



WIND ENGINEERING
CONSULTANTS

PEDESTRIAN WIND ASSESSMENT
CPP PROJECT 17939
9 MAY 2024

Compass Centre Bankstown

Bankstown, NSW

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Executive Summary

A wind tunnel study of the Compass Centre Bankstown development, to be built in Bankstown, NSW was conducted to assess the surrounding pedestrian wind environment. Measurements of winds likely to be experienced by pedestrians were combined with wind statistics and compared to wind comfort and safety criteria.

The wind tunnel testing was performed in a natural boundary layer wind tunnel of CPP. A model of the project was fabricated to a 1:300 length scale and centred on a turntable in the wind tunnel. Replicas of existing and approved surrounding buildings within a 430 m radius were constructed and placed on the turntable. Approach boundary layers representative of the environment surrounding the proposed development was established in the test section of the wind tunnel.

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 49 locations for 16 wind directions each. These points were tested around the development site focusing on pedestrian access routes, entries, and outdoor seating or recreation 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.

The results of the wind assessment can be summarized as follows:

GROUND LEVEL:

The wind environment around the development was found to be generally suitable for Pedestrian Standing to Walking style activities with calmer conditions in alcove areas, which were classified as suitable for Pedestrian Sitting. These conditions are considered suitable for the intended use of public domain spaces. No adverse wind conditions as a result of the proposed development are foreseen. All tested locations satisfy the Lawson safety criteria.

PODIUM TERRACE:

Wind comfort conditions were found to be generally suitable for Pedestrian Standing and Pedestrian Walking. These conditions align with the intended purpose of public domain spaces. Local mitigation measures would be recommended at undercut corner areas if longer term stationary activity such as sitting is desired. There are no significant adverse wind conditions anticipated due to the proposed development. All tested locations meet the safety criteria.

BALCONIES:

Conditions were found to be generally suitable for Pedestrian Sitting and Standing with reference to the Lawson comfort criteria. Balconies on the western sides of Towers B and C were found to be calmer and achieved an Outdoor Dining comfort rating. All tested locations were found to satisfy the recommended safety criteria.

ROOF TERRACES:

The wind environment on the roof terraces within the development were found to be suitable for Pedestrian Sitting and Pedestrian Standing style activities from a comfort perspective with reference to the Lawson criteria. These conditions are suitable for their intended use.

Document Tracking and Version Control

REVISION	RELEVANT INFORMATION
R00	Date Issued: 9 May 2024
	Prepared by: Jordan Black
	Reviewed by: Joe Paetzold, PhD
	Approved by: Joe Paetzold, PhD
	Document Name: CPP17939_Compass Centre Bankstown_REP_PW_R00.pdf

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1. Introduction

GENERAL INFORMATION

Pedestrian wind studies are conducted to investigate pedestrian comfort and safety in and around developments. This assessment of the wind environment around developments can inform designers about the suitability of outdoor areas for their intended uses. Where necessary, design modifications can be made, or intervention measures added to mitigate areas with the potential for excessive wind speeds.

This report contains information regarding the local wind climate analysis, wind tunnel testing and analysis procedures, a discussion of the test results, and recommendations to improve wind conditions in areas where any adverse wind conditions may be identified. The test parameters and configurations are summarised in Table 1.

All data collection was performed in accordance with the guidelines of the Australasian Wind Engineering Society (2019), and the American Society of Civil Engineers (1999, 2021). 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: Wind Tunnel Test Parameters

SUMMARY OF TEST PARAMETERS	
GENERAL INFORMATION	
Model Scale	1:300
Surrounding Model Radius (full scale)	430 m
Approach Terrain Category	Built-up environment approach
ENVIRONMENTAL WINDS STUDY	
Number of test locations	49
Reference height (full scale)	100 m
TEST CONFIGURATION(S)	
Configuration A	Site and surroundings as they currently exist and all approved or under construction developments within the modelled test radius as shown in Figure 1.

2. Methodology

WIND TUNNEL MODEL

The anticipated wind conditions around the project site were evaluated through wind tunnel testing of a 1:300 scale model of the development and surrounding area. This scale allowed for an adequate portion of surrounding developments and terrain to be included within an approximately 430 m radius of the site and all the relevant building details to be modelled accurately. The boundary-layer wind conditions beyond the modelled area were also appropriately simulated in one of CPP's wind tunnels (see Appendix A). The models were mounted on the turntable, located near the downstream end of the wind tunnel test section, allowing rotation of the modelled area for examination of wind speeds from any approach wind direction.

Photographs of the test and surrounds models installed in the wind tunnel are given in Figure 1.

MEASUREMENT POINTS

For this study, wind speed measurements were recorded at 49 locations to evaluate pedestrian wind comfort and safety in and around the project site. The selected test locations are shown in Figure 4 to Figure 11.

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, at outdoor recreation areas and terraces.

The hot-film signal was sampled for a period corresponding to one hour in full scale. All velocity data were digitally filtered to obtain the two to three second running mean wind speed at each point; this 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 100 m are plotted in polar form in Appendix B. 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.

The measured local wind velocities were combined with wind climate data described in the following section to allow assessment of the pedestrian wind environment.



Figure 1a: Photographs of Wind Tunnel Test and Surrounds Model



Figure 1b: Photographs of Wind Tunnel Test Model – Close up

WIND CLIMATE

The measured velocity data were normalized to an approach reference wind speed and then combined with a climatological model (wind frequency and direction) derived from data measured at a standard height of 10 m at Bankstown Airport. The project site is located approximately 4 kilometres to the east of the airport which provides the best source of historical wind data for the project.

This data is portrayed in the wind roses in Figure 2. The arms of the wind roses point in the direction where the wind is blowing from, the width and colour of the arm represent the wind speed, and the length of the arm indicates the percent of the time that the wind blows for that combination of speed and direction. These data were then adjusted to the site location using an analytical method to account for the exposure of the project site for each direction.

The distribution and frequency of winds on an annual basis were analysed to assess the project with regards to wind comfort and safety. As can be seen from the wind rose in Figure 2, winds from the west and south-east directions are predominant, with secondary winds occurring from the north-east directions. The locations tested around the development site may be susceptible to winds from these directions, depending on the relative position of the location tested to the geometry of the proposed development and surrounds.

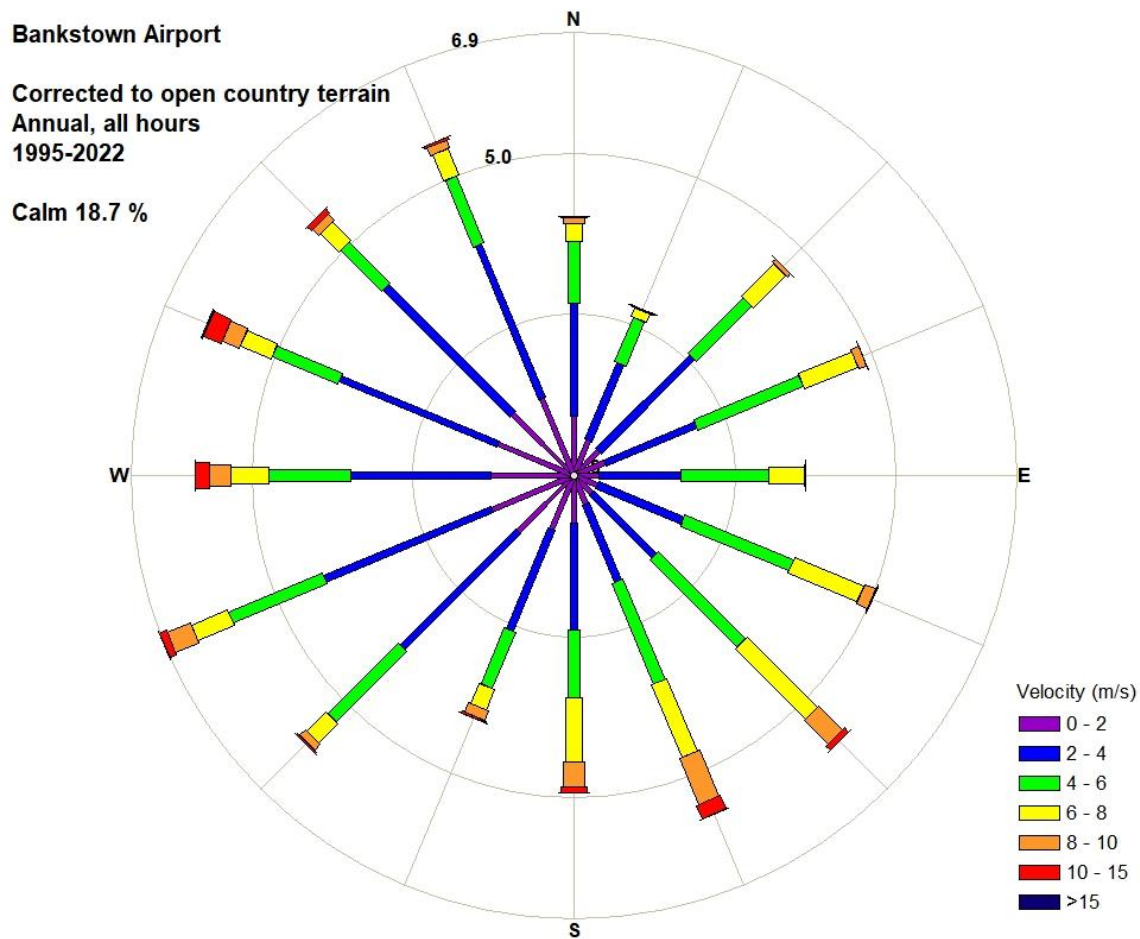


Figure 2: Probability of Wind Speeds by Direction – Bankstown Airport (1995 – 2022, All Hours)

WIND ASSESSMENT CRITERIA

To enable a quantitative assessment of the wind environment, the wind tunnel data and climatological model are combined to calculate wind speeds for comparison with pedestrian wind comfort and safety criteria at each test point.

A number of researchers have suggested quantitative methods for assessing wind comfort and safety based on wind tunnel data and local climate statistics. CPP uses a modified form of the widely-accepted pedestrian-level wind criteria developed by Lawson (1990). Lawson's criteria are divided into separate categories of comfort and distress (safety). The comfort criteria allow planners to assess the usability, with respect to the wind environment, of different locations for various purposes, such as for long-duration activities (e.g., sitting at an outdoor café) or strolling on walkways.

Lawson's criteria are based on wind speeds exceeded 5% of the time, and are described as categories for comfort ranging from 'Pedestrian Sitting' to 'Business Walking', allowing planners to judge the usability of locations for various intended purposes. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds, to identify locations where wind speeds may be hazardous to pedestrians.

Pedestrians' perception of wind can often be subjective and vary depending on regional difference in wind climate and thermal conditions, as well as by individual. Calibration to the local wind environment should be taken into account when evaluating predicted wind comfort conditions. Note that the ratings of 'Uncomfortable' and 'Safety' are the words of the published wind criteria and applicability may vary by project and location.

The categories and criteria are specified in Table 2.




Table 2: Wind Comfort and Safety criteria (after Lawson, 1990)

COMFORT RATING	U_{EQUIV}^*	DESCRIPTION
 Dining**	< 2 m/s	Calm / light breezes suitable for outdoor restaurant uses, seating areas, and other amenities based on CPP experience.
 Sitting	2-4 m/s	Calm or light breezes suitable for long duration seating areas, and other amenities.
 Standing	4-6 m/s	Gentle breezes suitable for sitting for shorter periods, main entrances and bus stops where pedestrians may linger.
 Pedestrian Walking	6-8 m/s	Moderate winds appropriate for window shopping and strolling along a downtown street, or park.
 Business Walking	8-10 m/s	Relatively high speeds that can be tolerated if one's objective is to walk, run, or cycle.
 Uncomfortable	> 10 m/s	Strong winds unacceptable for all pedestrian activities; wind mitigation is typically required.

* $U_{Equiv} = \text{Max}(U_{Mean}, U_{Gust} / 1.85)$.

* U_{Equiv} speeds are based on an annual exceedance of 5% (~8 hours / week) assessed over all hours.

** For regular outdoor dining, and in semi-enclosed spaces, it has been the experience of CPP that the comfort rating of Sitting may be windier than desired and a comfort criterion of 2 m/s or less may be more applicable.

SAFETY RATING	U_{EQUIV}^*	DESCRIPTION
 Pass	< 15 m/s	Meets wind safety criterion.
 Able-Bodied	15-20 m/s	Acceptable where only able-bodied people would be expected; not acceptable for frail persons or cyclists
 Fail	>20 m/s	Excessive wind speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is often required.

* $U_{Equiv} = \text{Max}(U_{Mean}, U_{Gust} / 1.85)$.

* U_{Equiv} speeds are based on an annual exceedance of 0.022% (~2 / year or 1 / season) assessed over all hours.

3. Results

A summary of the assessed comfort and safety ratings for each test location is given in Table 3 and Figure 3. The results of the study are graphically presented in Figure 4 to Figure 7 in which measurement locations are displayed on a site plan and colour coded to denote the predicted wind comfort and safety rating. 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.

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 B. In addition, the wind speeds corresponding to the 5% (comfort) and 0.022% (safety) thresholds are provided for direct comparison to the criteria. These plots also include directional criterion lines for the Lawson comfort levels to provide additional information regarding directional sensitivity at each location.

In general, wind conditions comfortable for Sitting and Standing are considered appropriate for areas such as entrances where pedestrians are likely to gather for longer durations, while wind conditions comfortable for Casual Walking and Business Walking are more appropriate for sidewalks where pedestrians are actively in transit. Locations rated as Uncomfortable are generally less suitable for most pedestrian activities and wind control solutions are often sought. Whether mitigation is needed at a location depends upon the intended pedestrian use of the location. Although conditions may be classified as acceptable, there may be certain wind directions that cause regular strong events.

