City Planning - Maunsell Joint Venture (CPMJV)

Kai Tak Development Comprehensive Planning and Engineering - Stage 1 Planning Review

Technical Note 4
(AVA Report for Draft PODP)

Final Report

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Technical Note 4

AVA Study for Draft PODP

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Contents

1 Introduction

1.1 Background of Air Ventilation Assessments

Further to the Team Clean report published in August 2003, Government undertook to examine the practicality of stipulating Air Ventilation Assessment (AVA) as one of the considerations for all major development or redevelopment proposals and in future planning in its "First Sustainable Development Strategy for Hong Kong" promulgated by the Office of the Chief Secretary for Administration in May 2005, a strategic objective to promote sustainable urban planning and design practices has been set out amongst other objectives with special regards to issues such as building affecting view corridors or restricting airflow. A framework for applying AVA was developed by Planning Department on the basis of the "Feasibility Study on Establishment of Air Ventilation Assessment" completed in 2005. The Technical circular No. 1/06 – Air ventilation Assessment was issued jointly by Housing, Planning and Land Bureau and Environment, Transport and works Bureau on 19 July 2006 addressing the technical and implementation issues of AVA in Hong Kong.

1.2 Objectives of AVA

As laid out in the **Housing, Planning and Lands Bureau Technical Circular No. 1/06; Environment, Transport and Works Bureau Technical Circular No. 1/06 – Air Ventilation Assessment** (*Technical Circular*)**,** dated 19 July 2006**,** the application and approach for AVA consulting study are as follows:

1.2.1 Purpose

The main purpose of AVA is to promote the awareness of project proponents to ensure that air ventilation impacts are duly considered as one of the main criteria in the planning and design process, so as to promote sustainable urban planning and design practices.

An AVA study contains 3 stages, namely Expert Evaluation, Initial Study and Detailed Study, with different focuses as follows:

- The Expert Evaluation provides a qualitative assessment to the design and/or design options and facilities the identification of problems and issues.
- The Initial Study will refine and substantiate the Expert Evaluation through the derivation of a general pattern and a rough quantitative estimate of wind performance at the pedestrian level, and to define the "focus" areas and scope of work for Detailed Study
- Detailed Study should accurately and "quantitatively" compare design opinions so that a better one could be selected.

For the Expert Evaluation and Initial Study, only the general and rough wind performance at the pedestrian level will be derived for the understanding of good design features and problem areas. The "focus" areas and scope of works for further detailed study should be defined and implemented in the Detailed Study report.

1.2.2 Current states of AVA

1.2.2.1 No absolute benchmark at present

The framework of AVA developed at current stage does not provide an absolute benchmark standard against which the air ventilation impacts can be confirmed to be acceptable or unacceptable.

1.2.2.2 Facilitate scheme comparison

The framework would however, enable comparison of design options in terms of external air ventilation and identification of potential problem areas for design improvement.

Major government projects that may bring about potential impact on air ventilation in the macro wind environment are strongly advised to include AVA in the planning and design of the projects.

1.3 AVA for KTD Planning Review

Located at the waterfront of South-East Kowloon, the Kai Tak Development (KTD), once completed, may impose substantial potential impacts to the wind environment of the surroundings and therefore the well being of the local residents. Because of its strategic location and the scale of the development, an effective urban planning for wind is crucial for the project at current planning stage.

To incorporate air ventilation considerations into the planning stage, and to take forward the recommendations of the "Feasibility Study for Establishment of Air Ventilation Assessment System" undertaken by PlanD, an AVA study is to be carried out as an additional task of the Planning Review.

The KTD Planning is the first project in the category of "Planning Studies for new development areas" that applies initial Air Ventilation Assessment to implement the policy directive ensuring that the air ventilation impacts are properly addressed in new development areas.

To achieve the objective of AVA, the AVA study should be carried out throughout KTD Planning & Engineering Review, including:

- 3 OCPs
- Draft PODP
- More detailed plan in Engineering Review Stage
- Further assessments for relevant development projects in focus areas

Currently, the Planning Department of HKSAR has commissioned City Planning – Maunsell Joint Venture of 24A, Manulife Tower, 169 Electric Road, North Point, Hong Kong (CPMJV) to provide professional services in connection with the Kai Tak Development – Feasibility study. CPMJV has appointed Ove Arup & Partners Hong Kong Ltd (Arup) to carry out the professional consultancy work of Air Ventilation Assessment – Area Wide Initial Evaluation as an ancillary study of the main study.

The AVA for the Planning Review is now implemented in two packages: The first package involved an initial evaluation on air ventilation performance of 3 OCP schemes. The wind availability and characteristics of the site have been carried out by the CLP Power Wind/Wave Tunnel Facility (WWTF) and initial AVA study conducted by Arup using advanced Computational Fluid Dynamics (CFD) techniques. "Focus areas" with potential ventilation issues have been identified with improvement measures being proposed.

Further to the works of the first package, the second package involved an Initial AVA study for the Draft PODP, which has incorporated the suggestions & findings for better air ventilation performance on planning scale achieved from previous OCP AVA studies. For this Initial Air Ventilation Study, the scope of works includes:

- Assessing the characteristics of the wind availability (V_∞) of the site

- Deriving a general pattern and a rough quantitative estimate of wind performance at the pedestrian level reported using Wind Velocity Ratio (V_R)
- Further refining the understanding (good design features and problem areas) of the Expert Evaluation
- Further defining the “focus” area, methodologies and scope of work of the Detailed Study

The methodology as set out in the Technical Guide of the Technical Circular has been largely followed, with slightly modification to suit the context of the KTD, particularly its vast land area. This report is prepared for the works of package 2.

2 AVA methodology

As specified in the *Technical Circular*, the following key factors are stipulated for initial study of AVA:

- Determining wind availability of the site
- Defining Project assessment area and surrounding areas
- Identifying test points for local and site ventilation assessment

The following paragraphs illustrate the details on how the current AVA study addressing these issues.

2.1 Wind availability of the site

The wind availability of the site is taken as the input condition for AVA study, which includes the wind directions and wind profile, as described in the *Technical Circular*'s Annex A - Technical Guide for Air Ventilation Assessment for Developments in Hong Kong (*Technical Guide*).

2.1.1 Wind directions

The wind rose is an important information to determine the prevailing wind directions and wind frequency of the site. In this study, wind rose was derived from the MM5 simulation result. Based on the results of MM5 simulation, the wind rose for the site is shown in Figure 1.

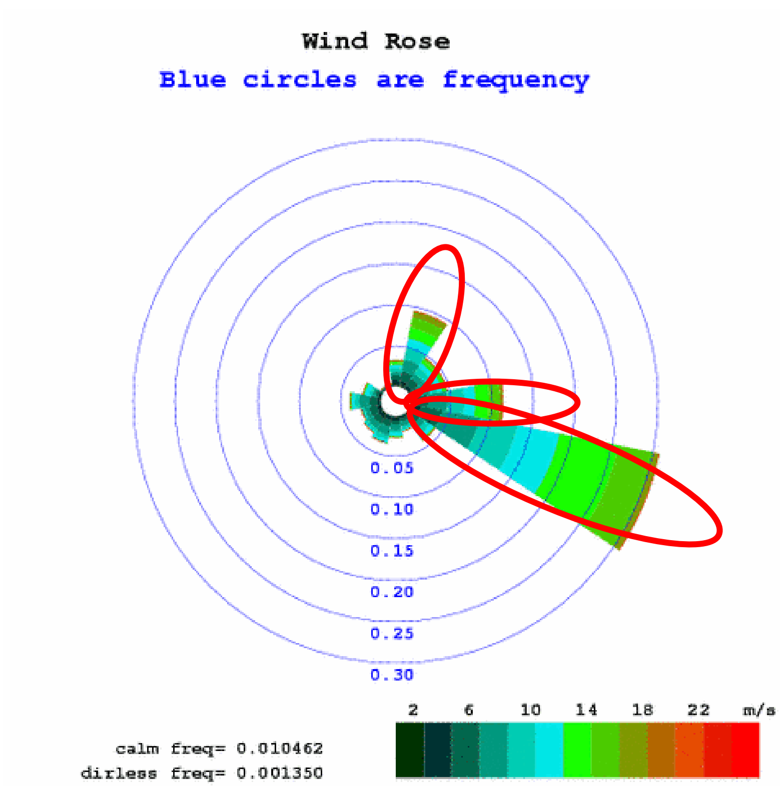

Figure 1 Wind rose based on MM5 simulation

Results show that the prevailing wind directions of the site are NNE, E and ESE corresponding to frequencies of occurrence of 19.5%, 17.4%, and 39.7% respectively. These three wind directions are applied for this AVA assessment to ensure that the cumulative probability of wind from those directions exceeding 75% of the time in a typical reference year.

2.1.2 Wind profiles

The wind profiles, including the mean wind speed and the turbulence intensity, measured in the wind tunnel test done by WWTF, are taken as input parameters in the CFD models.

The wind tunnel test has been carried out with a 1:2000 scale topographical model to study the wind profile at the site (Figure 2). The topographical study results were combined with a statistical model of the Hong Kong wind climate, based on measurements of non-typhoon winds taken by Hong Kong Observatory (HKO) at Waglan Island during the period of 1953 – 2000 inclusive, to determine site-specific distributions of directional mean wind speed for the three nominated locations.

The mean wind speeds and turbulence intensities at 3 locations, represented wind availability of the whole site at different areas, were measured (Figure 3).

Figure 2 Wind tunnel test model

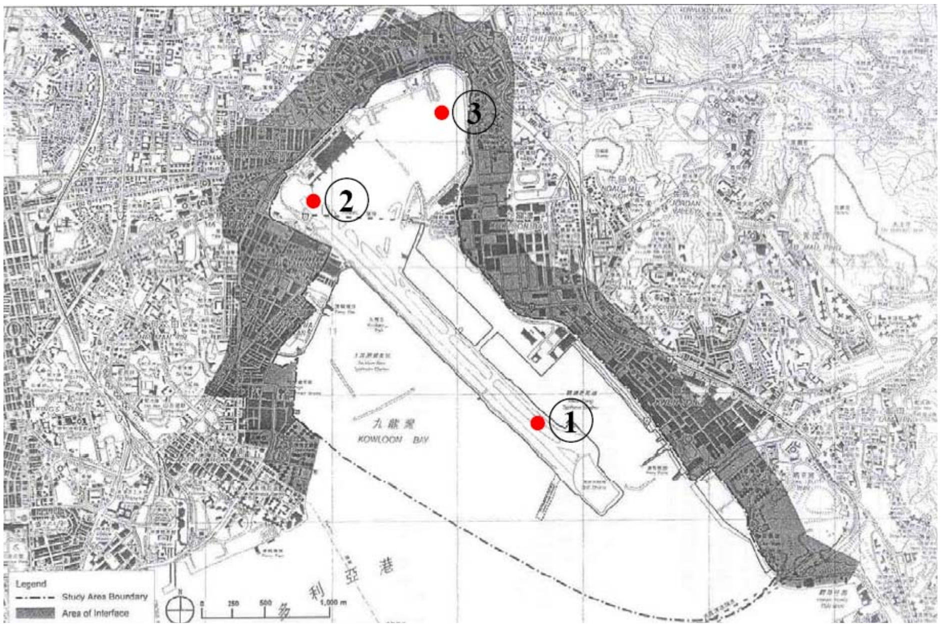

Figure 3 Measurement points of wind tunnel test

As shown in the Figure 3, the measurement point 1 and 2 are at the two ends of the runway and point 3 is in the northern part of the site. The wind profile results of measurement points 1 and 3, which are located at the upstream of the respective prevailing winds, were taken as the wind profile for E, ESE, and NNE wind respectively. The wind profiles for the three prevailing wind directions are shown in the following figures, where the normalized wind characteristics of mean wind speed represented the mean wind speed at the different height above the site against the wind speed at the height of 200 m above the sea level recorded in Waglan island:

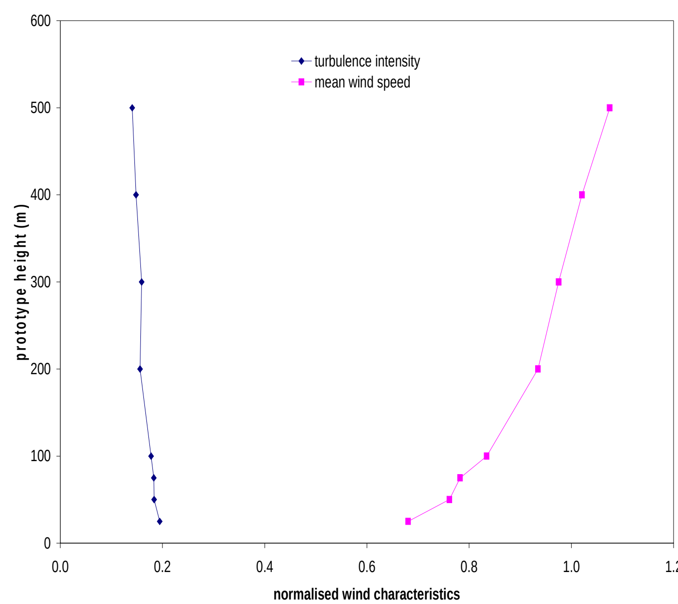

Figure 4 Wind profile at Point 1 (for E wind)

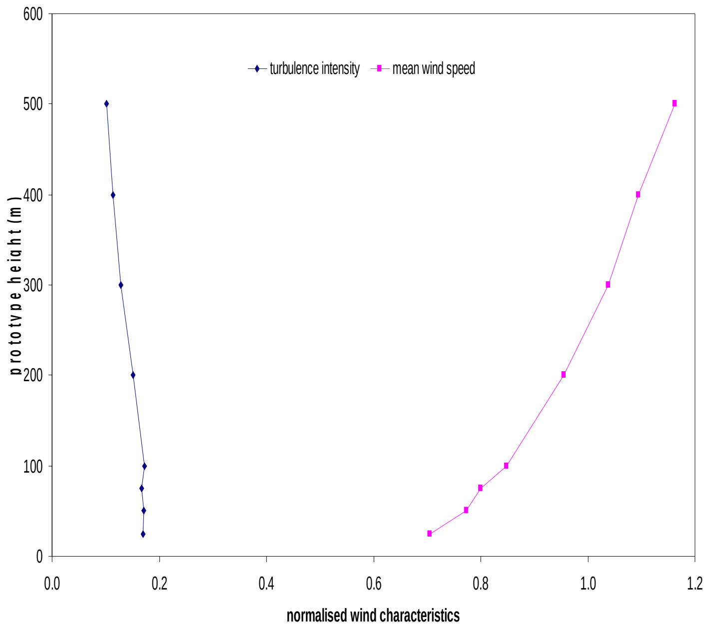

Figure 5 Wind profile at Point 1 (for ESE wind)

