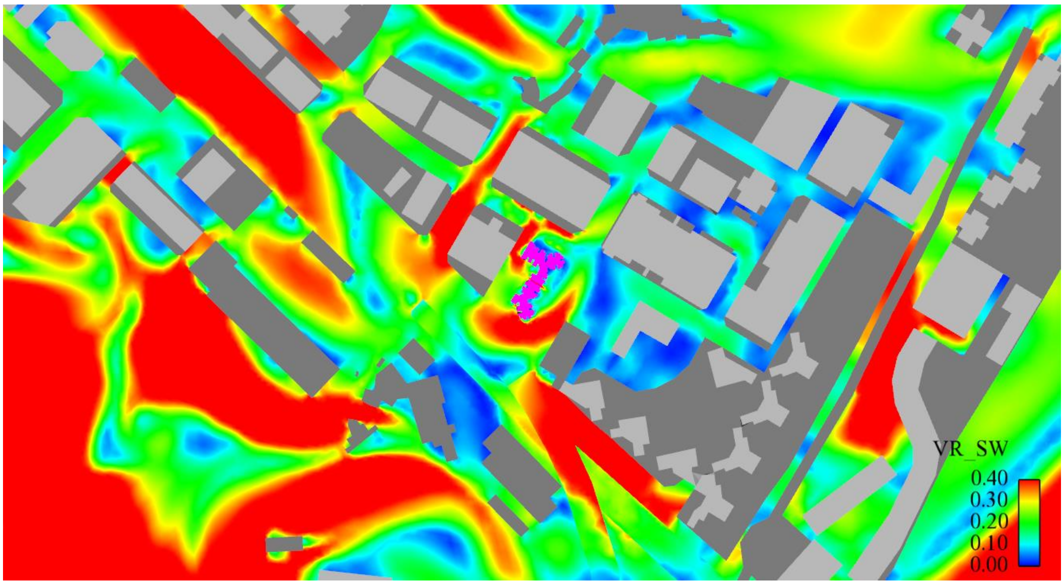
Contour Plots of Baseline Scheme under SSE Direction



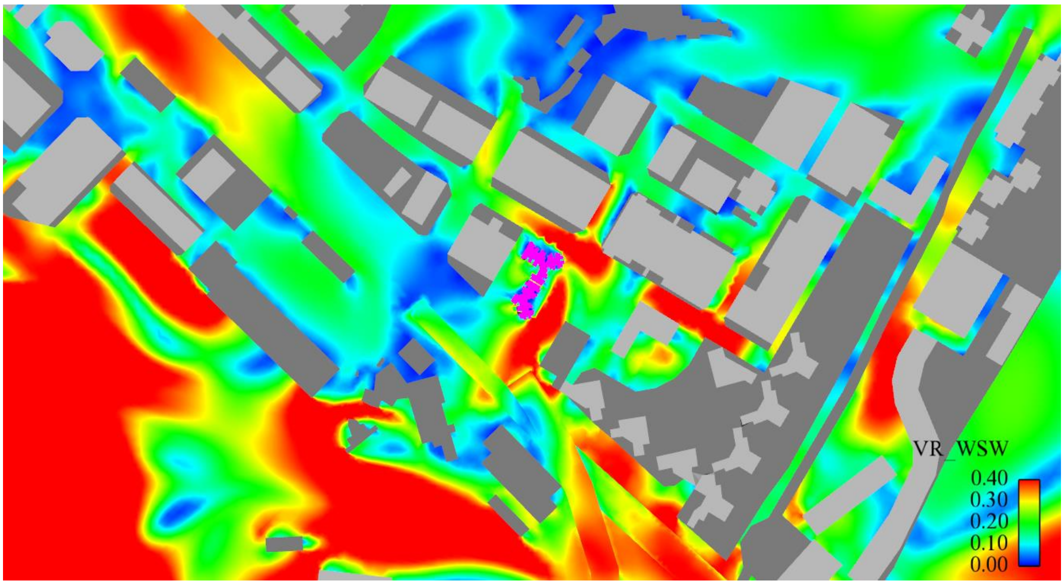
Contour Plots of Baseline Scheme under S Direction



