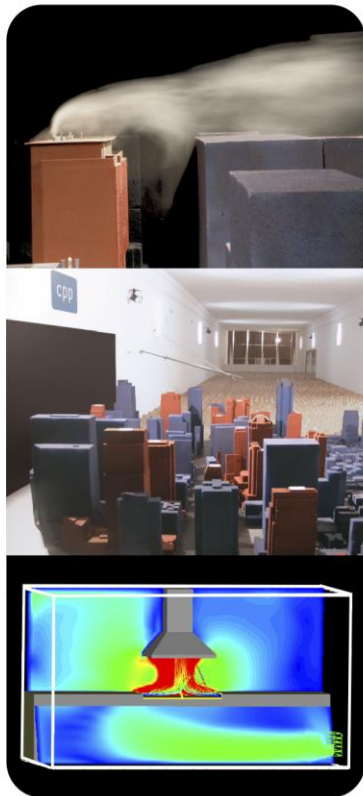




CERMAK  
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PETERSEN

WIND ENGINEERING AND AIR QUALITY CONSULTANTS

## Final Report



Pedestrian Wind Tunnel Tests for:  
Harbourside Shopping Centre  
Development  
Sydney, NSW, Australia

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## EXECUTIVE SUMMARY

A wind tunnel study of the proposed Harbourside Shopping Centre Development to be located in Sydney, NSW, Australia was conducted to assess the pedestrian wind environment in and around the development site. A model of the project was fabricated to a 1:400 scale and centred on a turntable in the wind tunnel. Replicas of surrounding buildings within a 570 m radius were constructed and placed on the turntable.

The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St. Peters. Approach boundary layers, representative of the environment surrounding the proposed development, were established in the test section of the wind tunnel. The approach wind flow had appropriate turbulence characteristics corresponding to a Suburban Approach as defined in Standards Australia (2011).

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 38 locations for 16 wind directions each. These points were tested around the development in the indicative design of the proposed development, focusing on access routes, doorways, balconies, and outdoor seating areas. The measurements were combined with site specific wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location. A subset of ground level locations was tested in the existing configuration as well as the proposed envelope configuration.

The wind environment around the development was found to be generally suitable for pedestrian standing and walking style activities from a comfort perspective with reference to the Lawson criteria, with a small number of locations rated as suitable for pedestrian sitting activities. All but one test location at ground level passed the Lawson distress criterion. A number of locations on elevated levels were found to be relatively windy, with potential mitigation strategies recommended.

## DOCUMENT VERIFICATION

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17/06/20	Initial release	JP/CS	PE	JP
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## LIST OF SYMBOLS

$D$	Characteristic dimension (building height, width, etc.), m
$n$	Mean velocity profile power law exponent
$T_u$	Turbulence intensity, $U_{rms}/U$
$U$	Local mean velocity, m/s
$U_{ref}$	Reference mean velocity at reference height $z_{ref}$ , m/s
$U_{pk}$	Peak wind speed in pedestrian studies, m/s
$U_{rms}$	Root-mean-square of fluctuating velocity, m/s
$z$	Height above surface, m
$\nu$	Kinematic viscosity of approach flow, m <sup>2</sup> /s
$\sigma( )$	Standard deviation of ( ), = ( )' <sub>rms</sub>
$\rho$	Density of approach flow, kg/m <sup>3</sup>
( ) <sub>max</sub>	Maximum value during data record
( ) <sub>min</sub>	Minimum value during data record
( ) <sub>mean</sub>	Mean value during data record
( ) <sub>rms</sub>	Root mean square about the mean

## 1 INTRODUCTION

Pedestrian acceptability of footpaths, entrances, plazas and terraces is an important design parameter of interest to the building owner and architect. Assessment of the acceptability of the pedestrian level wind environment is desirable during the project design phase so that modifications can be made, if necessary, to create wind conditions suitable for the intended use of the space.

Techniques have been developed which permit boundary layer wind tunnel modelling of buildings to determine wind velocities in pedestrian areas. This report includes wind tunnel test procedures, test results, and discussion of acquired test results. Table 1 summarises the model configurations, test methods, and data acquisition parameters used. All the data collection was performed in accordance with Australasian Wind Engineering Society (2001), and American Society of Civil Engineers (1999, 2010). While analytical methods such as computational fluid dynamics (CFD) have some utility in the field of pedestrian wind comfort, they are not yet capable of reliably and accurately predicting gust wind speeds for assessment of wind conditions from a safety perspective.

Table 1: Parameters and configurations for data acquisition.

<i>General Information</i>	
Model scale	1:400
Surrounding model radius (full-scale)	570 m
Reference height (full-scale)	200 m AGL
Approach Terrain Category	Suburban Approach (Terrain Category 3)
<i>Testing Configurations</i>	
Configuration 1 (test locations labelled X.1)	Existing Harbourside Shopping Centre Development with existing and approved surrounding buildings, as shown in Figure 3 and Figure 4(T).  Pedestrian winds measured at 15 locations for 16 wind directions at 22.5° increments from 0° (north).
Configuration 2 (test locations labelled X.2)	Proposed Harbourside Shopping Centre Development envelope with existing and approved surrounding buildings, as shown in Figure 4(M).  Pedestrian winds measured at 17 locations for 16 wind directions at 22.5° increments from 0° (north).
Configuration 3 (test locations labelled X.3)	Proposed Harbourside Shopping Centre Development indicative design with existing and approved surrounding buildings, as shown in Figure 4(B).  Pedestrian winds measured at 38 locations for 16 wind directions at 22.5° increments from 0° (north).

## 2 THE WIND TUNNEL TEST

Modelling of the aerodynamic flow around a structure requires special consideration of flow conditions to obtain similitude between the model and the prototype. A detailed discussion of the similarity requirements and their wind tunnel implementation can be found in Cermak (1971, 1975, 1976). In general, the requirements are that the model and prototype be geometrically similar, that the approach mean velocity and turbulence characteristics at the model building site have a vertical profile shape similar to the full-scale flow, and that the Reynolds number for the model and prototype be equal. Due to modelling constraints, the Reynolds number cannot be made equal and the Australasian Wind Engineering Society Quality Assurance Manual (2001) suggests a minimum Reynolds number of 50,000, based on minimum model width and wind velocity at the top of the model; in this study the modelled Reynolds number was over 50,000.

The wind tunnel test was performed in the boundary layer wind tunnel shown in Figure 1. The wind tunnel test section is 3.0 m wide, by 2.4 m high with a porous slatted roof for passive blockage correction. This wind tunnel has a 21 m long test section, the floor of which is covered with roughness elements, preceded by vorticity generating fence and spires. The spires, barrier, and roughness elements were designed to provide a modelled atmospheric boundary layer approximately 1.2 m thick with a mean velocity and turbulence intensity profile similar to that expected to occur in the region approaching the modelled area. The approach wind characteristics used for the model test are shown in Figure 2 and are explained more fully in Section 4.1.1.

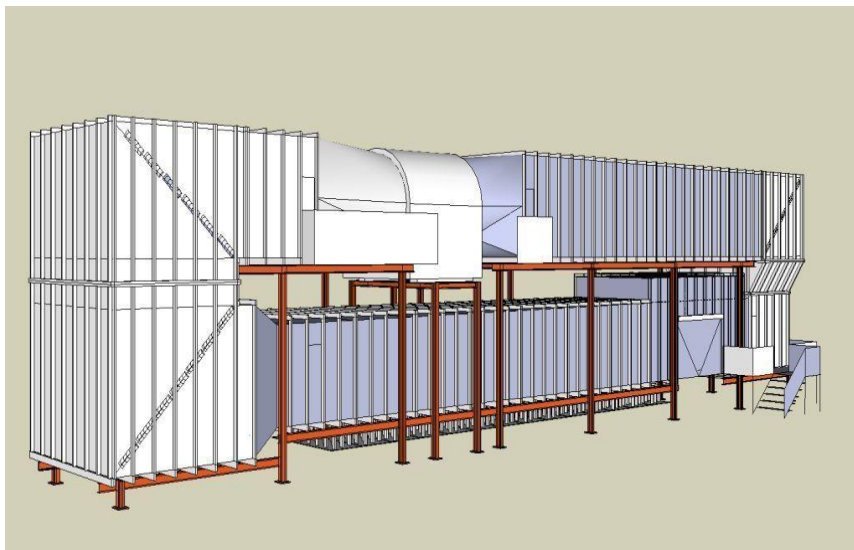


Figure 1: Schematic of the closed-circuit wind tunnel.

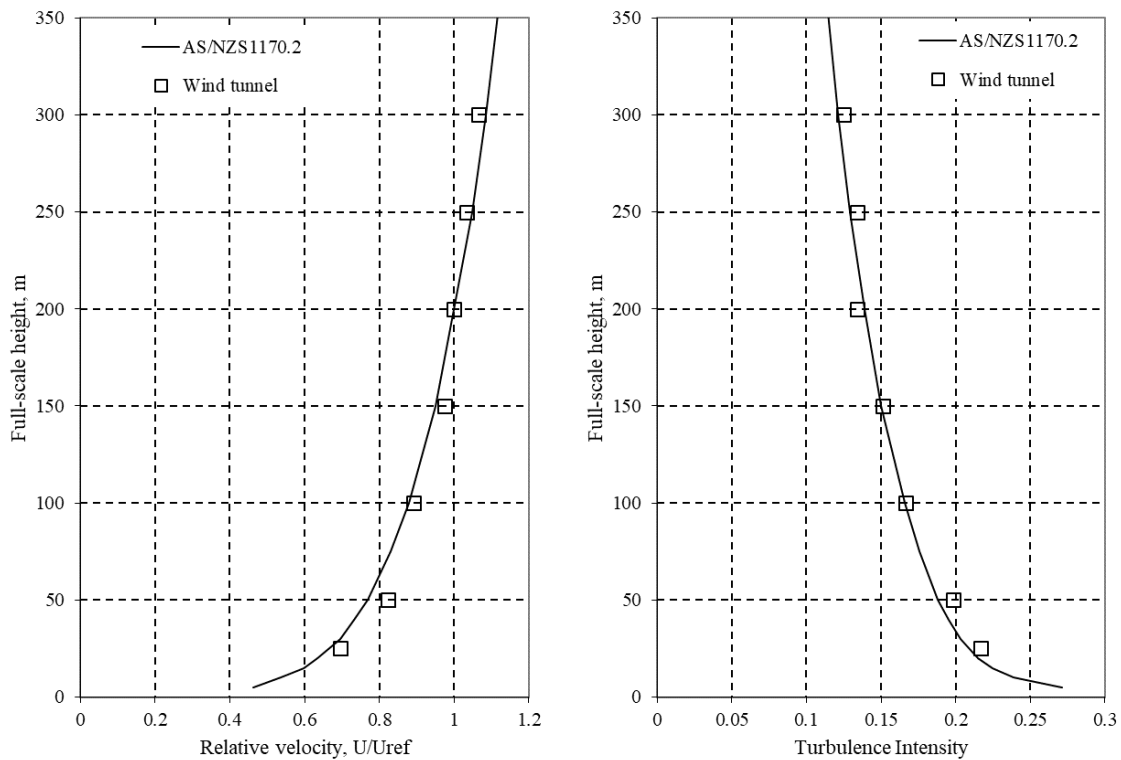


Figure 2: Mean velocity and turbulence profiles (Terrain Category 3) approaching the model.

A model of the proposed development and surrounds to a radius of 570 m was constructed at a scale of 1:400, which was consistent with the modelled atmospheric flow, permitted a reasonable test model size with an adequate portion of the adjoining environment to be included in a proximity model, Figure 3, and was within wind tunnel blockage limitations. Significant variations in the building surface were formed into the model. The models were mounted on the turntable located near the downstream end of the wind tunnel test section, Figure 5. The turntable permitted rotation of the modelled area for examination of velocities from any approach wind direction.



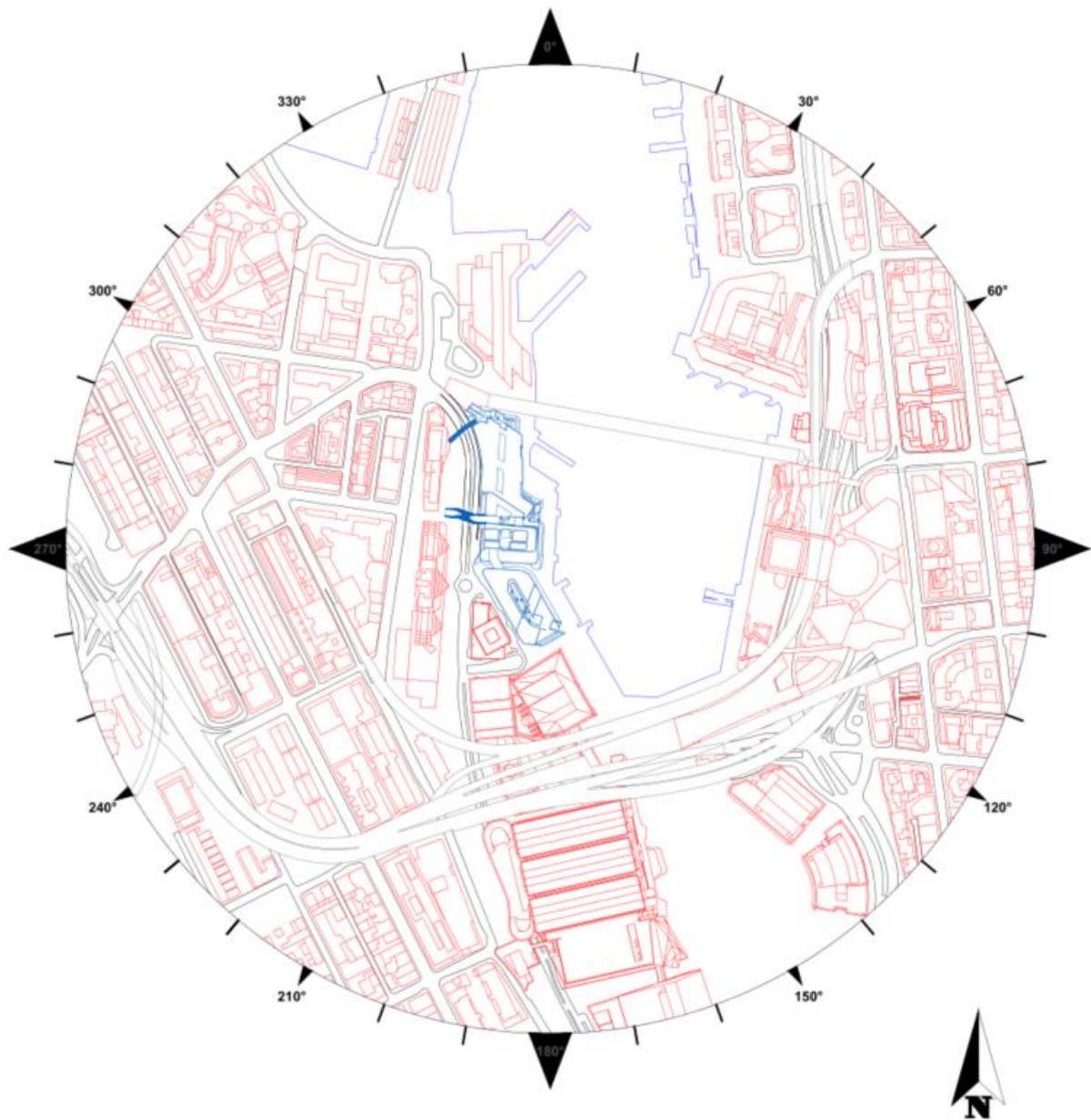


Figure 3: Project location and turntable layout (Configuration 3).

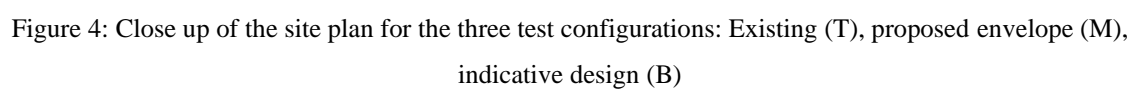




Figure 5: Proposed Harbourside Shopping Centre Development model in the wind tunnel viewed from the south-west (configuration 3).












Figure 6: Close up photographs of the three test configurations viewed from the north-east: Existing (T), proposed envelope (M), indicative design (B)

### 3 ENVIRONMENTAL WIND CRITERIA

It is understood that the City of Sydney DCP does not apply to this development, and no specific wind criteria are defined for the development. Over the years, a number of researchers have added to the knowledge of wind effects on pedestrians by suggesting criteria for comfort and safety. Because pedestrians will tolerate higher wind speeds for a smaller period of time than for lower wind speeds, these criteria provide a means of evaluating the overall acceptability of a pedestrian location. Also, a location can be evaluated for its intended use, such as for an outdoor café or a footpath. One of the most widely accepted set of criteria was developed by Lawson (1990), which is described in Table 2.

Lawson's criteria have categories for comfort, based on wind speeds exceeded 5% of the time, allowing planners to judge the usability of locations for various intended purposes ranging from "Business Walking" to "Pedestrian sitting". The level and severity of these comfort categories can vary based on individual preference, so calibration to the local wind environment is recommended when evaluating the Lawson ratings. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds<sup>1</sup>. In both cases, the wind speed used is the larger of a mean or gust equivalent-mean (GEM) wind speed. The GEM is defined as the peak gust wind speed divided by 1.85; this is intended to account for locations where the gustiness is the dominant characteristic of the wind. Assessment using the Lawson criteria provides a similar classification as using once per annum gust criteria, but also provides significantly more information regarding the serviceability wind climate.

Table 2: Summary of Lawson criteria.

<b>Comfort</b> (maximum of mean or gust equivalent mean (GEM <sup>+</sup> ) wind speed exceeded 5% of the time)		
< 4 m/s	Pedestrian Sitting (considered to be of long duration)	
4 - 6 m/s	Pedestrian Standing (or sitting for a short time or exposure)	
6 - 8 m/s	Pedestrian Walking	
8 - 10 m/s	Business Walking (objective walking from A to B or for cycling)	
> 10 m/s	Uncomfortable <sup>1</sup>	
<b>Distress</b> (maximum of mean or GEM wind speed exceeded 0.022% of the time)		
<15 m/s	not to be exceeded more than two times per year (or one time per season) for general access area	
<20 m/s	not to be exceeded more than two times per year (or one time per season) where only able-bodied people would be expected; frail or cyclists would not be expected	

Note: <sup>+</sup> The gust equivalent mean (GEM) is the peak 3 s gust wind speed divided by 1.85.