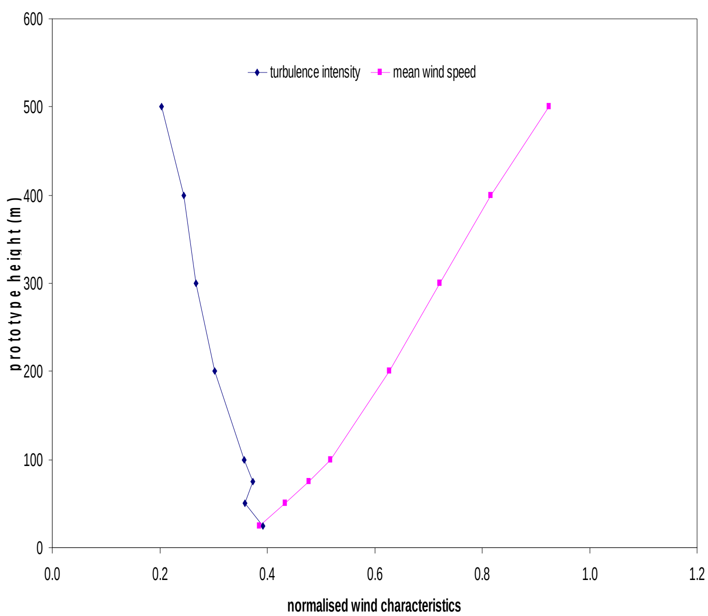

Figure 6 Wind profile at Point 3 (for NNE wind)

2.2 Project assessment area and surrounding area

2.2.1 Project area and surrounding area

Following the AVA assessment requirements as stipulated in the Technical Circular, the area of evaluation and assessment include all areas within the KTD site (Site Area), as well as a belt up to 400 meters around the landward boundary of KTD (AVA assessment and surrounding areas). Further, the model area is built to include 200 meters beyond the assessment area (Additional model Area).

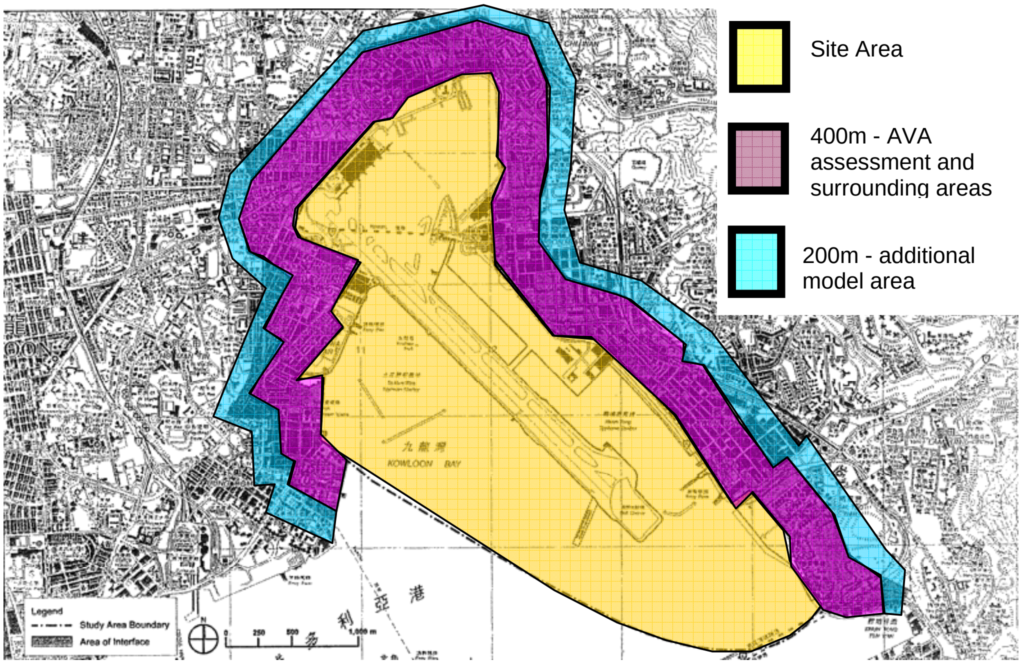

Figure 7 Project area and surrounding area taken into account of assessment

Details of the AVA assessment model is described in the Appendix A of this report.

2.2.2 Assessment parameter

The Wind Velocity Ratio (VR_w) as proposed by the Technical Circular for AVA is employed to assess the impact of the proposed development and to the surroundings. High VR_w across the development implies less impact associated with the proposed development. The calculation of VR_w is given by the following formula:

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

where

V_∞ = the wind velocity at the top of the wind boundary layer (typically assumed to be around 650m above the centre of the site of concern, or at a height where wind is unaffected by the urban roughness below).

V_p = the wind velocity at the pedestrian level (2m above ground) after taking into account the effects of buildings.

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

2.3 Test points for local and site ventilation assessment

2.3.1 Perimeter test point - Site VR_w

The purpose of determining the SVR_w is to evaluate the impact of the development to their immediate surroundings. The perimeter points are positioned on the project site boundary. The averaged values SVR_W determined for these test points are collective values. Each averaged SVR_w represented the area weighted-average value of individual test points, with the number of measuring points ranging from 20 to 40. This gives an indication how the proposed development impacts on the wind environment of its immediate vicinity within the site. For example, the Section 19 represents impact caused by KTD on the wind environment of Kowloon City.

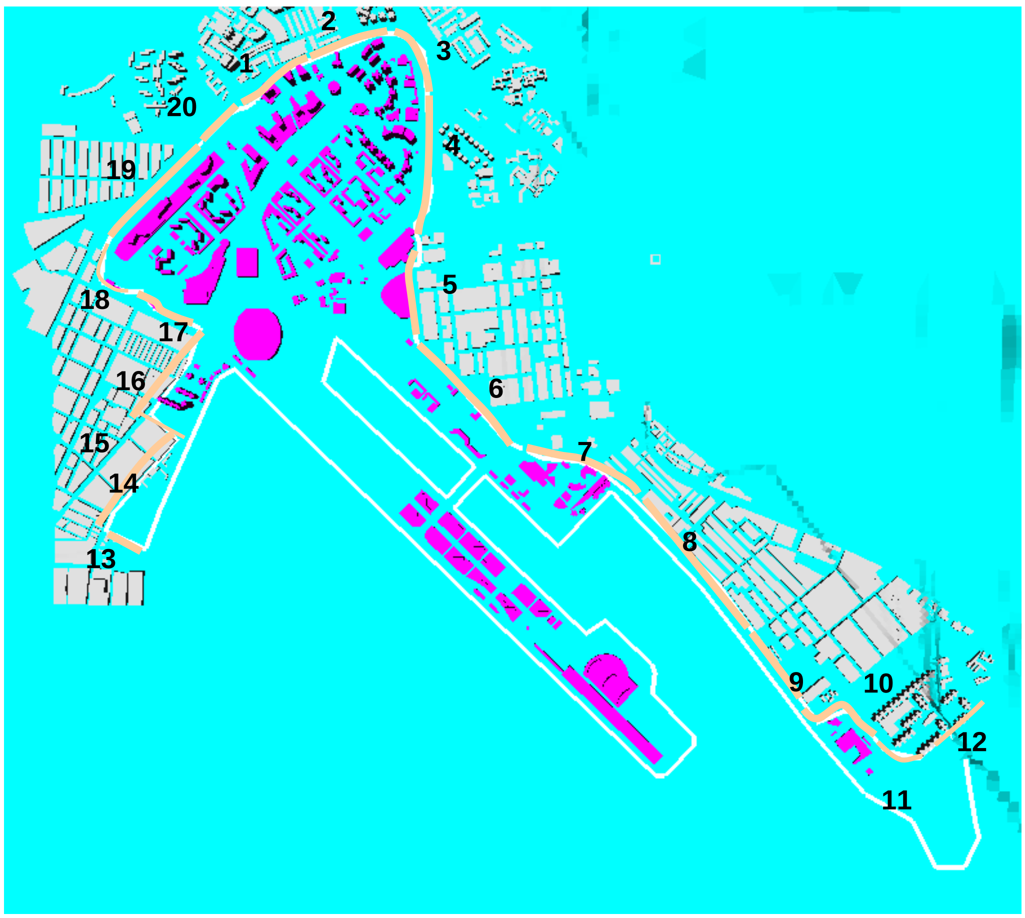

Figure 8 Demarcation of the test locations for site air ventilation assessment

2.3.2 Overall test points - Local VR_w

The purpose of LVR is to determine how the development proposal impacts on the wind environment of the local areas. Due to the large scale of KTD, it is necessary to sub-divide the site into smaller sub-zones to work out the spatial averages. Therefore, the spatial averaged value of LVR_w is determined at different locations across the site to test the effect of proximity of individual lots. Each zone is compartmentalized based on the main district of building layout of the site planning, separated by the main road or different building forms. The demarcation of the measured locations is indicated in the following figure. For each of these 32 zones, the number of measurement points for averaging in each zone varies in a range of 50 to more than 100 points, depending upon the dimensions of the zones.

The above test zones, together with the site wind velocity ratio, form the local air ventilation assessment.

The most recent research on wind study undertaken by Japanese computational wind study experts, Prof. Mochida and Prof. Yoshie[1], indicated that the simulation on the effect of surrounding urban blocks would be satisfactory for practical application if two or more rows of buildings were maintained in the surroundings of the zone to be evaluated. Therefore, in present AVA study, the test points that are located far behind the existing development of the surrounding area of the KTD site are not taken into the consideration since the wind environment at those locations are mainly influenced by the buildings themselves, not the proposed development within the KTD site.

[1] Yoshie et al (2005). Cooperative project for CFD prediction of pedestrian wind environment in the Architectural Institute of Japan. EACWE4

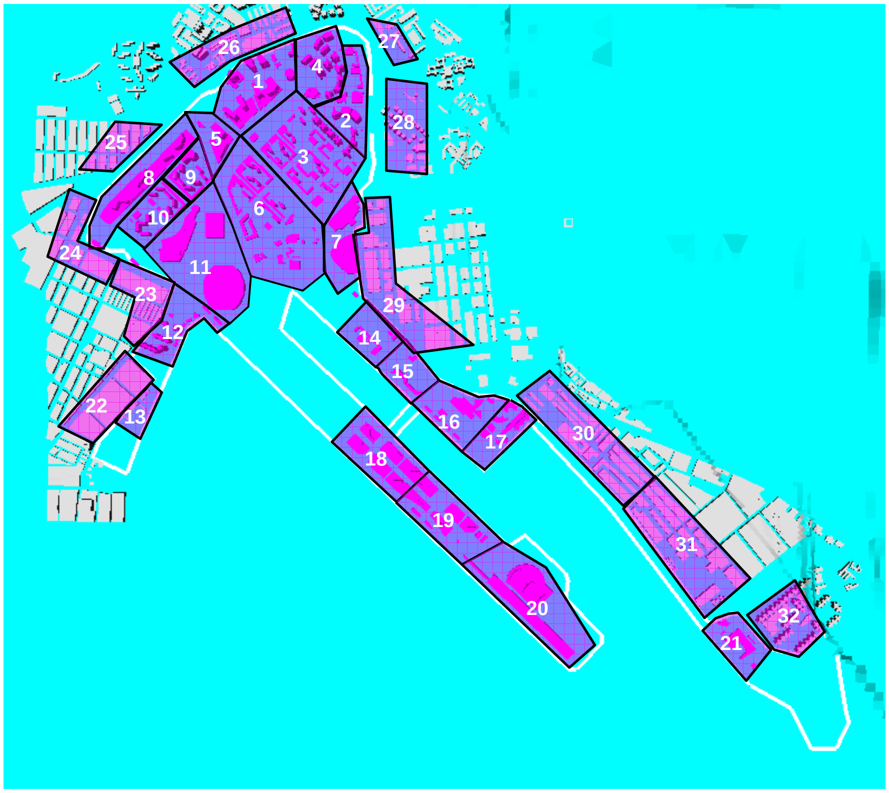

Figure 9 Demarcation of the measurement locations for local air ventilation assessment

2.3.3 Special test points

Some special test points are also positioned in the concerned areas, to provide additional information. With the advantage of CFD simulation, those locations can be identified through the contour map of the wind performance after the simulation has been done, instead of predefining before by assumptions, as in the wind tunnel test assessment.

The locations and results on velocity ratio of these special test points for the concerned areas are described in Chapter 4.

2.4 Choice of assessing tools

It is required to identify the appropriate tools to study the performance of different design schemes. In general, as described in the Technical Circular, wind tunnel and CFD are considered as the appropriate tools for air ventilation assessment.

However, where compared with wind tunnel test, there are some advantages of using CFD for AVA study, especially at the initial stage, these include:

- Fast track for arriving solutions
- Flexible to cater for the changes in design
- Understandable presentation
- Convenient distribution of the measurement points

In this connection, the AVA study is carried out with the advanced CFD technique (DES model) here. Details of CFD model can be found in Appendix A.

3 Results & discussion

3.1 3 OCP schemes : AVA result

CFD simulations have been conducted for the 3 OCPs, to study the wind environment created by the proposed building layout design of the KTD site. As specified by the Technical Circular, indicator of ventilation performance should be the Wind Velocity Ratio (VR_w), defined as the ratio of the wind velocity at the pedestrian level (2m above ground) to the wind velocity at the top of the wind boundary layer. Site VR_w (SVR_w) and a Local VR_w (LVR_w) should be determined so that the immediate effects, as well as the overall effects of the OCPs could be assessed. The details of the assessment result for 3 OCPs could be found in the previous Technical Note 2 – Initial evaluation and Technical Note 3 – Result reporting.