Contour Plots of Baseline Scheme under SSW Direction

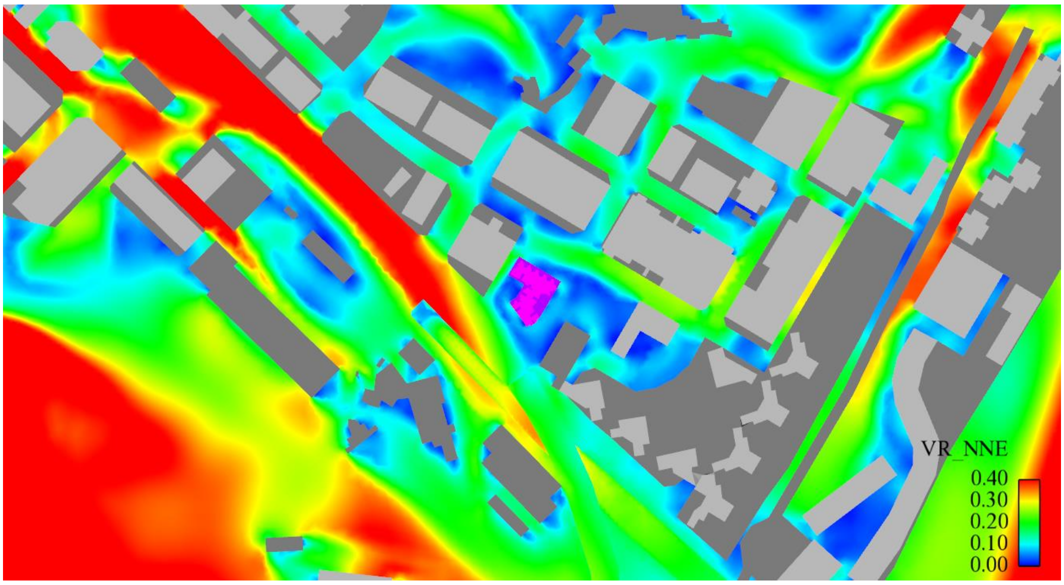


Contour Plots of Baseline Scheme under SW Direction

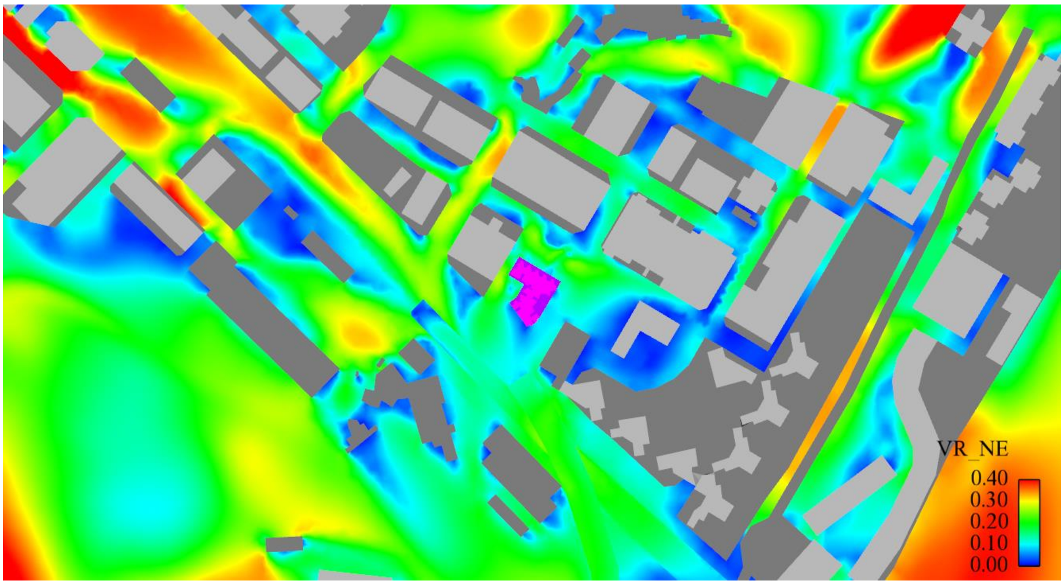


Contour Plots of Baseline Scheme under WSW Direction

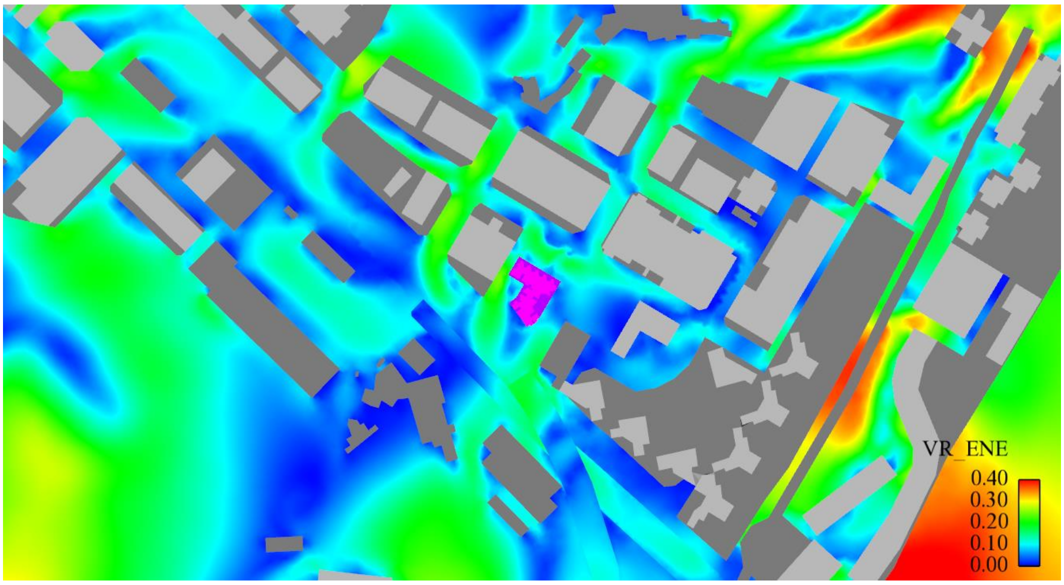
B2 Proposed Scheme



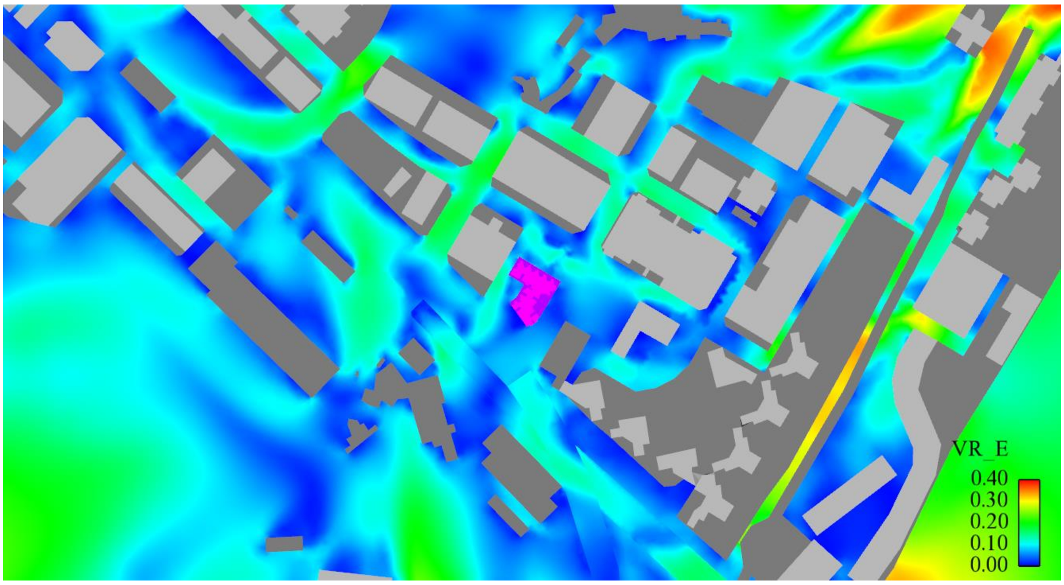
Contour Plots of Proposed Scheme under NNE Direction



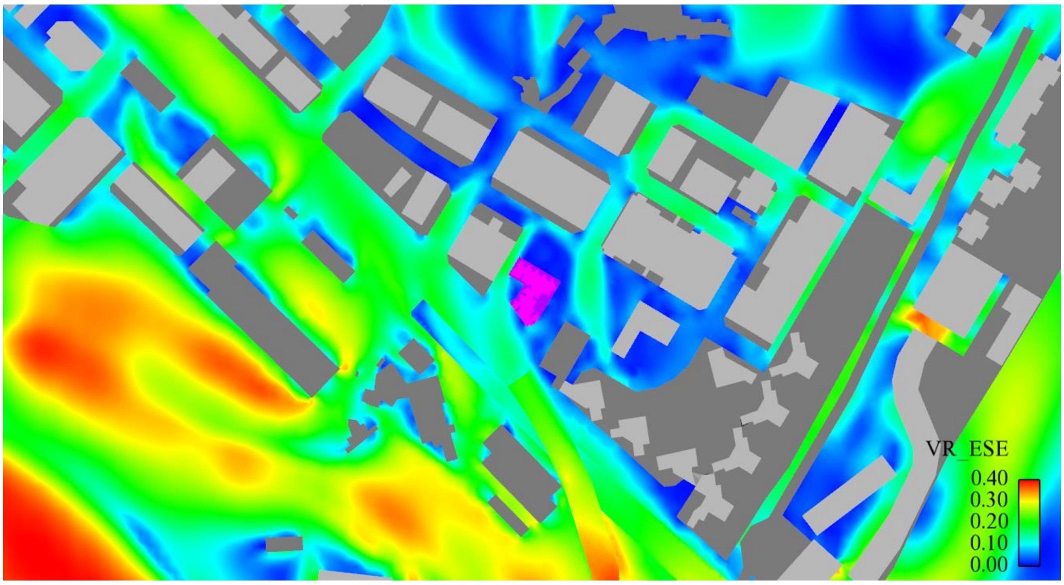
Contour Plots of Proposed Scheme under NE Direction



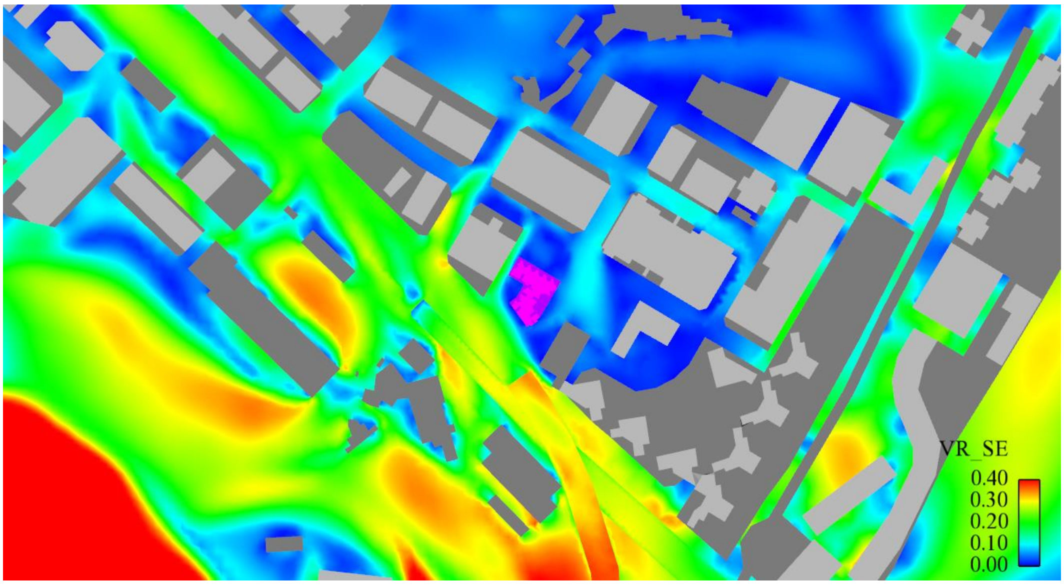
Contour Plots of Proposed Scheme under ENE Direction



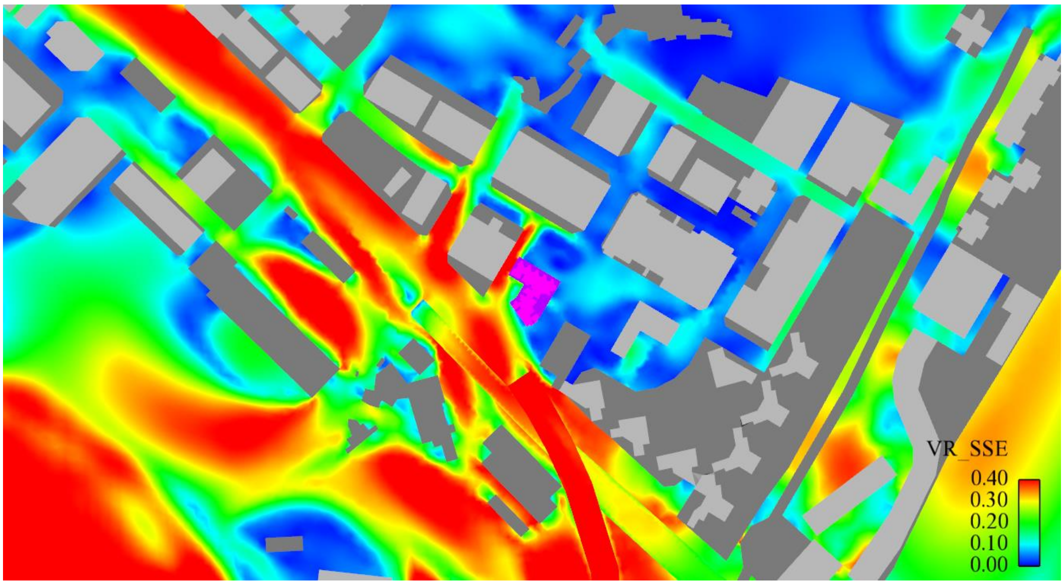
Contour Plots of Proposed Scheme under E Direction