<sup>1</sup> The rating of "uncomfortable" in Table 2 is the word of the acceptance criteria author and may not apply directly to any particular project. High wind areas are certainly not uncomfortable all the time, just on windier days. The word uncomfortable, in our understanding, refers to acceptability of the site by pedestrians for typical pedestrian use; i.e., on the windiest days, pedestrians will not find the areas "acceptable" for walking and will tend to avoid such areas if possible. The distress rating fail indicates some unspecified potential for causing injury to a less stable individual who might be blown over. The likelihood of such events is not well described in the literature and is likely to be strongly affected by individual differences, presence of water, blowing dust or particulates, and other variables in addition to the wind speed.

## 4 DATA ACQUISITION AND RESULTS

### 4.1 Velocities

Velocity profile measurements were taken to verify that appropriate boundary layer flow approaching the site was established and to determine the likely pedestrian level wind climate around the test site. Pedestrian wind measurements and analysis are described in Section 4.1.2. All velocity measurements were made with hot-film anemometers, which were calibrated against a Pitot-static tube in the wind tunnel. The calibration data were described by a King's Law relationship (King, 1914).

#### 4.1.1 Velocity Profiles

Mean velocity and turbulence intensity profiles for the boundary layer flow approaching the model are shown in Figure 2. Turbulence intensities are related to the local mean wind speed. These profiles have the form as defined in Standards Australia (2011) and are appropriate for the approach conditions.

#### 4.1.2 Pedestrian Winds

The development site is located on the western side of Darling Harbour, Figure 3, with the high-rise buildings of the Sydney CBD to the east quadrant. Surroundings to the south and west mainly consist of medium- to low-rise structures, with the high-rise Sofitel Darling Harbour located to the immediate south-west.

For this report, wind speed measurements were recorded at 15 locations, as described in Table 1, to evaluate pedestrian wind comfort and safety in and around the project site shown in Figure 8 to Figure 15. Velocity measurements were made at the model scale equivalent of 1.5 to 2.1 m above the surface for 16 wind directions at 22.5° intervals. Locations were chosen to determine the degree of pedestrian wind comfort and safety at building corners where relatively severe conditions are frequently found, near building entrances and passageways, along the main pedestrian area along the water to the east of the development, and at upper level outdoor locations.

The hot-film signal was sampled for a period corresponding to one hour in prototype. All velocity data were digitally filtered to obtain the two to three second running mean wind speed at each point; this is the minimum size of a gust affecting a pedestrian and is the basis for the various acceptability criteria. These local wind speeds,  $U$ , were normalised by the tunnel reference velocity,  $U_{ref}$ . Mean and turbulence statistics were calculated and used to calculate the normalised effective peak gust using:

$$\frac{U_{pk}}{U_{ref}} = \frac{U + 3U_{rms}}{U_{ref}}$$

The mean and gust equivalent mean velocities relative to the free stream wind tunnel reference velocity at a full-scale elevation of 200 m are plotted in polar form in Appendix 1. The graphs show velocity magnitude and the approach wind direction for which that velocity was measured. The polar

plots aid in visualisation of the effects of the nearby structures or topography, the relative significance of various wind azimuths, and whether the mean or gust wind speed is of greater importance.

To enable a quantitative assessment of the wind environment in the region, the wind tunnel data were combined with wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 m at Sydney Airport from 1995 to 2019, Figure 7.

From these data, directional criterion lines for the Lawson rating wind speeds have been calculated and included on the polar plots in Appendix 1; this gives additional information regarding directional sensitivity at each location.

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarised in Figure 7 to rate each location. From the cumulative wind speed distributions for each location, the percentage of time each of the Lawson comfort rating wind speeds are exceeded are presented in tabular form under the polar plots in Appendix 1. In addition to the rating wind speeds, the percentage of time that 2 m/s is exceeded is also reported. This has been provided as it has been found that the limiting wind speed for long-term stationary activities such as fine outdoor dining should be about 2 to 2.5 m/s rather than 4 m/s.

Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806, for use at sea; the Beaufort scale is reproduced in Table 3 including qualitative descriptions of wind effects.

The tables in Appendix 1 additionally provide the wind speed exceeded 5% and 0.022% of the time for direct comparison with the Lawson comfort and distress criteria, and the associated Lawson ratings for both mean and GEM wind speeds. A colour coded summary assessment of pedestrian wind comfort and safety with respect to the Lawson criteria is presented in Figure 8 to Figure 15 for each test location. The implications of the results are discussed in Section 5.

**Sydney Airport**

Corrected to open country terrain  
Annual, all hours  
1995-2019

Calm 1.0 %

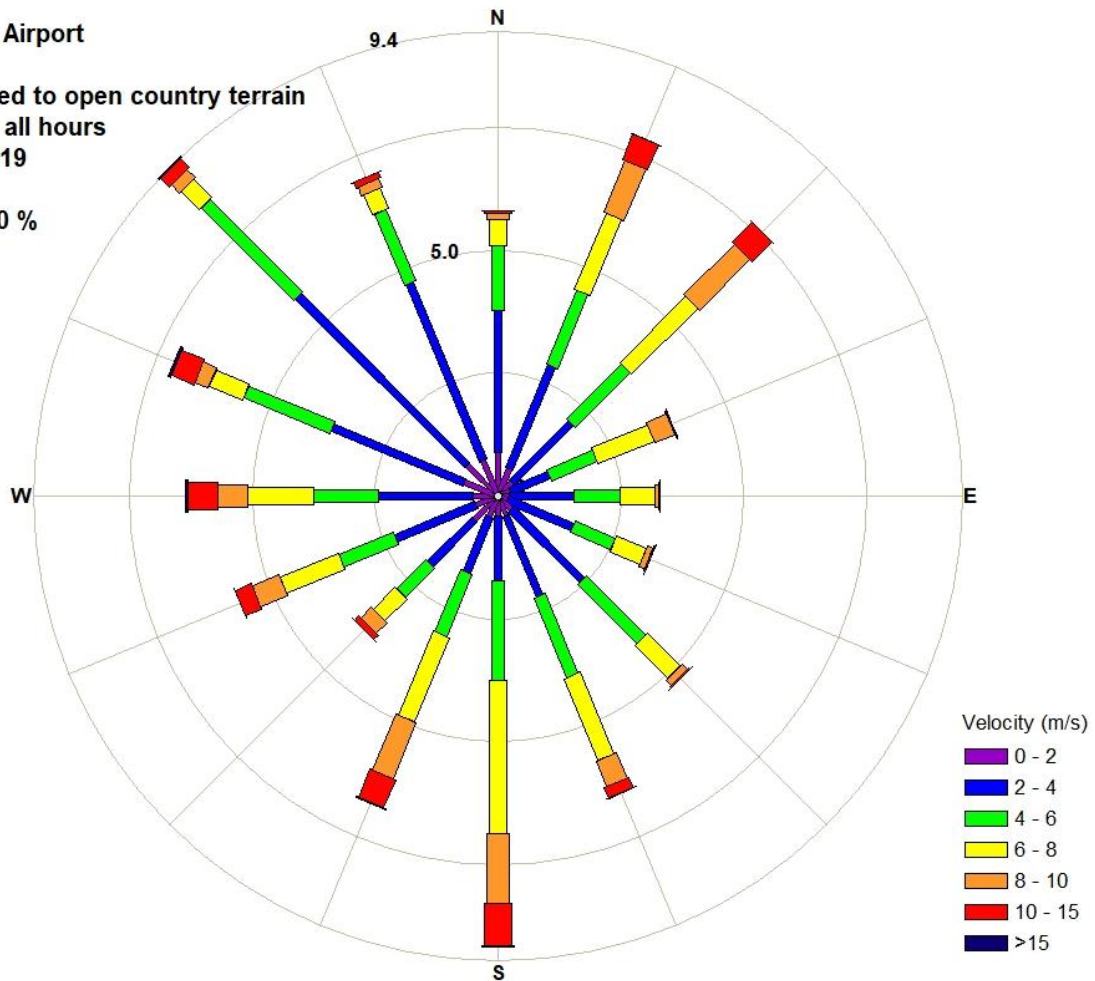


Figure 7: Wind rose for Sydney Airport.

Table 3: Summary of wind effects on people, Penwarden (1973)

Description	Beaufort Number	Speed (m/s)	Effects
Calm, light air	0, 1	0–2	Calm, no noticeable wind.
Light breeze	2	2–3	Wind felt on face.
Gentle breeze	3	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps
Moderate breeze	4	5–8	Raises dust, dry soil, and loose paper. Hair disarranged.
Fresh breeze	5	8–11	Force of wind felt on body. Drifting snow becomes airborne. Limit of agreeable wind on land.
Strong breeze	6	11–14	Umbrellas used with difficulty. Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	7	14–17	Inconvenience felt when walking.
Gale	8	17–21	Generally impedes progress. Great difficulty with balance in gusts.
Strong gale	9	21–24	People blown over by gusts.



## 5 DISCUSSION

The wind climatology chart of Figure 7 indicates that the most frequent strong winds are from the north-east and south, and west quadrants. The locations tested around the development site are susceptible to winds from these directions, depending on the relative position of the location tested to the geometry of the proposed development and surrounds. The influence of wind direction on the suitability of a location for an intended purpose can be ascertained from the polar plots in Appendix 1. The polar plots show the severity, distribution, and frequency of steady winds and gusts from 16 directions at 22.5° intervals.

A summary of the expected wind rating targets based on the intended use of the space at the investigated locations and the wind tunnel results, including the Lawson comfort and safety ratings, is provided in Table 4.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 8 to Figure 15, which depict the locations selected for investigation along with the Lawson comfort and distress criteria ratings. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes or exceeds the distress criterion, Table 2. Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people found in Table 3.

Note that testing was performed without existing and proposed trees, and other plantings to provide a worst-case assessment; heavy landscape planting typically reduces the wind speeds by less than 10%. However, landscaping cannot be relied on to provide sufficient shielding from winds that potentially pose a safety risk due to their vulnerabilities. Mitigation measures are likely to be required for orange and red locations and may be necessary for other locations depending on the intended use of the space. Although conditions may be classified as acceptable, there may be certain wind directions that cause regular strong events, and these can be determined by an inspection of the polar plots in Appendix 1.

Table 4: Summary of expected wind rating targets versus wind tunnel results.

		Lawson Comfort Criteria, 5% exceedance wind speeds (m/s), all hours			Lawson safety rating, 0.022% exceedance wind speed (m/s), all hours		
Test Location		Existing Configuration	Proposed Envelope	Indicative design	Existing Configuration	Proposed Envelope	Indicative design
Ground Level	1	4.8	6.0	5.8	8.5	11.4	10.7
	2	6.1	5.6	7.2	12.2	11.1	14.0
	3	6.7	6.1	5.2	13.1	12.0	9.6
	4	6.1	6.8	5.6	12.1	12.1	10.1
	5	6.3	7.0	7.1	12.4	12.6	14.9
	6	5.7	7.9	7.5	11.8	15.1	13.2
	7	4.2	2.9	3.9	8.9	8.1	8.5
	8	5.6	4.6	5.3	10.2	9.2	11.4
	9	3.7	2.8	3.3	6.7	5.9	6.3
	10	4.6	4.8	5.4	9.2	9.9	10.9
	11	5.6	5.0	5.8	9.9	9.7	11.6
	12	3.9	4.2	4.7	7.8	8.1	9.2
	13	6.3	7.0	6.8	11.9	13.9	12.8
	14	6.3	6.6	7.6	12.5	12.1	14.3
	15	5.0	5.7	5.3	10.4	10.6	9.8
	16			5.7			11.3
	17			5.1			9.6
	18			2.9			5.5
	19			4.2			7.7
	20			5.4			10.1
	21			5.3			10.3
	22			4.9			9.4
	23			5.0			9.9
	24			6.3			14.0
Podium Levels	25			4.7			9.8
	26			7.1			13.9
	27			9.9			20.2
	28	7.7		6.3	15.2		13.8
	29	6.4		7.2	16.3		15.1
	30			4.5			10.6
	31			9.3			17.2
Balconies	32			4.1			8.1
	33			4.2			11.2
	34			5.3			12.3
	35			4.0			8.0
	36			4.1			9.4
	37			5.9			15.5
	38			8.1			15.0

**LEGEND**

Comfort Criteria	Wind Speed range (m/s)	Safety Criteria	Wind Speed range (m/s)
Outdoor Dining	<2	Pass	0 - 15
Pedestrian Sitting	>2 to 4	Able-bodied	15 - 20
Pedestrian Standing	>4 to 6	Fail	> 20
Pedestrian Walking	>6 to 8		
Business Walking	>8 to 10		
Uncomfortable	>10		

### Ground Level

In the existing configuration, the wind conditions at ground level around the site were found to be suitable for pedestrian standing and walking under the Lawson comfort criteria with individual more sheltered locations near the upper limit of the pedestrian sitting criterion, Locations 9 and 12, Figure 8. The proposed redevelopment shows overall similar ground level wind conditions as the existing configuration, with some locations becoming slightly windier in the proposed configurations, Figure 9 and Figure 10.

In the main pedestrian area along the water, to the east of the development in Locations 11 through 15, the conditions in all three configurations are similar with the same Lawson comfort ratings, with the exception of Location 12 which becomes slightly windier in the proposed configurations changing from a Lawson comfort rating of pedestrian sitting to standing.

The area to the south and south-west of the site is rated as suitable for pedestrian walking in the existing configuration, in line with the use as a general pedestrian accessway, Locations 2 through 5, with Location 1 experiencing calmer conditions with a pedestrian standing rating. In the proposed envelope, conditions in this space are generally similar with some points becoming slightly windier and others calmer; Location 2 improves in the comfort rating, while Location 1 degrades from standing to walking in this configuration. In the indicative design, Locations 3 and 4 between the subject site and the Sofitel tower improve to a pedestrian standing rating, while the wind speeds in Locations 1, 2, and 5 increase slightly compared with the existing configuration, however remaining in the same comfort category.

The space to the west of the development near the base of the proposed tower in Location 6 is affected by downwash off the tower façade for winds from the north-east quadrant in the two proposed configurations as well as accelerated flow under the pedestrian bridge and changes from a pedestrian standing rating in the existing configuration to a pedestrian walking rating. This is considered suitable for the intended use as a pedestrian accessway.

Locations 7 through 10, to the north and north-west of the development site are generally calmer than locations on the southern side, with ratings as suitable for pedestrian standing and sitting. Similar conditions were observed in all three test configurations.

Additional ground level locations were tested in the indicative design in areas closer to the façade of the podium and near entrances to the through site links, Locations 16 through 24. The locations on the eastern side, Locations 16 through 21, are overall calmer than the test locations in the centre of the walkways, though most are rated as suitable for pedestrian standing. For the intended retail seating areas along that frontage local wind mitigation would be required. This can be developed during detailed design.

Location 23 near the western entrance of the tower is relatively sheltered and subjected to calmer wind conditions than the nearby Location 6. Furthermore, Location 24 at the western end of the through site link was found to be suitable for pedestrian walking, with potential for pressure driven flows causing adverse wind conditions. Local mitigation methods, such as vertical screen or high-foliage landscaping, may be required if long-term stationary activities in this region are intended.

All test locations at ground level pass the Lawson distress criterion with the exception of Location 6, marginally exceeding the pass criterion, on the western side of the tower in the proposed envelope configuration. Winds from the north-east quadrant generate downwash on the north façade of the tower which affects the ground level wind conditions in this area combined with accelerated flow underneath the pedestrian bridge. It is noted that the indicative design passes the safety criterion in this location, Figure 10.

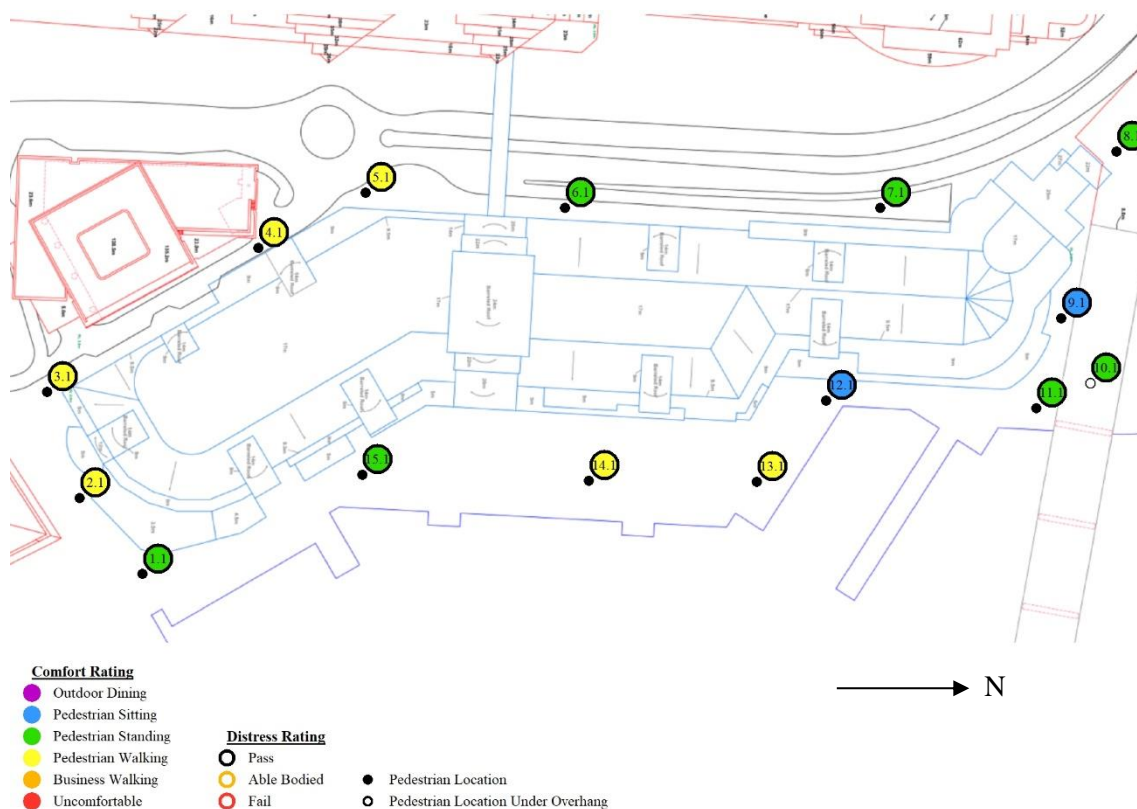


Figure 8: Pedestrian wind speed measurement locations with comfort/distress ratings – Existing Configuration.