The following paragraphs summarized the results and findings on the AVA assessment of 3 OCPs.

3.1.1 Average VR for OCPs

The average wind velocity ratio (VR), defined as the weighted average w.r.t. the percentage of occurrence of the prevailing winds of 3 OCPs, are shown in Figure 10, Figure 11 and Figure 12 respectively. The results were used to calculate the site VR and local VR as defined in Para. 2.3.

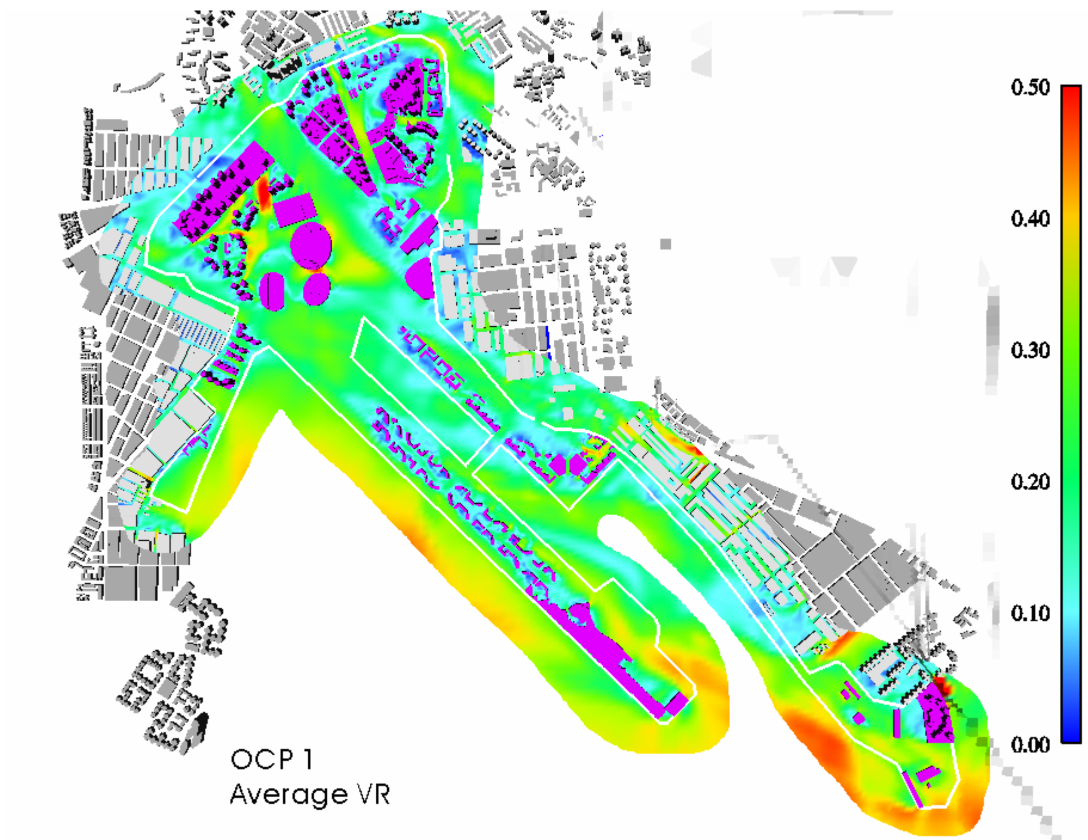

Figure 10 Average VR for OCP 1 : City in the Park

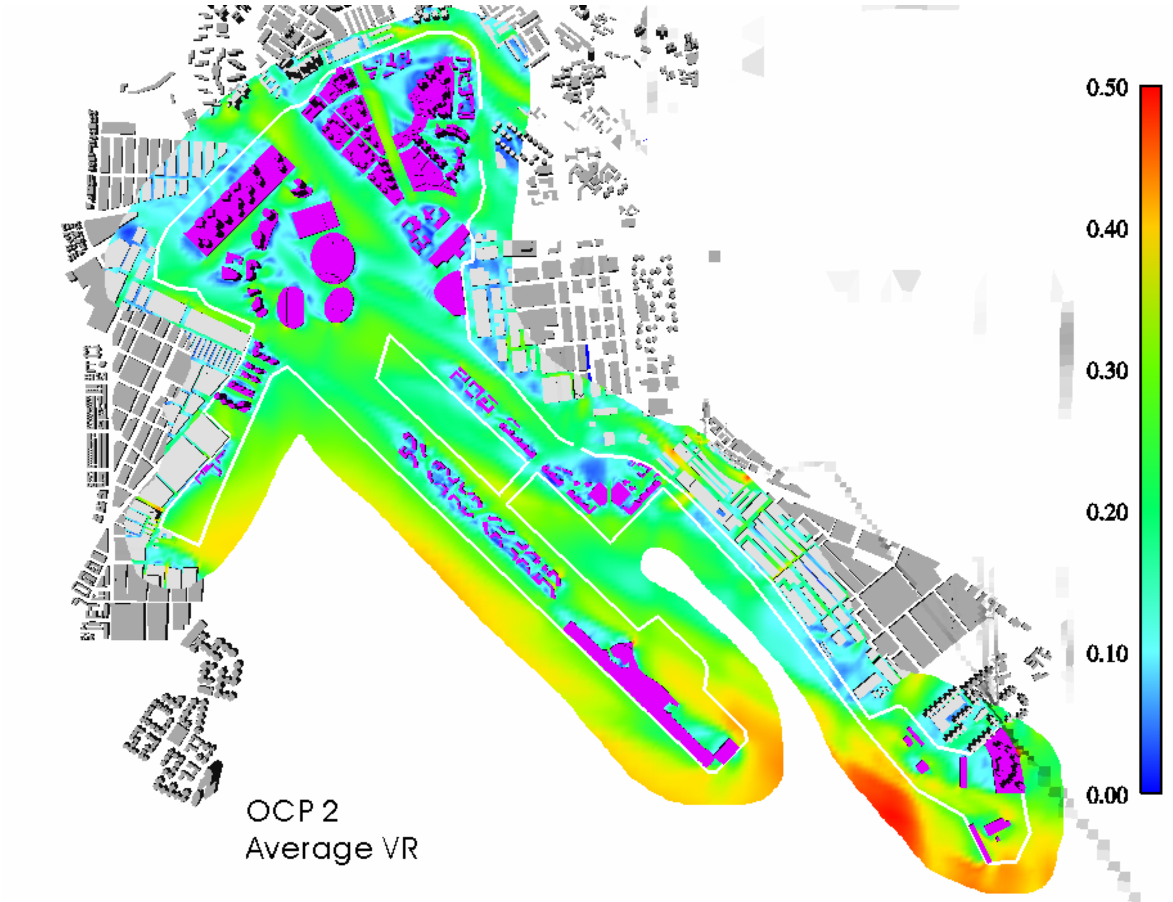

Figure 11 Average VR for OCP 2 : Kai Tak Glamour

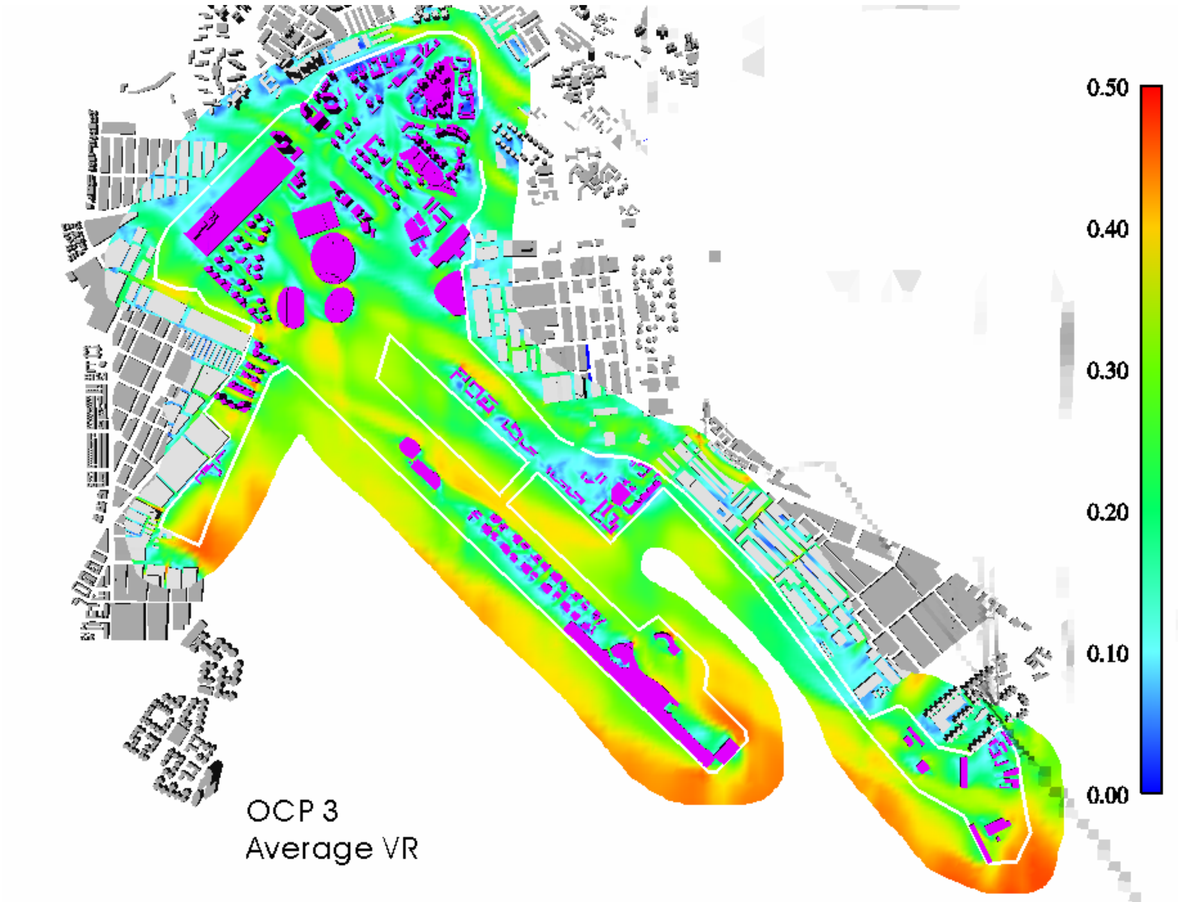

Figure 12 Average VR for OCP 3 : Sports by the Harbour

For OCP 1, air ventilation performance with VR > 0.2 was found in most of the runway area. However, it can be shown in Figure 10 that the proposed housing area at the northwest of the Multi-purpose Stadium and another housing area at the northern end of north apron area of KTD were designed with large block of buildings and podiums which may shelter the wind and consequently lead to relative lower air ventilation at those areas. VR values over those areas were generally around 0.1. Furthermore, compared to the other locations within the site, the relative higher wind velocity ratio (VR > 0.5) was observed at the area near the northern part of the Multi-purpose Stadium. This may be due to the design of two high-rise blocks, which forms the wind channel, amplifying the ESE wind at that specified location.

For OCP 2, the resultant wind environment as shown in Figure 11 was similar to that of OCP 1 with the distribution of VR similar to those of OCP1. However, no higher wind velocity ratio (VR > 0.5) was observed for OCP 2.

For OCP 3, more separate deposition of building layout at northwest of the Multi-purpose Stadium and the northern end of North Apron Area was found, which provided an improved wind environment, as compared with those of OCP 1 & 2 in this area (Figure 12). However, buildings at these locations still resulted in a relatively lower air ventilation performance as compared with the other sections within the site.

3.1.2 Site and local VR for OCPs

The site and local VR_w weighted by the frequencies of occurrence of different wind directions are summarized in the following table.

Section No	Site VR OCP 1	Site VR OCP 2	Site VR OCP 3
1	0.12	**0.13**	0.11
2	0.14	**0.19**	0.13
3	**0.19**	0.16	0.19
4	**0.18**	0.17	0.18
5	0.11	0.11	**0.12**
6	0.15	0.15	**0.21**
7	0.18	0.16	**0.19**
8	0.12	0.13	**0.14**
9	**0.15**	0.12	0.15
10	0.24	0.23	**0.25**
11	0.16	0.13	**0.21**
12	0.21	**0.22**	0.18
13	0.25	0.26	**0.28**
14	0.15	0.14	**0.16**
15	0.20	0.20	**0.27**
16	0.12	0.13	**0.18**
17	0.16	0.19	**0.27**
18	0.14	0.12	**0.18**
19	0.09	0.09	**0.12**
20	**0.22**	0.20	0.13
Total Average Site VR	0.16	0.16	0.18

Zone No	Local VR OCP 1	Local VR OCP 2	Local VR OCP 3
1	**0.10**	0.09	0.08
2	**0.12**	0.09	0.10
3	0.12	0.11	**0.12**
4	**0.13**	0.11	0.09
5	0.08	**0.10**	0.09
6	**0.13**	0.13	0.12
7	0.09	0.08	**0.14**
8	**0.17**	0.13	0.13
9	**0.19**	0.16	0.17
10	**0.15**	0.14	0.15
11	0.19	0.15	**0.19**
12	0.13	0.13	**0.21**
13	0.11	0.11	**0.14**
14	0.11	0.12	**0.14**
15	**0.13**	0.12	0.12
16	0.11	0.09	**0.11**
17	**0.18**	0.12	0.14
18	0.10	0.10	**0.22**
19	0.13	0.12	**0.15**
20	0.18	0.20	**0.21**
21	0.18	0.18	**0.21**
22	**0.11**	**0.11**	0.10
23	0.10	0.11	**0.12**
24	0.08	0.09	**0.11**
25	**0.09**	0.08	**0.09**
26	**0.09**	**0.09**	**0.09**
27	**0.12**	0.11	**0.12**
28	**0.13**	**0.13**	**0.13**
29	0.12	0.12	**0.13**
30	**0.16**	0.15	0.15
31	**0.11**	**0.11**	**0.11**
32	**0.09**	**0.09**	**0.09**
Total Average Local VR	0.14	0.13	0.15

Table 1 SVR_W and LVR_W for 3 OCPs

For the table above, the highlighted cells in each data row represent the highest VR_W among the 3 OCPs. Relatively, building layout and design of OCP 2 has resulted in lower air ventilation performance both within the site and across its leeward boundaries.