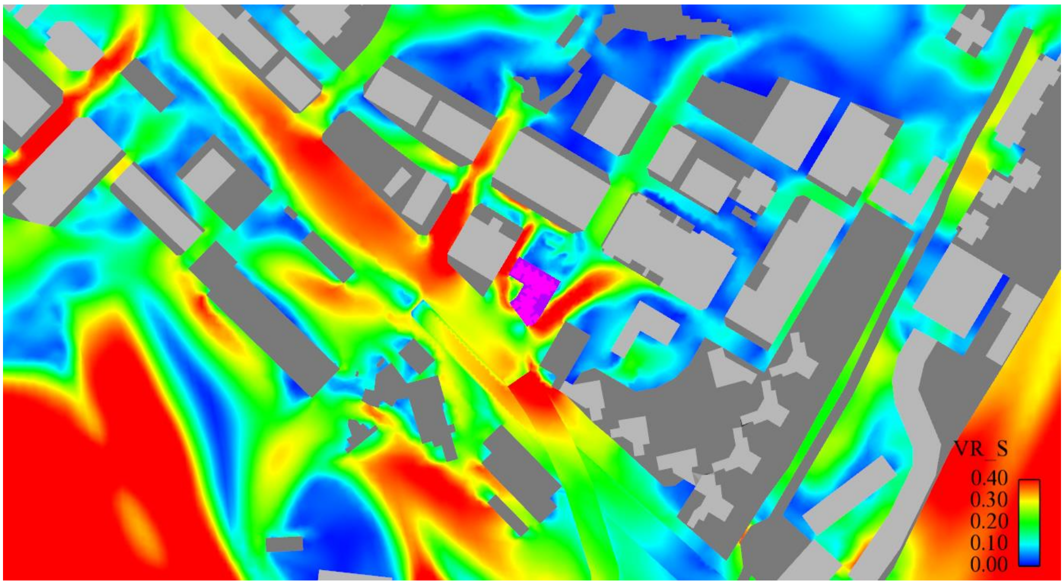
Contour Plots of Proposed Scheme under ESE Direction



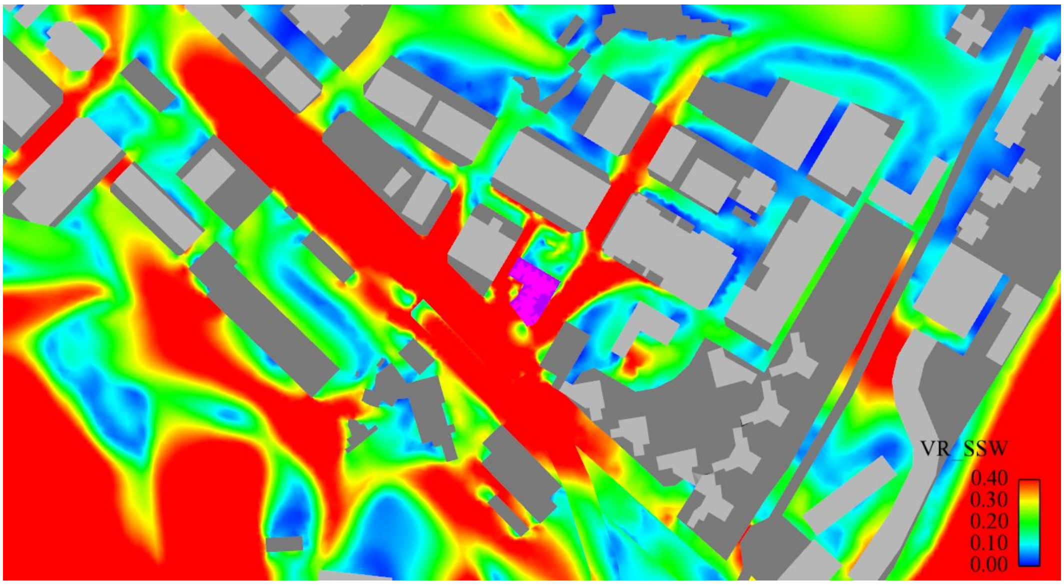
Contour Plots of Proposed Scheme under SE Direction



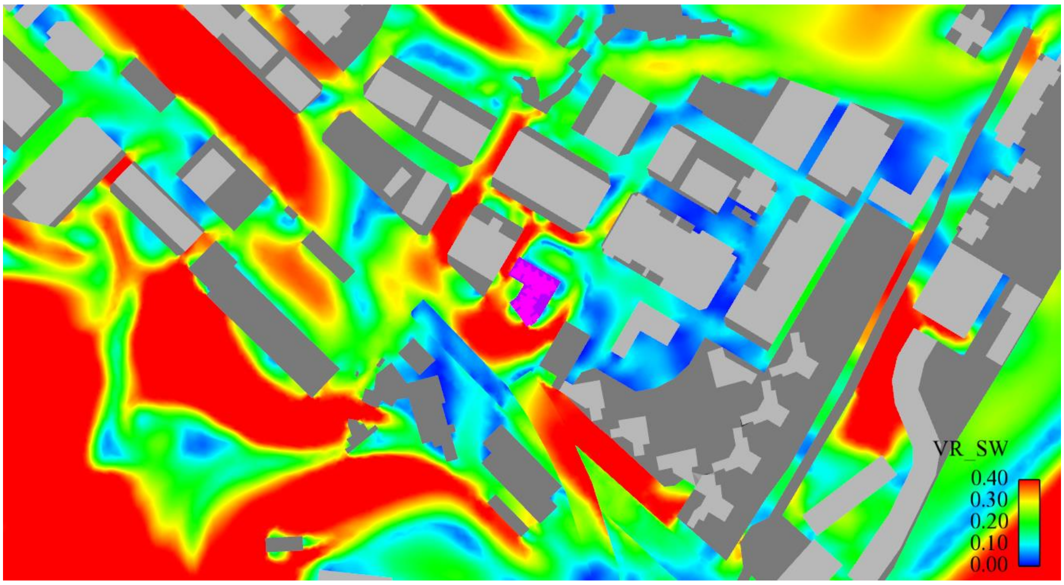
Contour Plots of Proposed Scheme under SSE Direction



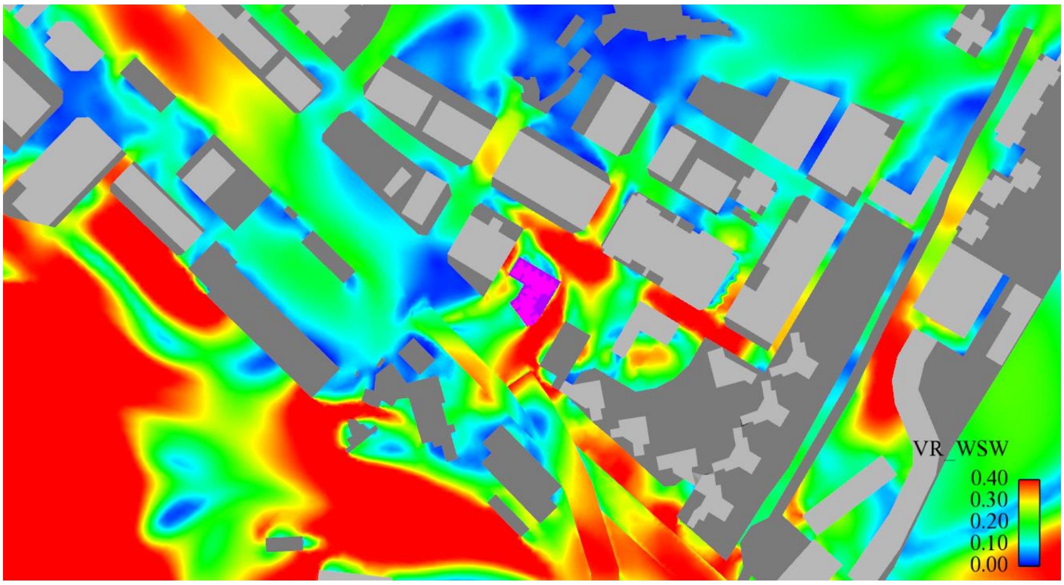
Contour Plots of Proposed Scheme under S Direction