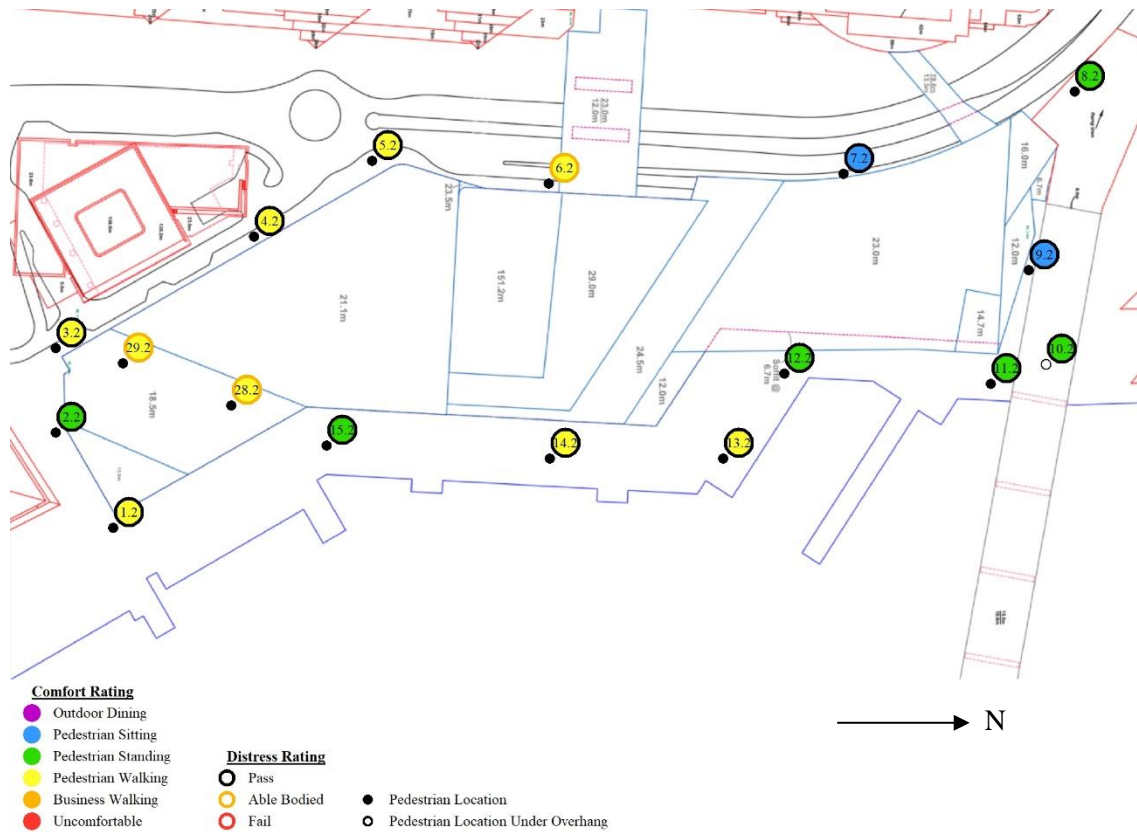


Figure 9: Pedestrian wind speed measurement locations with comfort/distress ratings – Proposed Envelope.

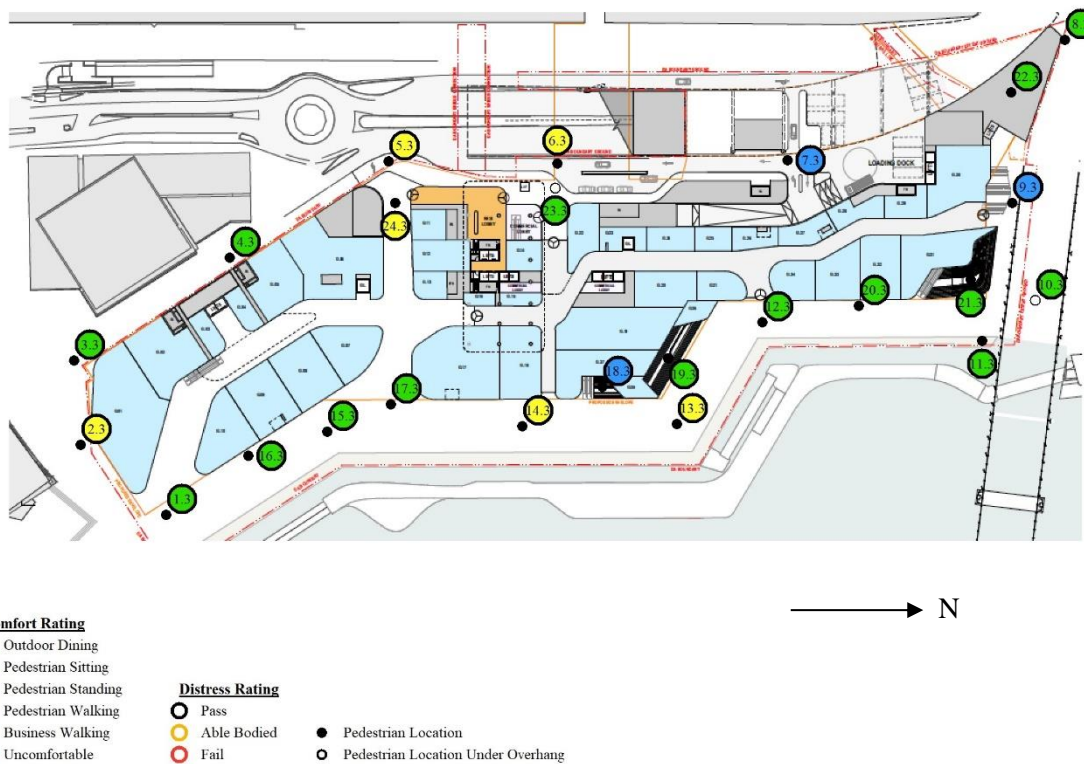


Figure 10: Pedestrian wind speed measurement locations with comfort/distress ratings – Indicative Design, Ground level.

### Podium Levels

Upper level locations were tested primarily in the indicative design, Figure 11 to Figure 15. Locations in less exposed walkways, such as Location 25 on Level 02 and Location 30 on Level 05, were found to be suitable for pedestrian standing. Windier conditions with a pedestrian walking comfort rating were observed near the Level 03 pedestrian bridge over Darling Drive in Location 26, as well as on the Level 04 terraces to the south, Locations 28 and 29. Locations 28 and 29 were also tested in the proposed envelope with similar wind conditions observed. In the envelope configuration, both locations exceeded the Lawson distress criterion with an able-bodied rating, while in the indicative design the respective exceedance wind speeds are slightly reduced with only Location 29 marginally exceeding the distress criterion. If these terraces are intended for outdoor seating, mitigation strategies are to be developed during detailed design.

Test locations at the podium levels near the tower base, Location 27 on Level 04 and 31 on Level 06, are both subjected to strong winds with a business walking comfort rating. These locations are exposed to downwash flow from the tower facades. Depending on the intended use of spaces near the base of the tower, mitigation may be required which can be developed during detailed design. Overhead protection in the form of an awning or canopy would be recommended to minimise the impact of the downwash flow on these spaces if they are planned to be used for recreational purposes.

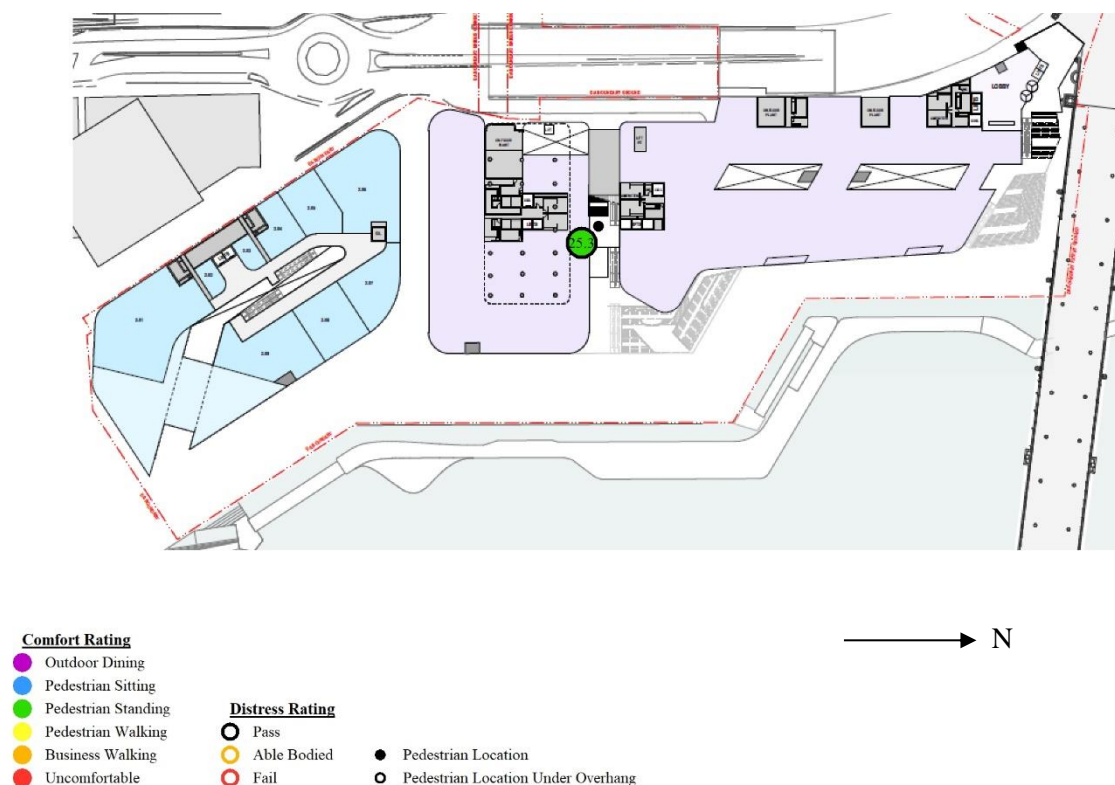


Figure 11: Pedestrian wind speed measurement locations with comfort/distress ratings – Indicative Design, Level 02.



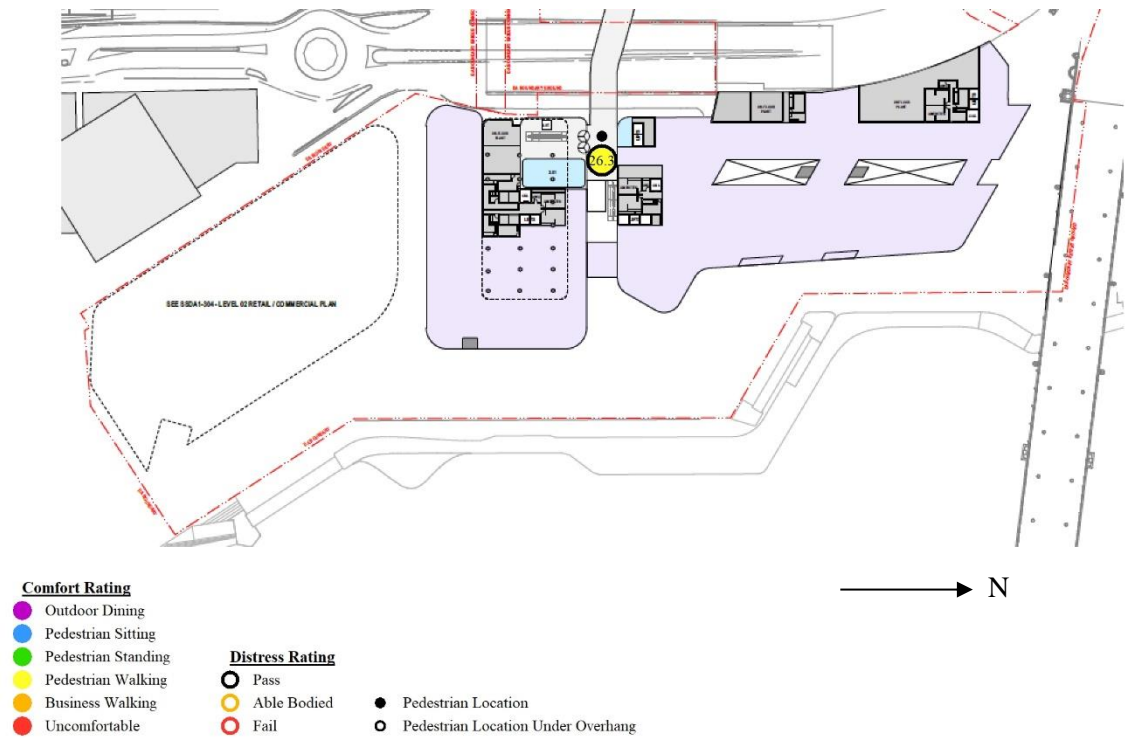


Figure 12: Pedestrian wind speed measurement locations with comfort/distress ratings – Indicative Design, Level 03.

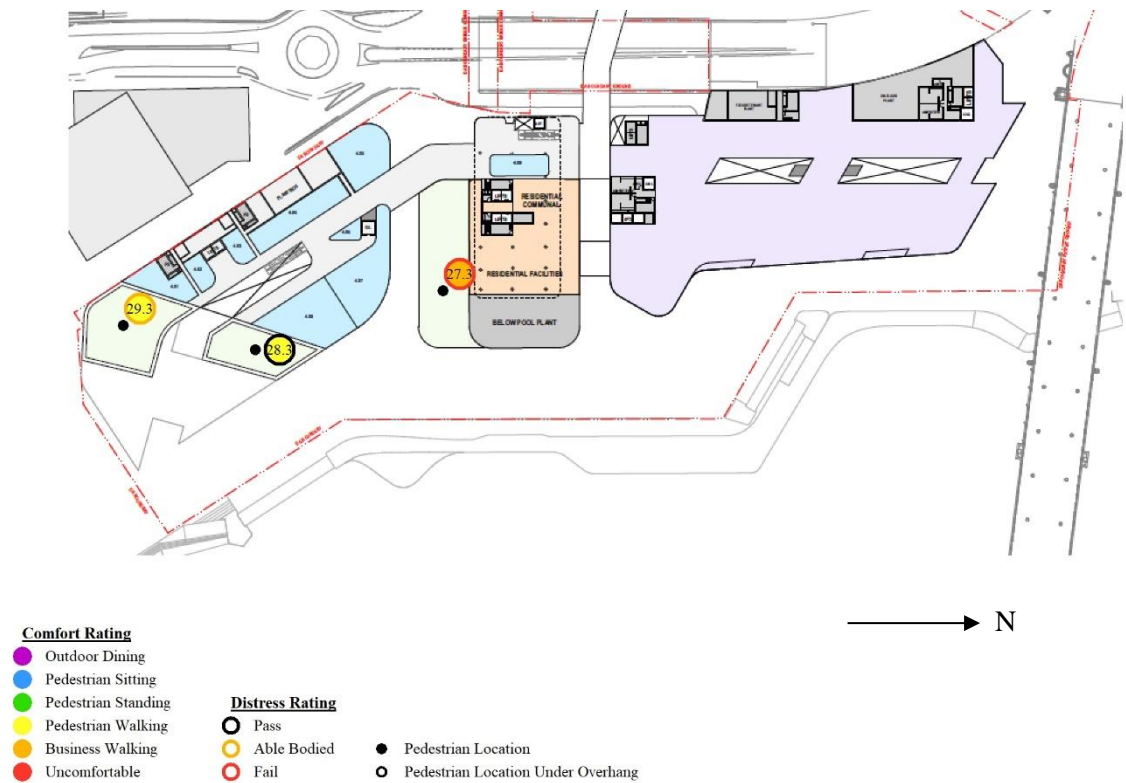


Figure 13: Pedestrian wind speed measurement locations with comfort/distress ratings – Indicative Design, Level 04.

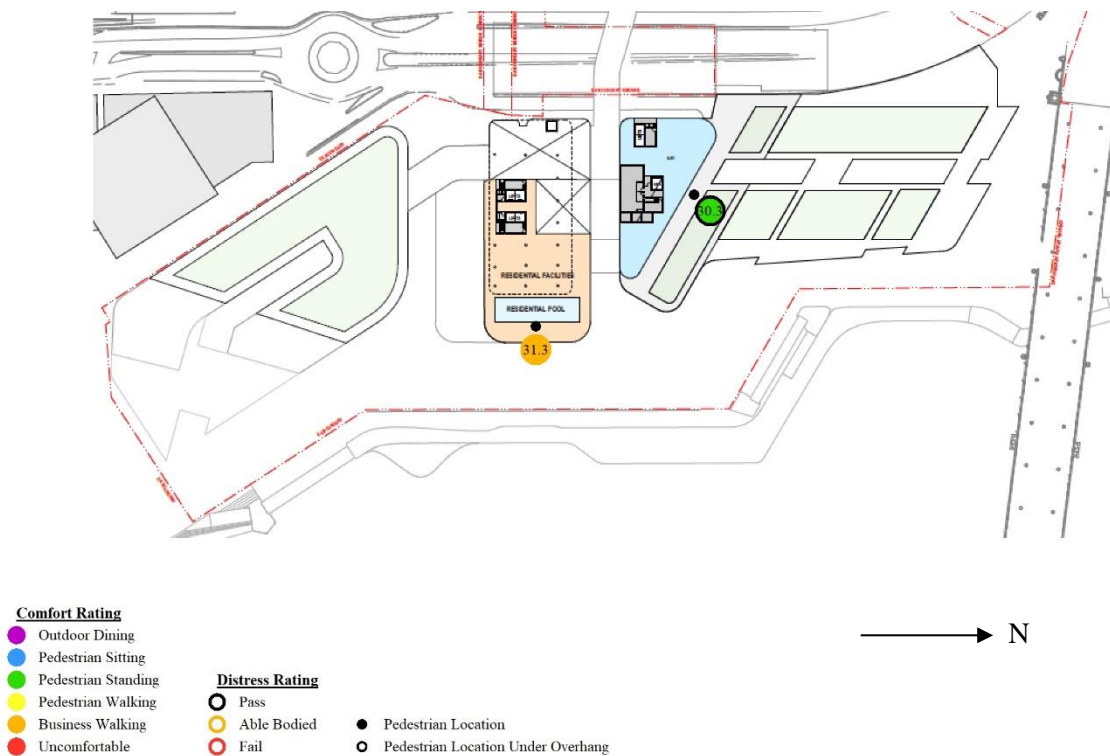


Figure 14: Pedestrian wind speed measurement locations with comfort/distress ratings – Indicative Design, Level 05+06.