The wind performance of OCP 3 was much better than that of OCP 1 in terms of Site VR_W. The sections where the highest Site VR_W was achieved in OCP 3, have accounted for 65% of the total 20 sections.

Similar air ventilation performance was achieved in OCP 1 and 3 in terms of Local VR_W. The former produces the highest Local VR_W values amongst the 3 OCPs in 9 zones out of the 32 zones within the site, while the latter results in the highest values in 10 zones out of the 32 zones.

For the zones outside the site boundary, their ventilation performance is similar. It might be that ventilation performance for those areas is mainly self-affected by their block layout rather than the development. Main deviation can be found in zone 24, better ventilation can be obtained in OCP 3 was due to its scatter blocking layout.

3.1.3 Focus areas of OCPs

The AVA investigations on the 3 OCPs have identified some areas that need focus study and improvement on the pedestrian wind environment. These main focus areas include:

1) Building alignment and profile – main street design not aligning with the prevailing wind direction
2) Podium design of buildings – large podium blocking the incoming wind
3) The depot area – large depot and the building development above it leading to a relative low ventilation at leeward side of depot

The following figure demonstrates the focus area of OCP1:

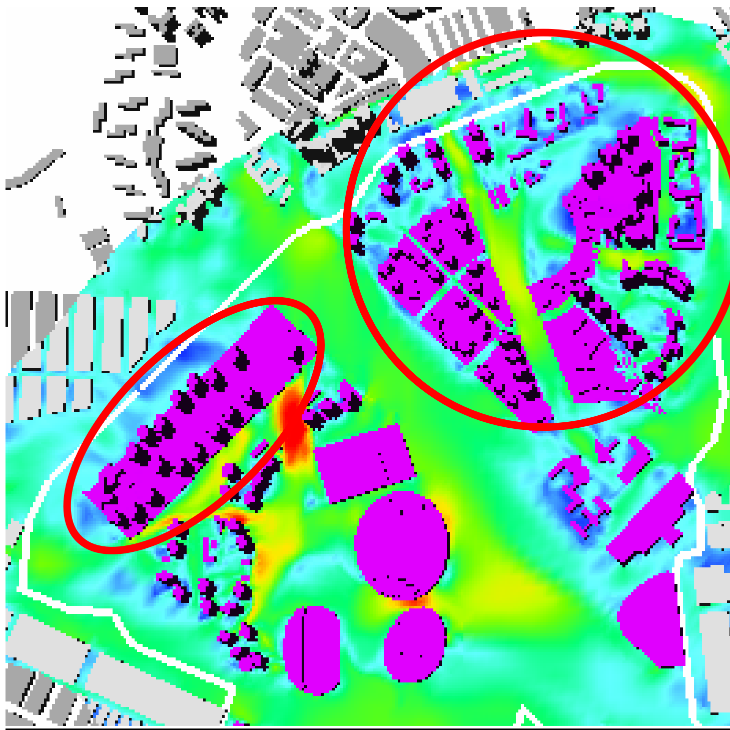

Figure 13 Focus area and arrangement of building clusters for better air ventilation

The draft PODP has taken into account the AVA findings on the 3 OCPs with a view to minimise the potential air ventilation impact in these areas.

3.2 Draft PODP : Improvement measures adopted based on AVA results of 3 OCPs

Taking into consideration the assessment findings of the 3 OCPs and other factors, improvement measures have been adopted in addressing the air ventilation concern during the preparation of the Draft PDOP (Figure 14).These improvements are shown in Figure 14 below:

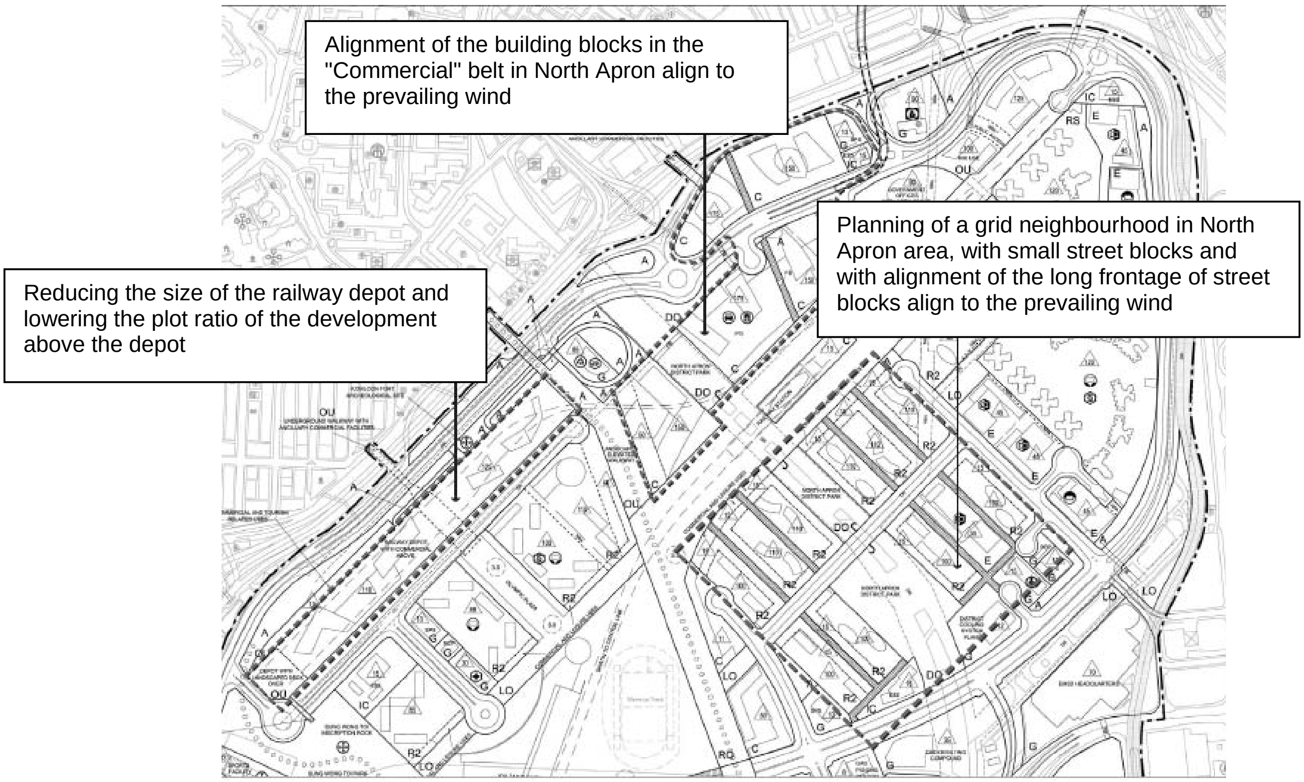

Figure 14 Improvements adopted in Draft PODP scheme

3.3 Draft PODP : AVA result

The AVA study of draft PODP scheme, incorporated the above-mentioned improvement measures, was also studied by CFD technique. The results of the weighted average VRs of draft PODP are described in the following paragraphs.

3.3.1 Weighted average wind velocity ratio

Weighted-average values of wind velocity ratio under different prevailing wind directions were determined to reflect the overall performance of the development. It is found that, the runway and cruise terminal areas, consisting of low-rise buildings with wider separation from adjacent buildings, are characterized by relative high air ventilation performance.

Nevertheless, with proposed high density housing areas at the North Apron Area of KTD, large block of buildings were found in the draft PODP design and leads to relatively lower air ventilation in some areas. Generally, VR values of these areas are around 0.15.

In general, designed with fewer podiums in this draft PODP scheme, the wind environment of the whole development is much improved as compared with previous 3 OCP designs.

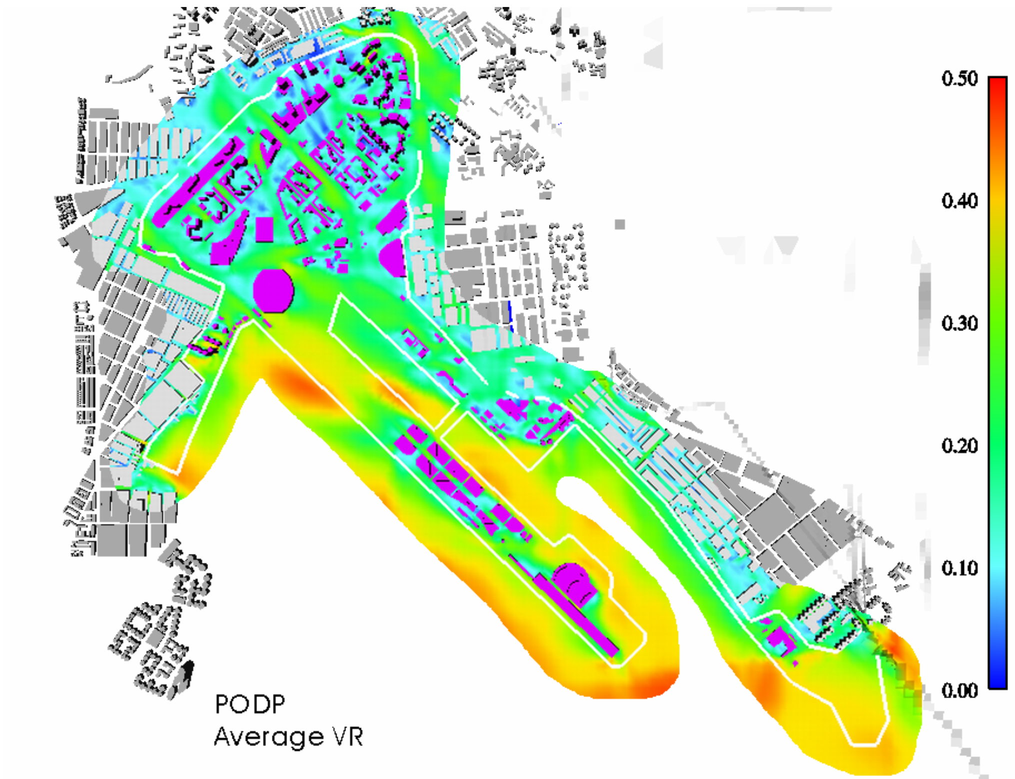

Figure 15 Annual average VR

3.3.2 Improvement of air ventilation performance on Draft PODP

3.3.2.1 Site VR_w

The values of site VR_w at Sections 3 to 12 represent the impact to the wind environment of Ngau Chi Wan, Kowloon Bay, Ngau Tau Kok, Kwun Tong & Lam Tin due to the proposed development. Located at the upstream of prevailing wind directions, the wind environment of these locations would not be affected by the proposed KTD.

Incorporated with a better building and street layout design that are identified in the previous 3 OCP studies, the wind environments of San Po Kong, Kowloon City and To Kwa Wan in draft PODP scheme, which are under the influence of the proposed development, are improved compared with previous 3 OCP schemes. As compared with the best wind performance of the 3 OCPs, the increases in velocity ratios are about 7%, 8% and 28% respectively.

However, in some areas, the wind performances for the draft PODP are still lower than previous OCP 3. These include Sections 2, 7 and 20 with the following reasons:-

- The buildings at Section 2 not fully aligned to the prevailing wind direction result in relatively lower air ventilation performance.
- Relative close building dispositions at Section 7 to the nearby buildings outside the site boundary cannot allow more wind to wash down to the street level.
- The relatively lower wind velocity ratio for the area along Prince Edward Road East near Kowloon City and San Po Kong (Section 20) is due to the relative narrow main street for air path at that location.

	Draft PODP				OCP 1	OCP 2	OCP 3
Section No [2]	**E**	**NNE**	**ESE**	**Average**	**Average**	**Average**	**Average**
1	0.06	0.31	0.09	**0.14**	0.12	0.13	0.11
2	0.11	0.11	0.10	0.11	0.14	**0.19**	0.13
3	0.21	0.10	0.28	**0.22**	0.19	0.16	0.19
4	0.20	0.16	0.22	**0.20**	0.18	0.17	0.18
5	0.26	0.09	0.13	**0.15**	0.11	0.11	0.12
6	0.19	0.13	0.27	**0.22**	0.15	0.15	0.21
7	0.17	0.13	0.12	0.14	0.18	0.16	**0.19**
8	0.16	0.25	0.16	**0.18**	0.12	0.13	0.14
9	0.27	0.22	0.14	**0.19**	0.15	0.12	0.15
10	0.44	0.38	0.12	**0.26**	0.24	0.23	0.25
11	0.36	0.21	0.33	**0.31**	0.16	0.13	0.21
12	0.58	0.23	0.20	**0.29**	0.21	0.22	0.18
13	0.28	0.18	0.40	**0.32**	0.25	0.26	0.28
14	0.22	0.11	0.19	**0.18**	0.15	0.14	0.16
15	0.37	0.20	0.32	**0.30**	0.20	0.20	0.27
16	0.21	0.16	0.22	**0.20**	0.12	0.13	0.18
17	0.19	0.11	0.39	**0.27**	0.16	0.19	0.27
18	0.10	0.25	0.17	**0.18**	0.14	0.12	0.18
19	0.08	0.21	0.11	**0.13**	0.09	0.09	0.12
20	0.09	0.31	0.16	0.18	**0.22**	0.20	0.13
Total Average Site VR				0.21	0.16	0.16	0.18

Table 2 Site VR of Draft PODP & 3 OCPs

[2] Please refer to Figure 8 for reference

3.3.2.2 Local VR_w

The LVR_W values of 32 zones throughout the development under the 3 prevailing wind directions are tabulated in Table 3. The fourth data column of the table represents the weighted average of the LVR_W values under prevailing wind directions of E, NNE, and ESE.

The highest LVR_W of 0.34 is found in zone No. 20 when the wind is from ESE direction and the lowest value is 0.08 in Zone 11 under NNE wind direction.

For most of the measured locations, there is a general trend that the LVR_W decreases with the prevailing wind direction in the sequence of ESE, E, and NNE. In other words, the best air ventilation performance is achieved under ESE wind direction whereas the worst scenario takes place under NNE wind direction.

Compared with the 3 OCP design options, the draft PODP design can provide much better and evenly distributed wind environment to the site, with VR above 0.15 for nearly all zones, and 80% of site area in draft PODP design scheme can provide better air ventilation performance than previous 3 OCP designs.