Satisfaction of the safety rating is generally required for areas accessible to the general public. A rating of 'Able-Bodied' may be acceptable for areas with managed access or where pedestrians are unlikely to be present under adverse conditions. Mitigation measures are generally required to address any locations deemed to fail the safety assessment.

Table 3: Summary of wind comfort and safety assessment results

Description / Location		Wind Tunnel Results	
		Comfort rating, 5% exceedance wind speed (m/s)	Safety rating, 0.022% exceedance wind speed (m/s)
Ground	1	5.9	11.2
	2	5.7	10.9
	3	4.3	8.1
	4	5.8	10.8
	5	5.9	11.1
	6	4.9	9.6
	7	3.0	6.7
	8	3.8	9.5
	9	4.0	7.7
	10	5.5	10.3
	11	5.7	10.8
	12	4.3	8.1
	13	4.8	10.4
	14	4.7	10.6
	15	4.8	10.2
	16	7.4	13.9
	17	5.6	11.8
	18	4.2	7.5
	19	3.7	7.4
	20	5.8	10.7
	21	4.7	9.8
	22	4.8	11.1
	23	4.9	10.2
	24	7.2	14.5
Podium	25	4.4	8.5
	26	5.9	12.7
	27	3.1	6.8
	28	4.5	9.1
	29	6.5	13.7
	30	7.1	12.9
	31	7.7	14.9
	32	6.2	12.0
	33	7.0	13.1
	34	5.6	13.5
	35	2.5	6.4
	36	4.1	9.2
	37	4.4	11.4
	38	3.6	7.2
Balconies	39	2.5	5.0
	40	4.2	11.3
	41	3.7	7.2
	42	3.1	6.8
	43	2.9	7.2
	44	4.6	11.9
	45	1.5	4.6
	46	1.2	3.1
Roof Terrace	47	3.9	9.1
	48	4.0	9.6
	49	2.7	6.2

LEGEND	
Comfort Criteria	
	Outdoor Dining
	Pedestrian Sitting
	Pedestrian Standing
	Pedestrian Walking
	Business Walking
	Uncomfortable
Safety Criteria	
	Passes safety criteria
	Able bodied
	Fails safety criteria

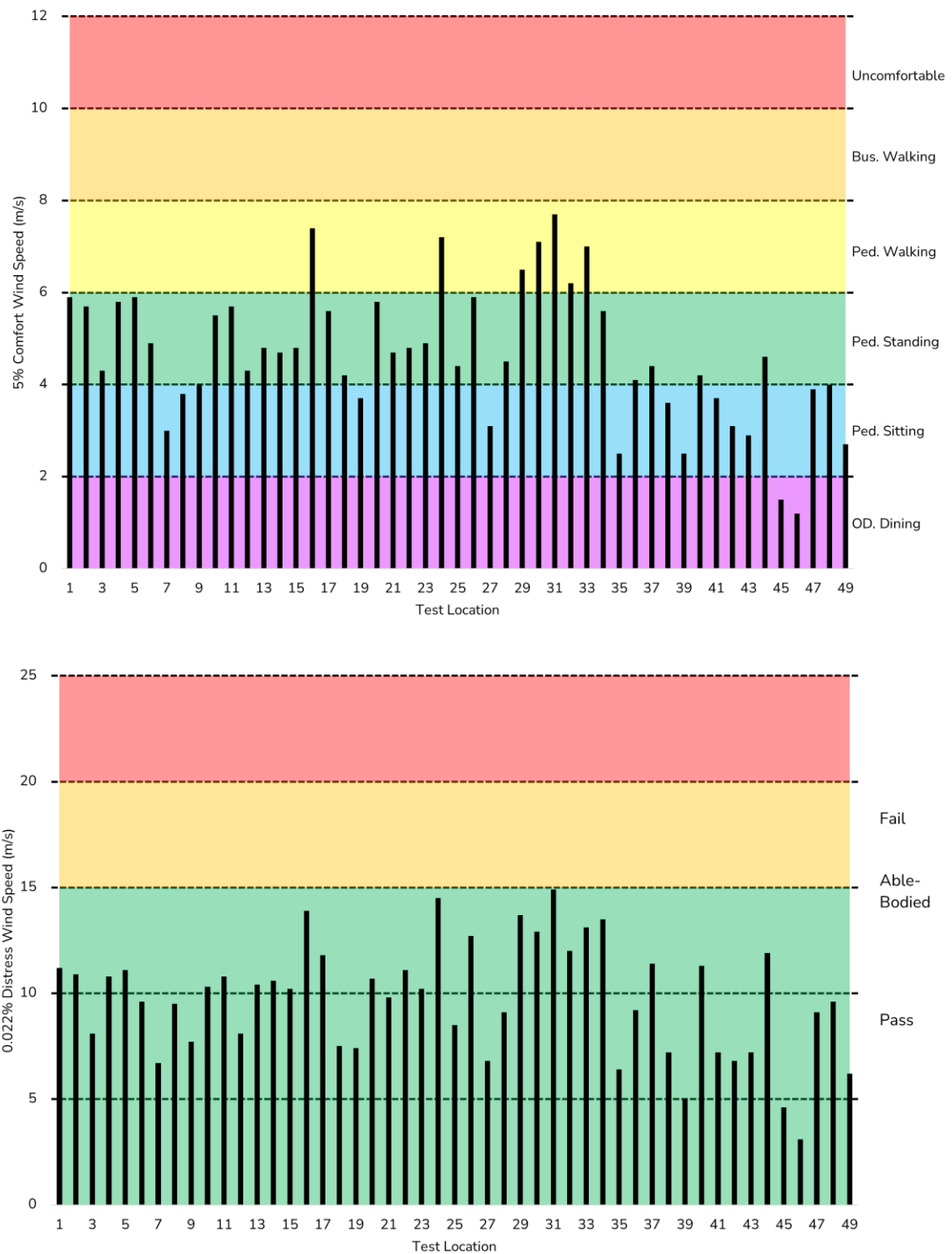


Figure 3: Summary of wind comfort and safety assessment results.

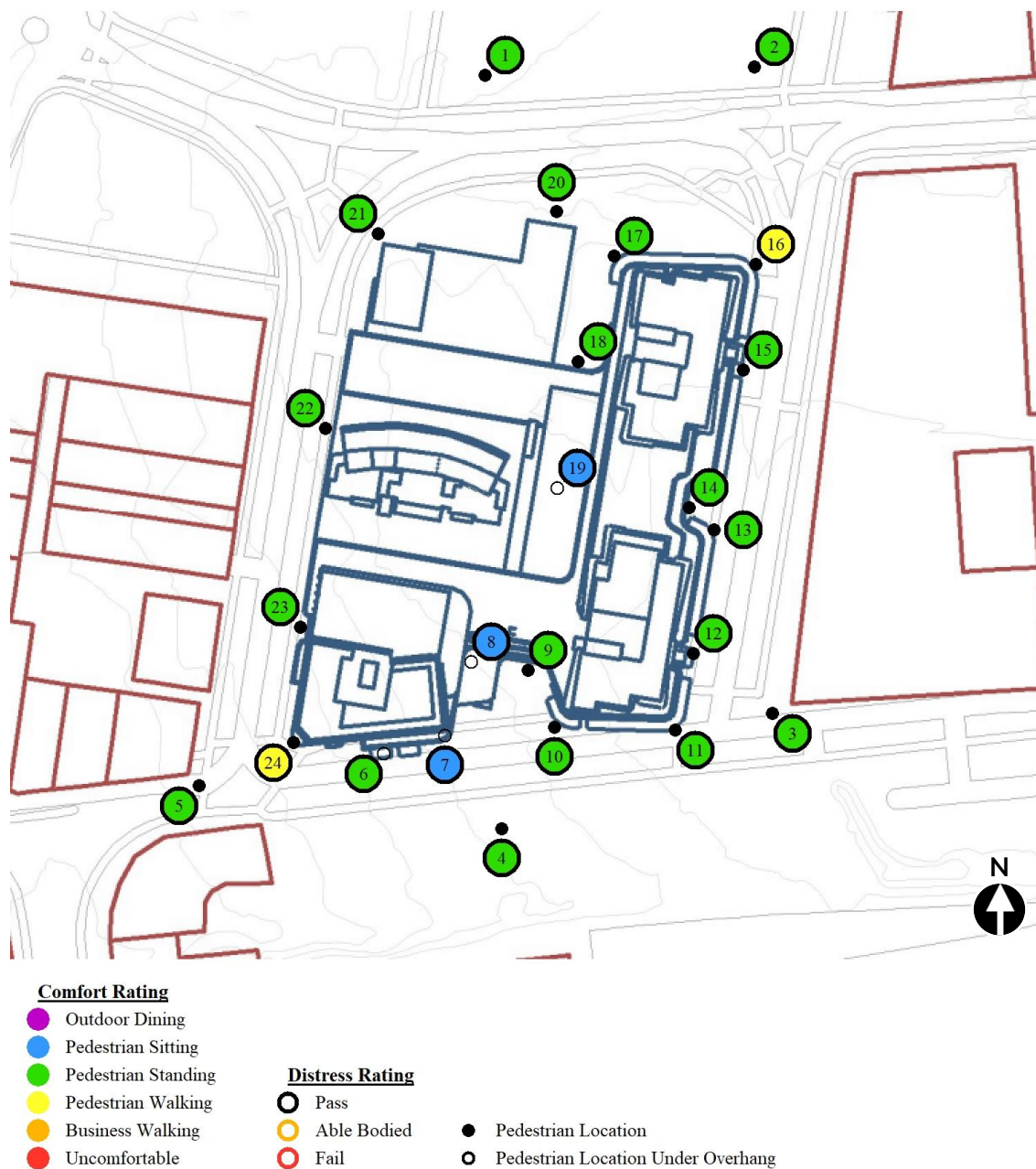


Figure 4: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground – Plan View

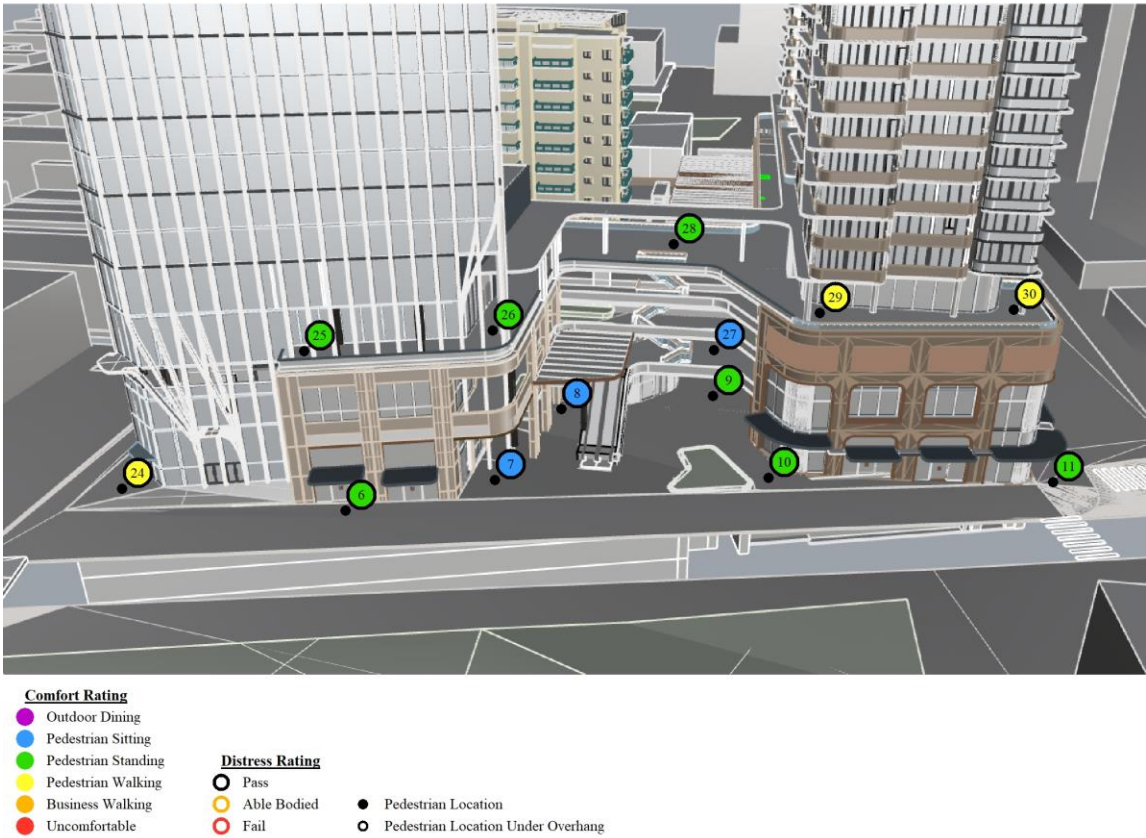


Figure 5: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground/Podium Level – South Isometric view.