### Balconies

Exposed corner balconies are susceptible to cross-winds due to downwash or unimpeded approach winds potentially necessitating amelioration depending on how these areas are to be used. Seven locations on tower balconies were tested in the indicative design, the majority of which were on corner balconies, Figure 15. At the medium elevations of the tower, the three corner balconies tested in Locations 32 to 34 were found to be classified as pedestrian standing. This may be suitable for residential balconies as the requirements for private outdoor spaces are typically less stringent than for public areas, as patrons tend to adjust their behaviour based on wind conditions. It is noted that the exceedance wind speeds on the southern balconies, Locations 32 and 33, are marginally above the sitting criterion. The inset balconies tested at the higher elevations, Locations 35 and 36, exhibit calmer conditions than the corner balconies, with a pedestrian sitting rating in Location 35 and an exceedance wind speed just above the sitting criterion for Location 36. The windiest conditions from a safety viewpoint were recorded at the top floor's corner balcony, Location 37, with the least desirable comfort rating at Location 38, subject to downwash flow accelerating around the corner of the tower. In order to improve conditions at Locations 37 and 38, partition screens or taller edge balustrades may be considered to prevent cross-winds.



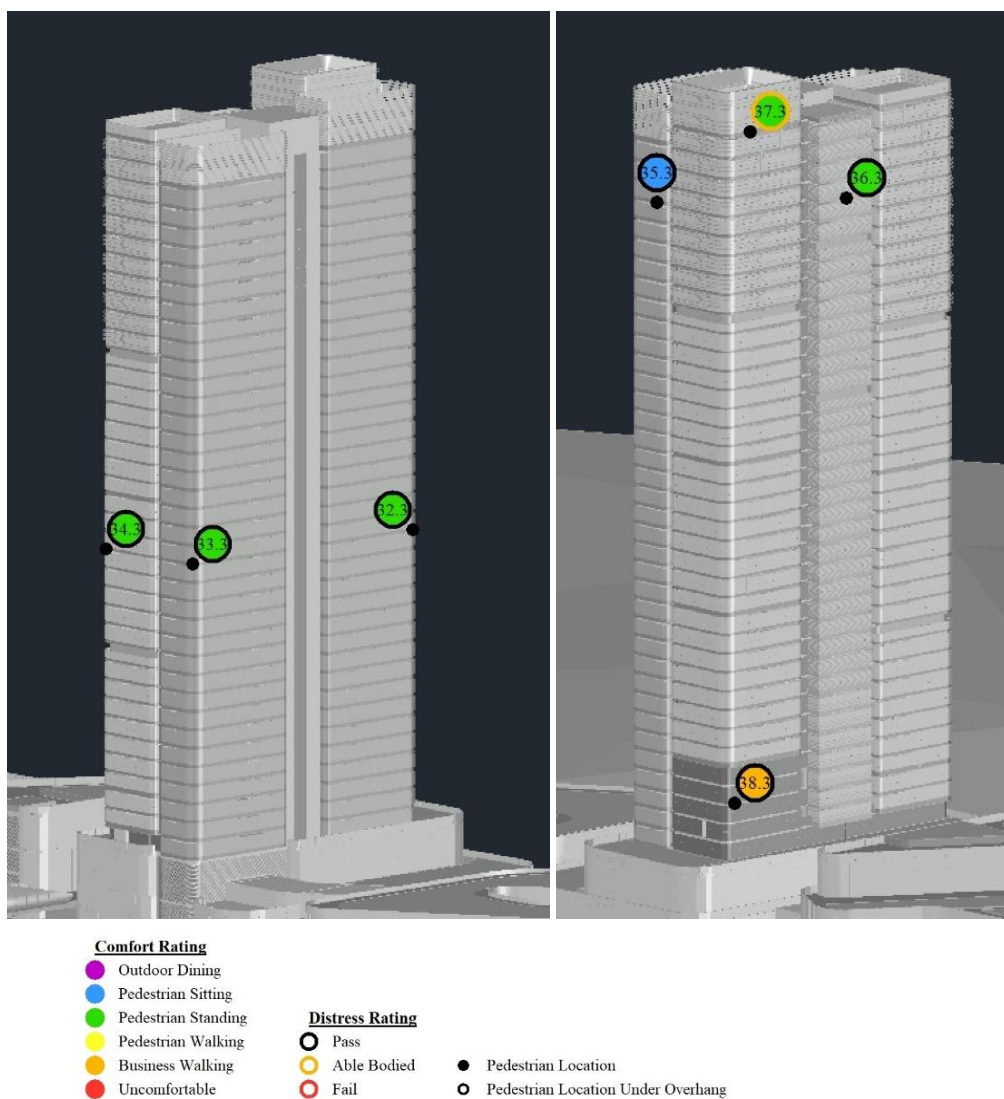


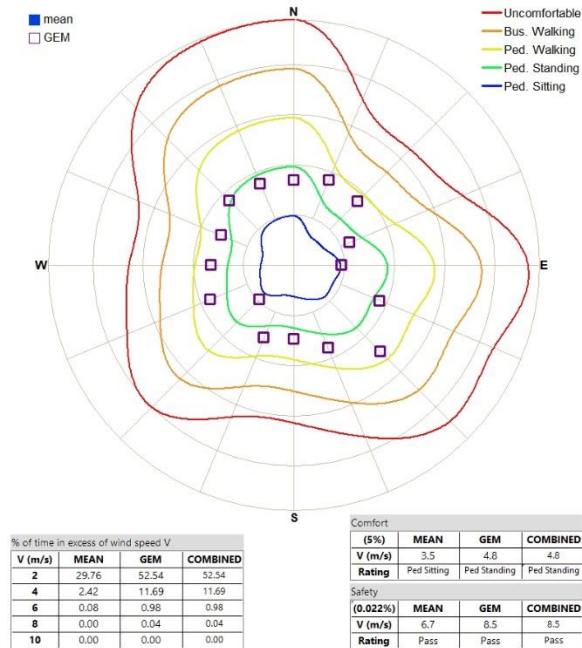
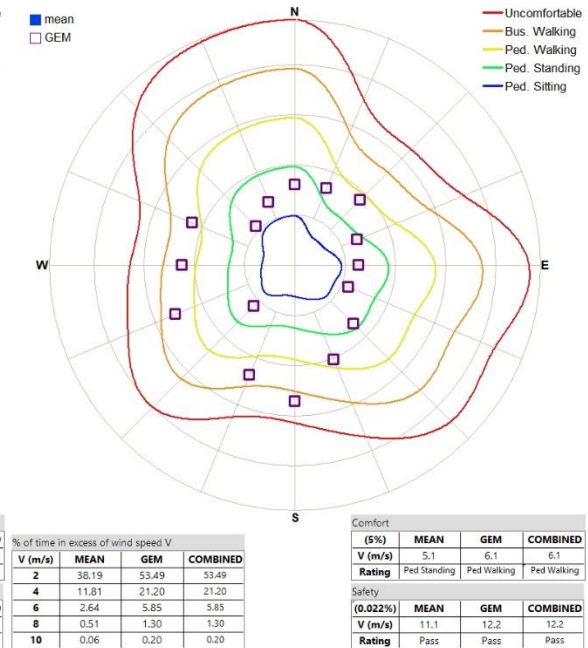
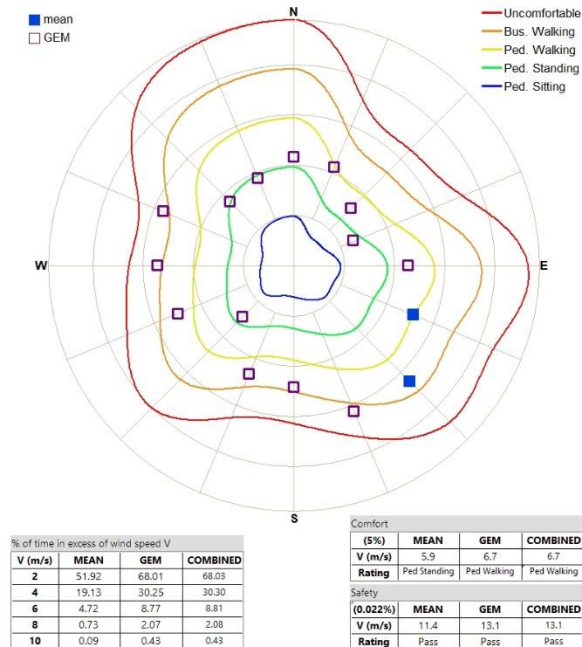
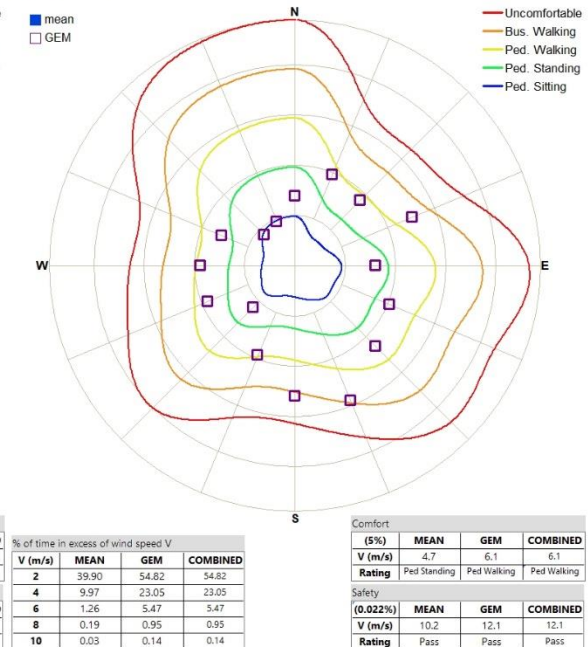
Figure 15: Pedestrian wind speed measurement locations with comfort/distress ratings – Indicative Design Balconies.

## 6 CONCLUSION

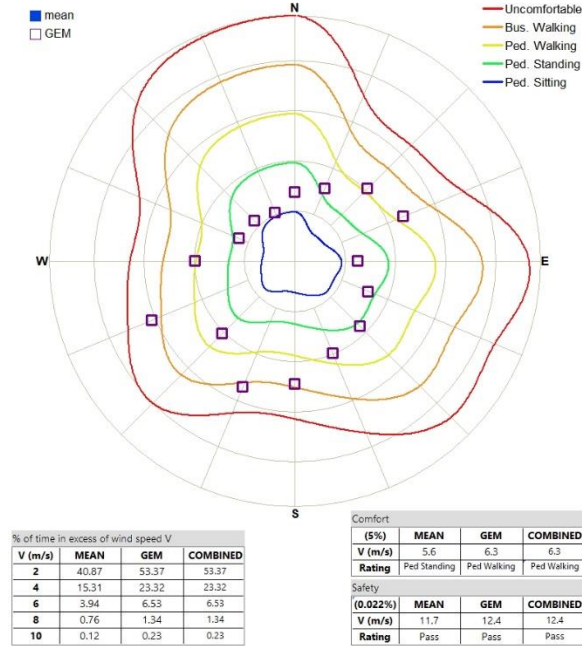
A wind tunnel investigation of the pedestrian level wind environment in and around the proposed Harbourside Shopping Centre redevelopment has been conducted. Testing was conducted in two configurations for the proposed development, the proposed envelope and the indicative design, as well as in the existing configuration. The wind environment at ground level near the development site was found to be generally suitable for pedestrian standing and walking in most areas. The proposed configurations were found to slightly increase the wind speeds in individual locations, however all ground level test locations were found to be mostly similar to the existing configuration, particularly in the main pedestrian area along the water on the eastern side of the development site. Several upper level locations, particularly on the southern podium terraces and near the corners at the base of the tower were found to be exposed to strong wind conditions and would require mitigation measures to be developed during detailed design to improve the wind conditions.

## 7 REFERENCES

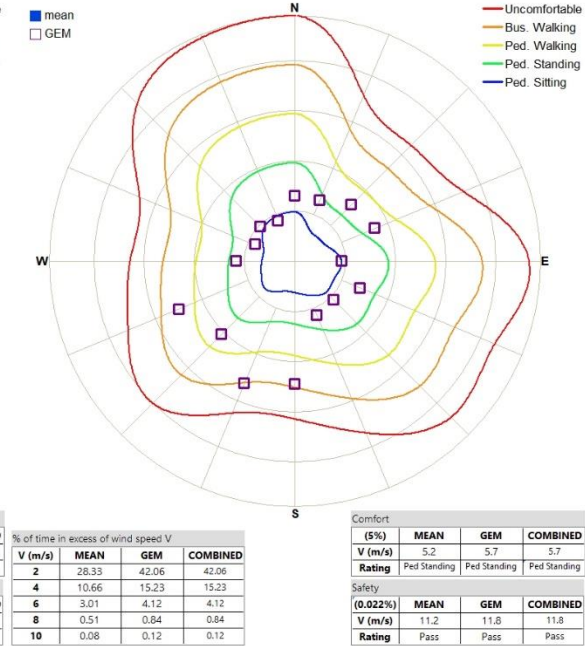
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**Appendix 1: Directional wind results****Configuration 1 – Existing****LOCATION 1.1****LOCATION 2.1****LOCATION 3.1****LOCATION 4.1**

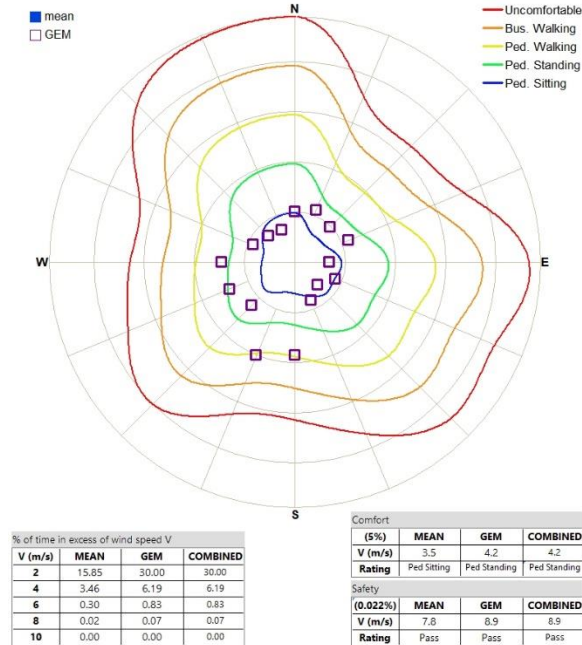
### LOCATION 5.1



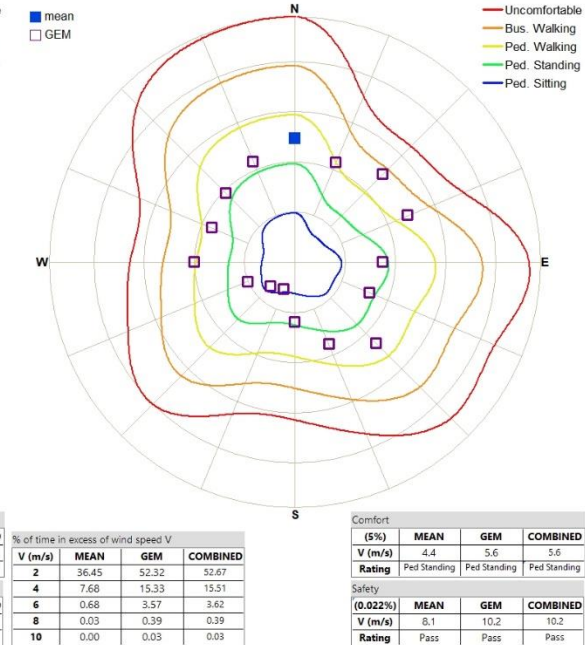
### LOCATION 6.1



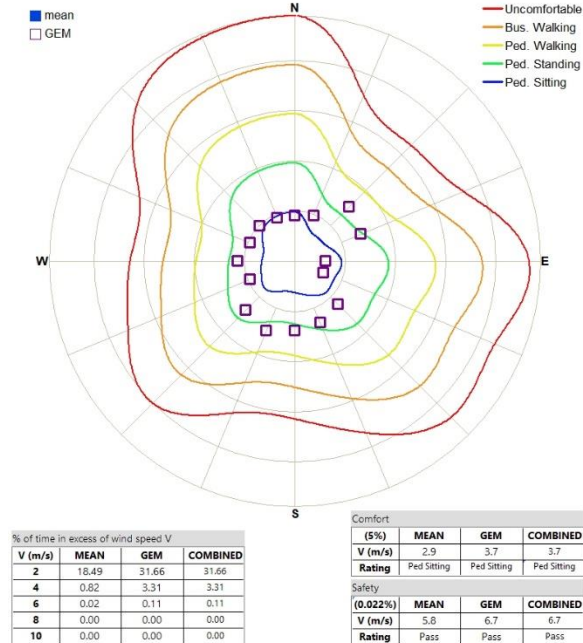
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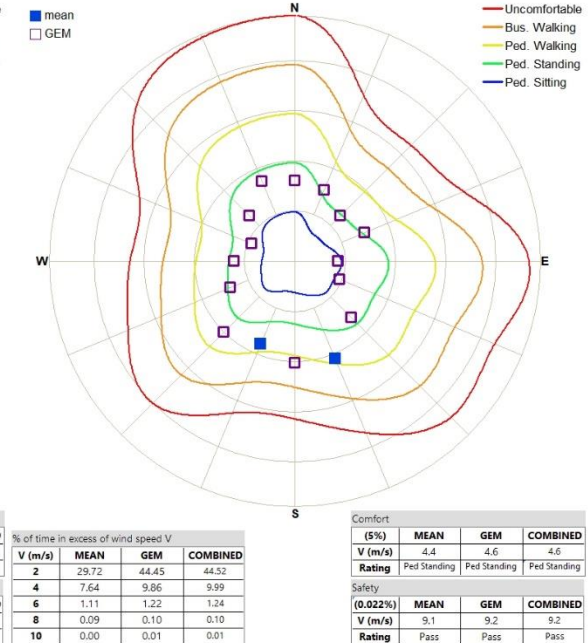
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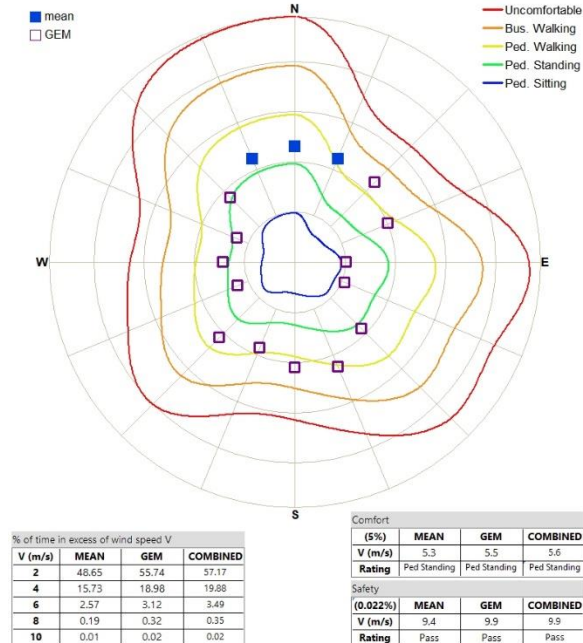
### LOCATION 9.1