Again, similar ventilation performance could be found for all OCP and PODP at the zone outside the side boundary as those areas are mainly self-affected.

	Draft PODP				OCP 1	OCP 2	OCP 3
Zone NO.[3]	Wind direction			Annual Averaged			
	E	NNE	ESE	Average	Average	Average	Average
1	0.08	0.15	0.10	**0.11**	0.10	0.09	0.08
2	0.15	0.10	0.19	**0.16**	0.12	0.09	0.10
3	0.12	0.10	0.13	**0.12**	0.12	0.11	0.12
4	0.17	0.11	0.15	**0.15**	0.13	0.11	0.09
5	0.18	0.29	0.17	**0.20**	0.08	0.10	0.09
6	0.19	0.13	0.17	**0.17**	0.13	0.13	0.12
7	0.19	0.12	0.15	**0.15**	0.09	0.08	0.14
8	0.11	0.25	0.13	0.15	**0.17**	0.13	0.13
9	0.12	0.19	0.13	0.14	**0.19**	0.16	0.17
10	0.14	0.13	0.16	**0.15**	0.15	0.14	0.15
11	0.14	0.08	0.15	0.13	**0.19**	0.15	0.19
12	0.21	0.17	0.27	**0.23**	0.13	0.13	0.21
13	0.18	0.08	0.17	**0.15**	0.11	0.11	0.14
14	0.17	0.22	0.22	**0.21**	0.11	0.12	0.14
15	0.17	0.16	0.17	**0.17**	0.13	0.12	0.12
16	0.12	0.18	0.13	**0.14**	0.11	0.09	0.11
17	0.16	0.14	0.18	0.17	**0.18**	0.12	0.14
18	0.21	0.29	0.21	**0.23**	0.10	0.10	0.22
19	0.29	0.22	0.24	**0.25**	0.13	0.12	0.15
20	0.32	0.30	0.36	**0.34**	0.18	0.20	0.21
21	0.34	0.27	0.28	**0.29**	0.18	0.18	0.21
22	0.12	0.08	0.12	**0.11**	**0.11**	**0.11**	0.10
23	0.11	0.07	0.12	0.11	0.10	0.11	**0.12**
24	0.08	0.1	0.09	0.09	0.08	0.09	**0.11**
25	0.05	0.11	0.09	**0.09**	**0.09**	0.08	**0.09**
26	0.07	0.09	0.09	**0.09**	**0.09**	**0.09**	**0.09**
27	0.11	0.12	0.13	**0.12**	**0.12**	0.11	**0.12**
28	0.11	0.11	0.14	**0.13**	**0.13**	**0.13**	**0.13**
29	0.11	0.09	0.16	**0.13**	0.12	0.12	**0.13**
30	0.12	0.16	0.15	0.15	**0.16**	0.15	0.15
31	0.1	0.09	0.12	**0.11**	**0.11**	**0.11**	**0.11**
32	0.14	0.1	0.07	**0.09**	**0.09**	**0.09**	**0.09**
Total Average Local VR				0.18	0.14	0.13	0.15

Table 3 Local VR of Draft PODP & 3 OCPs

[3] Please refer to Figure 9 for reference

3.4 Draft PODP : Focus areas identified for future improvement

3.4.1 Focus areas : Kai Tak Grid Neighbourhood and Depot

Although the design of draft PODP has improved the air ventilation performance as compared with the OCPs, two focus areas, namely Kai Tak Grid Neigbourhood and the Depot site respectively, are identified for further improvement for revising the draft PODP and due consideration in the subsequent detailed design stage.

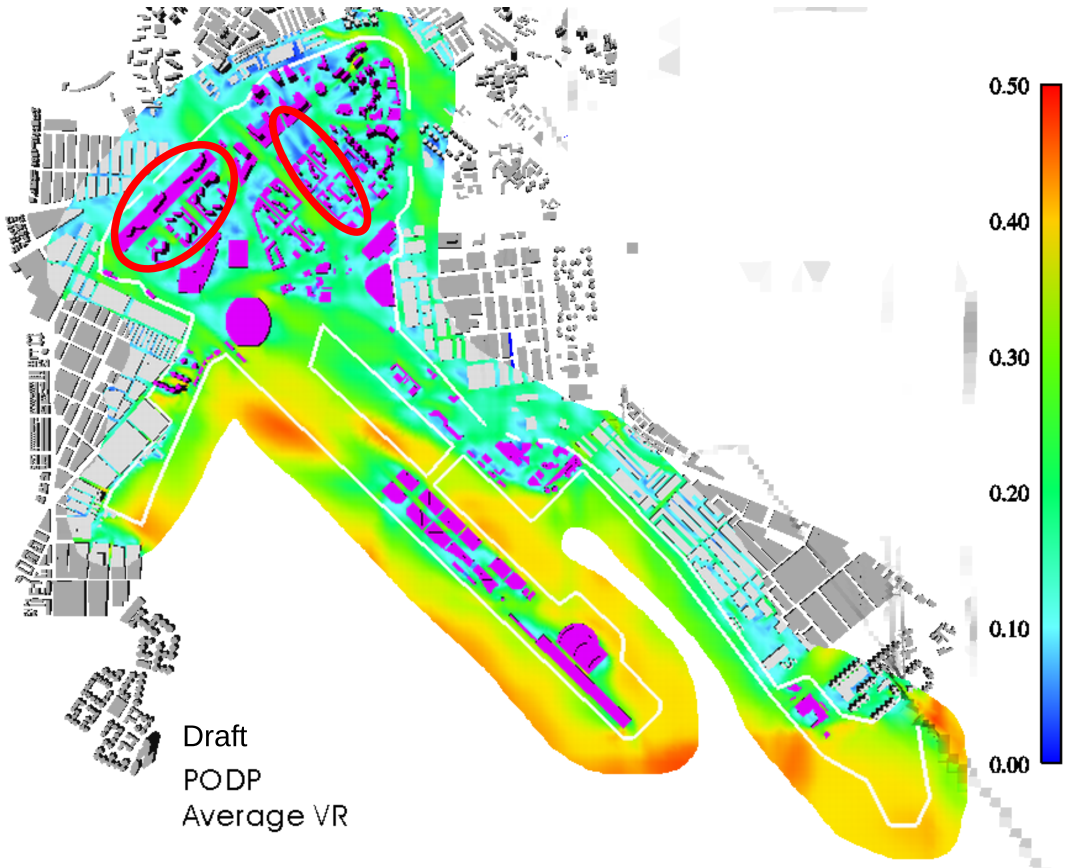

Figure 16 Focus Areas

The depot site (with development above) has large blocks of buildings and extensive podium. It shelters the winds and results in relatively low ventilation rate. The courtyard designs of the Grid Neighbourhood block the incoming wind at the leeward side and render relatively low ventilation rate at the internal zone of courtyard areas.

4 Possible air ventilation impacts to the surrounding areas due to KTD

4.1 Air ventilation performance of surrounding area

For such a large scale KTD, the public is most concerned about the impacts of air ventilation performance to the surrounding areas. To evaluate the possible impacts, the current air ventilation performance of the surrounding areas needs to be established.

The physical site condition indicates that, the KTD is surrounded by the so-called "OLD" Districts, such as Ngau Tau Kok, Kowloon Bay, Ngau Chi Wan, San Po Kong, Kowloon City, and To Kwa Wan. Being built for more than 30 years, the buildings in those districts have the characteristic of relative uniform lowrise (about 12 storeys) building height, high ground coverage, low street width/building height ratio etc. All of above lead to relative low air ventilation performance due to canyon wind effect and skimming flow. The similarity of building characteristic in these districts should result in similar wind performance in those areas.

The present AVA study model includes not only the KTD site itself, but also buildings in surrounding areas up to 400 meters beyond the site boundary. The result can also reflect, **preliminarily**, the current wind environment performance.

To gauge the current air ventilation performance at the surrounding districts, five test points are specially selected at the center of various neighboring town developments. These points represent the general **existing** wind environment of Kwun Tong, Kowloon Bay, San Po Kong, Kowloon City and To Kwa Wan. They are also placed far away from the KTD to minimize the influence of proposed site development to the wind environment. The result is given at the table below:

Special Test Points (Figure 17)	A1 (Kwun Tong)	A2 (Kowloon Bay)	A3 (San Po Kong)	A4 (Kowloon City)	A5 (To Kwa Wan)
Estimated existing VR	0.08	0.1	0.08	0.08	0.1

Table 4 Existing Velocity Ratio in the neighboring districts of KTD

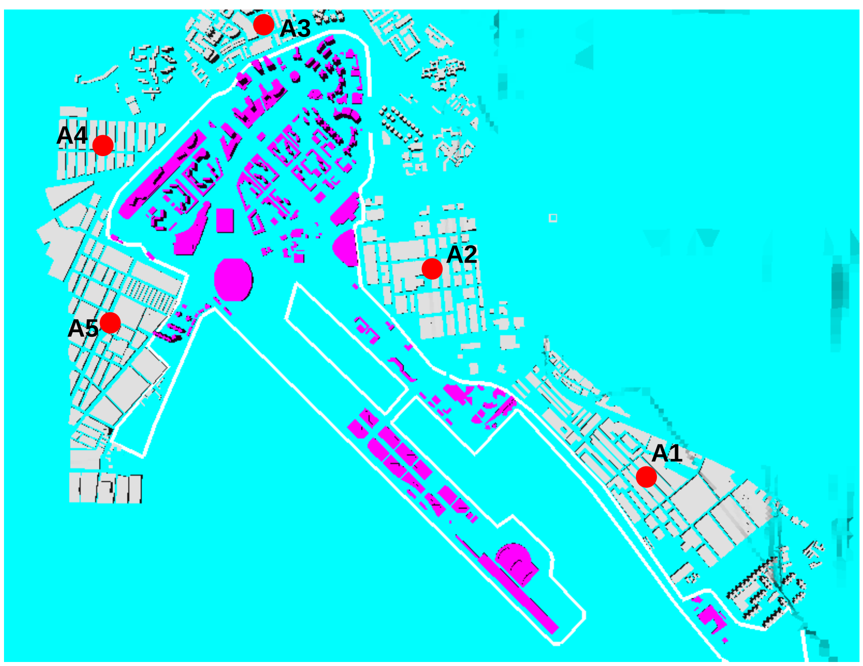

Figure 17 Existing wind performance in the neighboring districts of KTD (Based on draft PODP)

The existing VRs of the neighboring districts are generally **not greater than 0.1**.

4.2 Current variation of the existing wind environment from the seaside in the neighbouring districts

To Kwa Wan District is selected for investigation of this issue. As shown in Figure 18, located at the shore area near the buildings, there is quite a long distance between Point B1 and the proposed KTD (around 400 m), which means the influence from the proposed KTD to the wind performance of this point could be neglected. With no impact on wind performance from KTD and other buildings, the wind velocity ratio of point 1 is around 0.35. However, the wind velocity ratio at the location (Point B2) just about 2 or 3 rows away from the buildings at seaside tobogganed to 0.1, which is the general wind performance of that district.

It can be concluded that under the circumstance of such building layout, the building at the seaside could only affect the wind environment of buildings that lay within two or three rows from the seaside.

Similarly, KTD could only affect the wind environment of surrounding buildings that lay within two or three rows from the development.

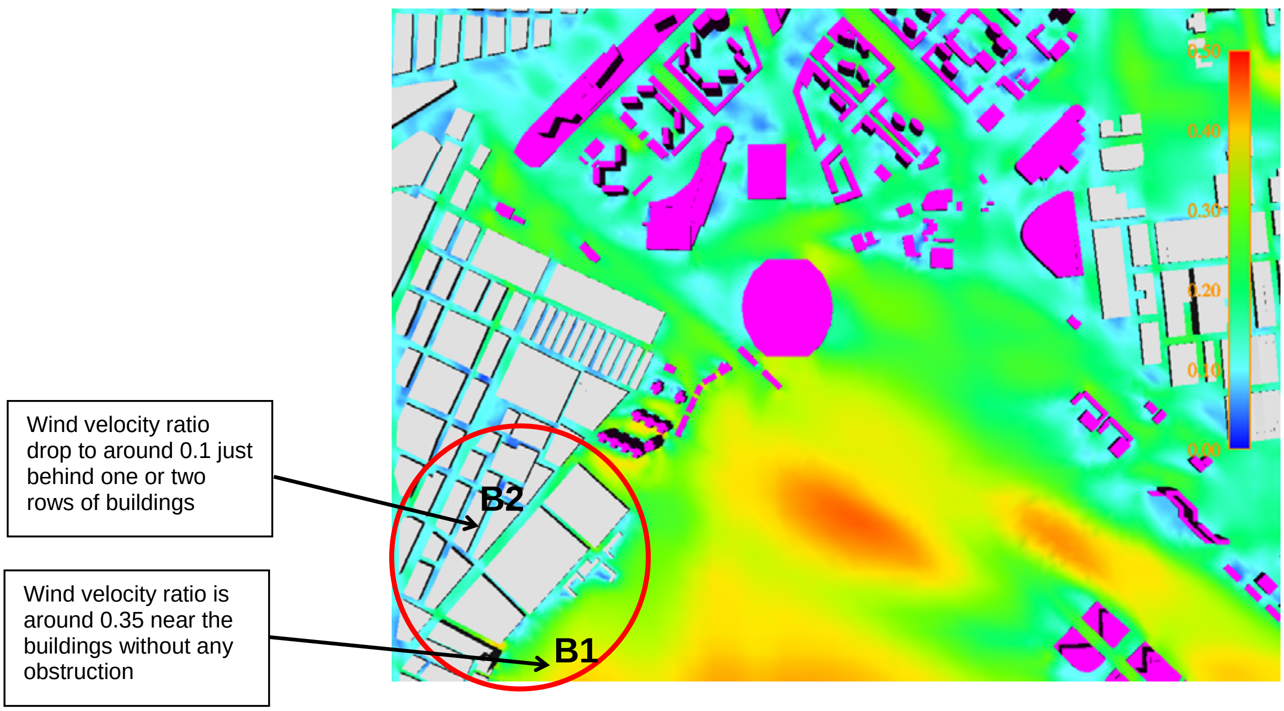

Figure 18 Wind velocity ratios at To Kwa Wan (Based on draft PODP)

4.3 Possible AVA impacts to the peripheral of Kowloon City and San Po Kong

Three special test points as shown in Figure 19 to help assess the influence of KTD to the peripherals of Kowloon City and San Po Kong. Point C2, that lying in the course of wind corridor, may well represent the **current** wind resources available to Kowloon City and San Po Kong. Point C1 and Point C3 may indicate the impacts of KTD to the peripherals of two neighboring districts respectively.