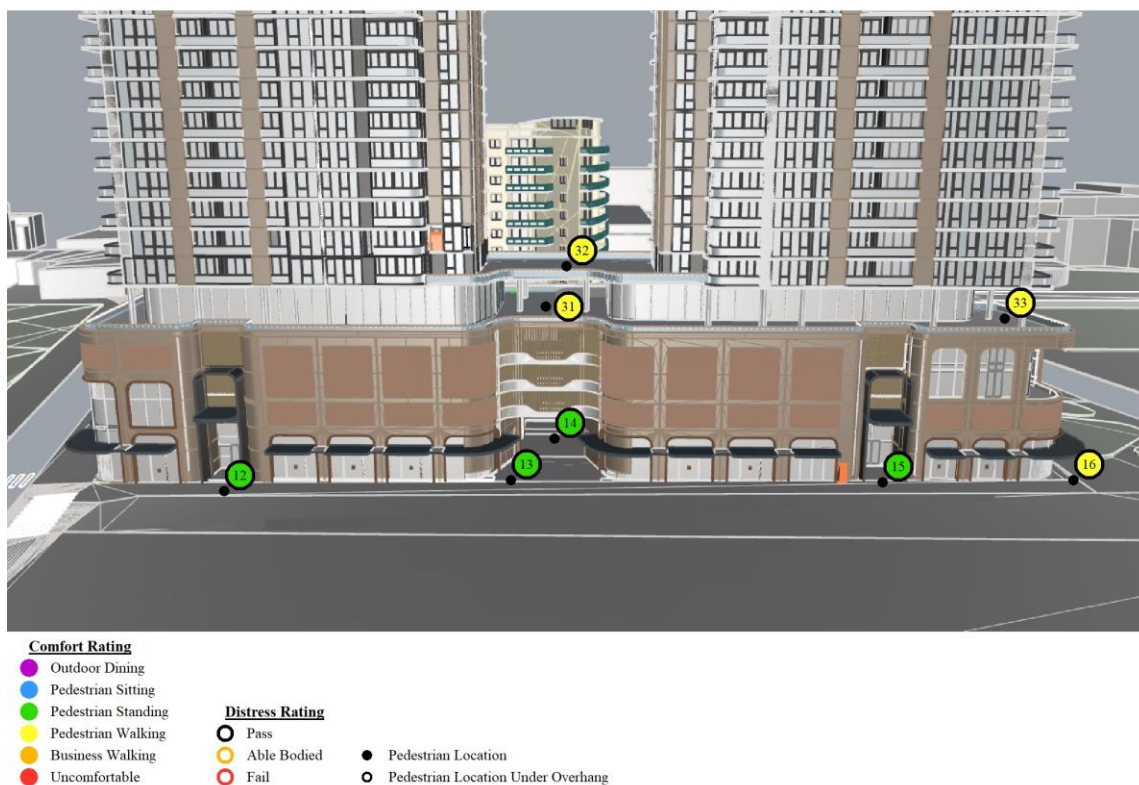


Figure 6: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground/Podium Level – East Isometric view.



Figure 7: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground/Podium Level – North Isometric view.

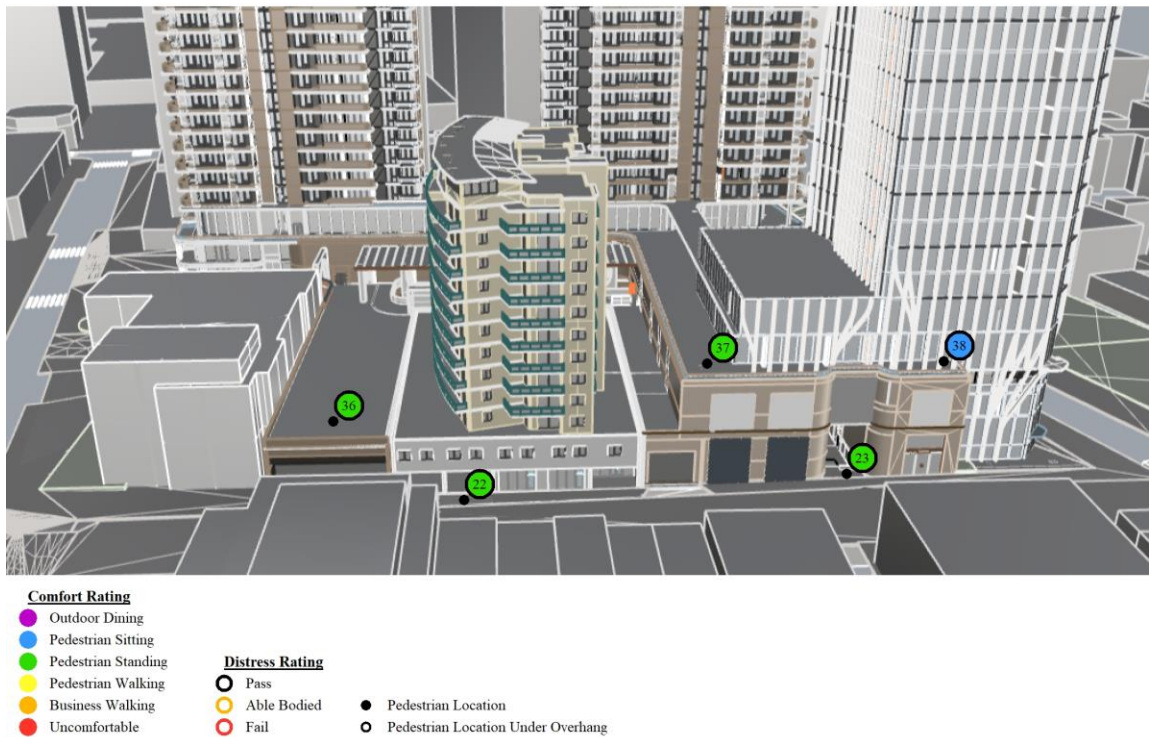


Figure 8: Pedestrian wind speed measurement locations with comfort/safety ratings – Ground/Podium Level – West Isometric view.

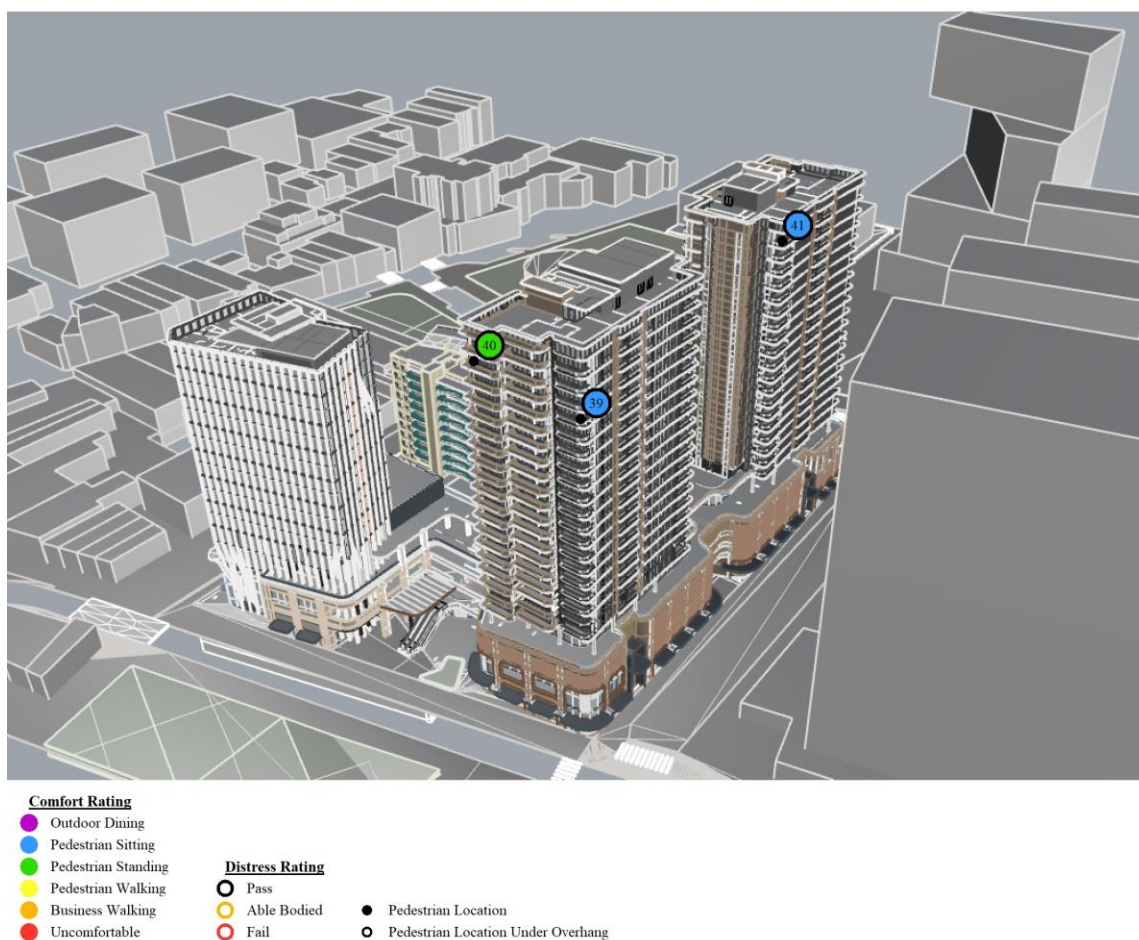


Figure 9: Pedestrian wind speed measurement locations with comfort/safety ratings – Balconies – South-east Isometric view

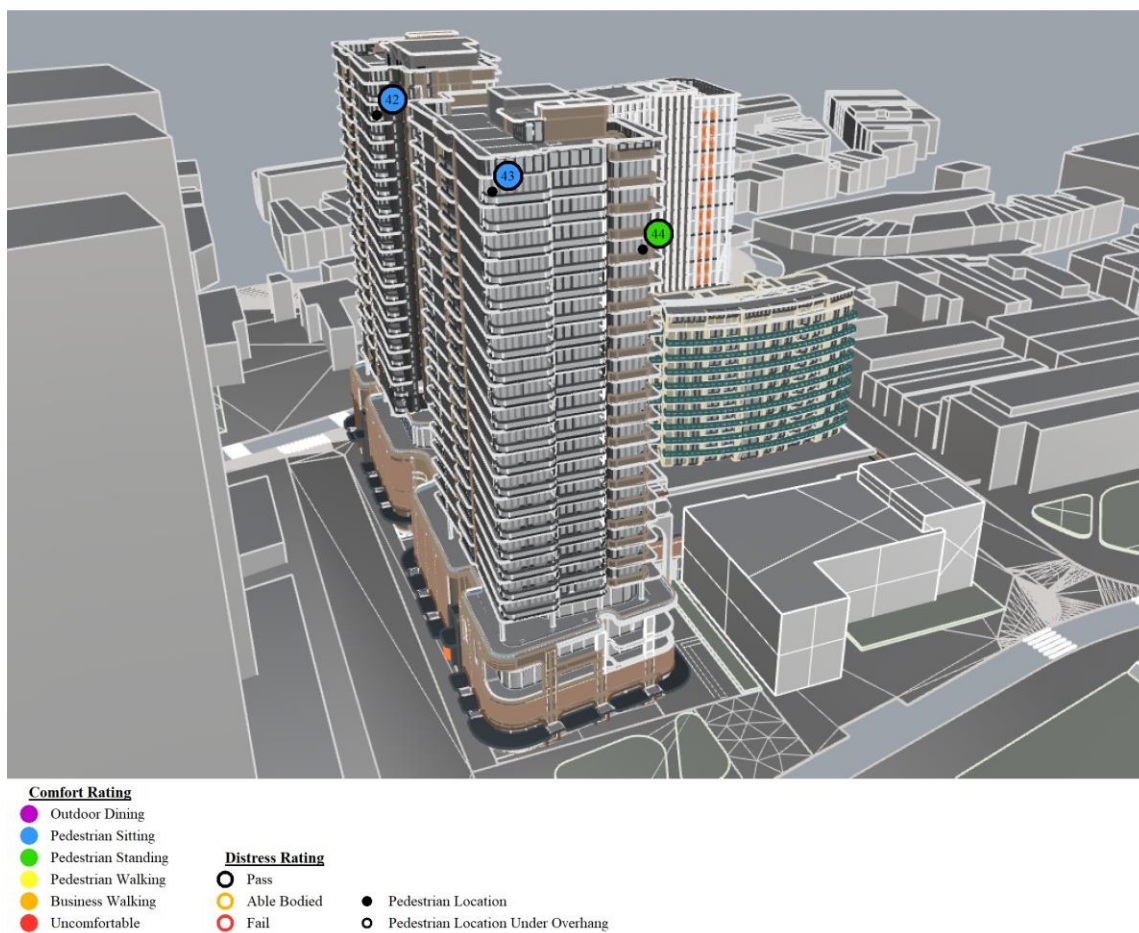


Figure 10: Pedestrian wind speed measurement locations with comfort/safety ratings – Balconies – North-east Isometric view.