Contour Plots of Proposed Scheme under SSW Direction



Contour Plots of Proposed Scheme under SW Direction

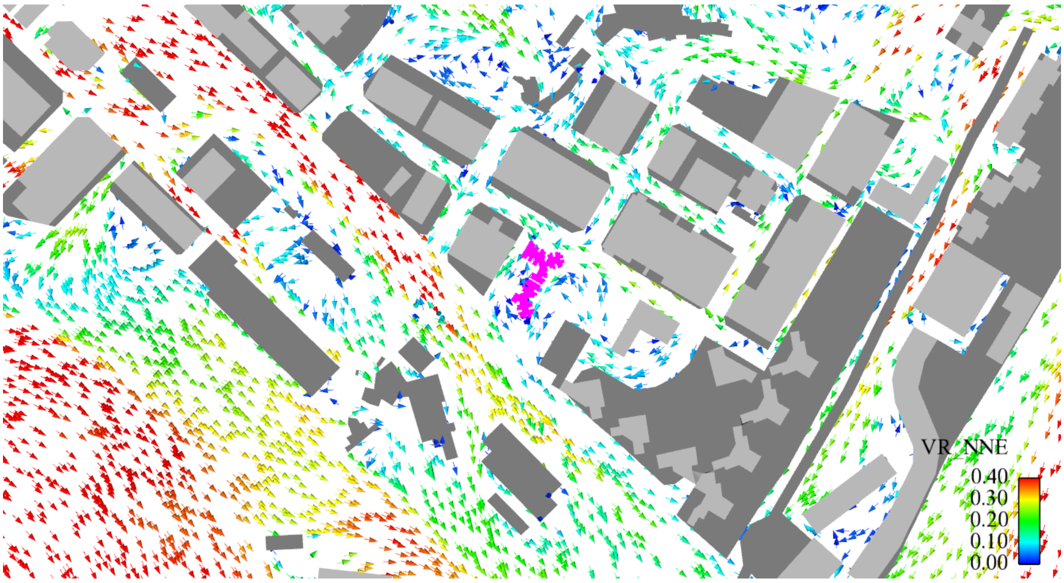


Contour Plots of Proposed Scheme under WSW Direction

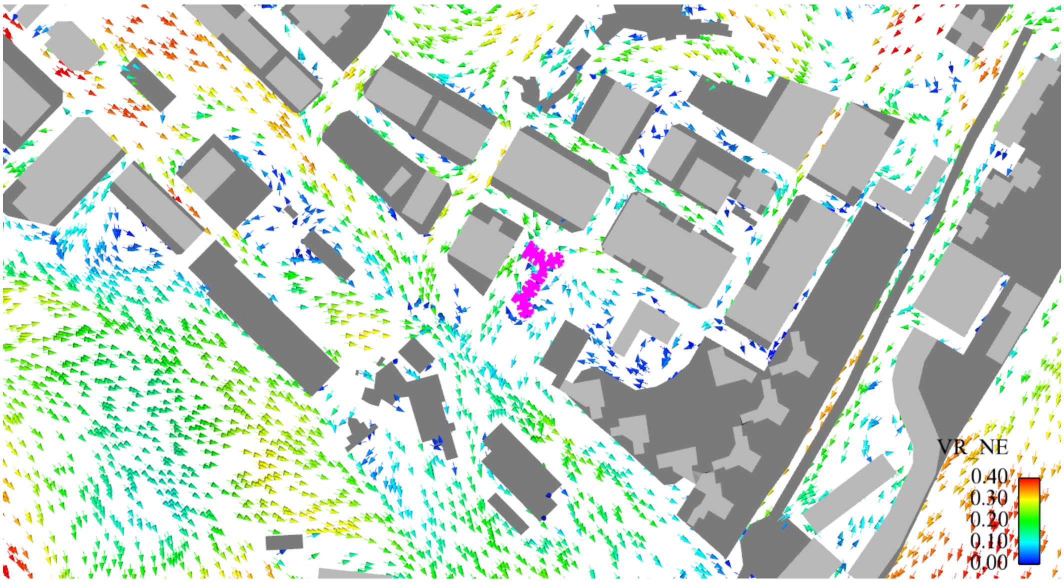
Appendix C

Direction VR Vector Plots

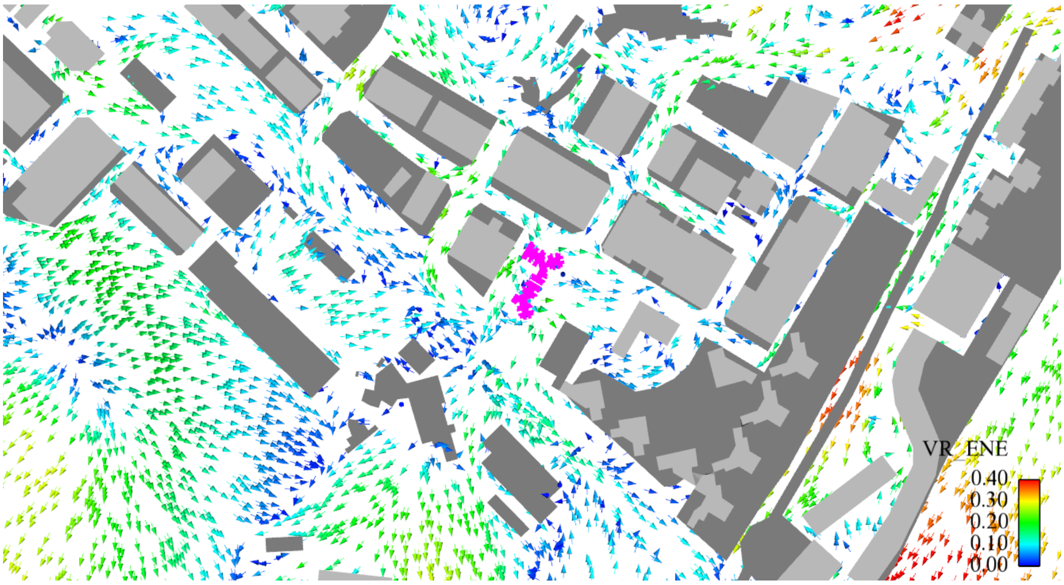
C1 Baseline Scheme



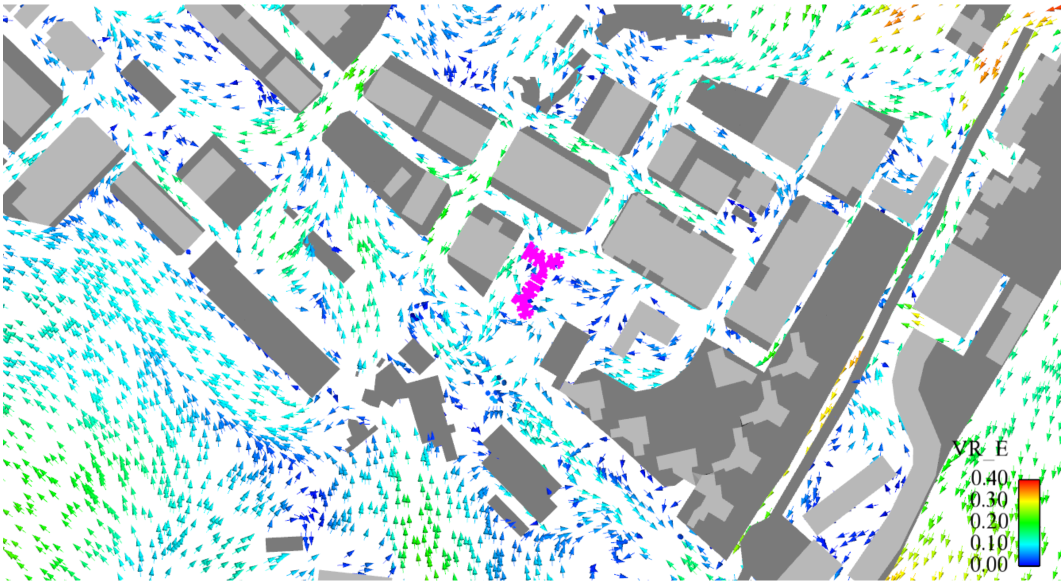
Vector Plots of Baseline Scheme under NNE Direction



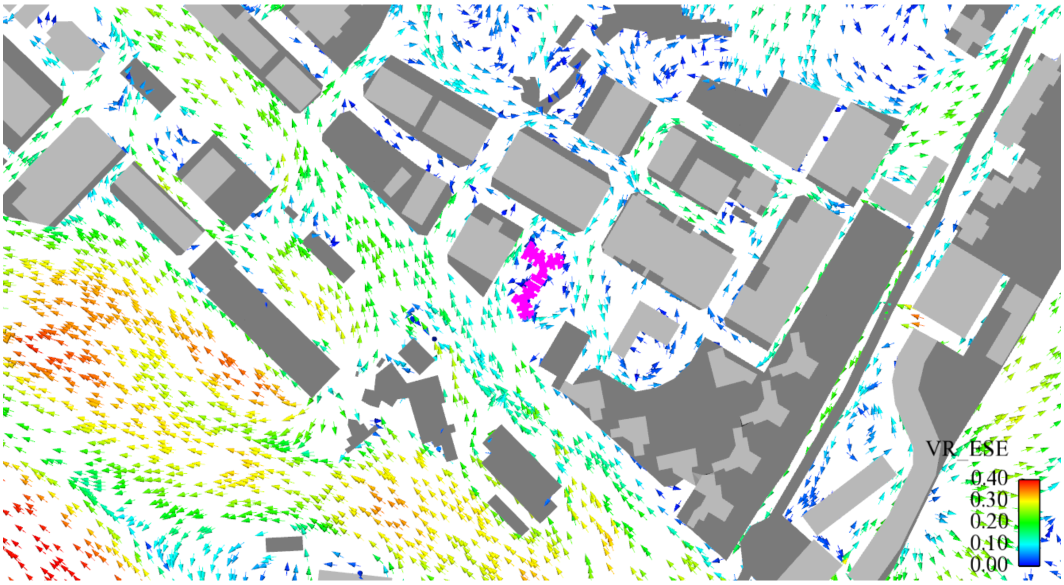
Vector Plots of Baseline Scheme under NE Direction