Special Test Points (Figure 19)	C1 (Impact to the peripheral of Kowloon City due to KTD)	C2 (Current wind resources)	C3 (Impact to the peripheral of San Po Kong due to KTD)
VR	0.18	0.25	0.07

Table 5 Special Test Points to investigate the possible AVA impacts of KTD to Kowloon City and San Po Kong

Point C1 (VR 0.18), dropping from Point C2 (VR 0.25), indicates the possible impacts of the KTD to the peripheral of Kowloon City. It represents the aggregate AVA impacts from the existing buildings in Kowloon City and the proposed KTD to the peripheral of Kowloon City. Although Point C1 (VR 0.18) yields the better wind performance than that in the inner Kowloon City (VR 0.08, Para. 4.1 refers), as compared with Point C2 (VR 0.25), it indicates the impact of the KTD to the peripheral of Kowloon City.

Point C3 (VR 0.07) represents the possible aggregate impacts from the KTD and the existing buildings at San Po Kong. However, Point C3 yields even poor wind performance than that in inner San Po Kong (VR 0.08, Para. 4.1 refers). Thus, the impacts from KTD to the peripheral of San Po Kong are evident.

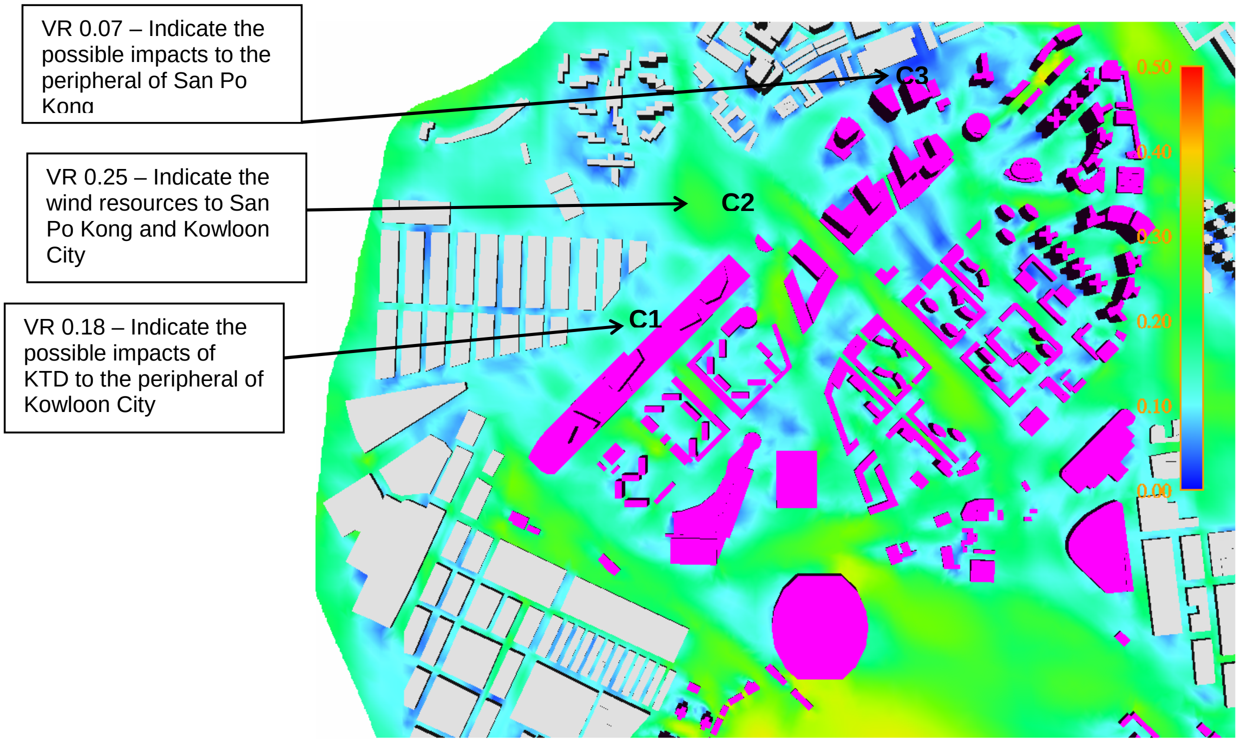

Figure 19 Wind velocity ratios at the peripherals of Kowloon City and San Po Kong (Based on draft PODP)

The results show that KTD would have AVA impacts on the peripheral of Kowloon City and San Po Kong.

4.4 Possible AVA impacts of the Depot Site

The depot design, acting as a long blank wall, may obstruct the wind penetration and lead to potential air ventilation issue at the leeward side of the depot. Relative low air ventilation performance is found at the boundary connecting to Kowloon City.

Based on the results of the AVA Initial Study, the depot site would have impact to the wind environment of the periphery of the Kai Tak site and may not directly contribute to the impact to the wind environment of the outer boundary of Kowloon City. However, to ascertain the impacts precisely and quantitatively, we would require further AVA detail studies.

Section No	Site VR		
	OCP 1	**OCP 2**	**OCP 3**
19 Along Prince Edward Road East (adjacent to depot site)	0.09	0.09	**0.12**
20 Along Prince Edward Road East (adjacent to Kai Tak Nullah)	**0.22**	0.2	0.13
	No development along Section 20	Building bulk Above Depot Development	Less buildings Above Depot Development

Extract of Table 1

Referring to the Extract of Table 1 above, Site VR of Sections 19 & 20 under 3 OCPs could be further interpreted to give some understanding of the issues.

It could be noted that without any buildings along the boundary of Kai Tak site (at the Prince Edward Road East adjacent to Kai Tak Nullah) under OCP1 at Section 20, the Site VR is approximately 0.22. At Section 19 under OCP2, which would be affected by the building bulk above the depot site, the Site VR would be reduced to 0.09. But, under OCP3 with less buildings above the depot site, the Site VR at Section 19 would increase to 0.12.

To undertake detailed analysis, Section 19 is divided into Sections 19a and 19b and respective VR is indicated in Figure 20. These results also reveal the AVA impacts from depot itself and above depot development. It clearly shows that the above depot development have caused more impacts on wind performance at the perimeter of the Kai Tak site than the depot itself.

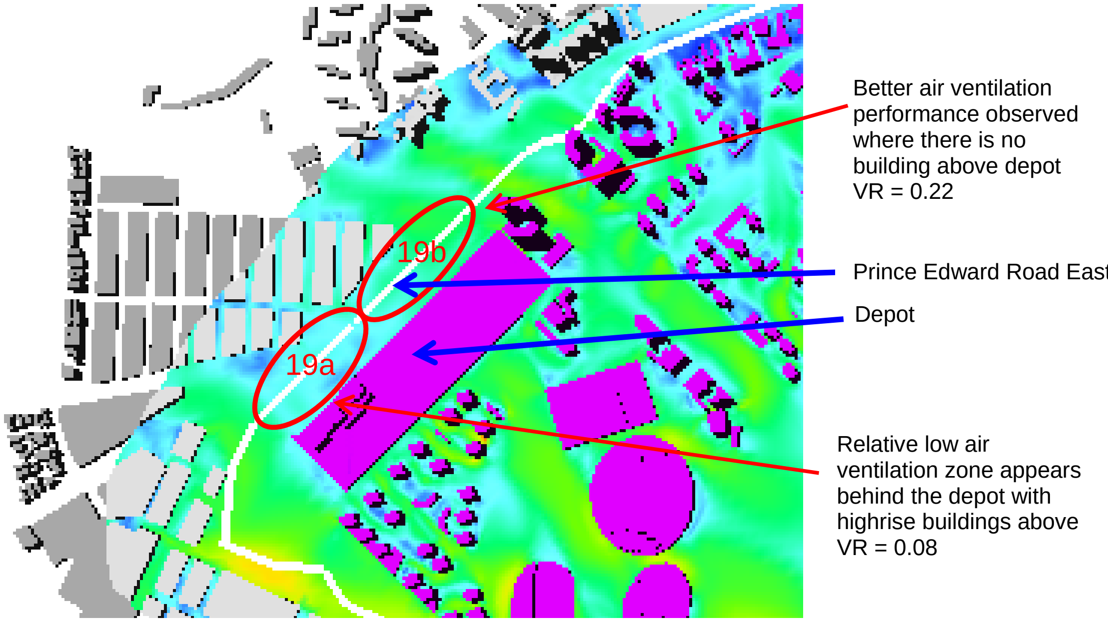

Figure 20 influence of air ventilation to Kowloon City due to depot and buildings above based on OCP 3

The reason that causes resultant air ventilation performance is complicated. It is not only related to the depot itself, but also the buildings above the depot, the distance between affected areas and depot, the prevailing wind directions etc.

One could conclude that the depot and/or the buildings above the depot have their respective impacts to the pedestrian wind environment. AVA study on the OCP 3 indicated that the low H/W ratio between the height of the depot (H) and width of Prince Edward Road East (W) could help to provide a sufficient space for wind washing down to pedestrian level, and keep a reasonable airflow entering to Kowloon City. Relatively, the depot itself may not affect much the wind environment of Kowloon City. But, the magnitude of the impact would require further AVA detailed study.

4.5 Possible AVA impacts of Above Depot development to the Kowloon City

To further investigate how the AVA impacts of the above depot development, six special test points are also placed at the locations closer to Kowloon City (See Figure 21).

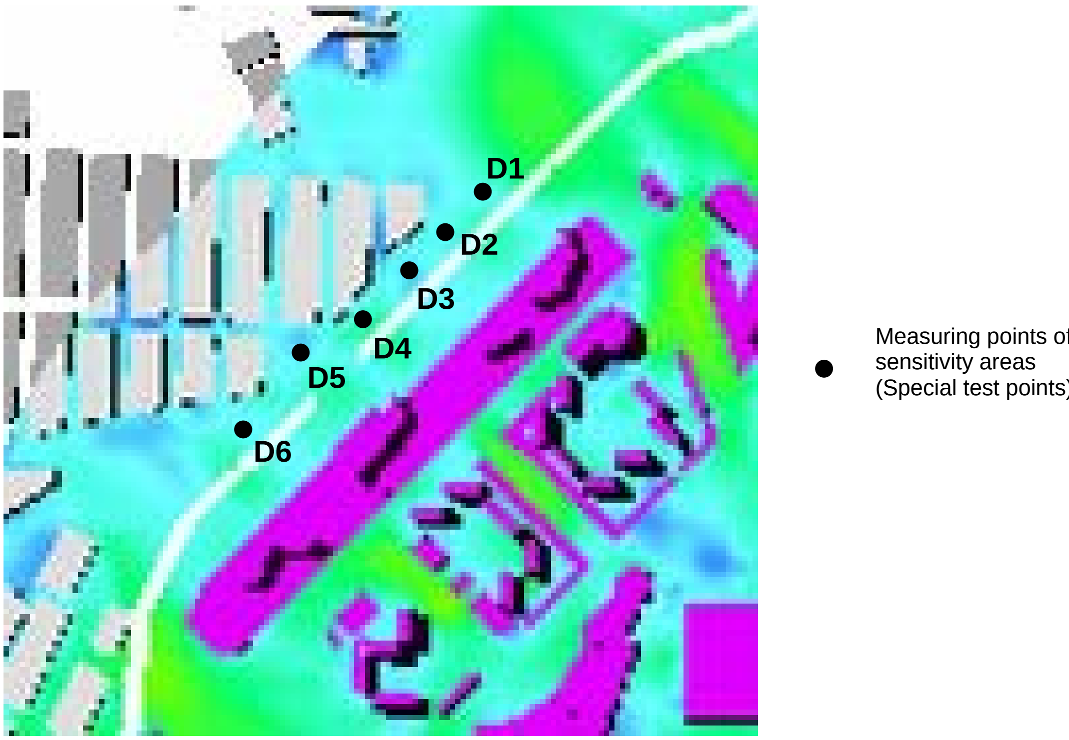

Figure 21 Special test points placed nearer Kowloon City (Based on draft PODP)

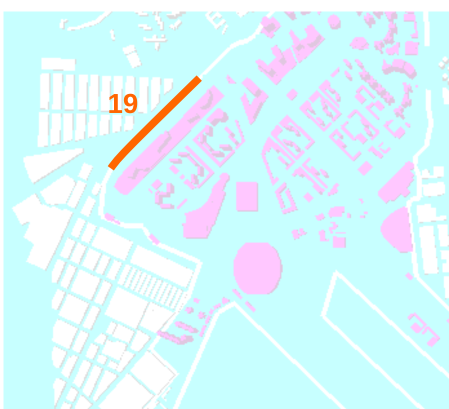

Figure 22 Site VRw - Section 19 : Average VR 0.13 (Based on draft PODP)

Special Test Points (Figure 20)	D1	D2	D3	D4	D5	D6
Depot	Yes	Yes	Yes	Yes	Yes	Yes
Above Depot Development	Yes		Yes		Yes	
Existing Kowloon City Buildings		Yes	Yes	Yes	Yes	Yes

Table 6: Major sources of influence on AVA performance on the special test points

The result is given at the table below:

Special Test Points (Figure 20)	D1	D2	D3	D4	D5	D6
VR	0.14	0.11	0.07	0.16	0.08	0.13
Difference with Section 19 VR (i.e. 0.13)	+0.01	-0.02	-0.06	+0.03	-0.05	same

Table 7: VR of the special test points

Although the six special test points are all placed further away from KTD compared with Section 19, they do not all give VRs respectively higher than that of Section 19. Only Point D4 yields a substantially higher VR. It represents the minimal impact from KTD that reasonably free from the impacts of the development above depot with the wide gap. Points D3 and D5 yield the worst VRs that substantially less than 0.13 indicating the aggregated AVA impacts from KTD and the existing buildings at Kowloon City. They performs not better than that in the existing inner Kowloon City does (VR 0.08, Para. 4.3 refers). The results show that

a. The wind performance at Kowloon City is subject to the impacts from the existing buildings there (Points D1 vs Points D3& D5).

b. The wider gap between buildings in the above depot development would reduce the AVA impacts to Kowloon City (Points D2 vs D4)

5 Recommended mitigation measures to revise the draft PODP

Incorporating the findings of the air ventilation assessment on the Draft PODP, the following improvement measures are proposed for the Final PODP:

5.1 Railway depot site

Several methods can be adopted to minimize air ventilation impact to Kowloon City. These include:

- Building heights should be reduced.
- The alignment of the building blocks is also recommended to align to the prevailing wind directions (please refer to Figure 23 and Figure 24 for the "with depot" and "without depot" scenarios).
- In case of the "with depot" scenario, the main frontage of the depot facing south-east should allow at least 30% opening to enhance air ventilation across.