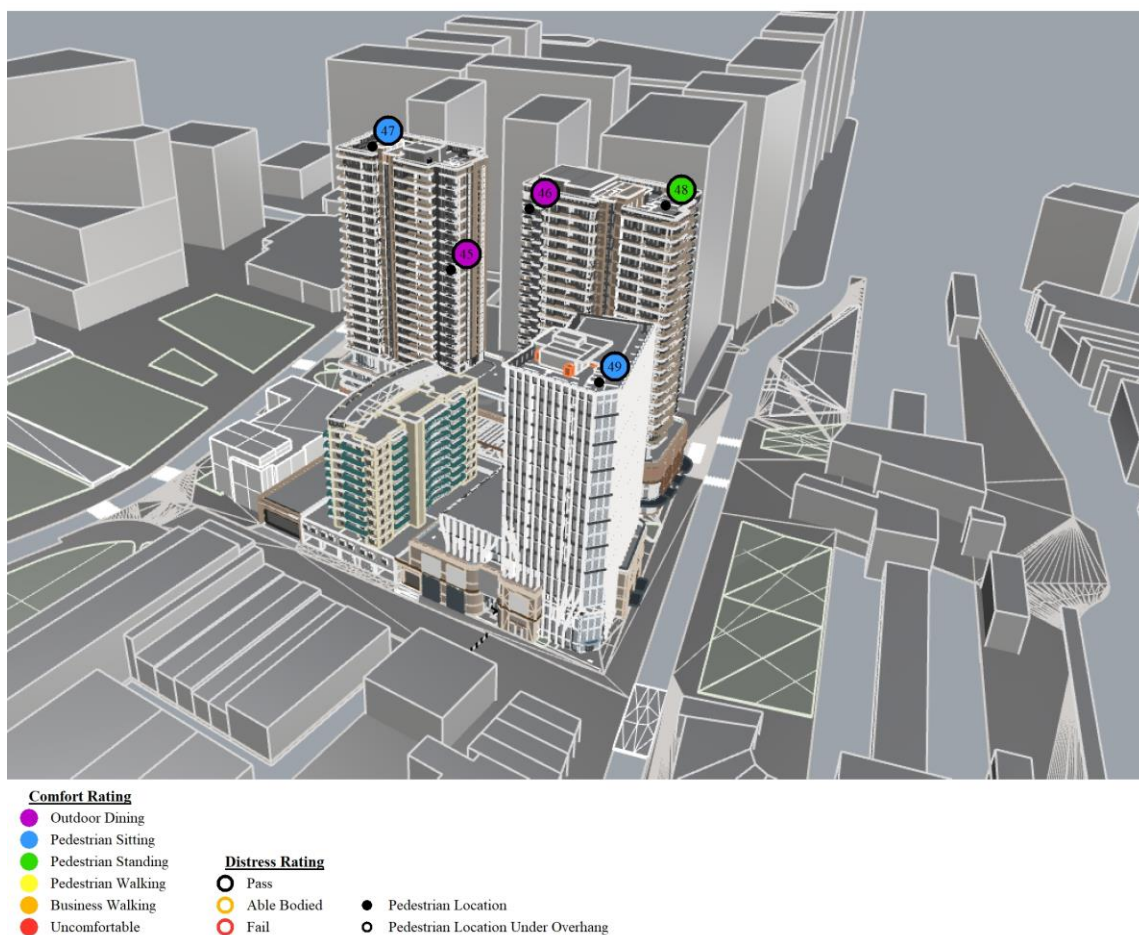


Figure 11: Pedestrian wind speed measurement locations with comfort/safety ratings – Balconies and Roof Terraces – South-west Isometric view.

4. Discussion

GROUND LEVEL

The comfort and distress ratings at ground level for the site are shown in Figure 4 to Figure 8. In general, most tested areas are in the Pedestrian Standing comfort category.

On the southern side of the site (Locations 4, 6, 9-11), conditions are typically rated Pedestrian Standing (Figure 4 and Figure 5). The strongest winds in this region generally come from the south-east quadrant. Slightly milder conditions were measured under the awnings at the south-eastern side of Tower A, where Locations 7 and 8 are rated Pedestrian Sitting. The highest wind speeds for Location 8, towards the eastern end of Featherstone Walk, come from the west and are due to pressure driven flow along the enclosed walkway. The windiest location in the southern plaza region, at the junction of Featherstone Walk and Compass Way, meets the wind speed associated with the Outdoor Dining classification for about 70% of the time. If comfortable conditions for outdoor dining are required on windier days, the addition of vertical screening elements such as raised planters and booth style seating is recommended.

The wind conditions along the eastern (Appian Way) side of the site (Locations 12-15) exhibit comparable conditions, with tested locations typically rated in the Pedestrian Standing comfort category (Figure 4 and Figure 6). The highest wind speeds for Locations 13 and 14, at the eastern end of the pedestrian link to the Compass Way arcade, come from the west and is likely due to pressure-driven flow through the enclosed corridor. At the centre of the Compass Way arcade (Location 19), conditions are slightly calmer and rated Pedestrian Sitting. Location 19 meets the wind speed associated with the Outdoor Dining classification for about 70% of the time. As mentioned previously, to increase the percentage of time suitable for Outdoor Dining, vertical screening elements such as raised planters and booth style seating may be used where necessary.

On the northern side of the site (Locations 1, 2, 17, 18, 20, 21), wind conditions are generally rated Pedestrian Standing (Figure 4 and Figure 7). Near the north-eastern corner of Tower C, wind speeds are higher, with Location 16 rated Pedestrian Walking. The higher wind speed at this location is a result of downwash generated off Tower C directing winds from the east and north quadrants to ground level, which are then accelerated around the tower corner. It is noted that calmer conditions are likely to be available closer to the tower and under the protection of the proposed awning that wraps around the north-eastern corner of Tower C. It is recommended that this feature be retained.

Comparable wind conditions are evident on the western side of the site, along Featherstone Street (Locations 5, 22, 23), with typical comfort ratings in the Pedestrian Standing category (Figure 4 and Figure 8). Higher winds speeds are noted at the south-western corner of Tower A, where location 24 is rated Pedestrian Walking. Downwash generated off Tower A directs winds from the west and south to ground level, accelerating flow around the tower corner.

The results indicate wind conditions in most pedestrian accessible areas around the site and near the site entries are acceptable for medium term stationary occupation, waiting (such as for transport), and sitting. Stronger wind conditions at the north-eastern and south-eastern corners of the development area suitable for general pedestrian access and thoroughfare. For areas intended for longer-term stationary occupation such as outdoor dining, the inclusion of vertical screening elements such as raised planters or booth style seating may be used to increase wind amenity. All areas pass the Lawson Safety criterion.

PODIUM TERRACE

Wind conditions on the podium terrace are shown in Figure 5 to Figure 8 and are generally rated Pedestrian Standing or Pedestrian Walking.

In the southern region of the podium terrace, conditions are predominately governed by exposure to winds from the south (Figure 5). From a comfort perspective, Locations 25, 26 and 28 are rated Pedestrian Standing, while Locations 29 and 30 are rated Pedestrian Walking. The increased wind speeds at locations 29 and 30 occur as downwash from Tower B directs flow toward the podium terrace, which accelerates through the undercut sections. Locations 29 and 30 meet the wind speed associated with Pedestrian Sitting for 80% and 75% of the time respectively. The addition of an awning that extends around the southern edge of Tower B will help to increase wind amenity in these areas if milder wind conditions are desired for this space. Relatively mild conditions are indicated for Location 27, in the southern region of the Level 1 terrace, with a comfort rating of Pedestrian Sitting.

The podium terrace areas on Levels 4 and 5, situated between Towers B and C at Locations 31 and 32, are prone to wind from the east and west channelling through the space between the buildings. Both of these locations are classified as suitable for Pedestrian Walking, with the windiest location meeting the wind speed associated with Pedestrian Sitting for approximately 70% of the time. The inclusion of vertical screening elements at both the Level 4 and 5 terrace areas, as well as an awning that wraps around the northern side of Tower B and the southern side of Tower C, at Level 5 should be considered, if conditions suitable for longer term stationary occupation are desired in these areas. Wind conditions at the north-eastern corner of Tower C are similar and rated Pedestrian Walking (Location 33). As mentioned previously, the undercut corner area experiences higher wind speeds as downwash accelerates through the undercut space. An awning around the northern side of Tower C will aid in reducing the impact of such flows and is recommended if milder wind conditions are desired.

Wind conditions in the northern and western regions of the podium terrace (Figure 7 and Figure 8 respectively) are rated Pedestrian Sitting or Pedestrian Walking (Locations 34-38). The strongest winds for these locations typically come from the south-west quadrant. Locations 34, 36 and 37 are rated Pedestrian Standing. Locations 35 and 38 are slightly calmer and rated Pedestrian Sitting.

In summary, the wind conditions at all areas on the podium terrace are acceptable for general pedestrian access/thoroughfare from a wind comfort perspective. Some areas, distanced from building corners or shielded by the tower structures, are calmer and suitable for medium-term stationary activities like standing or sitting. The residents' discretionary use of the podium space may render the need for further mitigation unnecessary. All locations satisfy the Lawson safety criterion.

BALCONIES

Wind conditions on a number of representative balconies and terraces are shown in Figure 9 to Figure 11. Wind conditions range from Outdoor Dining to Pedestrian Standing and all tested locations meet the safety standards defined by the Lawson criterion.

Balcony locations at the south-eastern and north-eastern corners of Tower B (Locations 39 and 42) and Tower C (Locations 41 and 43) are rated Pedestrian Sitting. Slightly stronger winds occur on balconies at the south-western corner of Tower B (Location 40) and the north-western corner of Tower C (Location 44), where a comfort rating of Pedestrian Standing was measured.

Balconies on the western side of Towers B and C (Locations 45 and 46) are suitable for Outdoor Dining with reference to the Lawson comfort criteria. The balconies as proposed are generally well designed and located from a wind perspective, representing relatively small volumes, and recessed within the floor plate.

Wind conditions on the tower balconies are suitable for medium to long-term stationary occupation. The windiest balcony location meets the wind speed associated with Pedestrian Sitting for 93% of the time and Outdoor Dining 75% of the time. Due to the discretionary use of balcony spaces by residence, further wind mitigation is likely unnecessary.

ROOF TERRACES

Wind conditions on the Tower roof terraces are shown in Figure 11 and are typically rated Pedestrian Sitting.

Location 49, on the roof terrace of Tower A, where the proposed rooftop bar is to be located, is rated Pedestrian Sitting. This location meets the wind speed associated with Outdoor Dining for 85% of the time. Similarly, Location 47, on the Tower C rooftop terrace is rated Pedestrian Sitting. Location 48, on the Tower B roof terrace is slightly windier and rated Pedestrian Standing.

The proposed roof terrace balustrades for each tower (approximately 2.1 m) reduces the exposed nature of the rooftops and created areas with reasonable wind comfort conditions.

All tested locations satisfy the Lawson safety criteria.

APPLICABILITY

Testing was performed without existing and proposed trees and other plantings to provide a worst-case assessment. Heavy landscape planting typically reduces wind speeds by less than 10% and in general should not be relied upon to mitigate strong winds due to variation in size and foliage and difficulty in accurate modelling. Further, trees or other plantings may pose a safety risk if damaged during high winds.

The results presented within this report are based on the 3D model labelled PA030557DA-PTW-AR-AA-M-A-1000.ifc received by CPP on 20 March 2024. If significant changes to the design of the development have occurred beyond this date or new information regarding the status of surrounding buildings becomes available, it is recommended that CPP be contacted to evaluate the impact of any changes.

5. Conclusion

CPP has conducted a wind tunnel study to quantify the pedestrian-level wind environment for the proposed Compass Centre Bankstown development. In general, most pedestrian-accessible areas around the site are assessed as suitable for Pedestrian Standing or Pedestrian Walking under the Lawson comfort criteria. These conditions are considered typical of those in the immediate surrounding areas and suitable for the intended use of public domain spaces. Milder wind conditions are available near the main entries to the building and in alcove areas. No significant adverse wind conditions as a result of the proposed development are foreseen, and all public domain areas satisfied the safety criterion. Conditions on the podium are similar and suitable for general pedestrian access/thoroughfare in all areas. Wind conditions on the tower balconies and roof terraces were shown to have milder conditions, suitable for discretionary use by occupants.

References

American Society of Civil Engineers (2021), *Wind Tunnel Testing for Buildings and Other Structures* (ASCE 49-21).

Australasian Wind Engineering Society (2019), *Wind Engineering Studies of Buildings* (AWES-QAM-1-2019).

Lawson, T.V. (1990), "The Determination of the Wind Environment of a Building Complex before Construction" Department of Aerospace Engineering, University of Bristol, Report Number TVL 9025.

Standards Australia (2021), *Australian/New Zealand Standard, Structural Design Actions, Part 2: Wind Actions* (AS/NZS1170.2:2021).

Appendix A – Wind Tunnel Test Facilities

The wind tunnel testing was performed at the CPP wind engineering laboratory in Sydney, Australia. Specifications for the wind tunnel used for this project are given in Figure A1.

The mean velocity profile approaching the modelled area for each direction has the form:

$$\frac{U}{U_{ref}} = \left(\frac{z}{z_{ref}} \right)^n$$

in which U is the mean velocity at height z , U_{ref} is a reference wind speed at reference height z_{ref} , and n is a constant which depends on the characteristics of the upstream roughness for each direction.

The profiles of longitudinal turbulence intensity in the flow approaching the modelled area are also modelled. The turbulence intensities are appropriate for the approach mean velocity profiles selected.