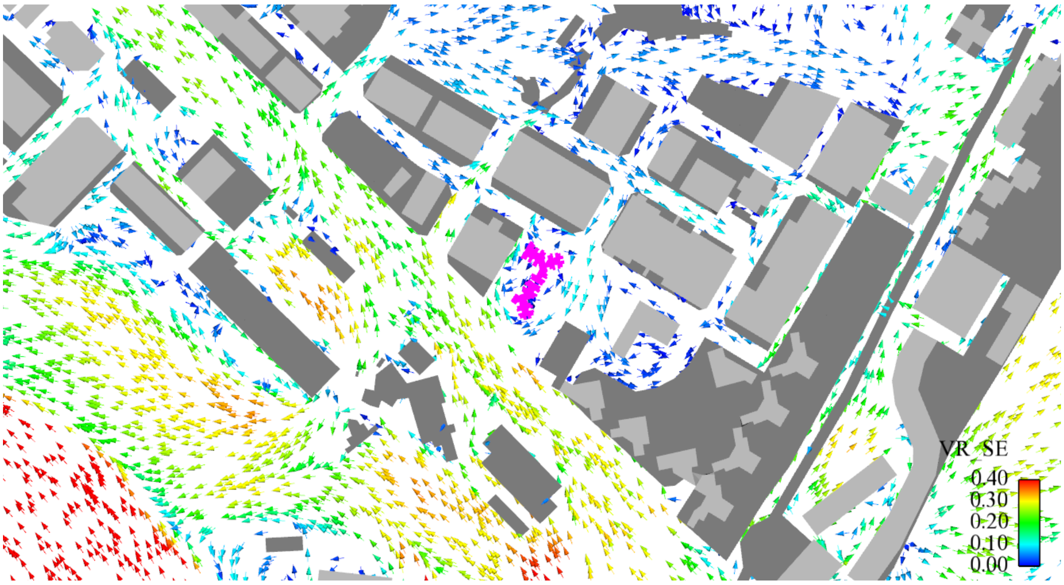
Vector Plots of Baseline Scheme under ENE Direction



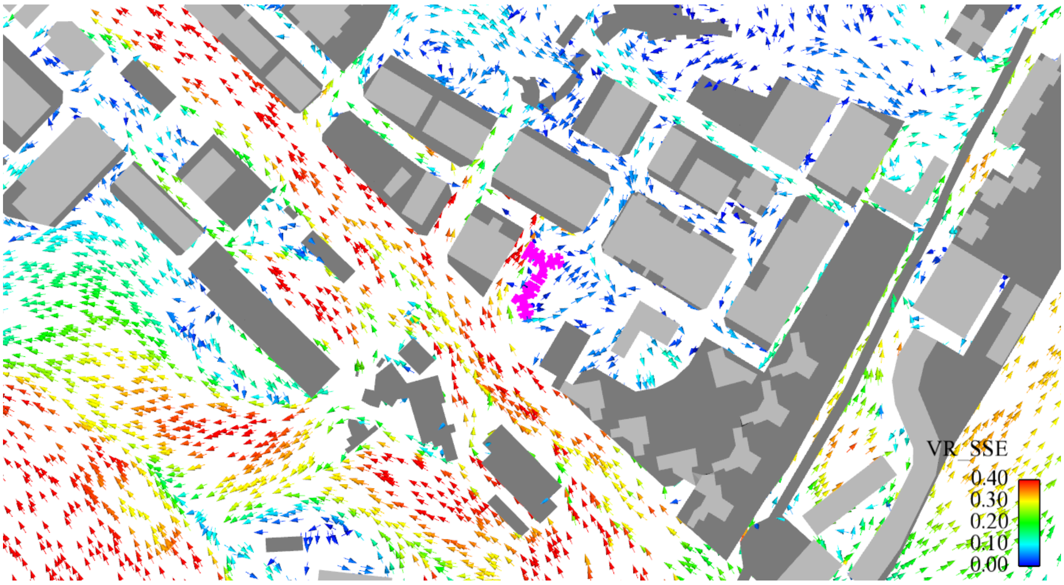
Vector Plots of Baseline Scheme under E Direction



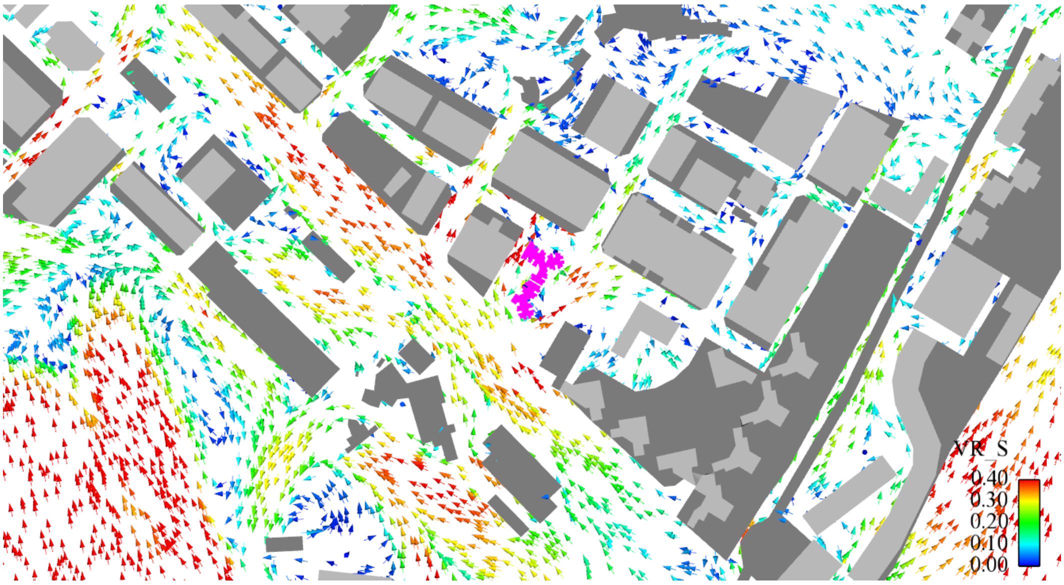
Vector Plots of Baseline Scheme under ESE Direction



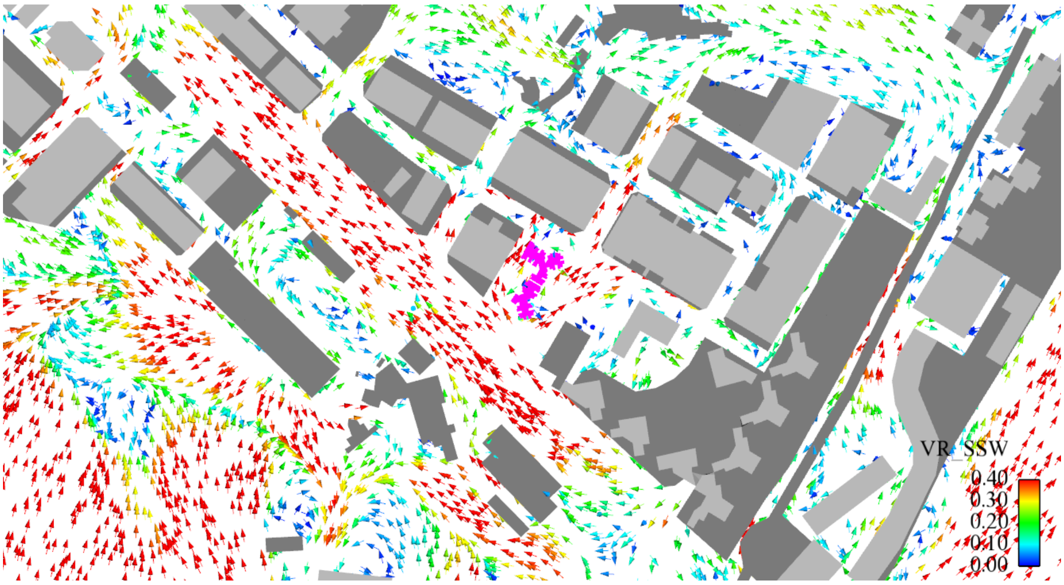
Vector Plots of Baseline Scheme under SE Direction