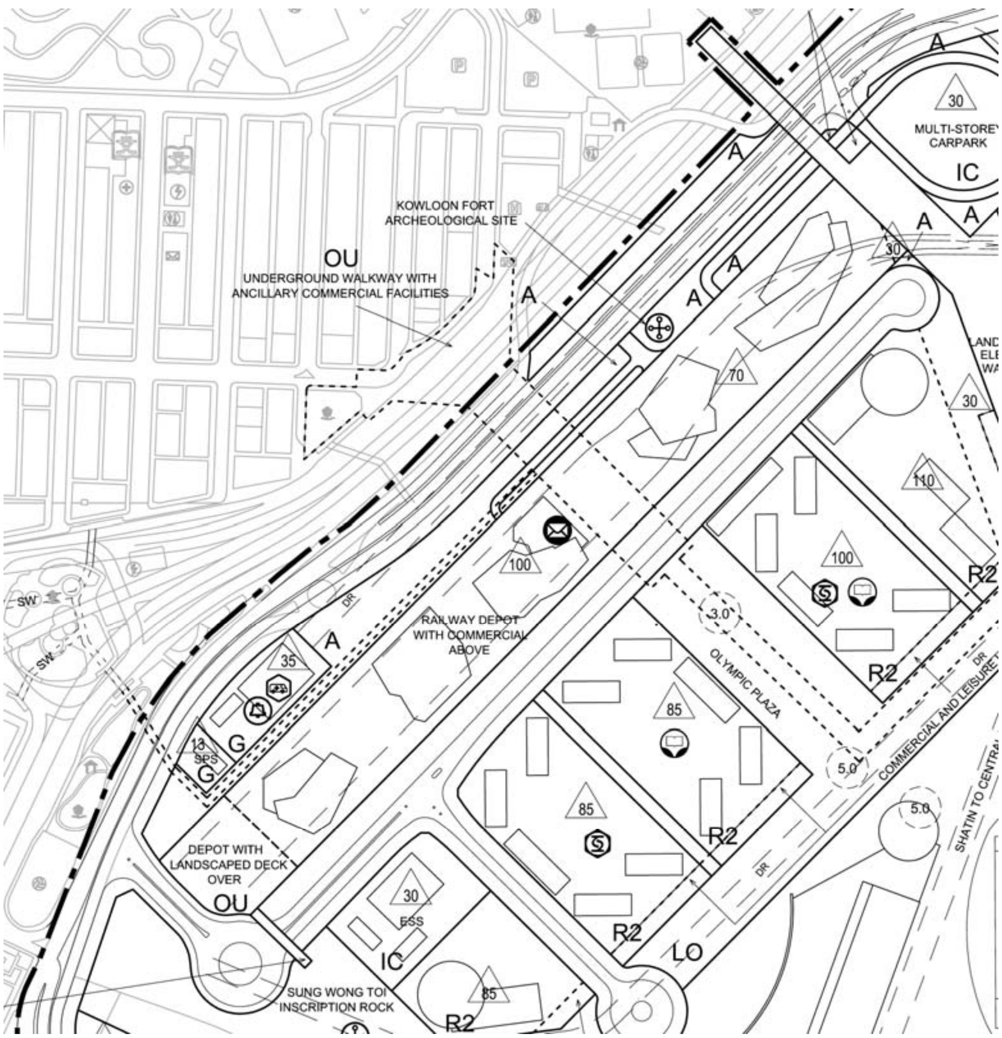

Figure 23 Proposed design of building blocks under " with depot" scenario

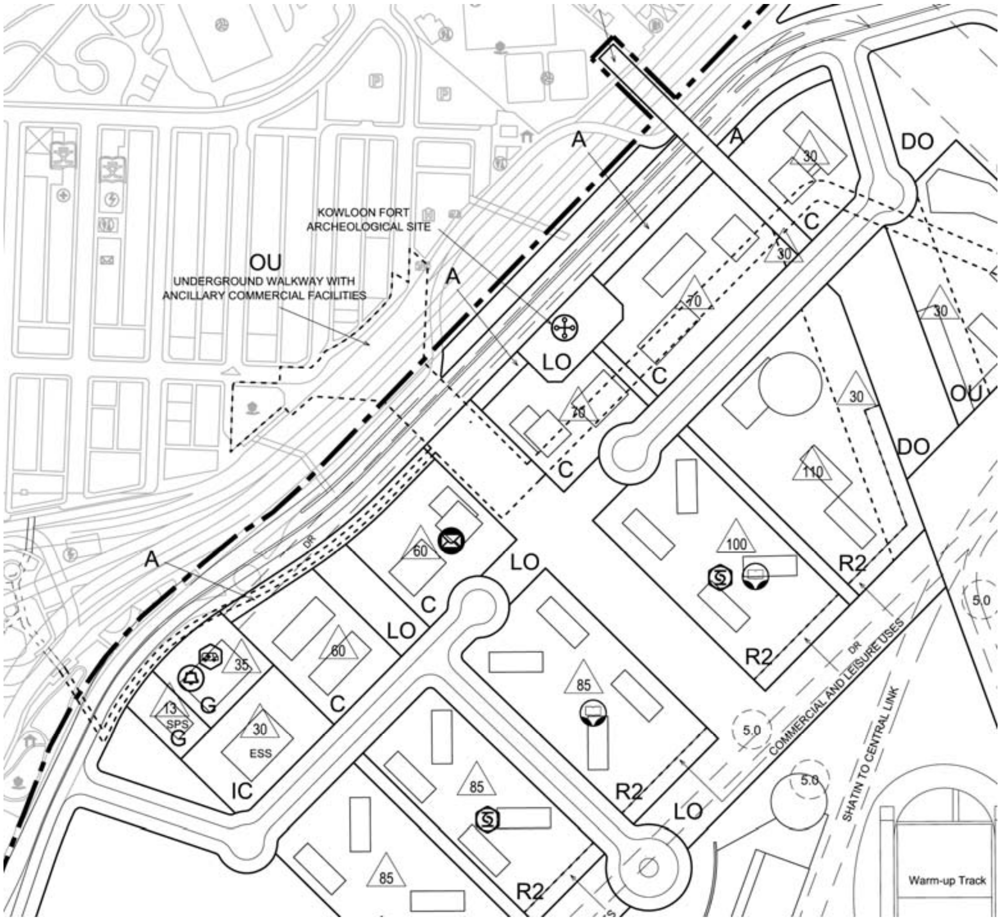

Figure 24 Proposed design of building blocks under " without depot" scenario

5.2 Kai Tak Station mixed use belt

In proposed draft PODP scheme, large podium design has almost been eliminated while considering the recommendation from previous 3 OCP schemes. There is no doubt that large coverage of the podium could block the wind penetration. To enhance wind penetration, any podium design should adopt the following:

- Minimum 30% opening area or permeability at the pedestrian / lower level should be provided in order to enhance air ventilation performance at pedestrian level.
- Wind ventilation gaps are recommended to be provided between buildings to maximize the air permeability of the development, the width of which is preferably half of that of the building frontages facing the prevailing wind (Figure 25).

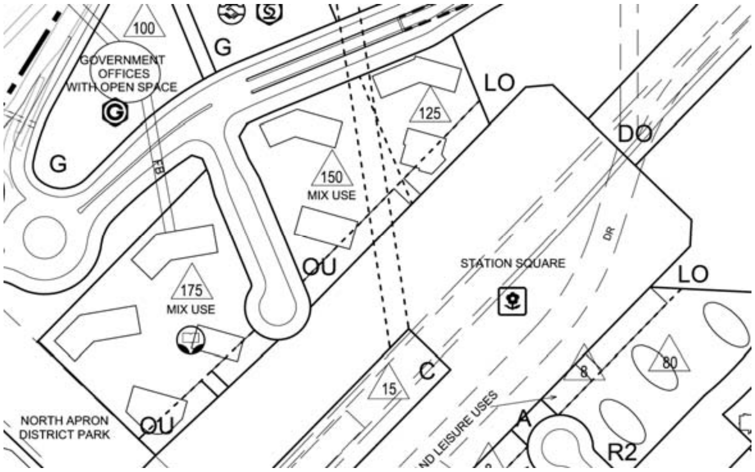

Figure 25 Proposed podium design with openings to facilitate air ventilation

5.3 Grid neighbourhood

The courtyard design could create an isolated internal zone from the external urban area that would discourage unhindered wind penetration through the site.

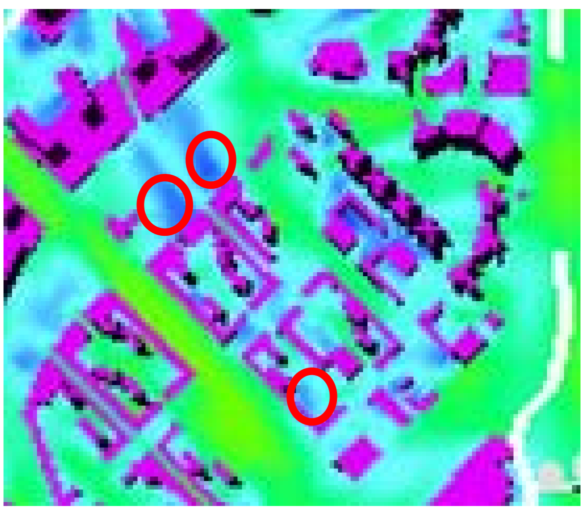

Figure 26 Stagnant zones in a typical courtyard

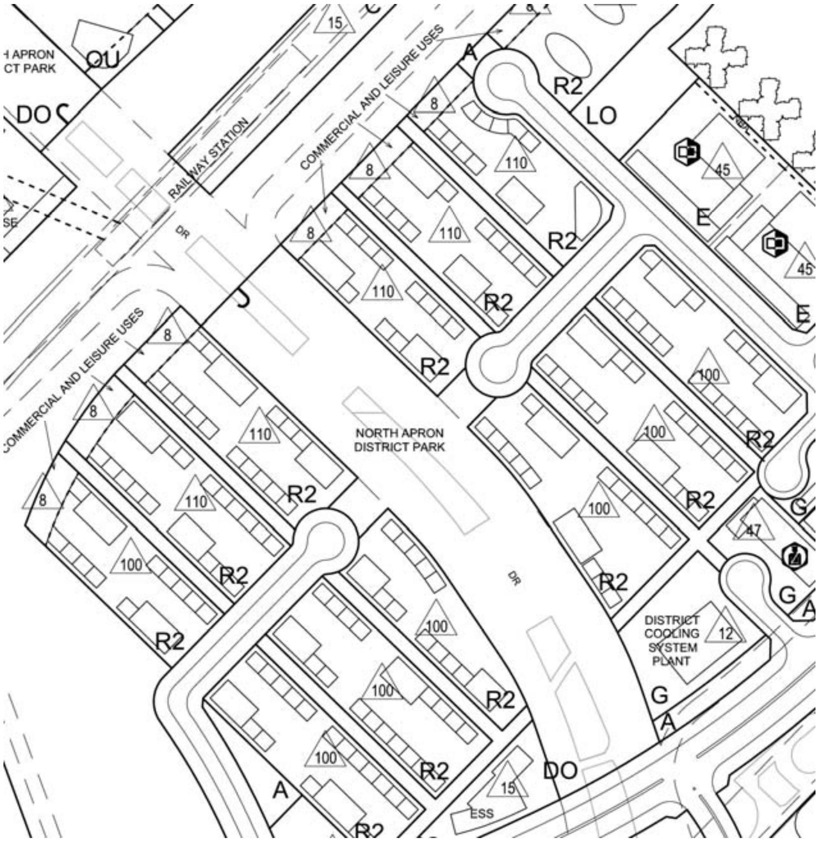

Figure 27 Proposed changes for Grid Neighbourhood - imposing building height restrictions for short frontages and including openings

Where possible, the short frontages of the grid lots facing the Station Square would be restricted to maximum 8mPD. The opening area of the courtyard should occupy a minimum of 30% of the grid lot width, and the opening orientation should align to the prevailing wind direction (Figure 27).

5.4 Land parcels adjoining San Po Kong

Buildings along Prince Edward Road East adjoining San Po Kong district should be reduced to minimise their potential AVA impact. Podium design is also generally discouraged in KTD to enhance air ventilation performance at pedestrian/low level.

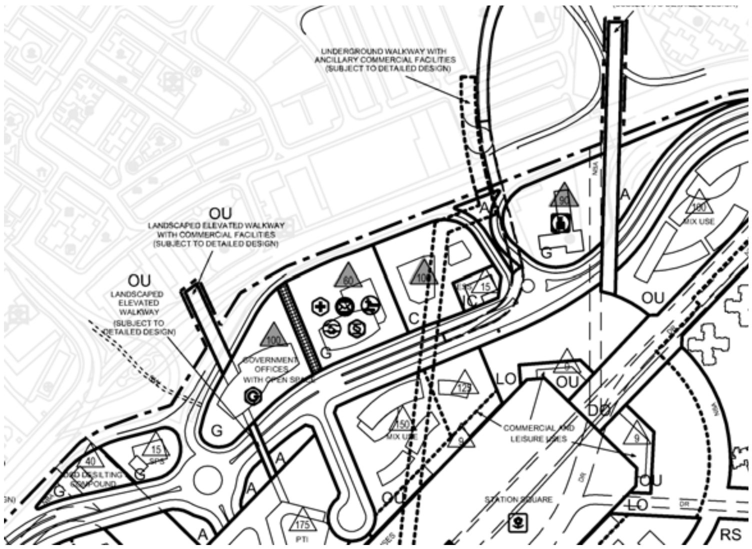

Figure 28 Proposal to revise the draft PODP - reducing building heights and discouraging podium in KTD to reduce AVA impact to San Po Kong

6 Conclusion

The Initial AVA study for the 3 OCPs and draft PODP schemes was carried out based on the established AVA methodology using the advanced CFD technique.