CPP SYDNEY WIND TUNNELS	
DIMENSIONS	
Test section length	21 m (69 ft)
Test section width	3 m (10 ft)
Ceiling height	2.4 m (8 ft)
DRIVE SPECIFICATIONS	
Total power	110 kW
Type of drive	Single Axle motor/12 blade axial fan
Speed Control	Variable frequency drive
FLOW CHARACTERISTICS	
Mean Velocity	0 to 20 m/s (0 to 66 ft/s)
Boundary-layer thickness*	1.2 m (4 ft) (nominal)
Turbulence	About 2% at entrance to test section
Longitudinal pressure gradient	Zero by blockage tolerant roof

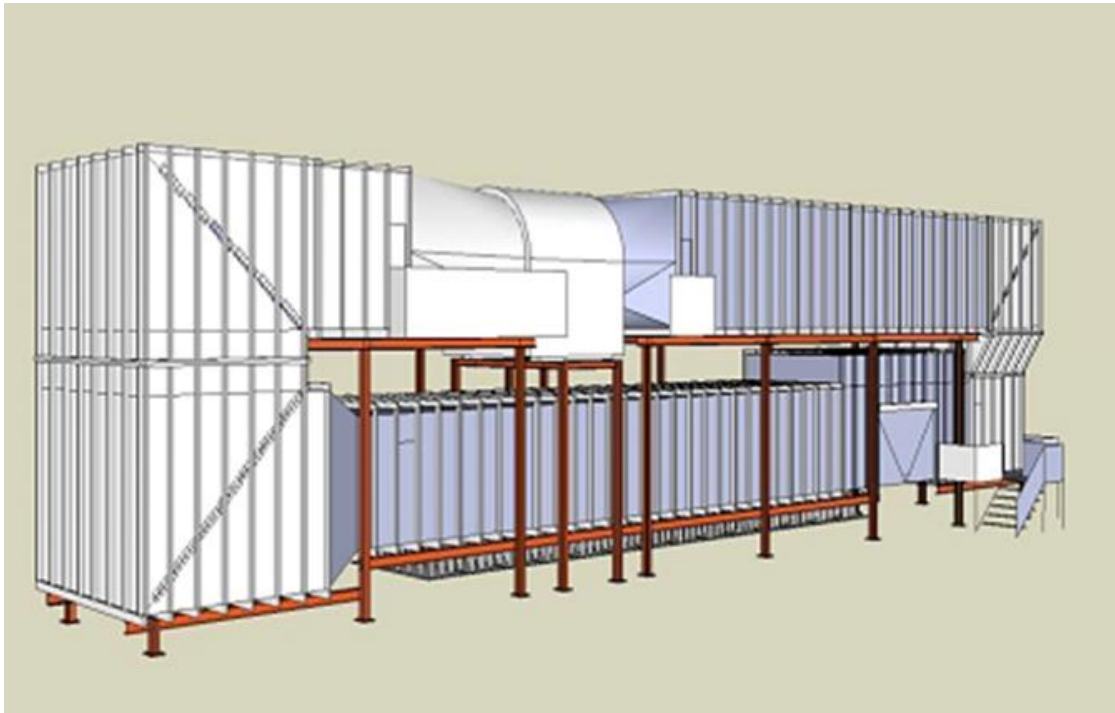
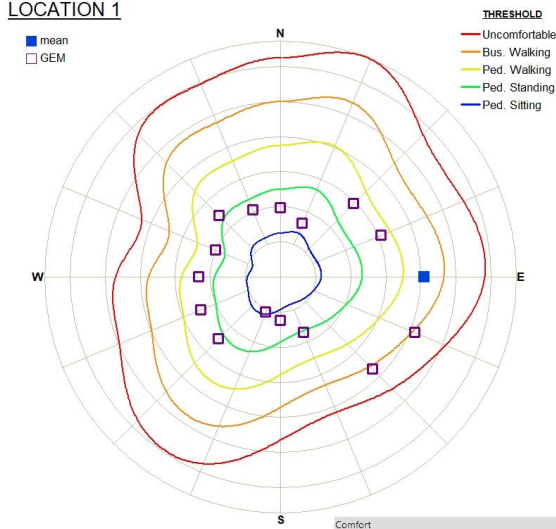


Figure A1: CPP Wind Tunnel - Sydney, Australia

Appendix B - Directional wind results

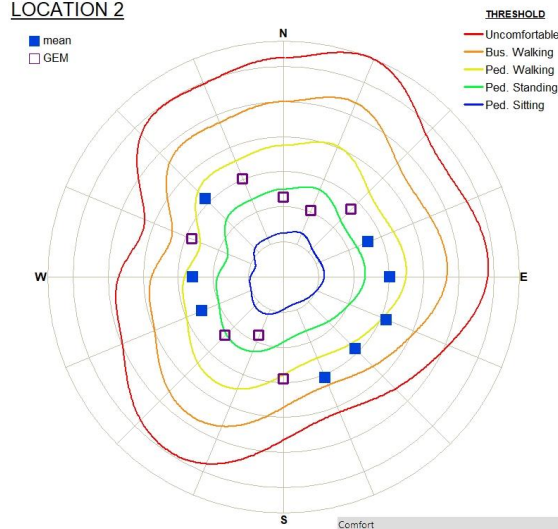
LOCATION 1



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	30.61	42.35	42.48
4	11.37	15.65	15.95
6	2.89	4.53	4.86
8	0.32	0.80	0.84
10	0.03	0.09	0.09

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.2	5.8	5.9
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.1	11.2	11.2
Rating	Pass	Pass	Pass

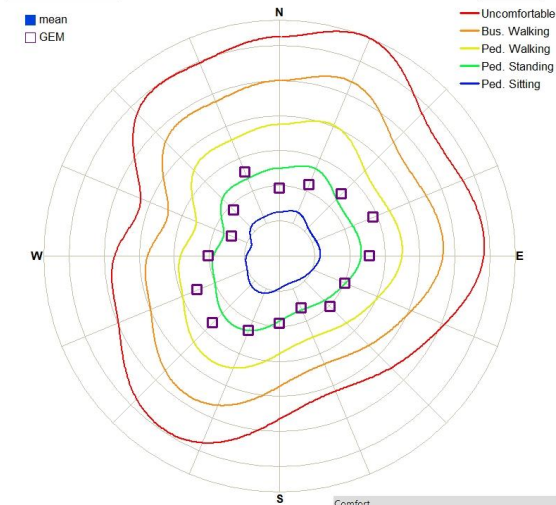
LOCATION 2



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	46.66	50.45	51.64
4	15.73	16.07	17.78
6	3.51	3.24	3.98
8	0.48	0.42	0.54
10	0.05	0.04	0.06

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.5	5.4	5.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	10.7	10.9
Rating	Pass	Pass	Pass

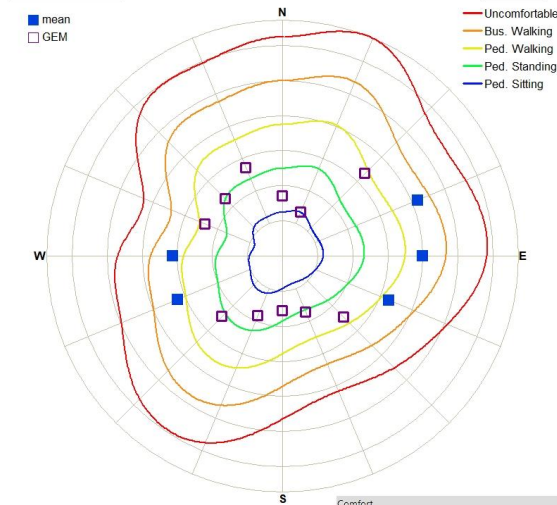
LOCATION 3



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	25.96	40.17	40.17
4	3.18	7.40	7.40
6	0.18	0.57	0.57
8	0.01	0.03	0.03
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	4.3	4.3
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.3	8.1	8.1
Rating	Pass	Pass	Pass

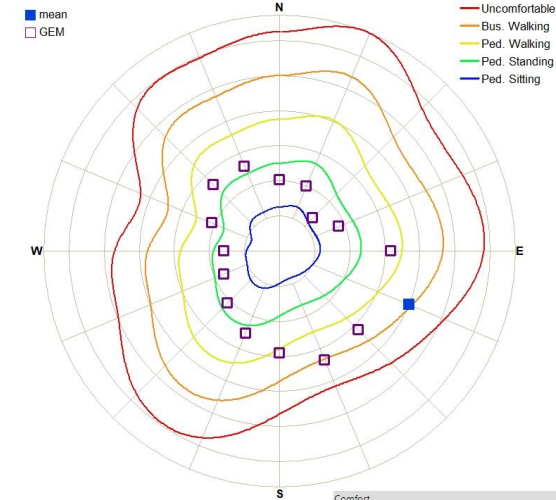
LOCATION 4



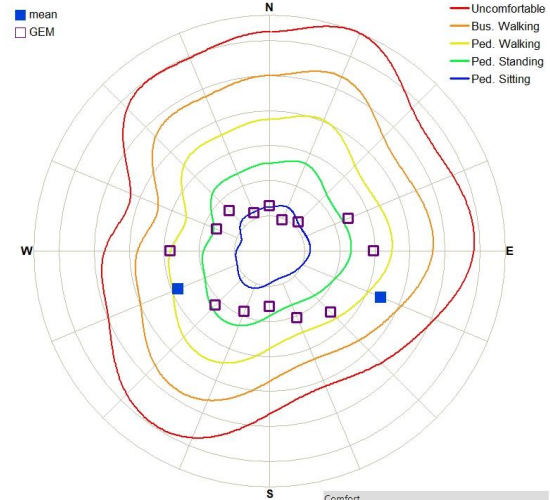
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	33.82	46.81	47.43
4	11.69	15.79	16.58
6	3.56	3.58	4.38
8	0.51	0.43	0.56
10	0.05	0.04	0.06

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.5	5.6	5.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	10.6	10.8
Rating	Pass	Pass	Pass

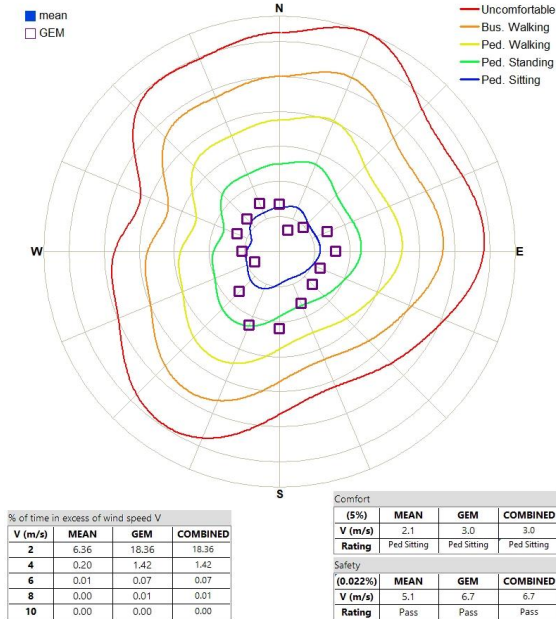
LOCATION 5



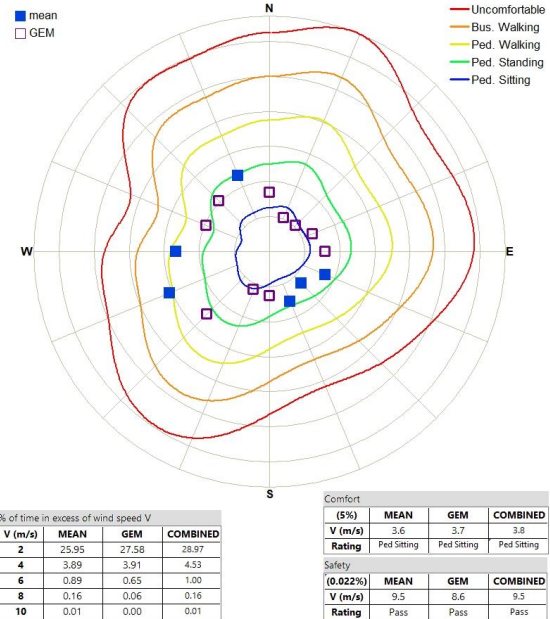
LOCATION 6



LOCATION 7

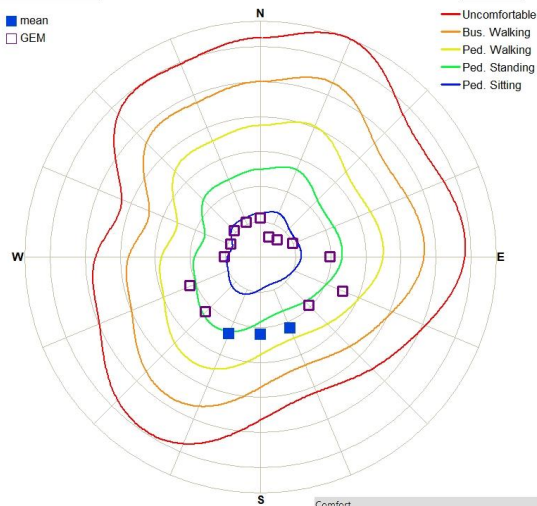


LOCATION 8



LOCATION 9

■ mean
□ GEM

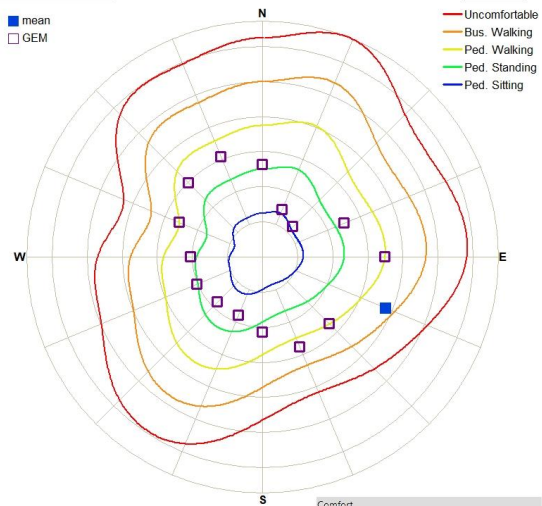


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	20.71	24.89	25.56
4	3.43	4.49	5.37
6	0.19	0.19	0.30
8	0.01	0.01	0.02
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	3.9	4.0
Rating	Ped Sitting	Ped Sitting	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.4	7.3	7.7
Rating	Pass	Pass	Pass

LOCATION 10

■ mean
□ GEM

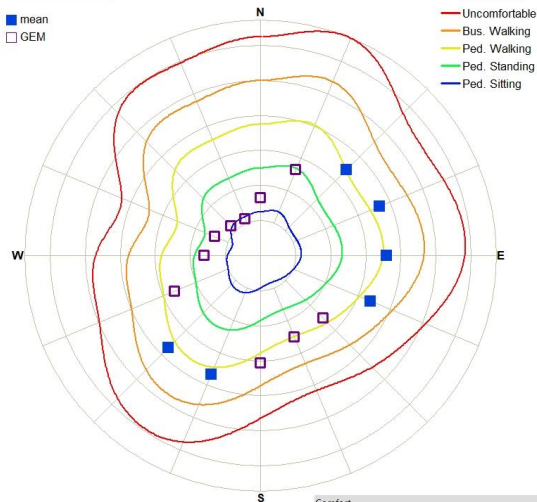


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	32.20	44.81	44.96
4	9.12	14.39	14.80
6	1.79	2.77	3.32
8	0.20	0.27	0.38
10	0.01	0.02	0.03

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.4	5.5
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.6	10.0	10.3
Rating	Pass	Pass	Pass