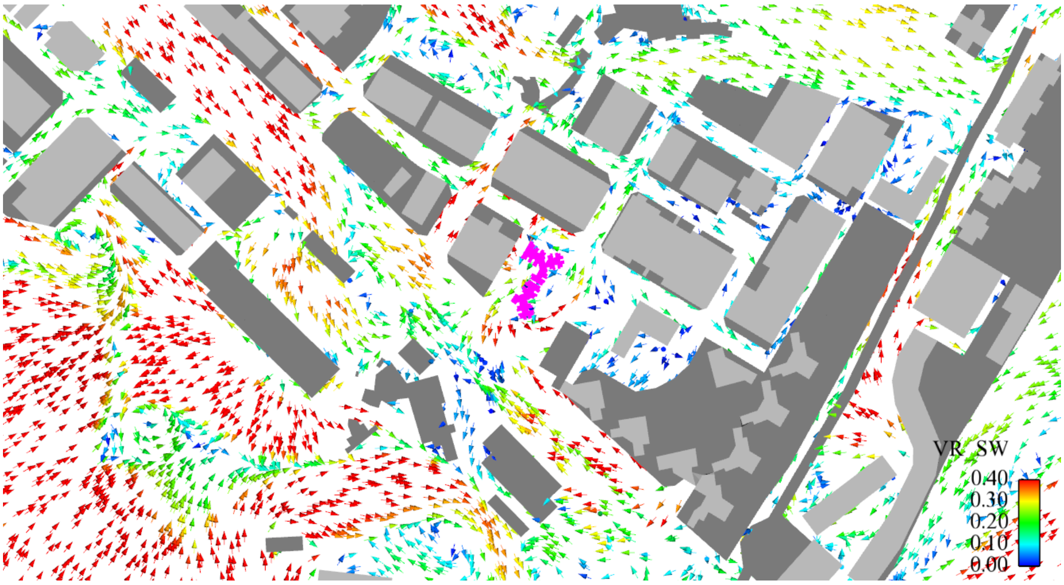
Vector Plots of Baseline Scheme under SSE Direction



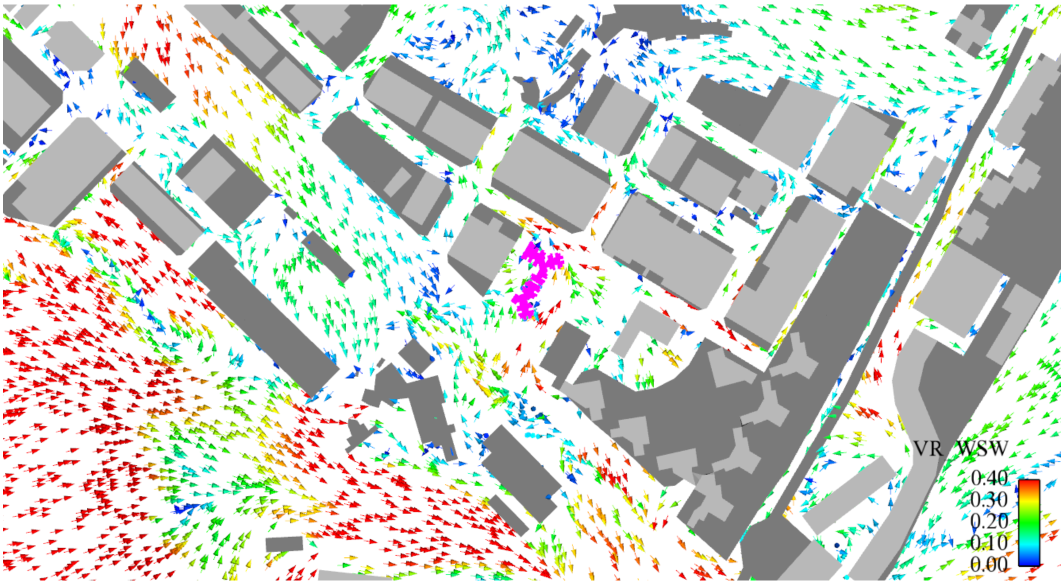
Vector Plots of Baseline Scheme under S Direction