The draft PODP has incorporated the following findings the AVA study for the OCPs to achieve a better overall wind performance:

6.1 Improvements achieved on the draft PODP based on the Initial AVA Study for 3 OCPs (Figure 23)

- Aligning the building blocks in the "Commercial" belt in North Apron align to the prevailing wind
- Reducing the size of the railway depot and lowering the plot ratio of the development above the depot
- Planning of a grid neighbourhood in North Apron area, with small street blocks and with alignment of the long frontage of street blocks align to the prevailing wind

The AVA study for the draft PODP has further identified some areas (Chapters 3 & 4) and proposed design guidelines (Chapter 5) for improving wind performance within KTD and reducing AVA impacts to the neighbouring districts for the subsequent planning and engineering design stages.

6.2 Recommended mitigation measures to revise the draft PODP (Chapter 5)

For Above Depot Development

- Reducing building heights
- The alignment of the building blocks akin to the prevailing wind directions

For Kai Tak Station mixed use belt

- Minimum 30% opening area or permeability at the pedestrian / lower level
- Wind ventilation gaps between buildings

For Grid neighbourhood

- Restricting the short frontages of the grid lots facing the Station Square to maximum 8mPD.
- The opening area of the courtyard with a minimum of 30% of the grid lot width
- The opening orientation aligning to the prevailing wind direction

For land parcels adjoining San Po Kong

- Reducing building heights
- Discouraging podium generally in KTD

Further Detailed AVA Study on air ventilation assessments for individual developments based on the proposed design guidelines should be carried out in the subsequent detail design stages to verify the effectiveness.

A1 Assessment methodology

A1. CFD Model

A1.1 CFD software: STAR-CD

The CFD Software STAR-CD (Version 3.26) was applied in this study. The STAR-CD Program is a product of London-based Computational Dynamics Ltd. It is one of the leading, multi-purpose thermofluid analysis programs for industry. This software is widely favoured by engineers requiring a robust and efficient tool, capable of modelling fluid flow, heat transfer, mass transfer and chemical reaction. The STAR-CD Program has achieved this by not only incorporating the latest physical models and numerics, but also by being fast, efficient, and flexible enough to analyse the whole geometry with sufficient resolution. Its main attributes include:

- A self-contained, fully-integrated and user-friendly program suite comprising pre-processing, analysis and post-processing facilities;
- A general geometry-modelling capability that renders the code applicable to the complex shapes often encountered in external wind study
- Extensive facilities for automatic meshing of complex geometries, either through built-in tools or through interfaces to external mesh generators
- Built-in models of an extensive and continually expanding range of flow phenomena, including transients, compressibility, turbulence, heat transfer, mass transfer, chemical reaction and multi-phase flow
- Fast and robust computer solution techniques that enhance reliability and reduce computing overheads,
- Easy-to-use facilities for setting up and running very large CFD models using State-of-the-art *Parallel computing* techniques.
- Has been validated locally for external flow through a number of Arup projects of environmental study for Housing Department and Buildings Department.

A1.2 Input data

To build the CFD model that could achieve the most accurate result as the real condition, three kinds of the information are needed, These include:

a. GIS information about the surrounding topography

b. GIS information about the surrounding buildings

c. Building layout of the proposed planning scheme

A2. Domain of CFD model

The CFD model contained the information of the surrounding buildings and site topography that would affect the wind environment of the studied site. Under the aid of Geographical Information System (GIS) techniques, the CFD model incorporated with the surrounding buildings as well as site topographies precisely.

Following the AVA assessment requirements, the building external assessment area would include 400 m beyond the landward boundary of KTD. As a result, the CFD model incorporated with buildings whose extent up to 600 m beyond the landward boundary of KTD, such that boundary effects were eliminated to enhance the accuracy.

Following the European external wind guideline and the most recent research findings, the vertical computational domain are kept as 3 times as the highest building around the site. Considering the topographical effect, the vertical computational domain was set to 1600 m, which is high enough to achieve the sufficient accuracy.

As shown in following figure, the CFD model was built-up with an extreme large domain of 7.2 km (L) x 6 km (W) x 1.6 km (H).

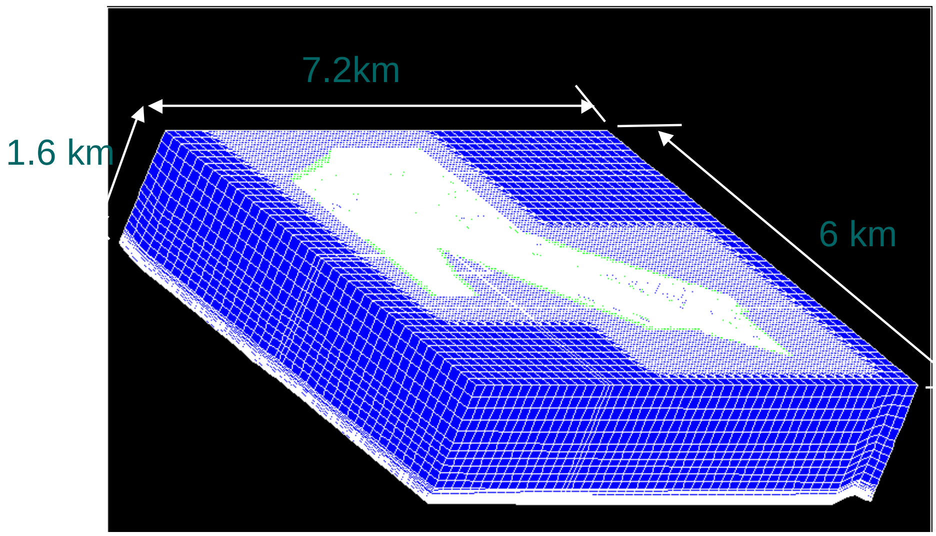

Figure A1 Computational domain

Finer grid system was applied to the most concerned area based on preliminary judgement, while coarse grid system was applied to the area of surrounding buildings for better computational performance while maintaining satisfactory result. The total model size built for the study is about 6 million cells.

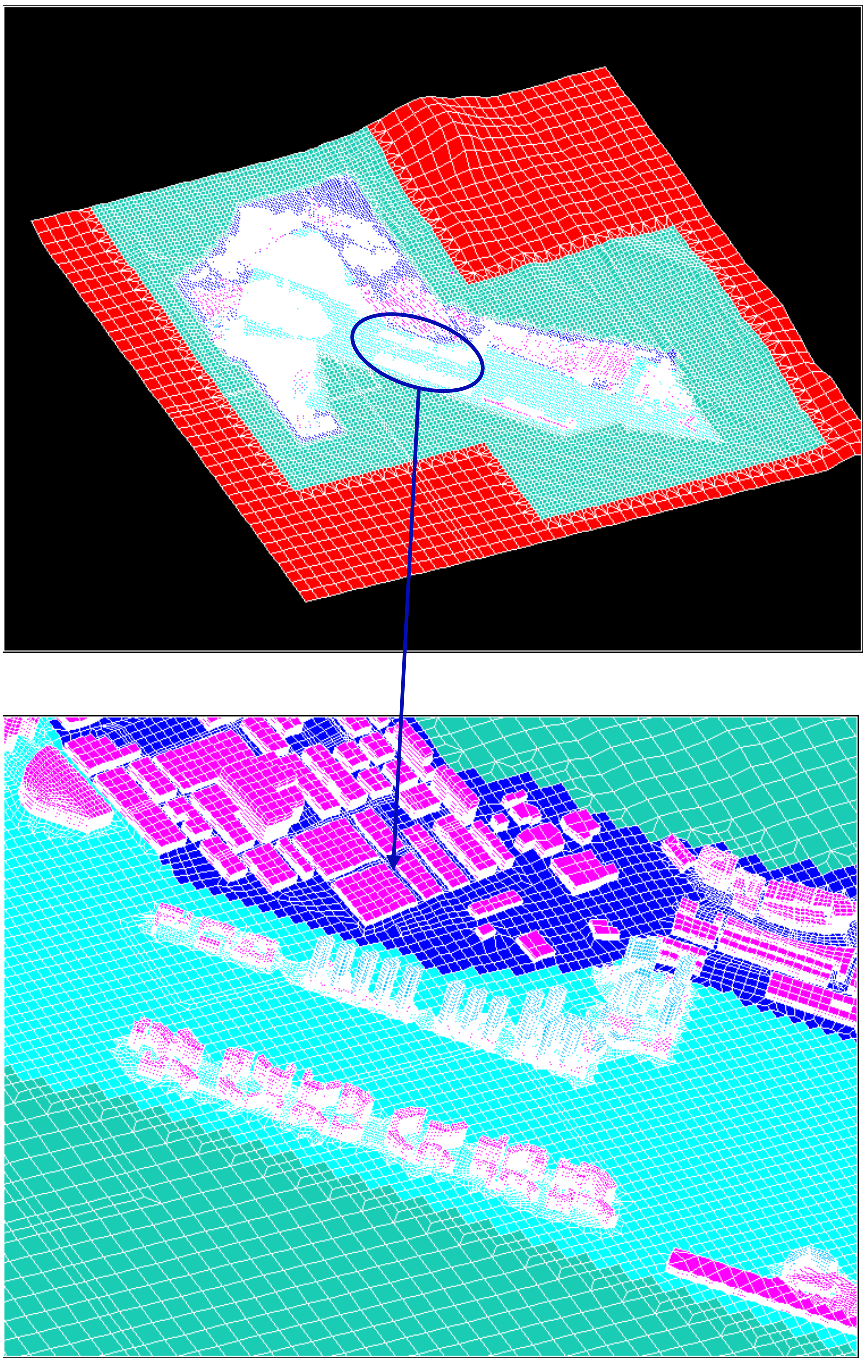

Figure A2 Grid arrangement for CFD Model

The surrounding building layout and the building heights were extracted from the GIS data provided by CP-M JV. All existing buildings and planned building were built based on the information provided by CP–M JV in CAD format. All remaining buildings were assumed to be located at vacant development sites taking into account the statutory planning control and the built form of adjacent similar developments.

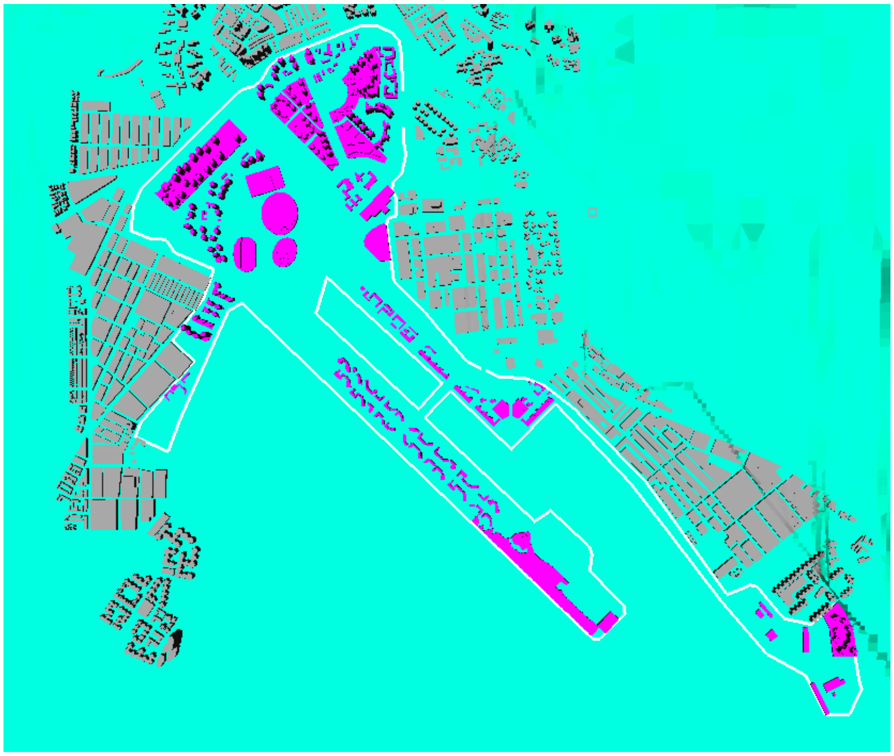

Figure A3 Layout of surrounding buildings

A3 Turbulence model

As highlighted in recent academic and industrial research literatures by CFD practitioners, the widely used **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 sections around building.

To address this issue, Arup has developed expertise in the state-of-the-art of advanced CFD technique - **Detached Eddy Simulation (DES)** running on parallel computers. The technique provides a more accurate representation of the levels of turbulence that can be expected in an urban environment. These are also very useful for presentation purposes, providing a detailed understanding of the flow characteristics throughout the flow domain. The DES model was applied in present studies.

Since the CFD guideline for wind environment in HK is absent, the settings for this Computational Fluid Dynamic study follow the European External Wind Guideline and the most recent research findings undertaken by Japanese computational wind study experts, Prof. Mochida and Prof. Yoshie. The table below summarizes the CFD modelling settings of the present study.

		Condition Setting Criteria*	CFD Model for Kai Tak Development
Computational domain	**Horizontal**	Certain extent outside the rim of the surrounding blocks	Edge of domain is 600m from the surrounding buildings
	Vertical	≥ 3H	1600m
Grid resolution		One side of high-rise building divided into 10 portions or more	One side of high-rise building divided into at least 15 portions
Extent of surrounding building blocks		2 or more rows of surrounding urban blocks maintained	8 rows of surrounding urban blocks maintained
Turbulence model		Standard k-ε model or better	DES model: for CFD study of performance of design

Table A1 CFD modelling settings

* Ref: Yoshie et al, "Cooperative project for CFD prediction of pedestrian wind environment in the Architectural Institute of Japan", 4th European & African Conference of Wind Engineering, Prague, 11-15 July, 2005