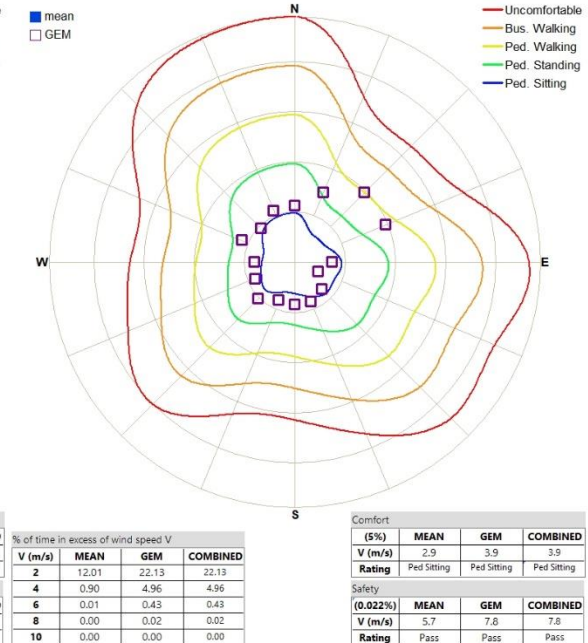
### LOCATION 10.1



### LOCATION 11.1

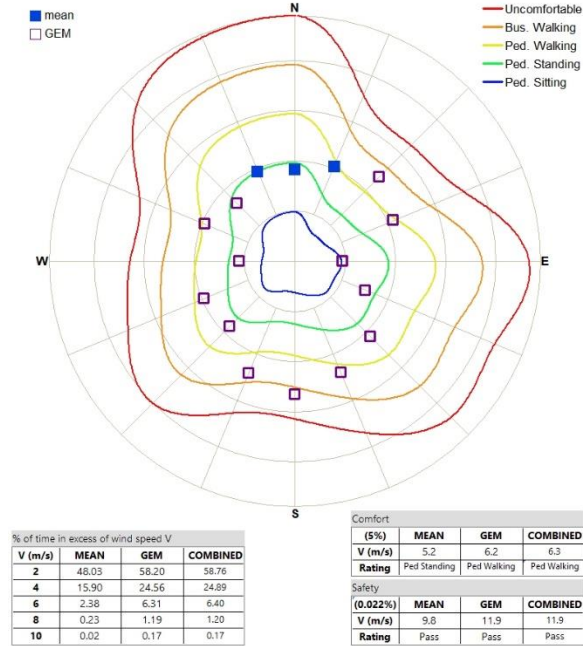


### LOCATION 12.1

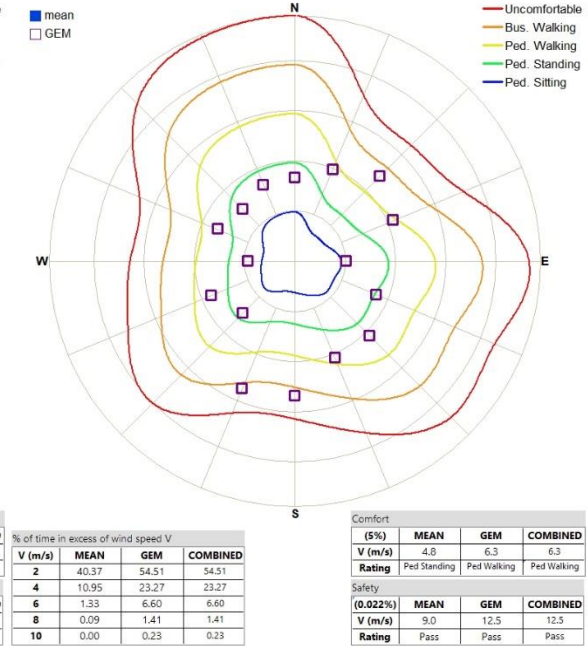




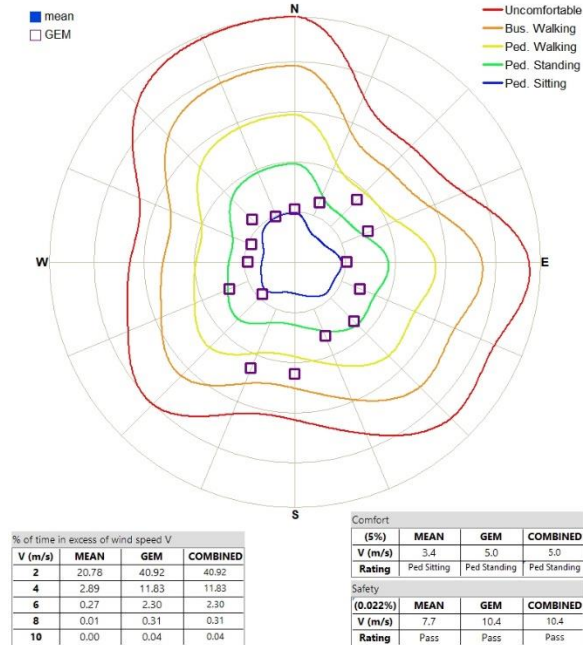
## LOCATION 13.1



## LOCATION 14.1

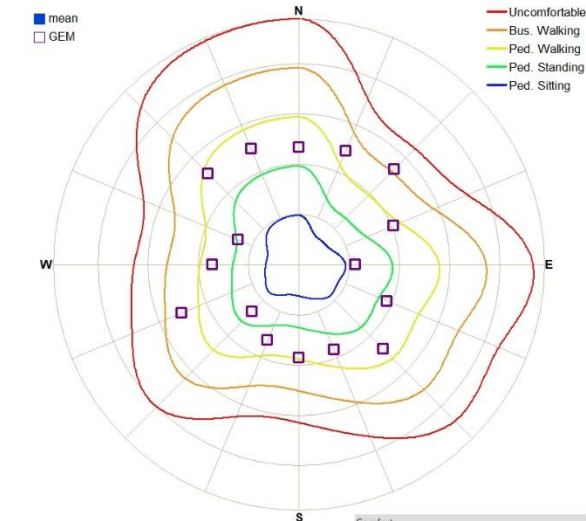


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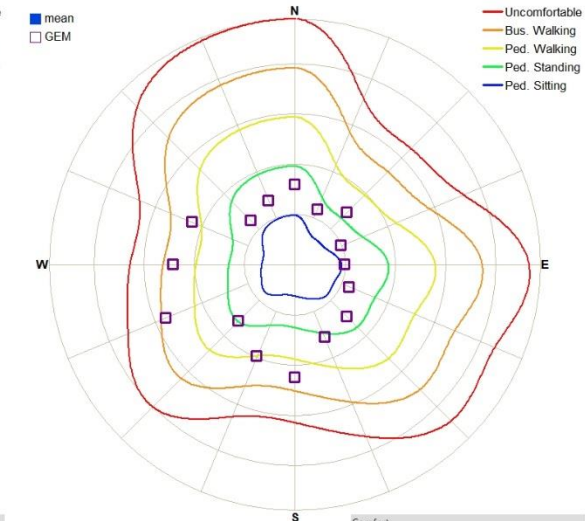


## Configuration 2 – Proposed Envelope

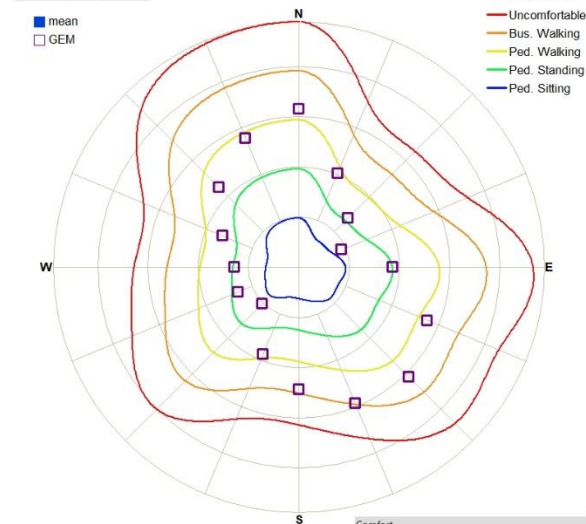
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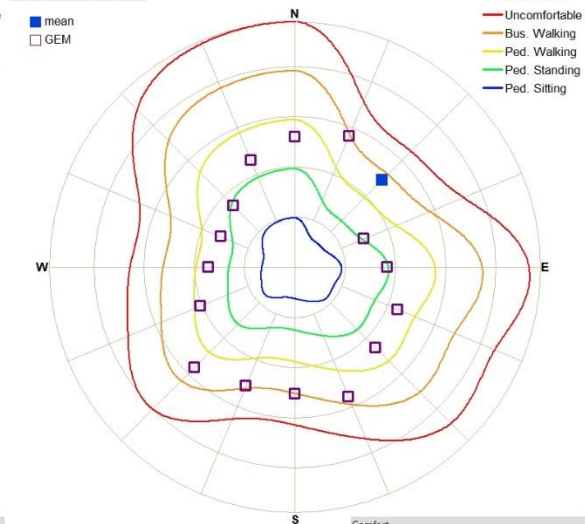
### LOCATION 2.2



### LOCATION 3.2



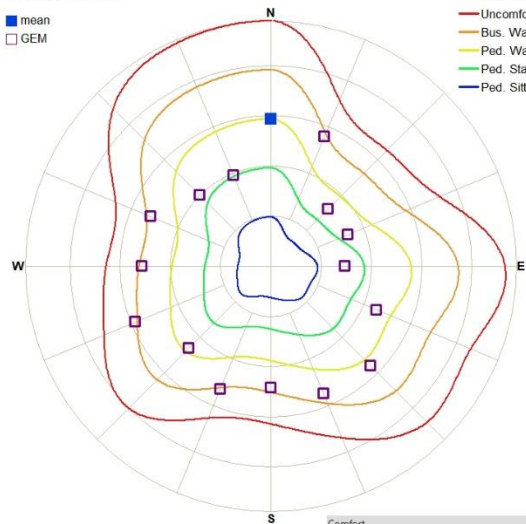
### LOCATION 4.2





## LOCATION 5.2

■ mean  
□ GEM

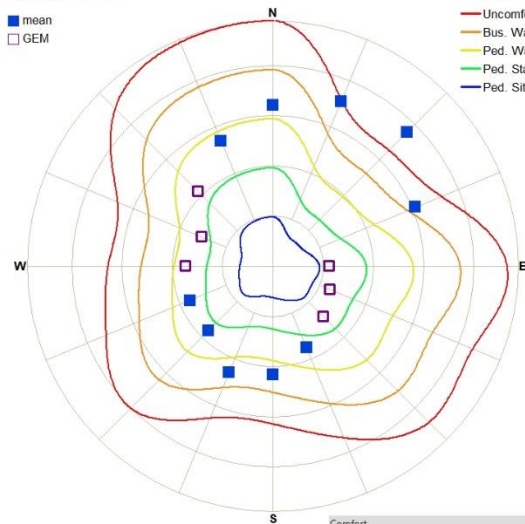


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	52.98	71.05	71.18	
4	18.70	32.20	32.28	
6	4.09	10.08	10.14	
8	0.70	2.26	2.29	
10	0.09	0.38	0.38	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.7	6.9	7.0
Rating	Ped Standing	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.0	12.6	12.6
Rating	Pass	Pass	Pass

## LOCATION 6.2

■ mean  
□ GEM

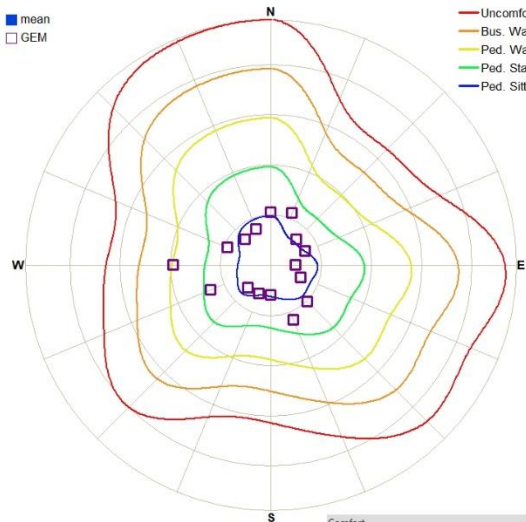


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	60.79	61.29	64.90	
4	27.39	22.17	27.80	
6	11.92	7.64	12.10	
8	4.66	1.64	4.90	
10	1.54	0.26	1.54	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	7.9	6.6	7.9
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.1	12.0	15.1
Rating	Able Body	Pass	Able Body

## LOCATION 7.2

■ mean  
□ GEM

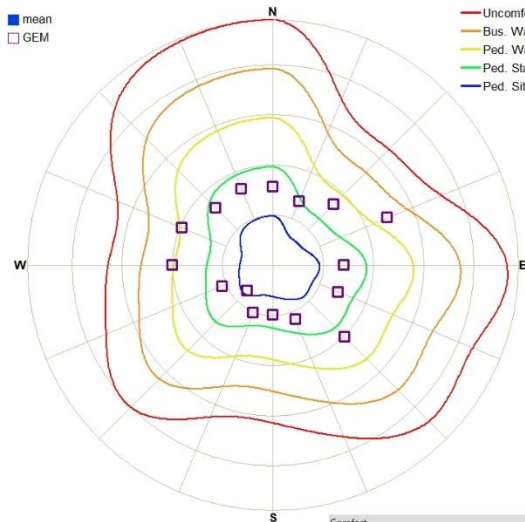


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	5.04	15.91	15.91	
4	0.87	1.67	1.67	
6	0.09	0.30	0.30	
8	0.00	0.03	0.03	
10	0.00	0.00	0.00	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.0	2.9	2.9
Rating	Outdoor Dining	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.9	8.1	8.1
Rating	Pass	Pass	Pass

## LOCATION 8.2

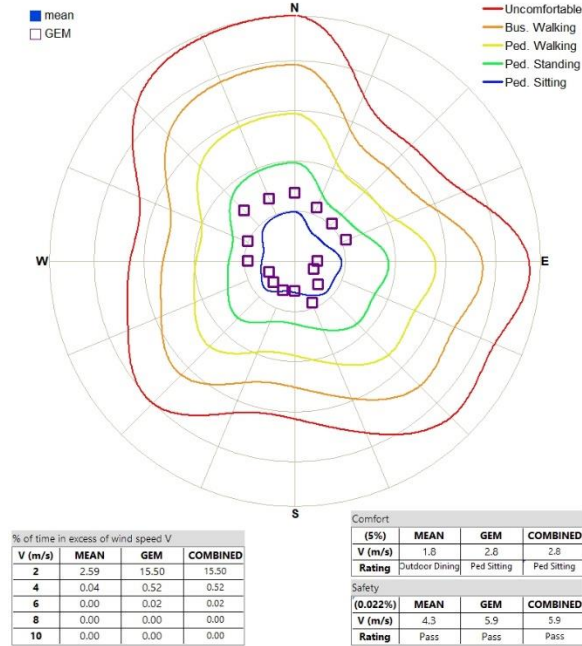
■ mean  
□ GEM



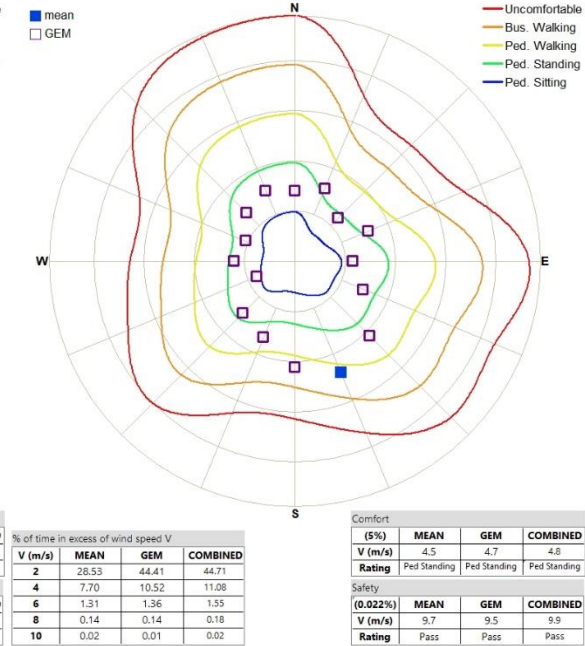
% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	17.81	42.92	42.92	
4	1.37	8.52	8.52	
6	0.04	1.48	1.48	
8	0.00	0.13	0.13	
10	0.00	0.01	0.01	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.0	4.6	4.6
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.3	9.2	9.2
Rating	Pass	Pass	Pass