Vector Plots of Baseline Scheme under SSW Direction

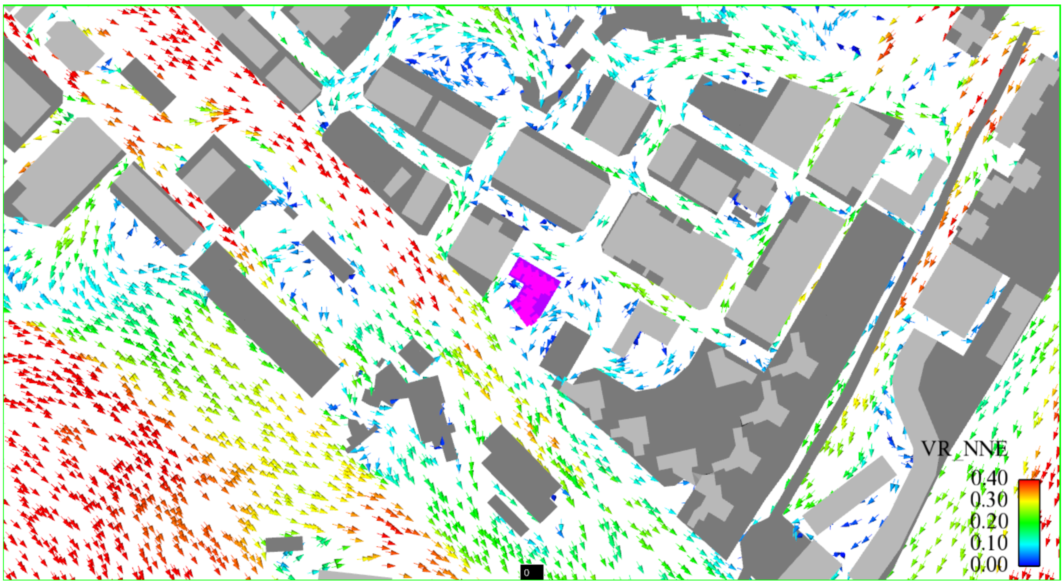


Vector Plots of Baseline Scheme under SW Direction

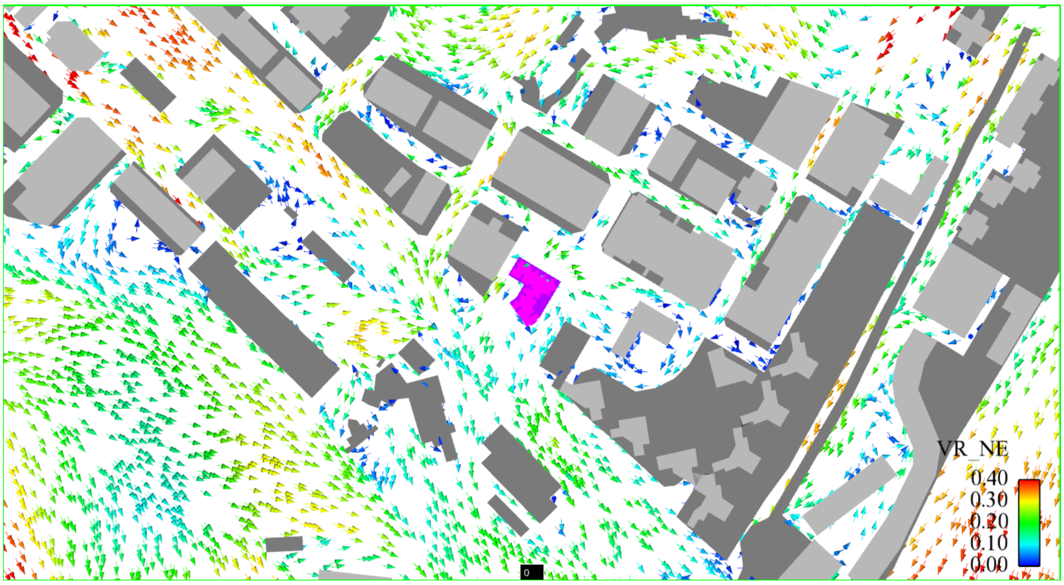


Vector Plots of Baseline Scheme under WSW Direction

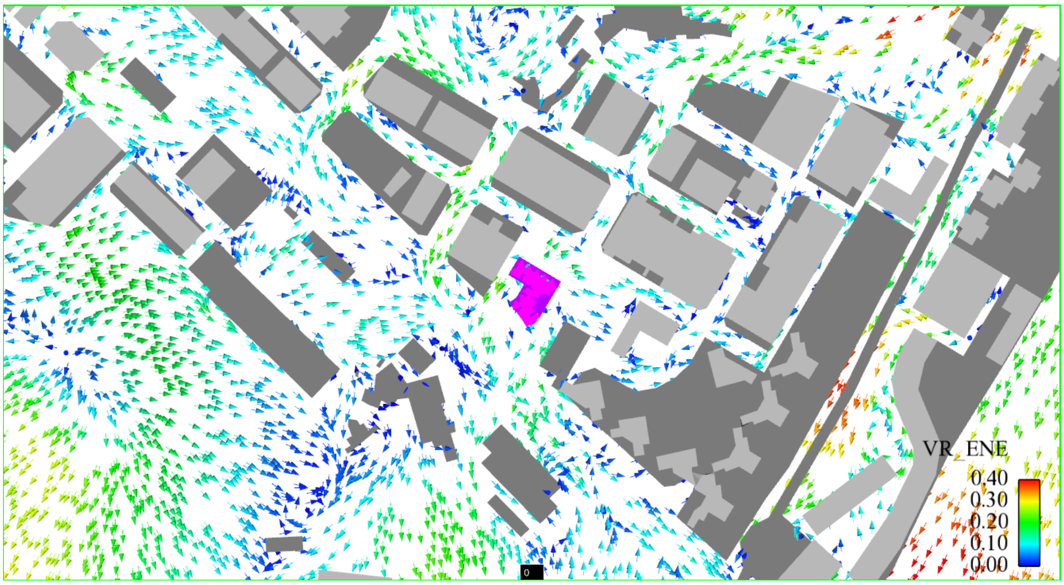
C2 Proposed Scheme



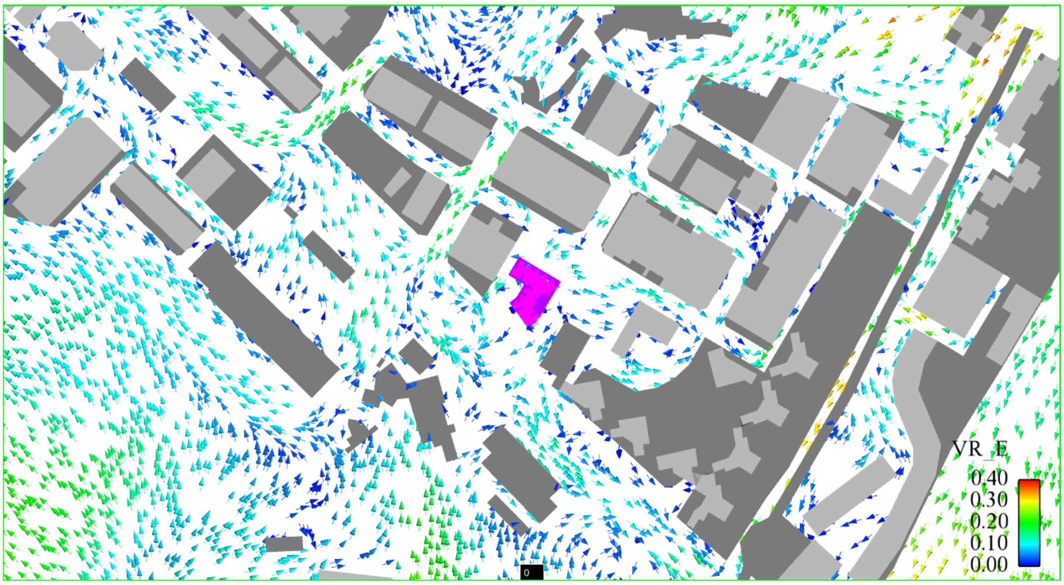
Vector Plots of Proposed Scheme under NNE Direction



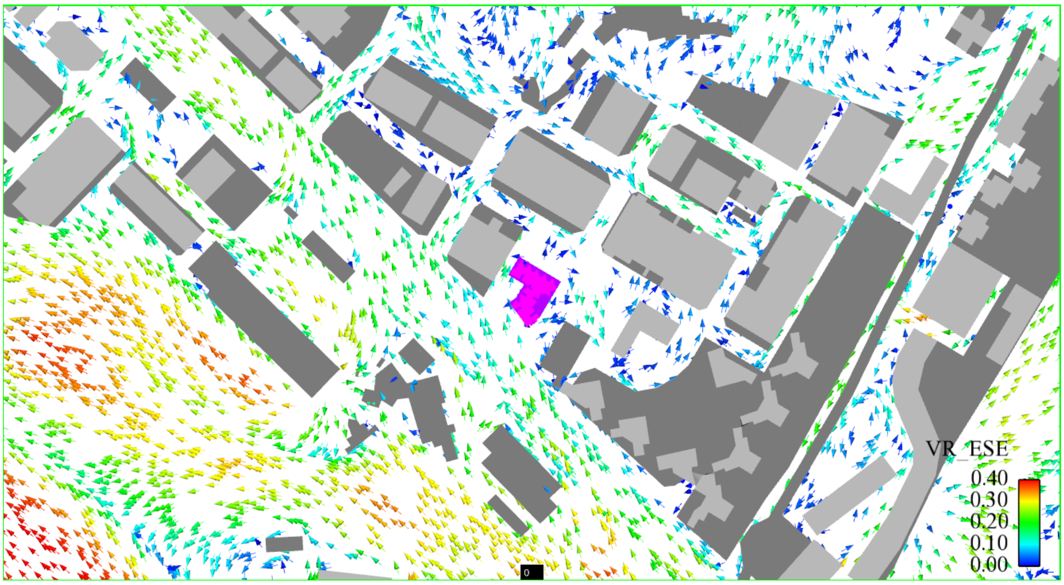
Vector Plots of Proposed Scheme under NE Direction



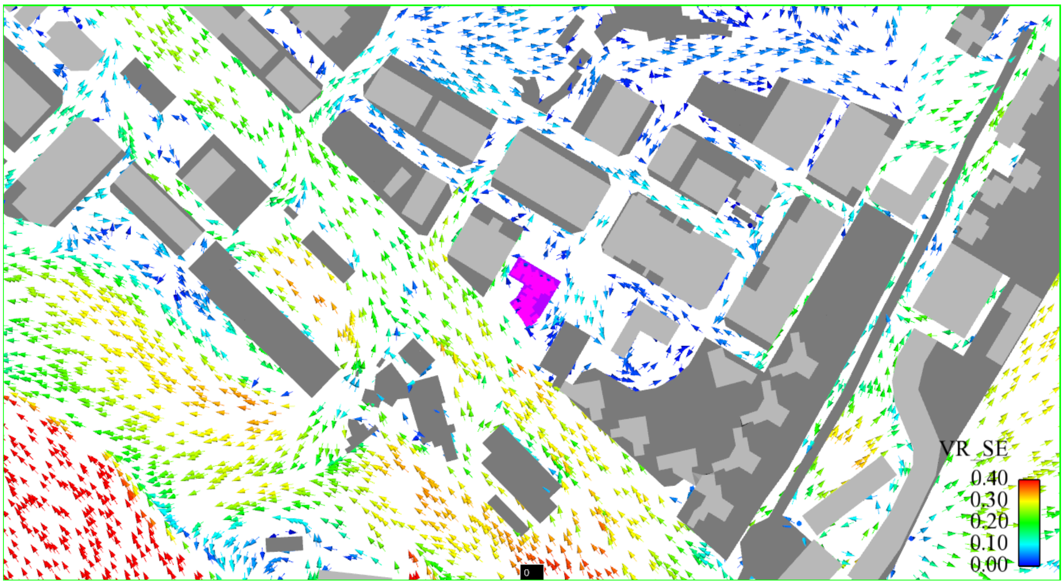
Vector Plots of Proposed Scheme under ENE Direction



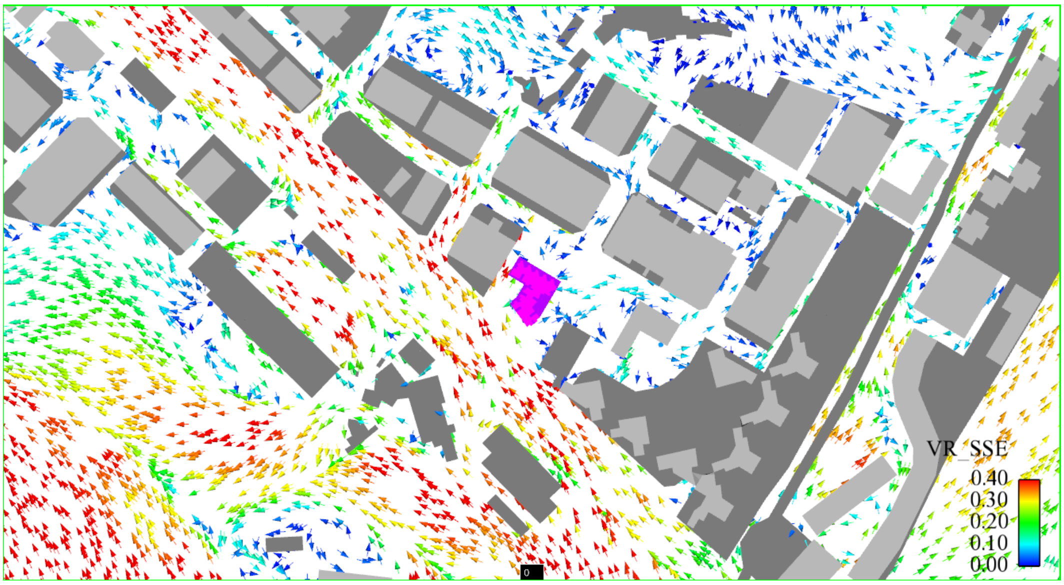
Vector Plots of Proposed Scheme under E Direction



