Lend Lease (Millers Point) Pty Limited

Barangaroo South - C3 Commercial Building

Environmental Wind Report - Project Application

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1 Introduction

This report supports a Project Application submitted to the Minister for Planning pursuant to Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act). The Application seeks approval for construction of a commercial building (known as Building C3) and associated works at Barangaroo South as described in the Project Summary Description section of this report.

1.1 Background

The 22 hectare Barangaroo site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Stage 2 and Barangaroo Stage 1 (herein after referred to as Barangaroo South).

Lend Lease was successfully appointed as the preferred proponent to develop Barangaroo Stage 1 (otherwise known as Barangaroo South) on 20 December 2009.

1.2 Planning History & Framework

On 9 February 2007 the Minister approved a Concept Plan for the site and on 12 October 2007 the land was rezoned to facilitate its redevelopment. The Approved Concept Plan allowed for a mixed use development involving a maximum of 388,300m^2 of gross floor area (GFA) contained within 8 blocks on a total site area of 22 hectares.

Modification No. 1 was approved in September 2007 which corrected a number of minor typographical errors.

On 25 February 2009 the Minister approved Modification No. 2 to the Concept Plan. The Approved Concept Plan as modified allowed for a mixed use development involving a maximum of 508,300m^2 of gross floor area (GFA) contained within 8 blocks on a total site area of 22 hectares.

On 11 November 2009 the Minister approved Modification No. 3 to the Concept Plan to allow for a modified design for the Headland Park and Northern Cove. The Approved Concept Plan as modified allows for a mixed use development involving a maximum of 489,500m^2 of gross floor area (GFA) across Barangaroo as a whole.

On 16 December 2010 the Minister approved Modification No. 4 to the Barangaroo Concept Plan. The Approved Concept Plan as modified allows for approximately 563,965m^2 Gross Floor Area of mixed use development across the entire Barangaroo site.

This Project Application forms one of a series of individual Applications that Lend Lease will be submitting to deliver Barangaroo South. This Project Application is consistent with the established planning framework for the site, including the approved Concept Plan (as modified).

A Project Application (MP10_0023) has been approved for the bulk excavation and construction of a basement car park to accommodate up to 880 car parking spaces and associated services and infrastructure to support the initial phases of

the future development of Barangaroo South. A Section 75W Modification Application was subsequently submitted seeking to modify MP10_0023 to extend the area of the approved basement to the south. This modification was approved by the Minister for Planning on 3 March 2011.

A further Section 75W application has been submitted to the Department of Planning and Infrastructure (the Department) and is currently being assessed, which seeks the Minister's approval to modify the depth of the excavation and change the reduced levels of the basement structure, using the same construction methodology as detailed and approved as part of the original project application. This includes:

- reduced excavation and bulk earthworks;
- reduced structural works – foundations, basement levels, perimeter retention system etc; and
- installation of associated services and infrastructure to support the initial phases of the future development of Barangaroo South.

A project application for the first commercial building, known as C4, was submitted to the Department of Planning on 29 October 2010. This application sought consent for construction and use of a new commercial Building C4 with a maximum 98,514m^2 GFA accommodating commercial and retail uses, a child care centre, bicycle parking and associated use and operation of car parking and loading facilities in the basement. Consent was issued by the Minister on 3 March 2011.

A Section 75W application has been submitted to the Department and is currently being assessed which seeks the Minister's approval to modify certain elements of the approved C4 building, including:

- mix of the uses within the building;
- total GFA;
- shape of floor plates of the podium and the tower elements of the building;
- facade details;
- roof treatment; and
- basement layout.

1.3 Site Location

Barangaroo is located on the north western edge of the Sydney Central Business District, bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and bounded to the south by a range of new development dominated by large CBD commercial tenants.

The Barangaroo site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Stage 2 (also known as Barangaroo Central) and Barangaroo South.

The area of land within which development is proposed under this Project Application extends over land generally known and identified in the approved Concept Plan as Block 3 which comprises Lot 5 in DP 876514.

1.4 Project Summary Description

This Project Application seeks approval for the construction of a 49 storey building, comprising ground floor retail, a commercial lobby, childcare, podium and office tower, provision for associated cars and bicycle parking and the construction of the surrounding ancillary temporary public domain which includes access streets and landscaping.

1.5 Purpose of this Report

This report has been prepared to accompany the Project Application for the C3 Commercial Building and associated works at Barangaroo South. It addresses the relevant Director-General Requirements for the project. These Director-General Requirements are discussed in the Environmental Assessment Report (EAR) that has been prepared to support the application.