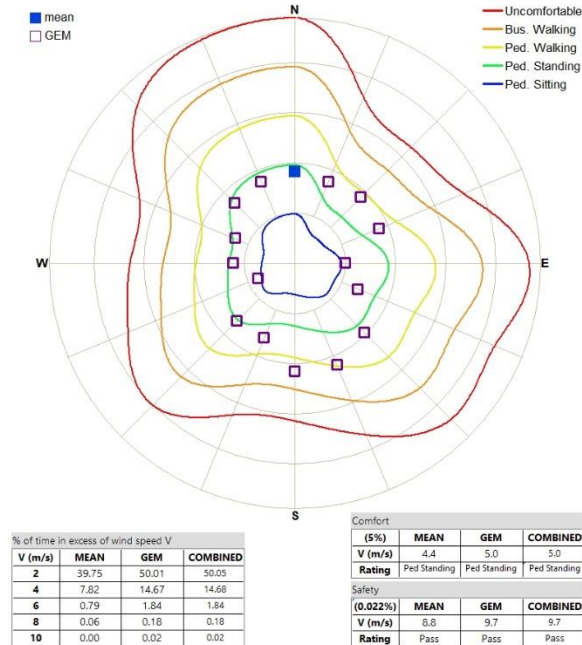
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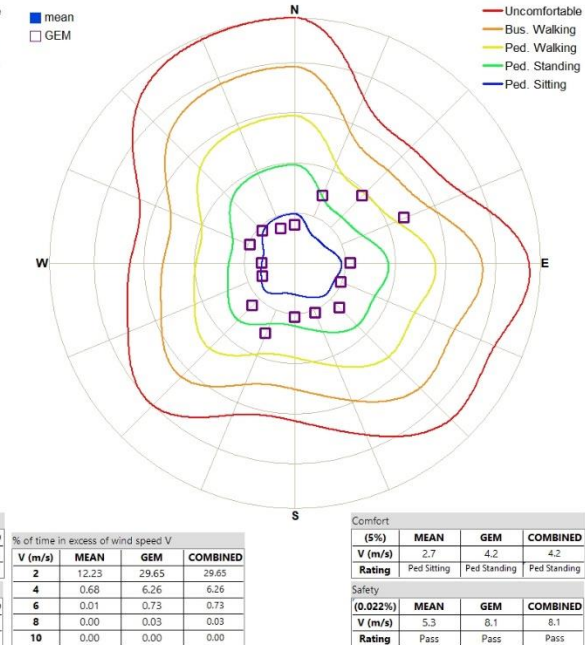
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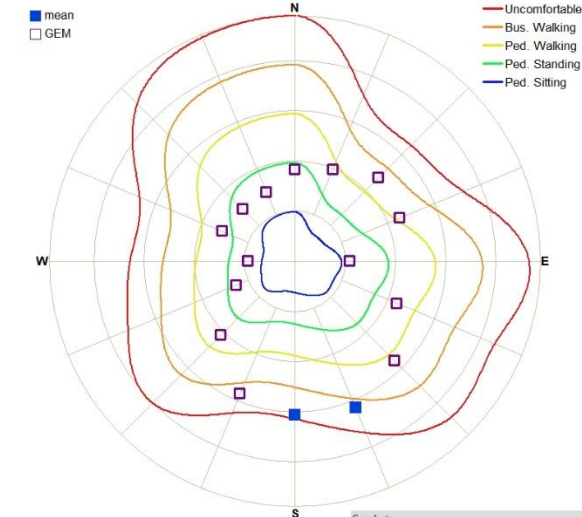
## LOCATION 11.2



## LOCATION 12.2



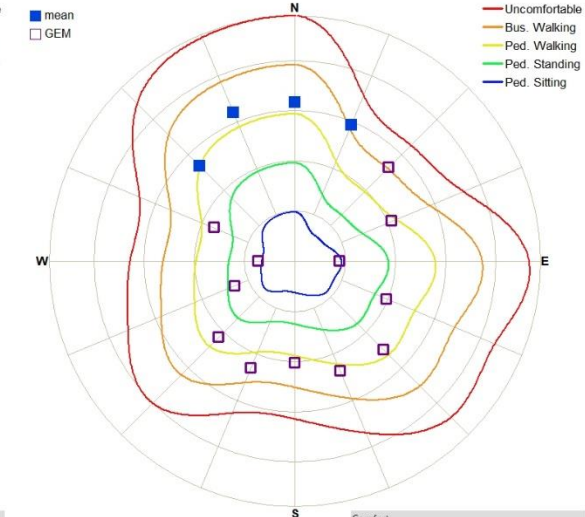
### LOCATION 13.2



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	44.84	56.38	56.47
4	19.45	27.50	27.74
6	6.82	9.66	10.14
8	2.00	2.48	2.64
10	0.52	0.56	0.64

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.4	6.9	7.0
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.8	13.7	13.9
Rating	Pass	Pass	Pass

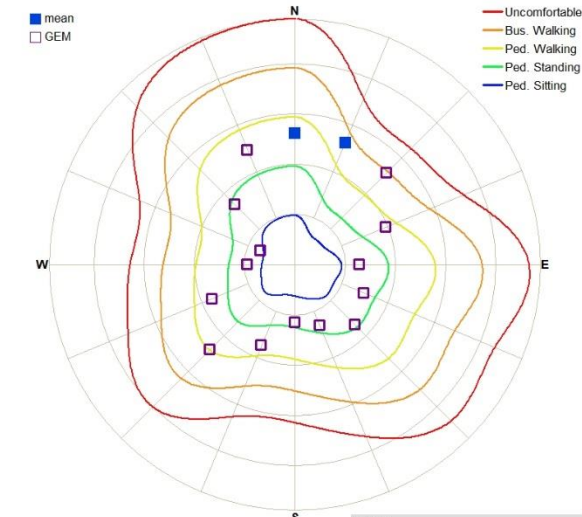
### LOCATION 14.2



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	58.10	64.87	66.89
4	19.10	26.03	27.43
6	4.68	7.31	8.12
8	1.06	1.26	1.67
10	0.15	0.16	0.23

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.9	6.5	6.6
Rating	Ped Standing	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.0	11.4	12.1
Rating	Pass	Pass	Pass

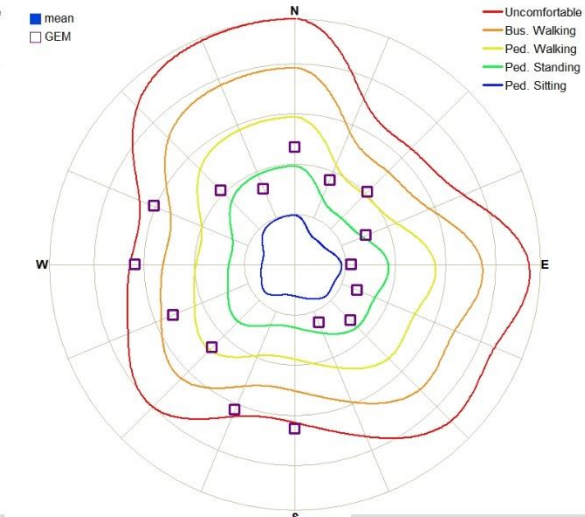
### LOCATION 15.2



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	34.04	52.47	52.89
4	9.90	14.90	15.29
6	2.44	3.78	4.15
8	0.28	0.52	0.62
10	0.02	0.05	0.06

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.6	5.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	10.4	10.6
Rating	Pass	Pass	Pass

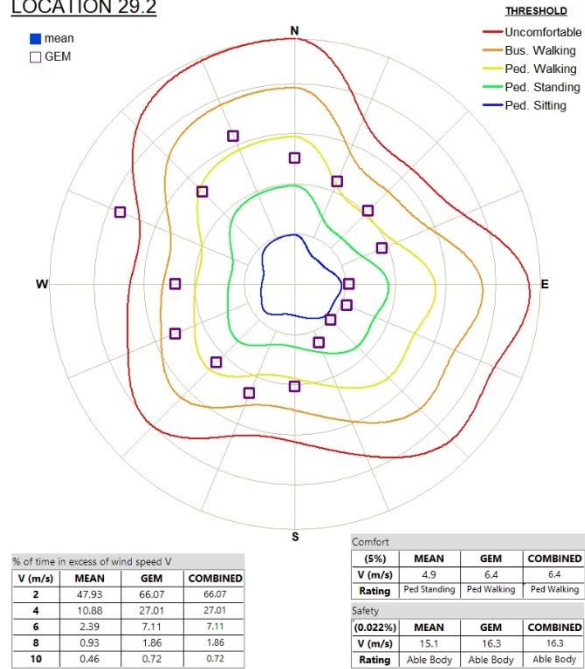
### LOCATION 28.2



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	41.80	63.13	63.13
4	15.92	28.02	28.02
6	5.15	11.90	11.90
8	1.35	4.40	4.40
10	0.28	1.36	1.36

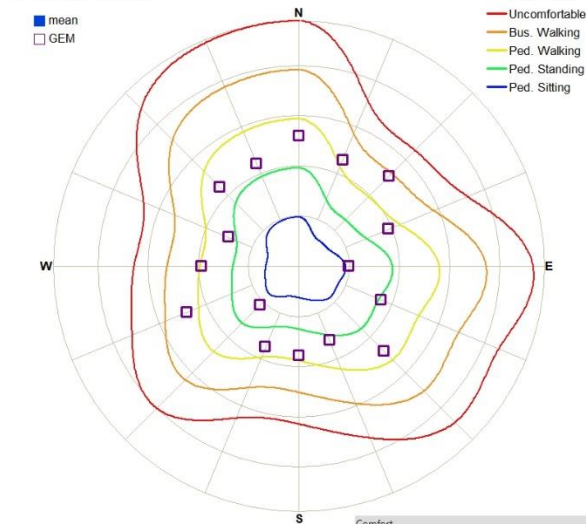
Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.0	7.7	7.7
Rating	Ped Standing	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.4	15.2	15.2
Rating	Pass	Able Body	Able Body

LOCATION 29.2



## Configuration 3 – Indicative Design

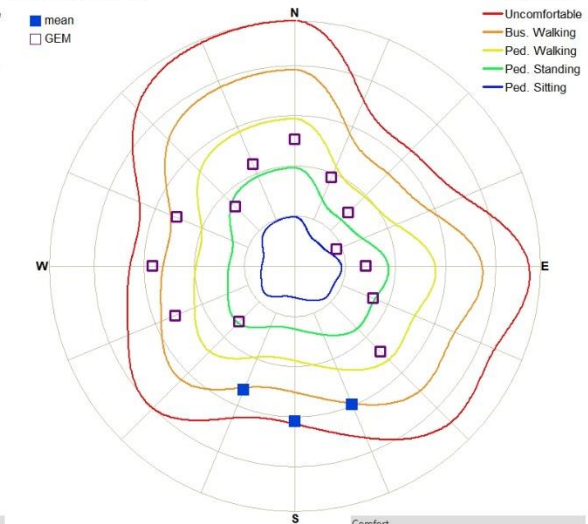
## LOCATION 1.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	45.74	61.84	61.84	
4	9.91	20.93	20.93	
6	1.27	4.49	4.49	
8	0.08	0.55	0.55	
10	0.01	0.05	0.05	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.8	5.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.8	10.7	10.7
Rating	Pass	Pass	Pass

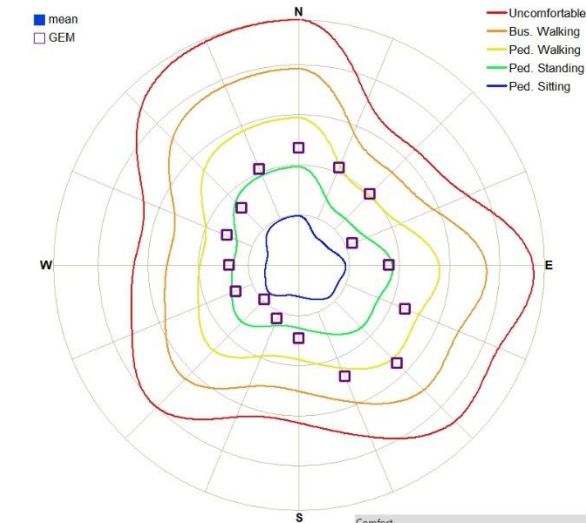
## LOCATION 2.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	52.30	64.08	64.35	
4	22.10	27.51	28.30	
6	8.42	8.79	10.19	
8	2.33	2.39	3.08	
10	0.57	0.51	0.76	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.8	6.8	7.2
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.8	13.2	14.0
Rating	Pass	Pass	Pass

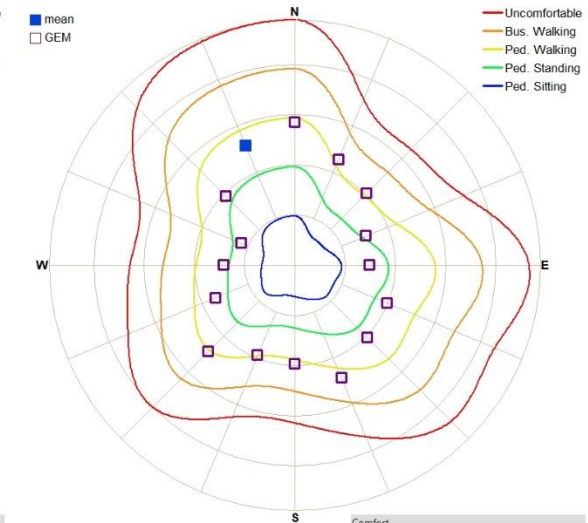
## LOCATION 3.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	37.41	55.69	55.69	
4	6.05	15.02	15.02	
6	0.50	2.15	2.15	
8	0.04	0.16	0.16	
10	0.00	0.02	0.02	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	5.2	5.2
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.4	9.6	9.6
Rating	Pass	Pass	Pass

## LOCATION 4.3

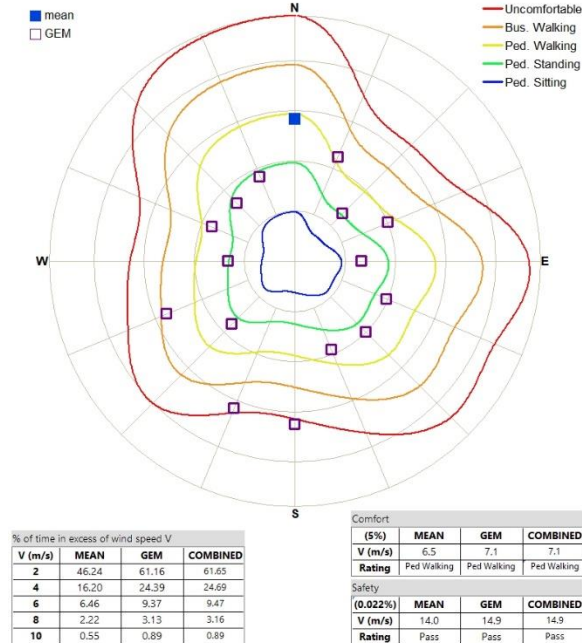


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	48.34	62.79	63.16	
4	10.50	20.52	20.65	
6	1.40	3.48	3.52	
8	0.10	0.34	0.36	
10	0.01	0.03	0.03	

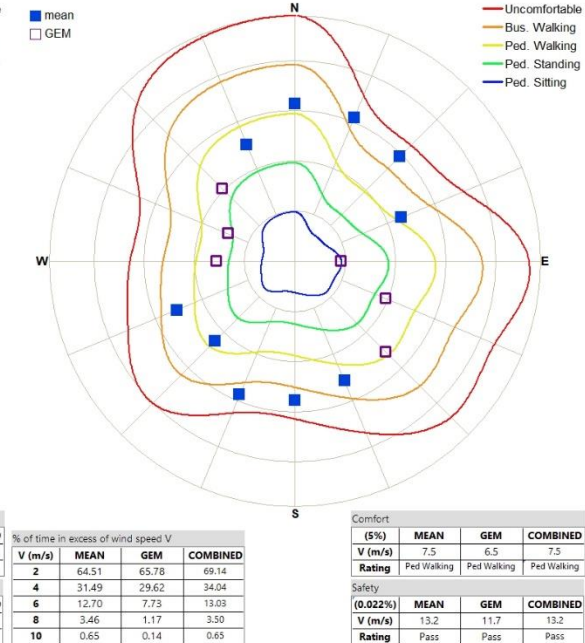
Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.6	5.6
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.1	10.1	10.1
Rating	Pass	Pass	Pass



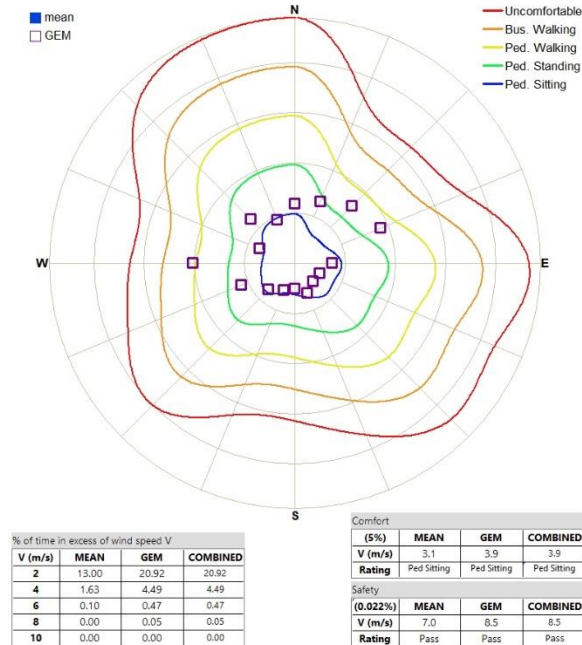
### LOCATION 5.3



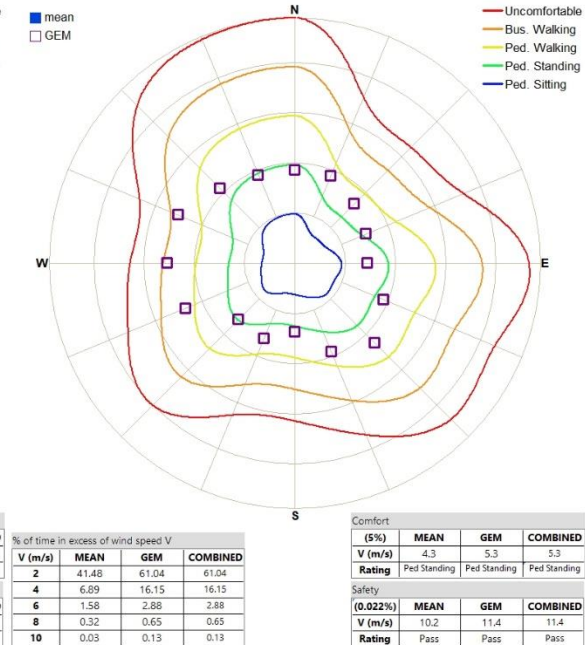
### LOCATION 6.3



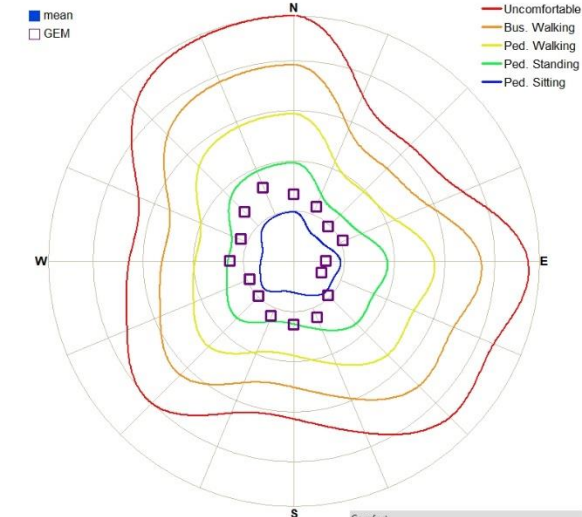
### LOCATION 7.3



### LOCATION 8.3



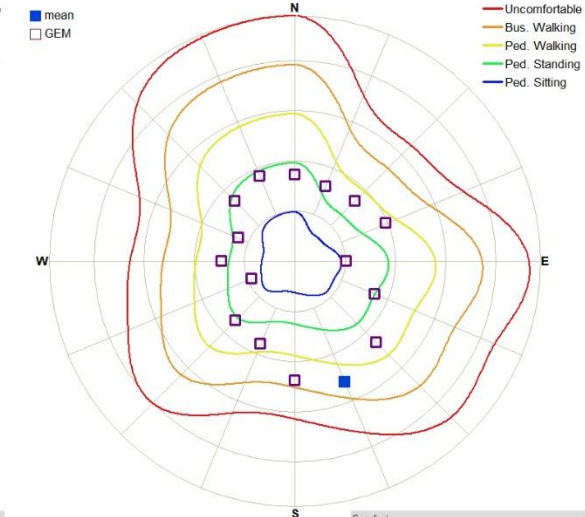
## LOCATION 9.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	12.49	29.88	29.88
4	0.32	1.66	1.66
6	0.01	0.04	0.04
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.5	3.3	3.3
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.3	6.3	6.3
Rating	Pass	Pass	Pass