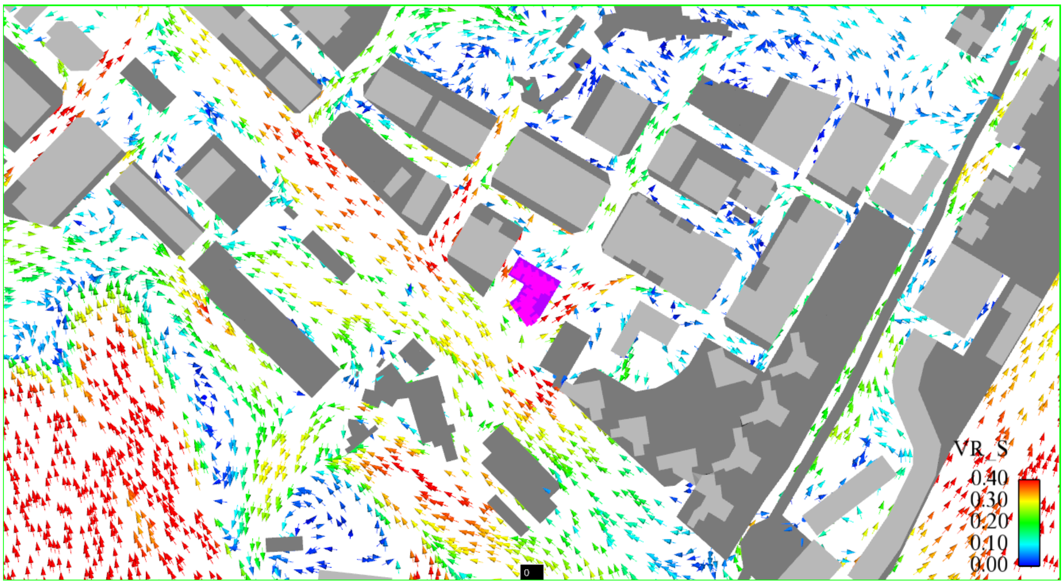
Vector Plots of Proposed Scheme under ESE Direction



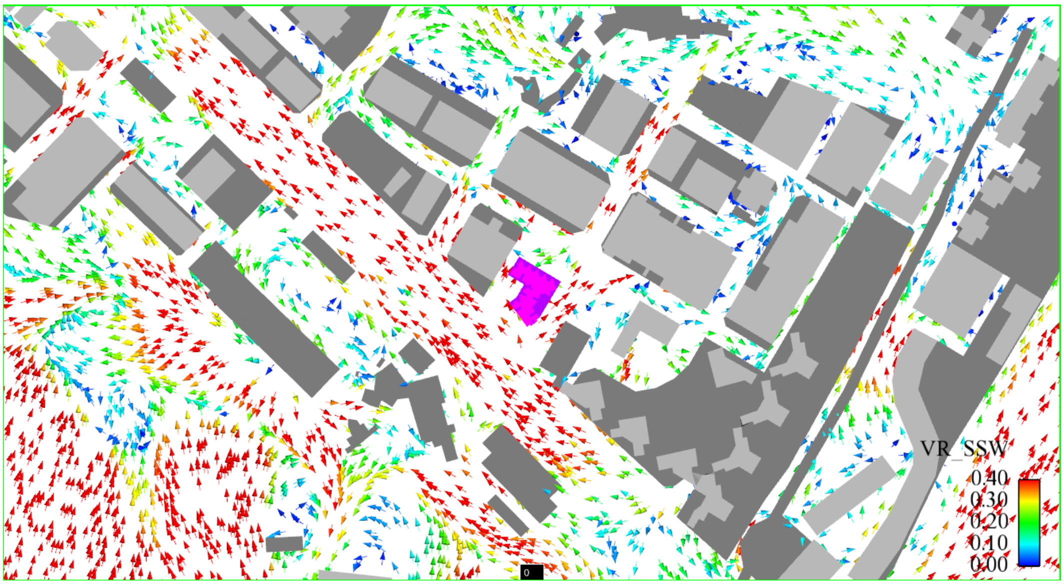
Vector Plots of Proposed Scheme under SE Direction



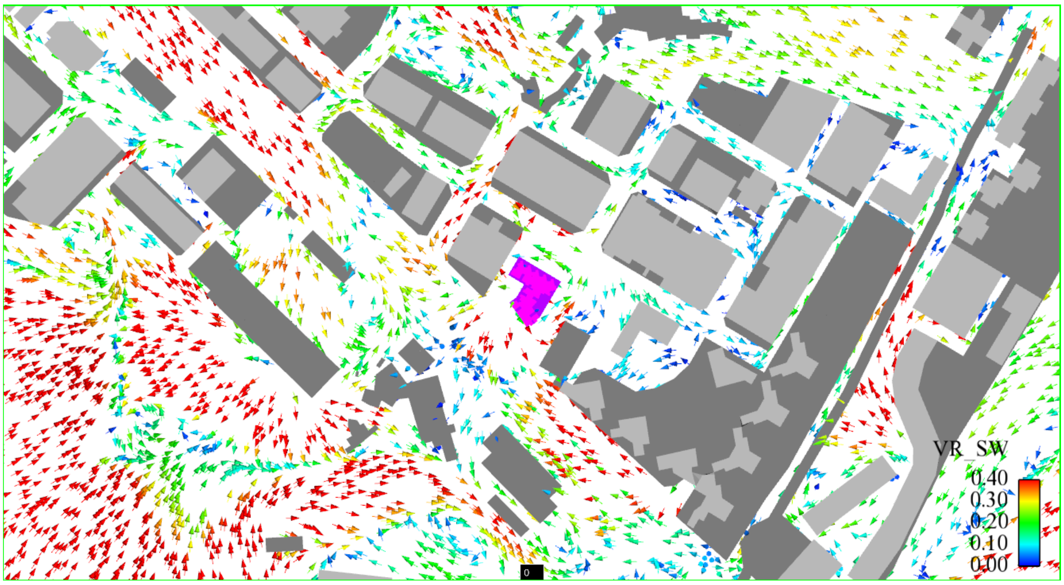
Vector Plots of Proposed Scheme under SSE Direction



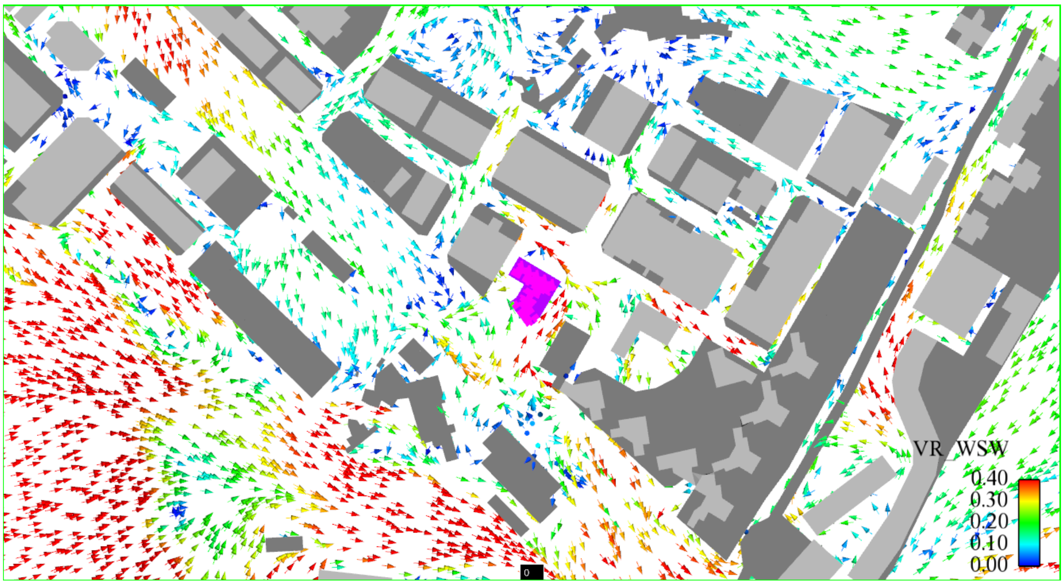
Vector Plots of Proposed Scheme under S Direction



Vector Plots of Proposed Scheme under SSW Direction



Vector Plots of Proposed Scheme under SW Direction



Vector Plots of Proposed Scheme under WSW Direction