Pedestrian acceptability of footpaths, entrances, plazas, and terraces is often 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.

2 The Wind Tunnel Test

Analytical methods such as computational fluid dynamics (CFD) are not capable, except in very simple geometries, of estimating wind pressures, frame loads, or windiness in pedestrian areas.

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 a discussion of test results obtained. 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, 2006).

Table 1: Configurations for Data Acquisition

Parameter	Description
Configuration A.0	
Geometry:	Proposed Barangaroo Building C3 development with surrounding existing buildings, as shown in Figure 4.
Pedestrian Velocities:	Pedestrian winds measured at 19 locations for 16 wind directions in 22.5° increments from 0° (north).
Configuration B.1	
Geometry:	Proposed Barangaroo Building C3 development with surrounding existing buildings and Barangaroo Building C4, as shown in Figure 7.
Pedestrian Velocities:	Pedestrian winds measured at 19 locations for 16 wind directions in 22.5° increments from 0° (north).
Configuration C.2	
Geometry:	Proposed Barangaroo Concept Plan development and with surrounding existing buildings, as shown in Figure 8 and Figure 11.
Pedestrian Velocities:	Pedestrian winds measured at 19 locations for 16 wind directions in 22.5° increments from 0° (north).

Modelling of the aerodynamic loading on 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 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 3.0m wide, by 2.4m high with a porous slatted roof for passive blockage correction. This wind tunnel has a 21m long test section, the floor of which is covered with roughness elements, preceded by a vorticity generating fence and spires The spires, fence, and roughness elements were designed to provide a modelled atmospheric boundary layer approximately

1.2m 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.

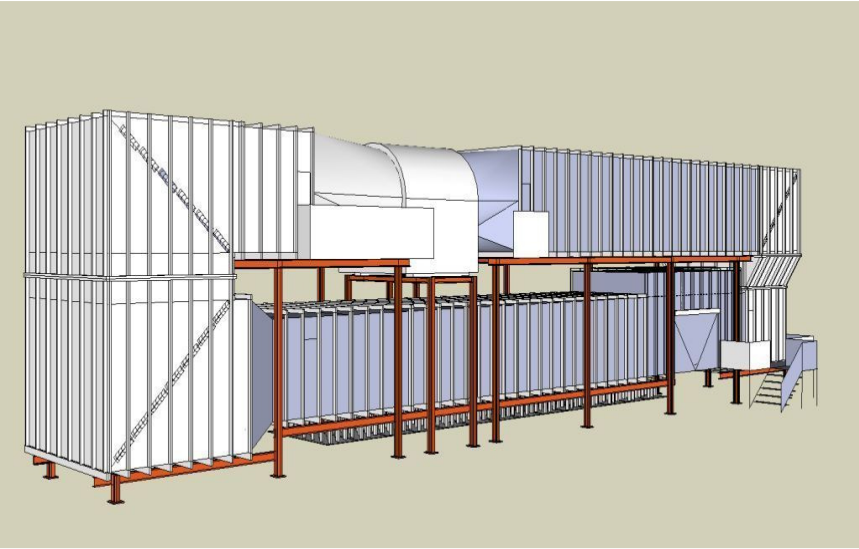

Figure 1: Schematic of the closed circuit wind tunnel

A model of the proposed development and surrounds to a radius of 570m 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, 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 as shown in Figure 3. The turntable permitted rotation of the modelled area for examination of velocities from any approach wind direction. Additional photos of the testing are included in Appendix B.