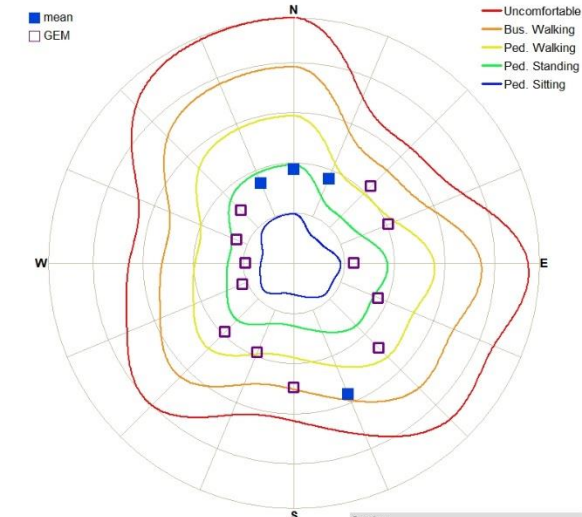
## LOCATION 10.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	40.59	52.40	52.52
4	11.72	17.29	17.62
6	2.33	2.70	2.89
8	0.40	0.41	0.46
10	0.05	0.05	0.06

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.0	5.3	5.4
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.8	10.7	10.9
Rating	Pass	Pass	Pass

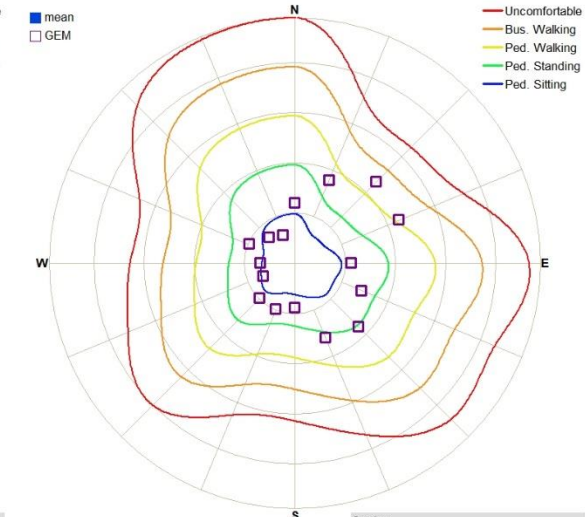
## LOCATION 11.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	45.62	52.79	53.29
4	15.88	20.82	21.17
6	3.07	4.24	4.57
8	0.51	0.73	0.79
10	0.07	0.08	0.09

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.4	5.8	5.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.2	11.3	11.6
Rating	Pass	Pass	Pass

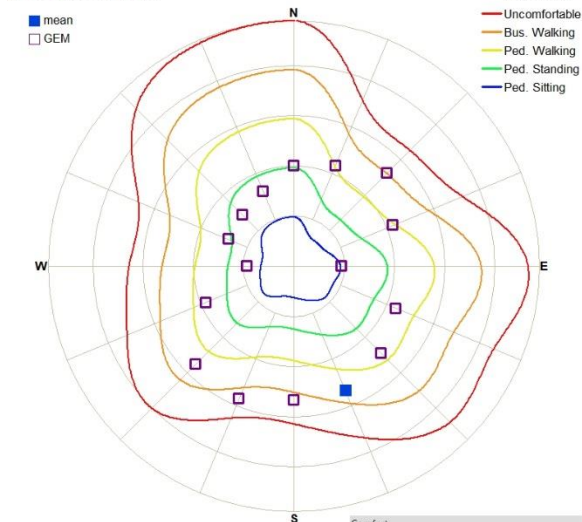
## LOCATION 12.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	15.12	31.65	31.65
4	1.67	8.14	8.14
6	0.04	1.49	1.49
8	0.00	0.17	0.17
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.2	4.7	4.7
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.1	9.2	9.2
Rating	Pass	Pass	Pass

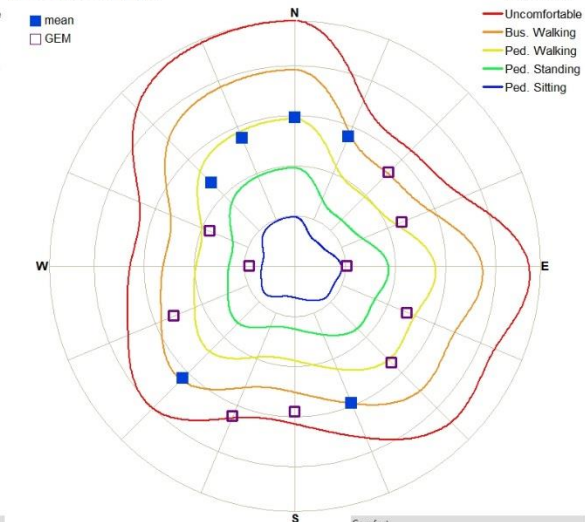
LOCATION 13.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	49.22	58.07	58.09	
4	20.64	28.19	28.24	
6	4.99	8.81	8.87	
8	0.92	1.95	1.97	
10	0.13	0.34	0.34	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.0	6.8	6.8
Rating	Ped Standing	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.8	12.8	12.8
Rating	Pass	Pass	Pass

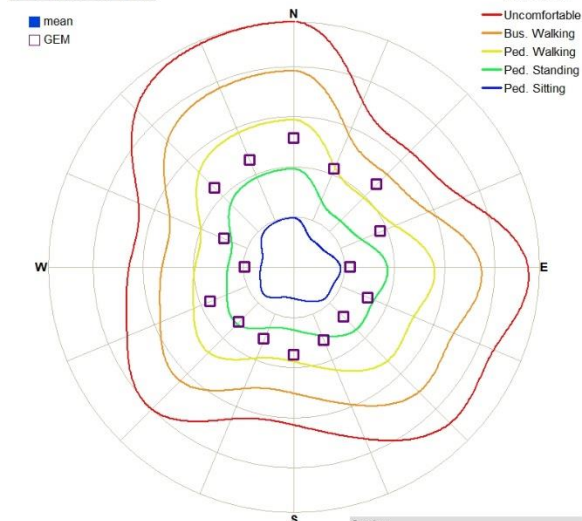
LOCATION 14.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	65.93	68.15	70.87	
4	31.12	34.53	36.14	
6	11.18	13.17	14.56	
8	2.60	3.44	3.92	
10	0.45	0.73	0.80	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	7.1	7.4	7.6
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.2	14.2	14.3
Rating	Pass	Pass	Pass

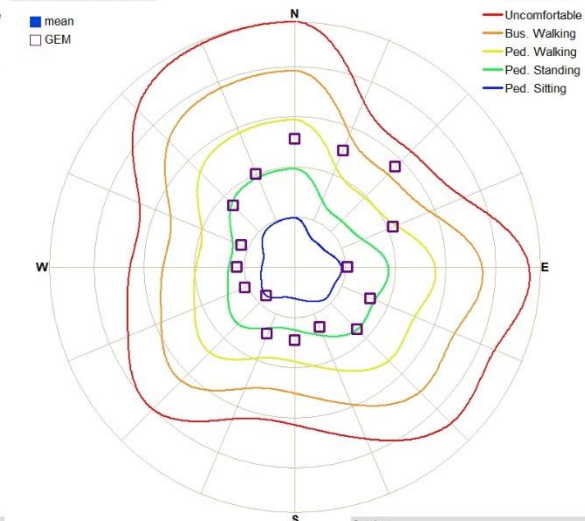
LOCATION 15.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	35.82	56.22	56.22	
4	5.05	15.22	15.22	
6	0.42	2.68	2.68	
8	0.02	0.31	0.31	
10	0.00	0.02	0.02	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	5.3	5.3
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.9	9.8	9.8
Rating	Pass	Pass	Pass

LOCATION 16.3



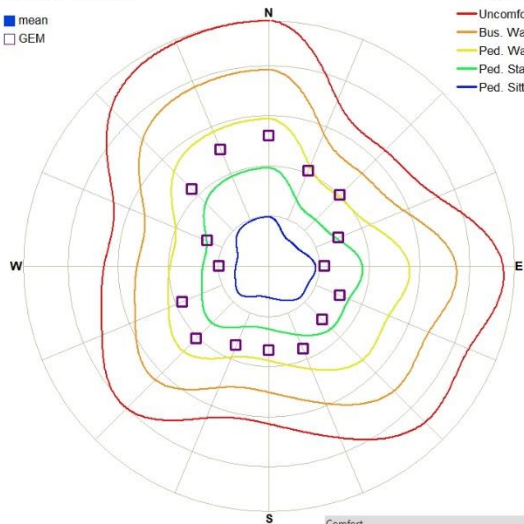
% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	31.96	50.46	50.46	
4	8.55	13.97	13.97	
6	1.78	4.17	4.17	
8	0.15	0.82	0.82	
10	0.00	0.14	0.14	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.7	5.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.1	11.3	11.3
Rating	Pass	Pass	Pass



## LOCATION 17.3

■ mean  
□ GEM

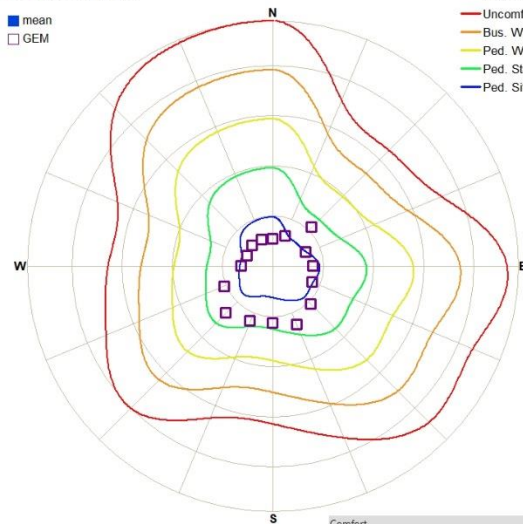


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	38.08	56.62	56.62	
4	5.06	14.58	14.58	
6	0.53	1.95	1.95	
8	0.05	0.17	0.17	
10	0.00	0.01	0.01	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	5.1	5.1
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.7	9.6	9.6
Rating	Pass	Pass	Pass

## LOCATION 18.3

■ mean  
□ GEM

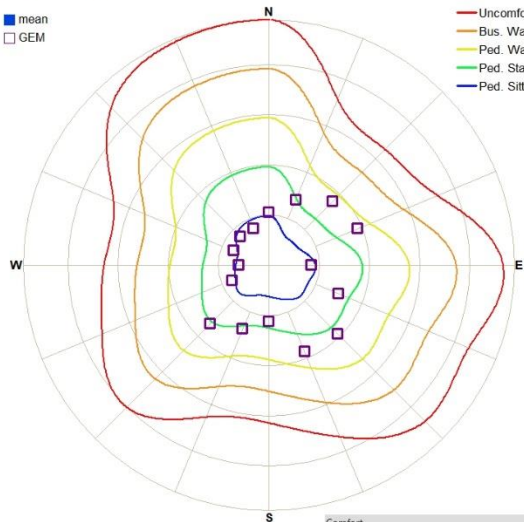


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	9.04	19.68	19.68	
4	0.13	0.66	0.66	
6	0.00	0.01	0.01	
8	0.00	0.00	0.00	
10	0.00	0.00	0.00	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.3	2.9	2.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.5	5.5
Rating	Pass	Pass	Pass

## LOCATION 19.3

■ mean  
□ GEM

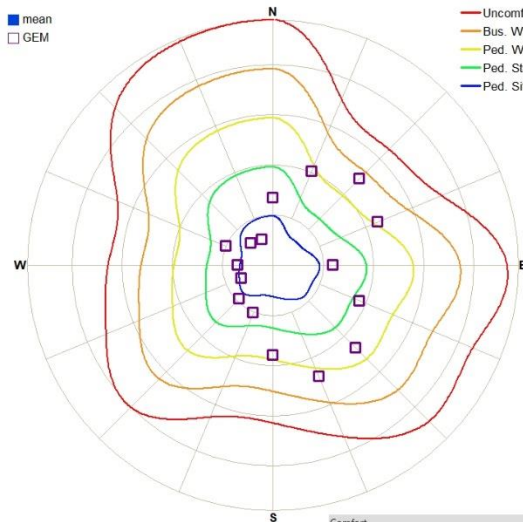


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	16.29	34.87	34.87	
4	0.41	6.44	6.44	
6	0.00	0.39	0.39	
8	0.00	0.01	0.01	
10	0.00	0.00	0.00	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.8	4.2	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.1	7.7	7.7
Rating	Pass	Pass	Pass

## LOCATION 20.3

■ mean  
□ GEM

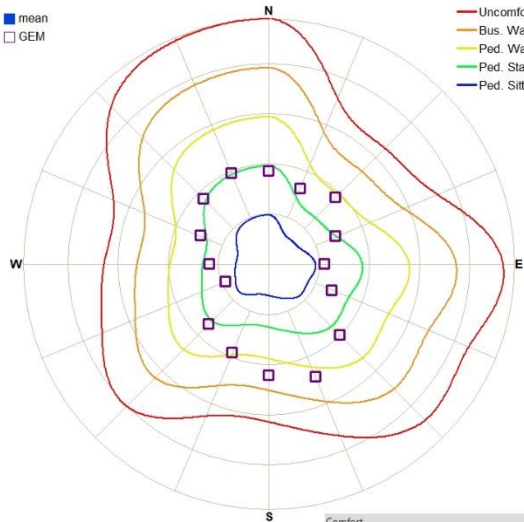


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	27.45	41.30	41.30	
4	5.27	14.94	14.94	
6	0.34	3.01	3.01	
8	0.02	0.35	0.35	
10	0.00	0.03	0.03	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	5.4	5.4
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.7	10.1	10.1
Rating	Pass	Pass	Pass

LOCATION 21.3

■ mean  
□ GEM

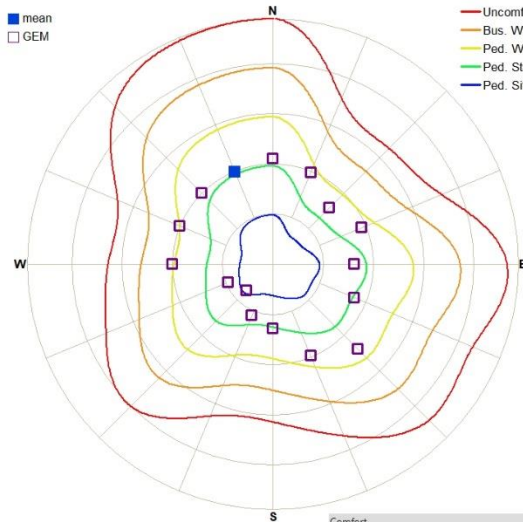


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	38.14	52.79	52.79	
4	10.03	16.04	16.04	
6	1.70	2.53	2.53	
8	0.20	0.30	0.30	
10	0.02	0.03	0.03	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.3	5.3
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.0	10.3	10.3
Rating	Pass	Pass	Pass

LOCATION 22.3

■ mean  
□ GEM

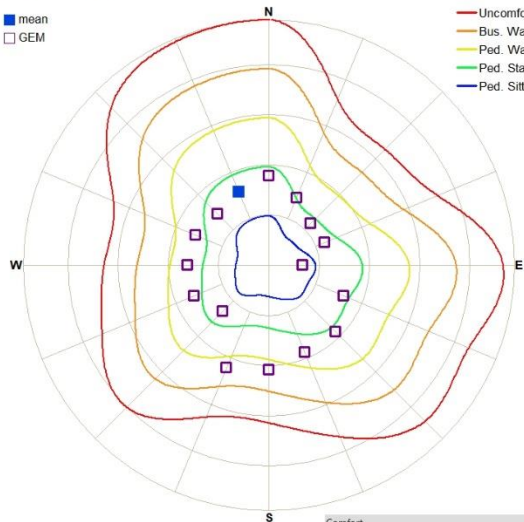


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	33.09	54.06	54.08	
4	3.87	12.35	12.35	
6	0.35	1.55	1.55	
8	0.02	0.17	0.17	
10	0.00	0.01	0.01	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.9	4.9
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.8	9.4	9.4
Rating	Pass	Pass	Pass

LOCATION 23.3

■ mean  
□ GEM

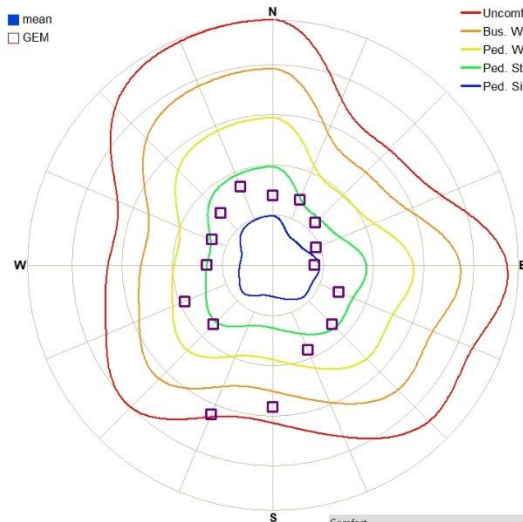


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	30.55	48.58	48.63	
4	5.63	12.06	12.07	
6	0.71	1.87	1.87	
8	0.07	0.21	0.21	
10	0.00	0.02	0.02	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	5.0	5.0
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.8	9.9	9.9
Rating	Pass	Pass	Pass