LOCATION 11

■ mean
□ GEM

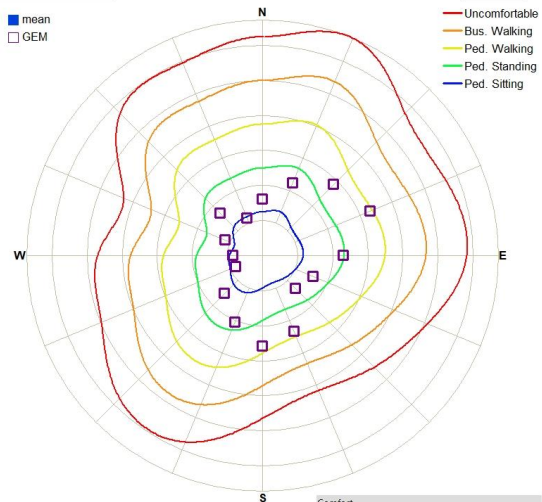


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	37.67	42.86	44.79
4	13.51	15.28	18.32
6	2.88	2.40	3.86
8	0.33	0.22	0.42
10	0.04	0.02	0.05

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.4	5.3	5.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	10.0	10.8
Rating	Pass	Pass	Pass

LOCATION 12

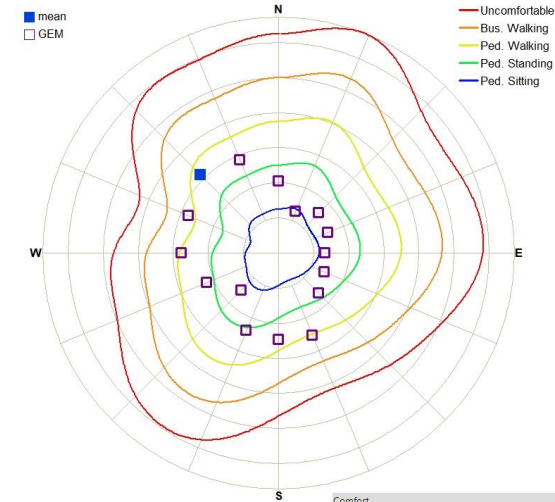
■ mean
□ GEM



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	15.72	28.42	28.42
4	2.81	6.75	6.75
6	0.09	0.68	0.68
8	0.00	0.03	0.03
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.4	4.3	4.3
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.7	8.1	8.1
Rating	Pass	Pass	Pass

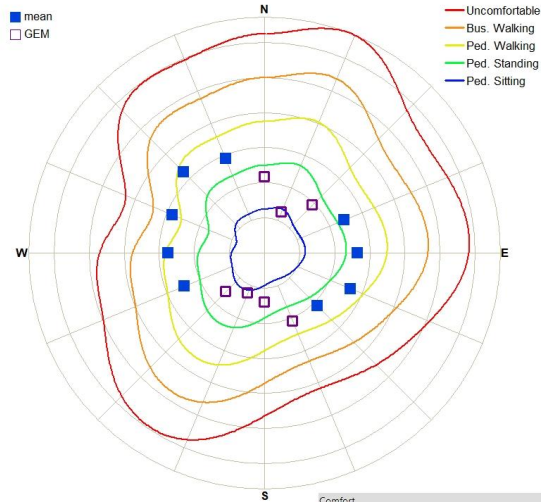
LOCATION 13



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	26.02	37.77	38.06
4	5.42	8.31	8.43
6	0.82	1.78	1.85
8	0.12	0.29	0.32
10	0.02	0.03	0.04

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	4.7	4.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	10.2	10.4
Rating	Pass	Pass	Pass

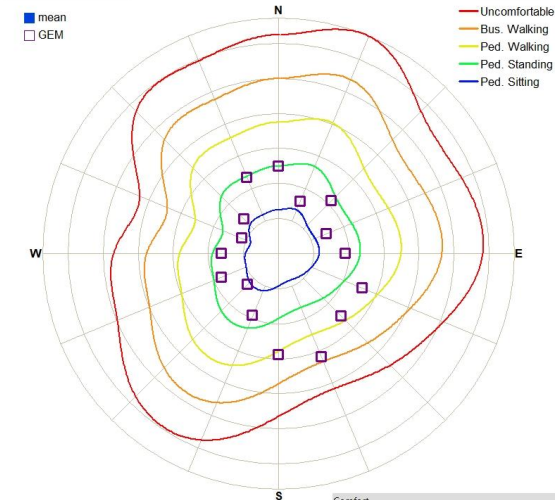
LOCATION 14



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	39.34	38.31	43.01
4	9.46	6.52	9.99
6	1.56	0.75	1.60
8	0.32	0.06	0.33
10	0.04	0.00	0.04

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	4.2	4.7
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.6	8.7	10.6
Rating	Pass	Pass	Pass

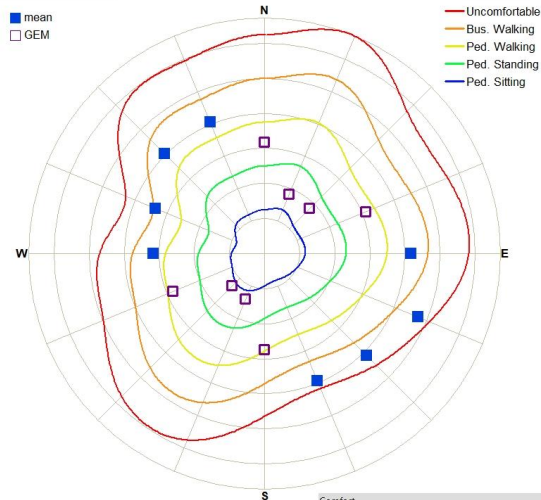
LOCATION 15



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	21.13	34.66	34.66
4	6.14	9.20	9.20
6	1.39	2.00	2.00
8	0.19	0.26	0.26
10	0.02	0.03	0.03

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.8	4.8
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.8	10.2	10.2
Rating	Pass	Pass	Pass

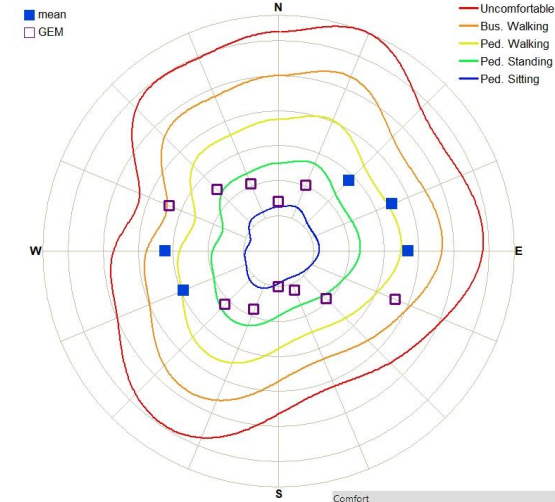
LOCATION 16



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	47.95	51.38	52.91
4	22.89	22.25	25.42
6	10.55	7.74	11.15
8	3.56	1.56	3.61
10	0.73	0.20	0.74

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	7.4	6.5	7.4
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.9	12.1	13.9
Rating	Pass	Pass	Pass

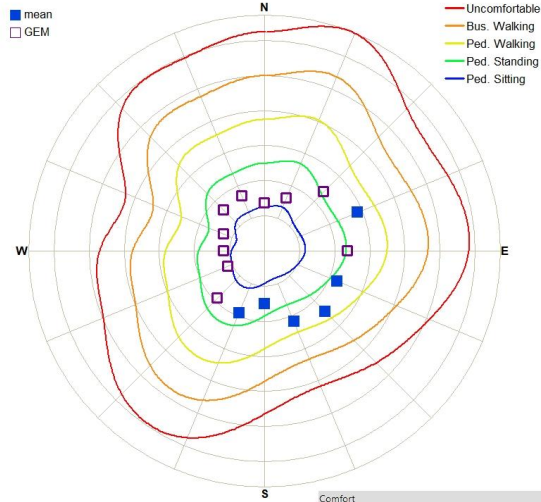
LOCATION 17



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	31.85	42.15	43.23
4	10.15	12.43	14.03
6	2.42	2.93	3.73
8	0.43	0.63	0.76
10	0.06	0.11	0.14

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.3	5.6
Rating	Ped. Standing	Ped. Standing	Ped. Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.9	11.5	11.8
Rating	Pass	Pass	Pass

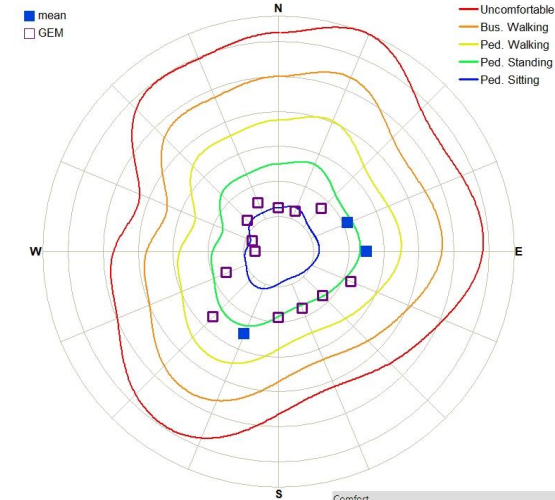
LOCATION 18



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	26.85	30.05	31.20
4	5.66	4.39	6.32
6	0.31	0.09	0.32
8	0.01	0.00	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	3.9	4.2
Rating	Ped. Standing	Ped. Sitting	Ped. Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.5	6.7	7.5
Rating	Pass	Pass	Pass

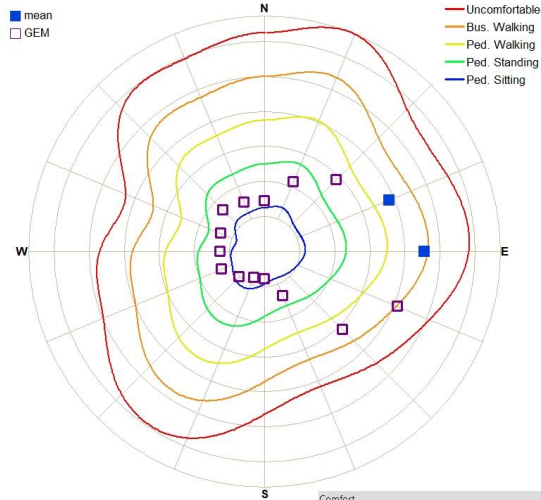
LOCATION 19



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	24.80	27.34	28.08
4	2.76	2.90	3.43
6	0.14	0.15	0.18
8	0.01	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.6	3.6	3.7
Rating	Ped. Sitting	Ped. Sitting	Ped. Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.2	7.3	7.4
Rating	Pass	Pass	Pass

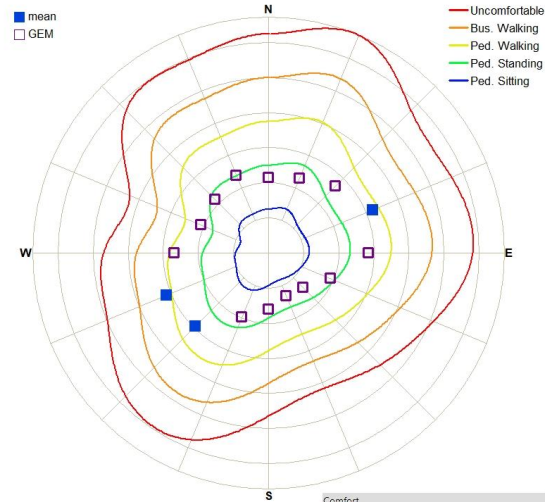
LOCATION 20



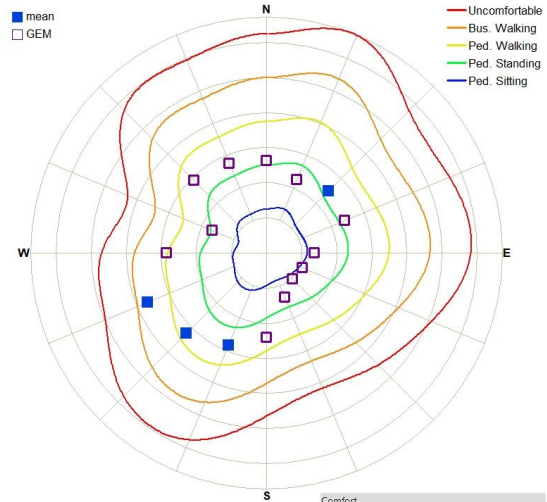
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	20.74	29.54	29.67
4	7.81	12.13	12.55
6	2.06	3.79	4.44
8	0.24	0.48	0.63
10	0.01	0.04	0.05

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.6	5.8
Rating	Ped. Standing	Ped. Standing	Ped. Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.4	10.4	10.7
Rating	Pass	Pass	Pass

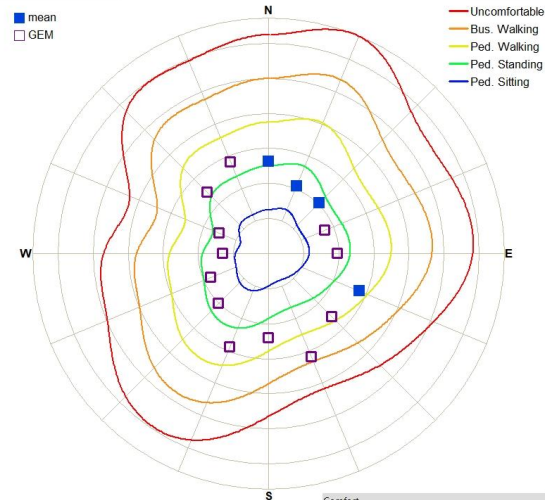
LOCATION 21



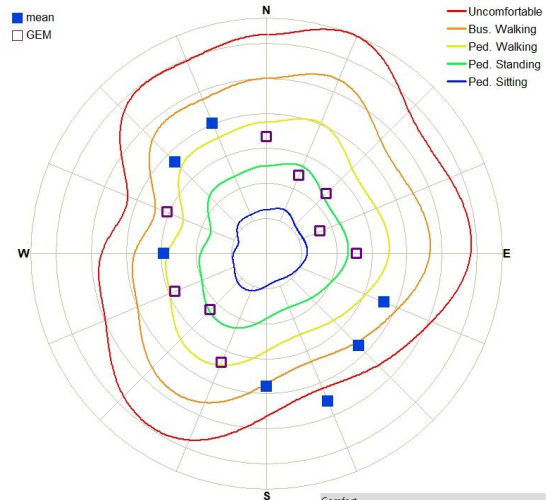
LOCATION 22



LOCATION 23

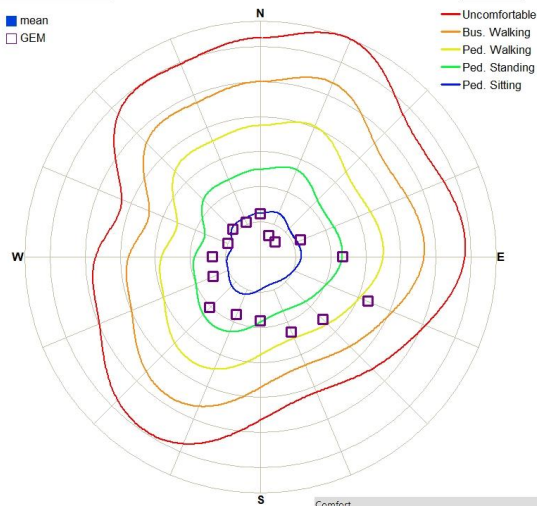


LOCATION 24



LOCATION 25

■ mean
□ GEM

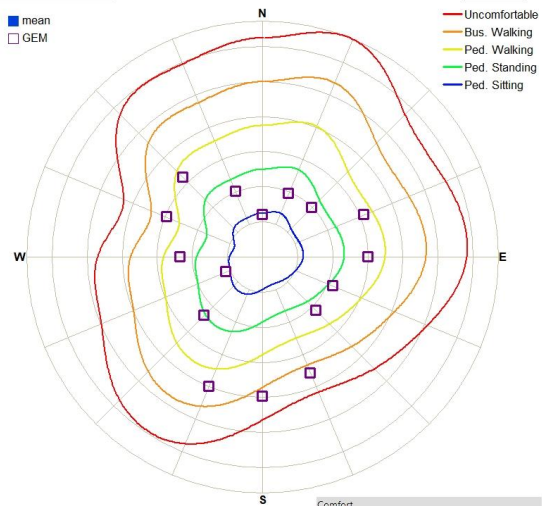


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	17.74	25.69	25.69
4	4.90	7.08	7.08
6	0.51	0.89	0.89
8	0.02	0.05	0.05
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.4	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.0	8.5	8.5
Rating	Pass	Pass	Pass

LOCATION 26

■ mean
□ GEM

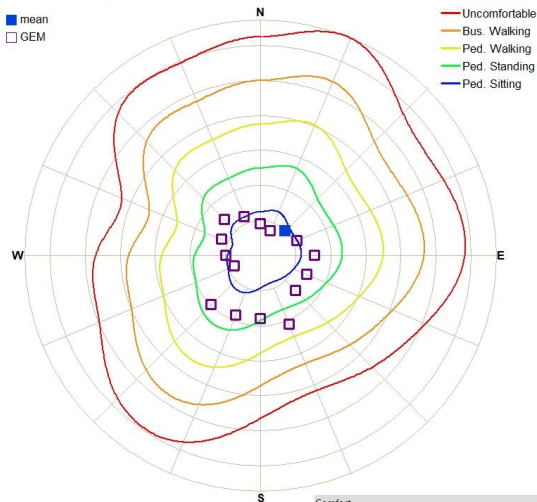


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	30.01	45.64	45.64
4	8.05	15.56	15.56
6	2.00	5.09	5.09
8	0.27	1.39	1.39
10	0.03	0.24	0.24

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.9	5.9
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.2	12.7	12.7
Rating	Pass	Pass	Pass

LOCATION 27

■ mean
□ GEM

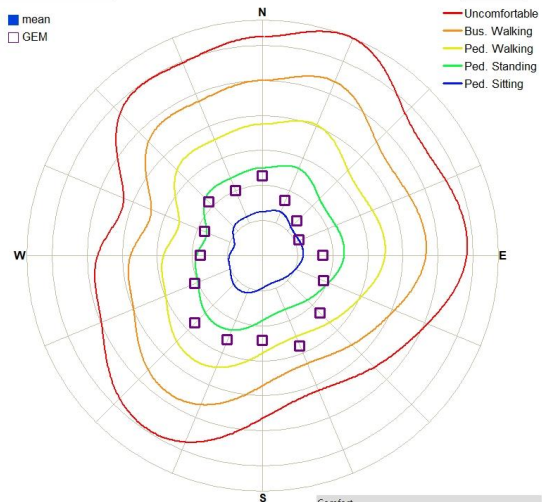


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	12.23	17.96	18.00
4	0.67	1.96	1.96
6	0.01	0.09	0.09
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	3.1	3.1
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.7	6.8	6.8
Rating	Pass	Pass	Pass

LOCATION 28

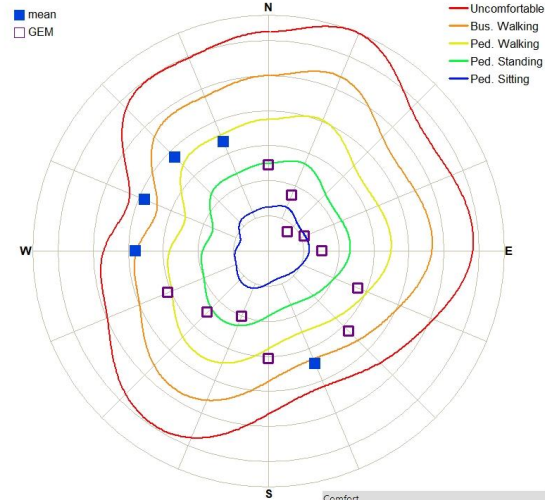
■ mean
□ GEM



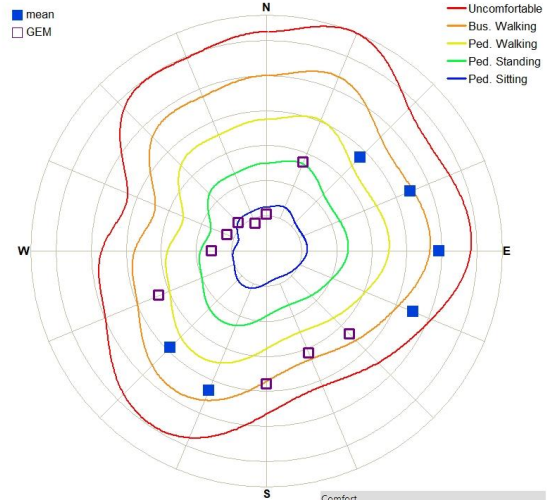
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	18.64	35.13	35.13
4	1.52	8.12	8.12
6	0.04	1.18	1.18
8	0.00	0.09	0.09
10	0.00	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	4.5	4.5
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.3	9.1	9.1
Rating	Pass	Pass	Pass

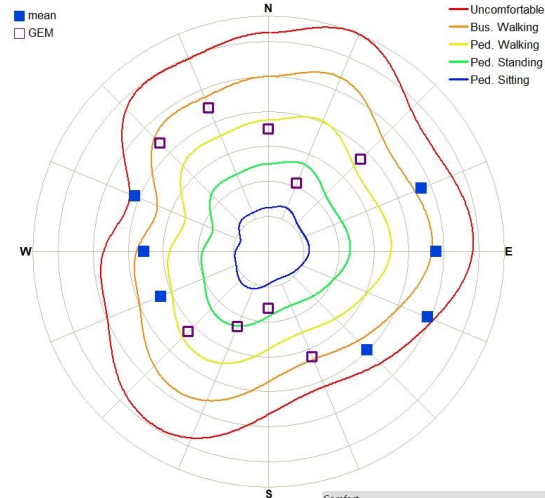
LOCATION 29



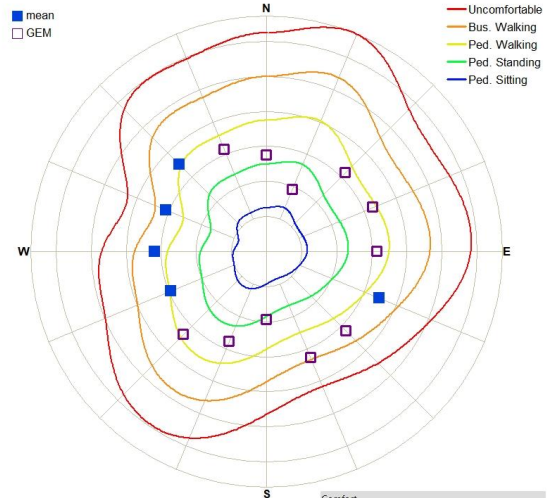
LOCATION 30



LOCATION 31

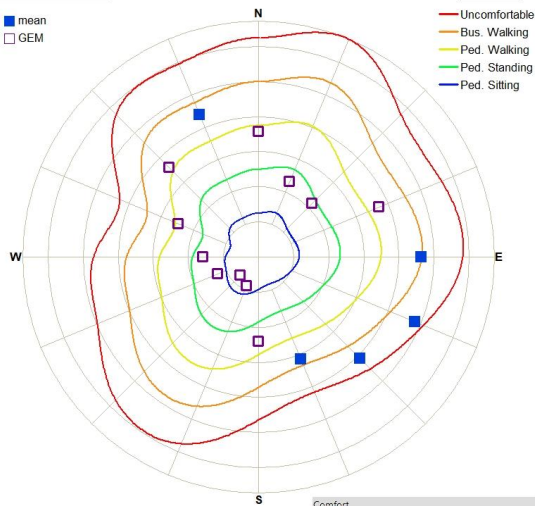


LOCATION 32



LOCATION 33

■ mean
□ GEM

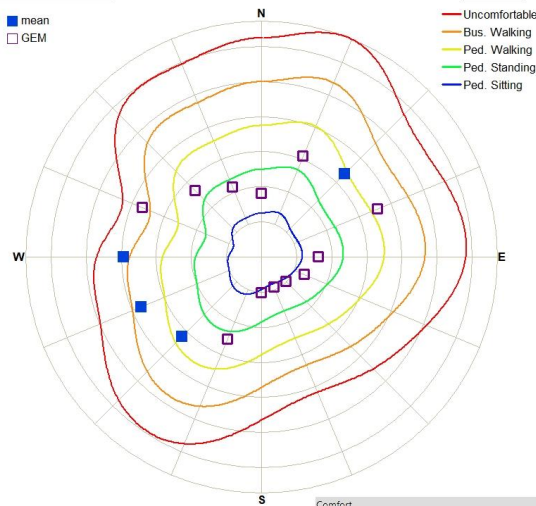


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	39.92	45.70	46.72
4	20.25	19.18	22.44
6	8.72	5.60	9.49
8	2.52	0.86	2.61
10	0.46	0.13	0.47

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	6.9	6.1	7.0
Rating	Ped Walking	Ped Walking	Ped Walking
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.1	11.8	13.1
Rating	Pass	Pass	Pass

LOCATION 34

■ mean
□ GEM

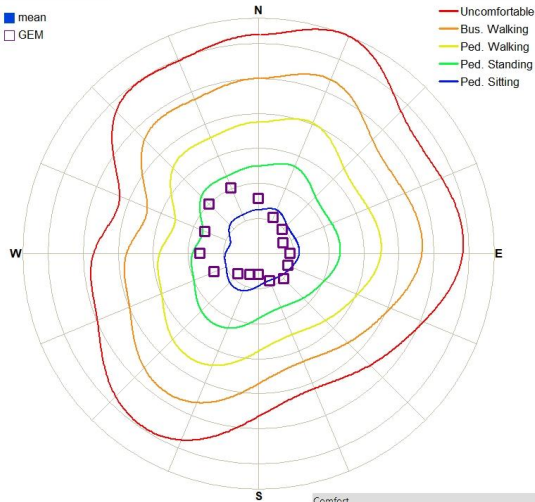


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	28.98	38.65	40.27
4	9.51	11.30	12.87
6	3.30	3.49	4.24
8	1.13	0.94	1.38
10	0.32	0.25	0.40

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	5.1	5.3	5.6
Rating	Ped Standing	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.1	12.6	13.5
Rating	Pass	Pass	Pass

LOCATION 35

■ mean
□ GEM

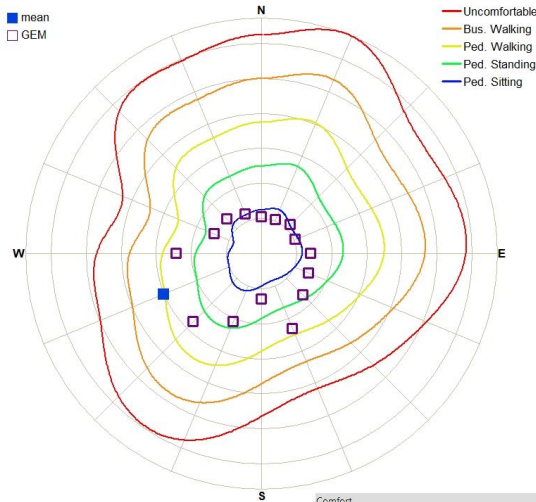


% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	3.73	9.55	9.35
4	0.11	0.97	0.97
6	0.00	0.05	0.05
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	1.8	2.5	2.5
Rating	Outdoor Dining	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.8	6.4	6.4
Rating	Pass	Pass	Pass