LOCATION 24.3

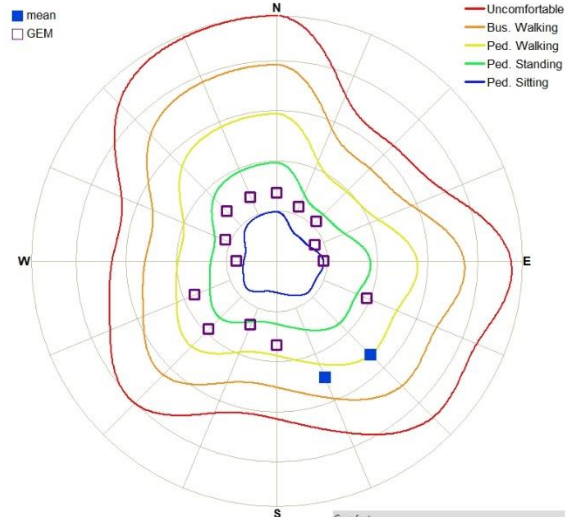
■ mean  
□ GEM



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	30.44	46.77	46.77	
4	9.65	15.47	15.47	
6	3.65	6.14	6.14	
8	1.02	2.11	2.11	
10	0.22	0.52	0.52	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.3	6.3	6.3
Rating	Ped Standing	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.0	14.0	14.0
Rating	Pass	Pass	Pass

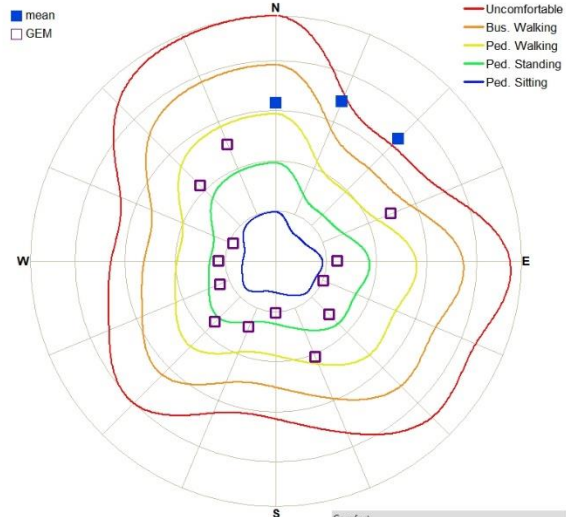
## LOCATION 25.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	28.27	41.90	42.10
4	5.82	8.73	9.25
6	0.94	0.97	1.24
8	0.13	0.09	0.15
10	0.02	0.01	0.02

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.6	4.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	9.3	9.8
Rating	Pass	Pass	Pass

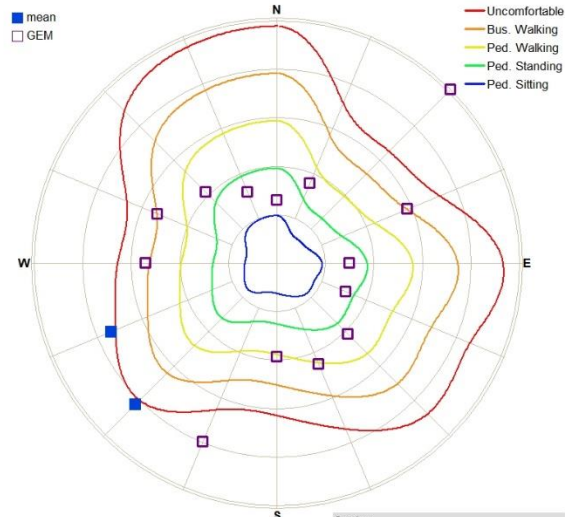
## LOCATION 26.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	38.57	53.65	54.48
4	14.49	16.77	18.21
6	7.49	6.85	8.49
8	3.29	1.85	3.39
10	0.85	0.32	0.86

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	7.0	6.5	7.1
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.9	12.3	13.9
Rating	Pass	Pass	Pass

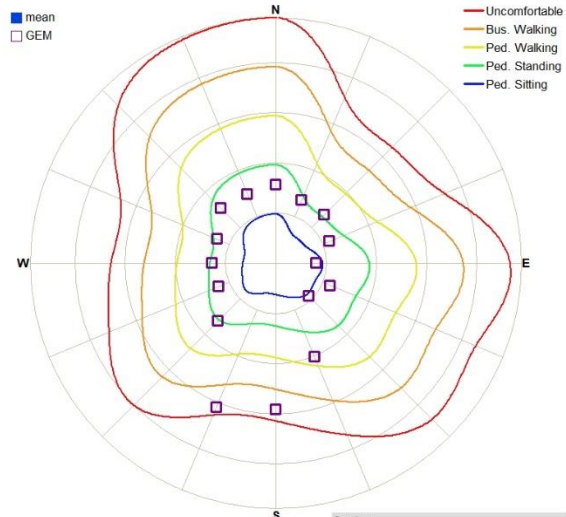
## LOCATION 27.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	51.72	67.09	67.46
4	23.78	33.02	33.52
6	12.22	16.60	17.37
8	5.77	8.71	9.36
10	2.21	4.74	5.04

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	8.2	9.7	9.9
Rating	Bus Walking	Bus Walking	Bus Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	16.3	20.2	20.3
Rating	Able Body	Fail	Fail

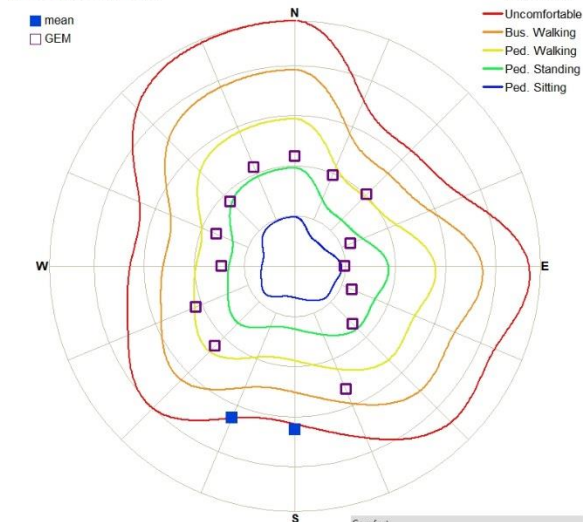
## LOCATION 28.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	28.10	44.05	44.05
4	10.74	15.05	15.05
6	4.48	6.10	6.10
8	1.22	2.07	2.07
10	0.26	0.50	0.50

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.7	6.3	6.3
Rating	Ped Standing	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.7	13.8	13.8
Rating	Pass	Pass	Pass

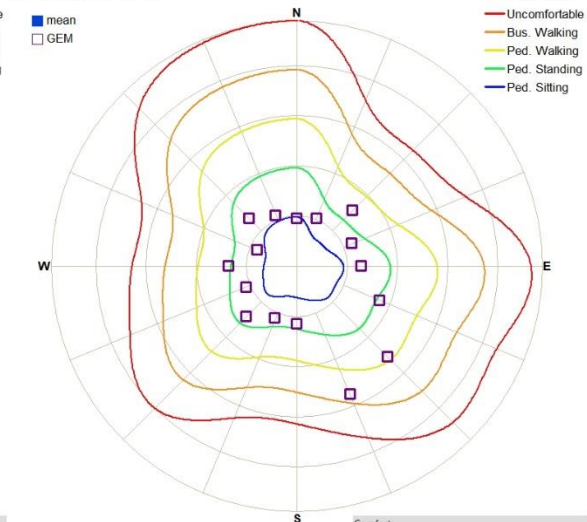
## LOCATION 29.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	42.15	59.58	59.86	
4	16.73	24.71	25.51	
6	7.88	7.81	9.76	
8	3.06	2.01	3.27	
10	0.91	0.46	0.94	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.9	6.6	7.2
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.1	13.5	15.1
Rating	Able Body	Pass	Able Body

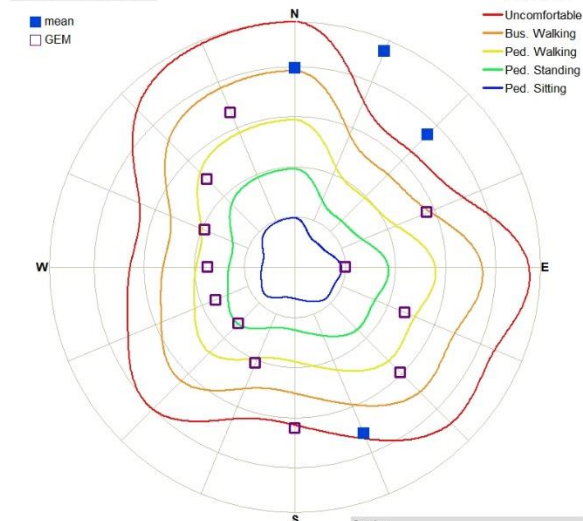
## LOCATION 30.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	15.35	40.05	40.05	
4	3.44	7.65	7.65	
6	0.44	1.30	1.30	
8	0.05	0.24	0.24	
10	0.00	0.04	0.04	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.4	4.5	4.5
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.8	10.6	10.6
Rating	Pass	Pass	Pass

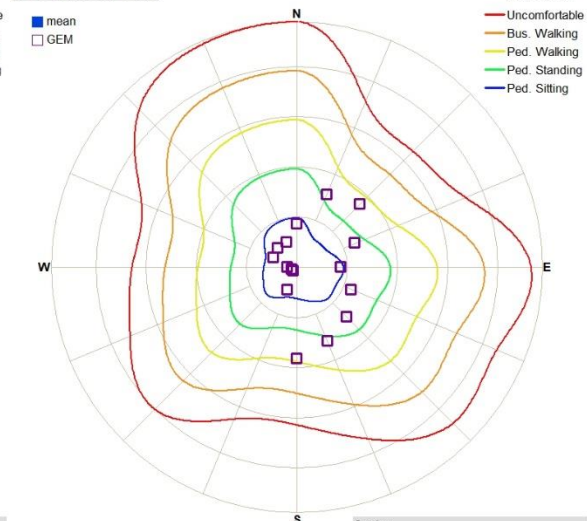
## LOCATION 31.3



% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	60.89	74.44	74.90	
4	31.51	38.02	39.74	
6	16.51	18.23	20.00	
8	8.17	6.67	9.07	
10	3.40	1.92	3.65	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	9.1	8.4	9.3
Rating	Bus Walking	Bus Walking	Bus Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	17.1	15.1	17.2
Rating	Able Body	Able Body	Able Body

## LOCATION 32.3

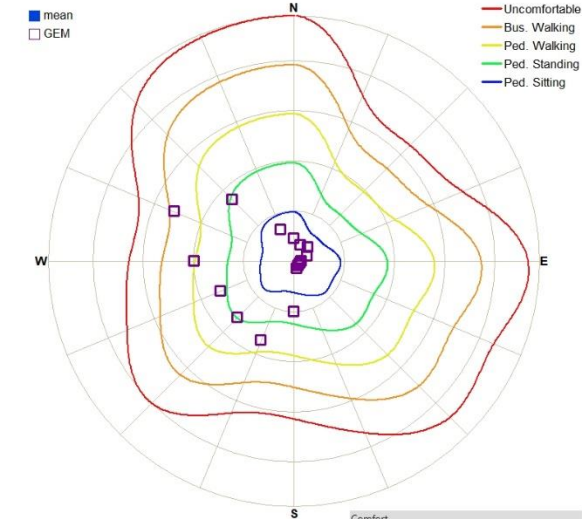


% of time in excess of wind speed V				
V (m/s)	MEAN	GEM	COMBINED	
2	15.94	26.72	26.72	
4	2.43	6.02	6.02	
6	0.19	0.59	0.59	
8	0.00	0.03	0.03	
10	0.00	0.00	0.00	

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.2	4.1	4.1
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.1	8.1	8.1
Rating	Pass	Pass	Pass



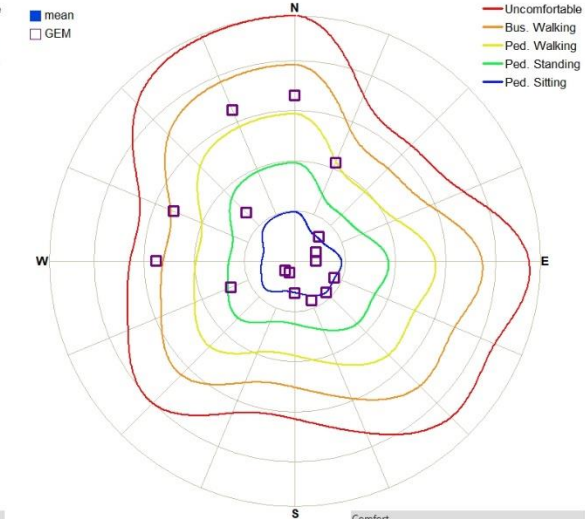
## LOCATION 33.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	14.55	25.16	25.16
4	2.45	5.92	5.92
6	0.52	1.31	1.31
8	0.06	0.36	0.36
10	0.00	0.10	0.10

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.2	4.2	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.6	11.2	11.2
Rating	Pass	Pass	Pass

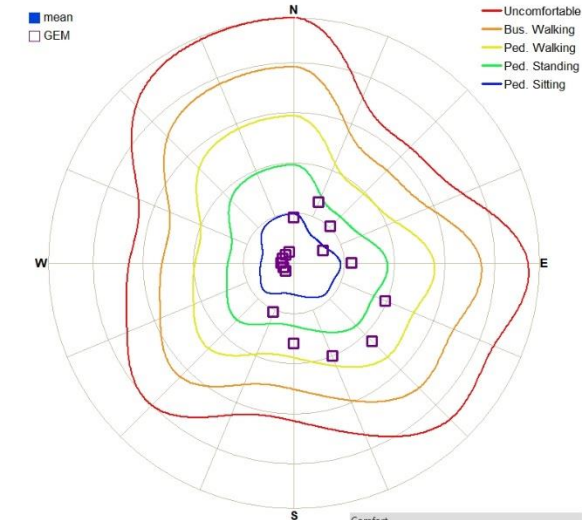
## LOCATION 34.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	20.43	31.92	31.92
4	5.14	11.05	11.05
6	1.47	3.37	3.37
8	0.26	1.10	1.10
10	0.02	0.25	0.25

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	5.3	5.3
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.8	12.3	12.3
Rating	Pass	Pass	Pass

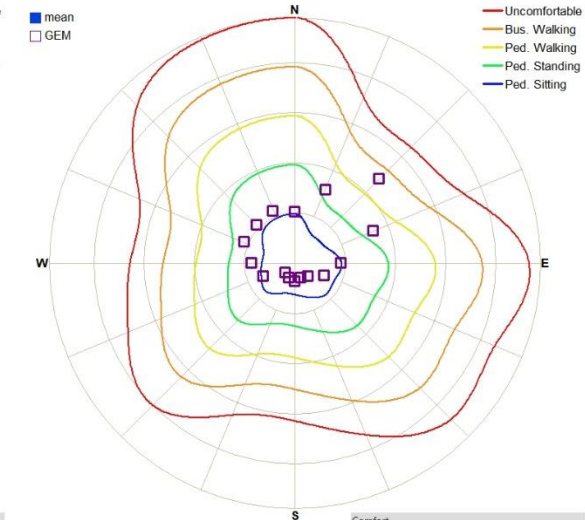
## LOCATION 35.3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	19.94	29.08	29.08
4	3.09	4.92	4.92
6	0.24	0.39	0.39
8	0.02	0.02	0.02
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	4.0	4.0
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.8	8.0	8.0
Rating	Pass	Pass	Pass

## LOCATION 36.3

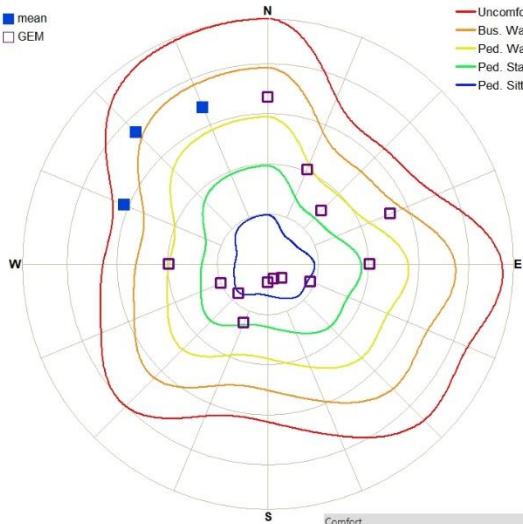


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	9.56	17.77	17.77
4	3.16	5.71	5.71
6	0.45	1.37	1.37
8	0.02	0.19	0.19
10	0.00	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	4.1	4.1
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.0	9.4	9.4
Rating	Pass	Pass	Pass

### LOCATION 37.3

■ mean  
□ GEM

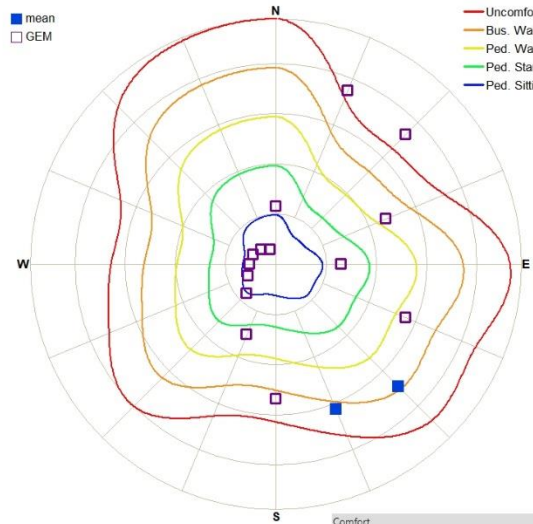


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	40.68	48.44	50.33
4	12.81	15.50	17.58
6	3.33	4.20	4.80
8	1.50	1.29	1.63
10	0.62	0.43	0.63

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.2	5.7	5.9
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	15.5	14.0	15.5
Rating	Able Body	Pass	Able Body

### LOCATION 38.3

■ mean  
□ GEM



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	35.04	46.61	46.80
4	16.82	27.40	28.00
6	5.70	12.99	13.62
8	1.00	5.28	5.46
10	0.17	1.63	1.68

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.1	8.0	8.1
Rating	Ped Walking	Bus Walking	Bus Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.3	14.9	15.0
Rating	Pass	Pass	Pass