LOCATION 36

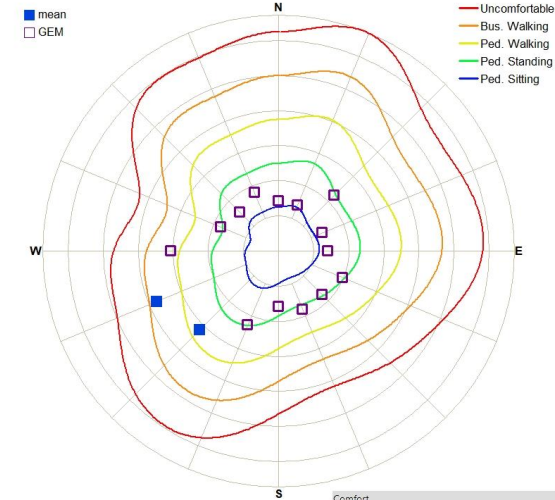
■ mean
□ GEM



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	13.72	26.11	26.47
4	2.57	5.21	5.44
6	0.59	0.85	0.99
8	0.08	0.08	0.11
10	0.01	0.01	0.01

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.2	4.0	4.1
Rating	Ped Sitting	Ped Sitting	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.0	8.9	9.2
Rating	Pass	Pass	Pass

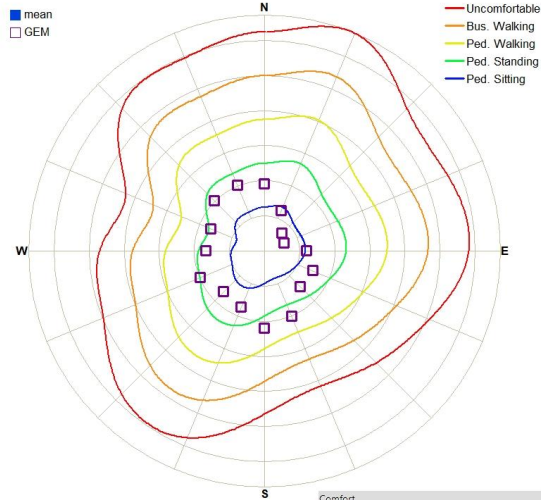
LOCATION 37



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	23.96	34.50	35.26
4	4.75	6.40	7.12
6	1.55	1.49	1.87
8	0.44	0.30	0.53
10	0.08	0.04	0.10

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.2	4.4
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	11.2	10.3	11.4
Rating	Pass	Pass	Pass

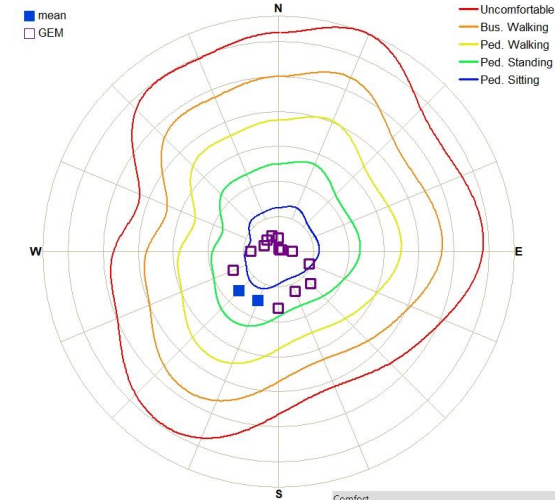
LOCATION 38



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	17.82	24.36	24.36
4	1.52	3.42	3.42
6	0.04	0.16	0.16
8	0.00	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	3.6	3.6
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.3	7.2	7.2
Rating	Pass	Pass	Pass

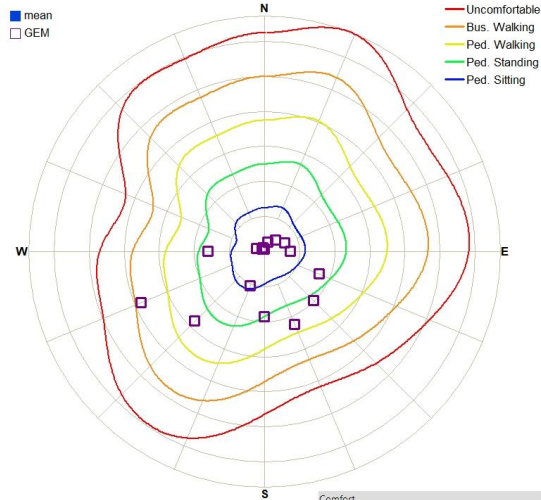
LOCATION 39



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	4.86	8.78	9.28
4	0.14	0.19	0.23
6	0.00	0.00	0.00
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.0	2.4	2.5
Rating	Outdoor Dining	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	4.7	4.9	5.0
Rating	Pass	Pass	Pass

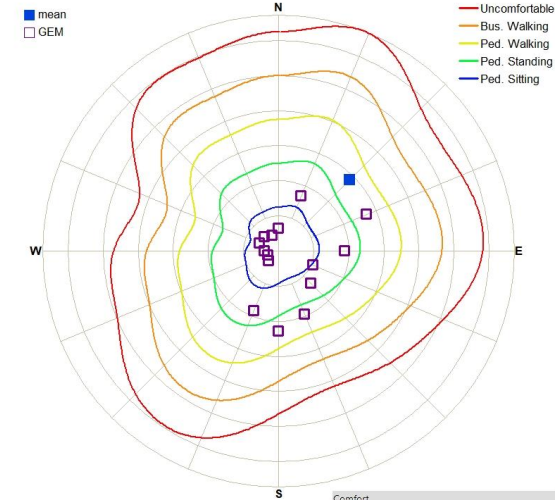
LOCATION 40



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	16.78	23.24	23.24
4	3.35	5.97	5.97
6	0.46	1.29	1.29
8	0.05	0.38	0.38
10	0.00	0.08	0.08

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.5	4.2	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.5	11.3	11.3
Rating	Pass	Pass	Pass

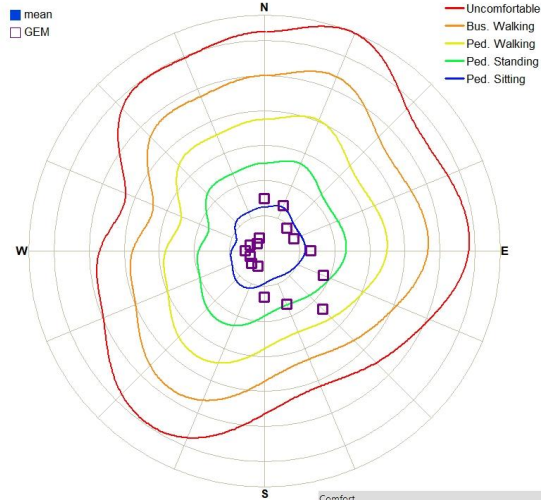
LOCATION 41



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	12.12	19.59	19.61
4	1.92	3.84	3.85
6	0.06	0.17	0.17
8	0.00	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.1	3.7	3.7
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.4	7.2	7.2
Rating	Pass	Pass	Pass

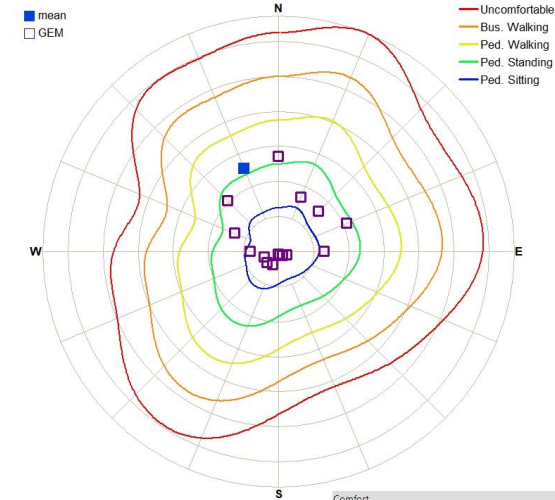
LOCATION 42



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	9.64	13.32	13.32
4	0.73	1.94	1.94
6	0.01	0.09	0.09
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.7	3.1	3.1
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.8	6.8	6.8
Rating	Pass	Pass	Pass

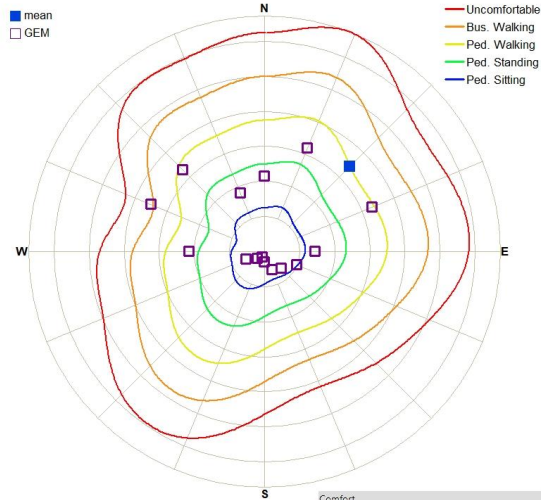
LOCATION 43



% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	10.43	13.30	13.46
4	0.96	1.32	1.38
6	0.09	0.13	0.14
8	0.01	0.01	0.01
10	0.00	0.00	0.00

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	2.9	2.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.9	7.1	7.2
Rating	Pass	Pass	Pass

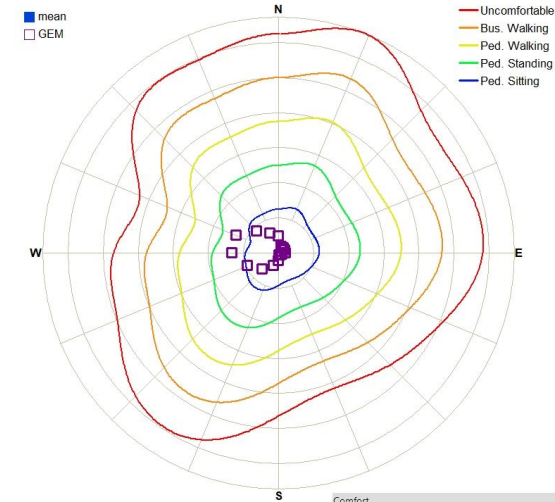
LOCATION 44



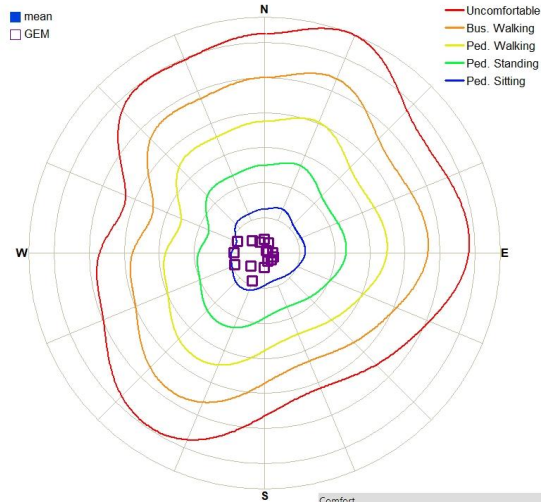
% of time in excess of wind speed V			
V (m/s)	MEAN	GEM	COMBINED
2	19.20	24.40	24.67
4	5.13	7.03	7.36
6	1.22	1.71	1.87
8	0.33	0.55	0.56
10	0.05	0.14	0.14

Comfort			
(5%)	MEAN	GEM	COMBINED
V (m/s)	4.0	4.5	4.6
Rating	Ped Sitting	Ped Standing	Ped Standing
Safety			
(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.7	11.9	11.9
Rating	Pass	Pass	Pass

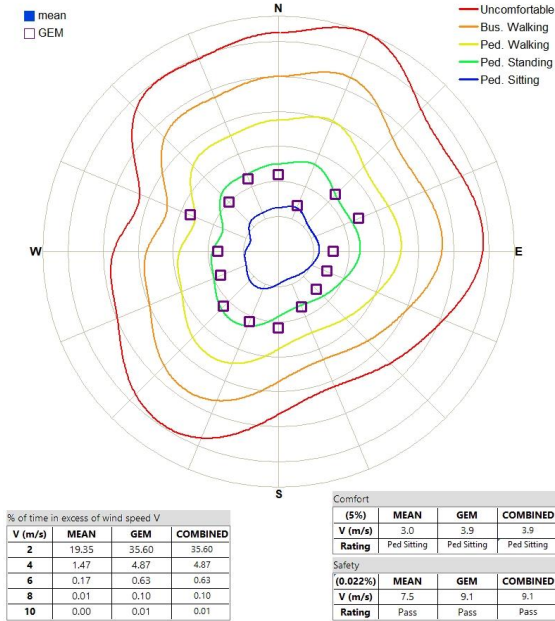
LOCATION 45



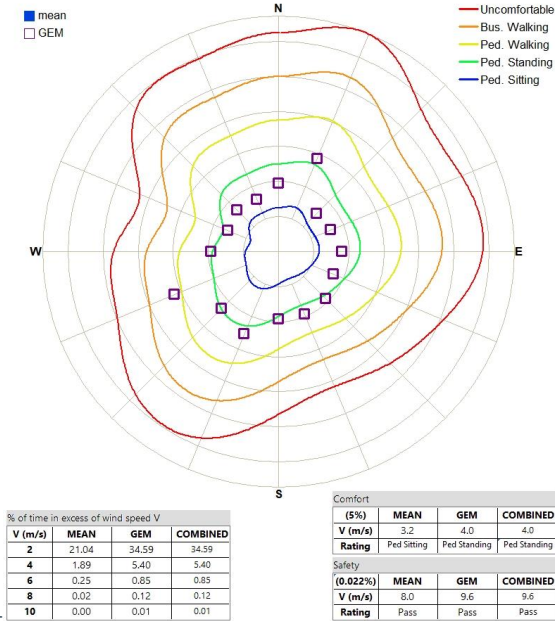
LOCATION 46



LOCATION 47



LOCATION 48



LOCATION 49