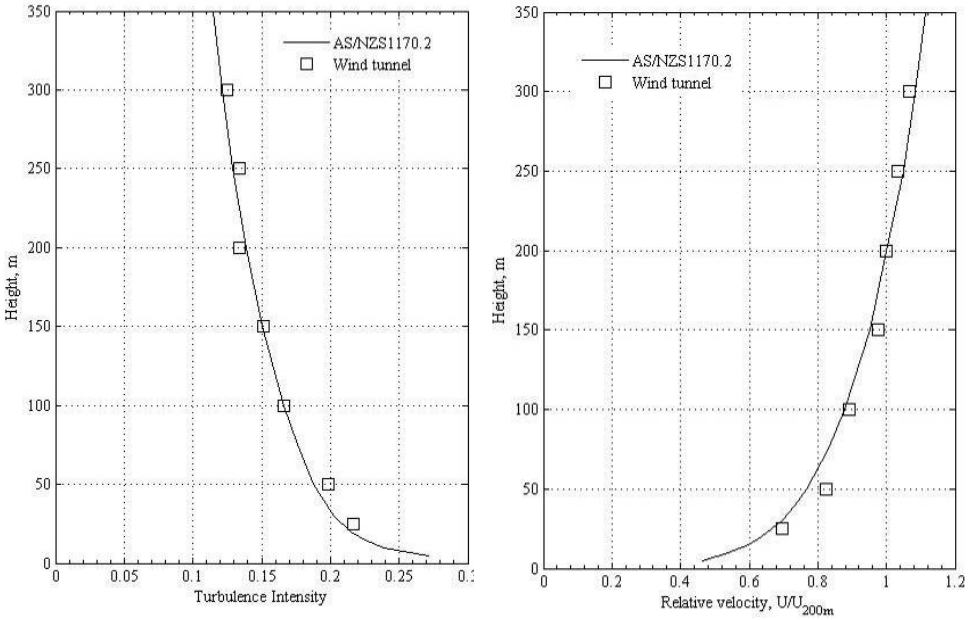

Figure 2: Mean velocity and turbulence profiles approaching the model

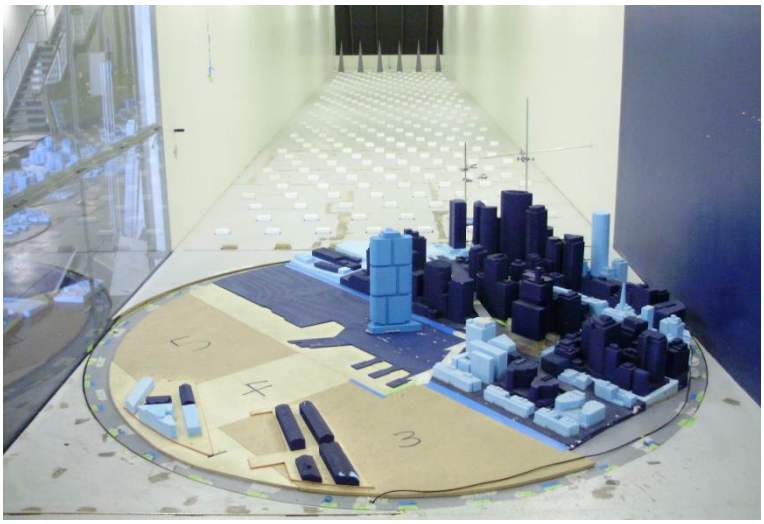

Figure 3: Photograph of the Barangaroo C3 model in the CPP wind tunnel

3 Environmental Wind Criteria

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 and Table 3.

Lawson's criteria have categories for discomfort, based on wind speeds exceeded five percent 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[1]. 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, which are the basis of the City of Sydney (2004) Development Control Plan (DCP), however provides significantly more information regarding the serviceability wind climate.

Table 2: Summary of Lawson Criteria for Comfort

Comfort (Maximum of mean or gust equivalent mean (GEM†) 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

†. The gust equivalent mean (GEM) is the peak 3s gust wind speed divided by 1.85.

The rating of 'uncomfortable' in Table 2 is the wording 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).

[1] 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.

Table 3: Summary of Lawson Criteria for Distress

Distress (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 people or cyclists would not be expected).

†. The gust equivalent mean (GEM) is the peak 3s gust wind speed divided by 1.85.

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

Barangaroo is located to the east of Darling Harbour and directly to the north of the King Street Wharf precinct. The topography rises steeply to the east of the site toward Kent Street and the Western Distributor road deck, Figure 4. The proposed C3 development consists of a single tower rising above a 3 level podium to a height of approximately 217 m above ground level. For this report wind speed measurements were recorded at 19 locations to evaluate pedestrian comfort in and around the project site, Figure 4 and Figure 5. The points tested close to the site were tested for the configurations described in Table 1. Velocity measurements were made at the model scale equivalent of 1.5 to 2.1 m above the local surface for 16 wind directions at 22.5° intervals. Locations were chosen to determine the degree of pedestrian comfort at the building corners where relatively severe conditions frequently are found, near building entrances, on adjacent pavements with heavy pedestrian traffic, and in open plaza areas. Six comparative pedestrian positions, three located in a familiar or relatively undisturbed area near the project site, were tested for reference purposes.

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. These local wind speeds, U, were normalised by the tunnel reference velocity Uref. Mean and turbulence statistics were calculated and used to calculate the normalised effective peak gust using:

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

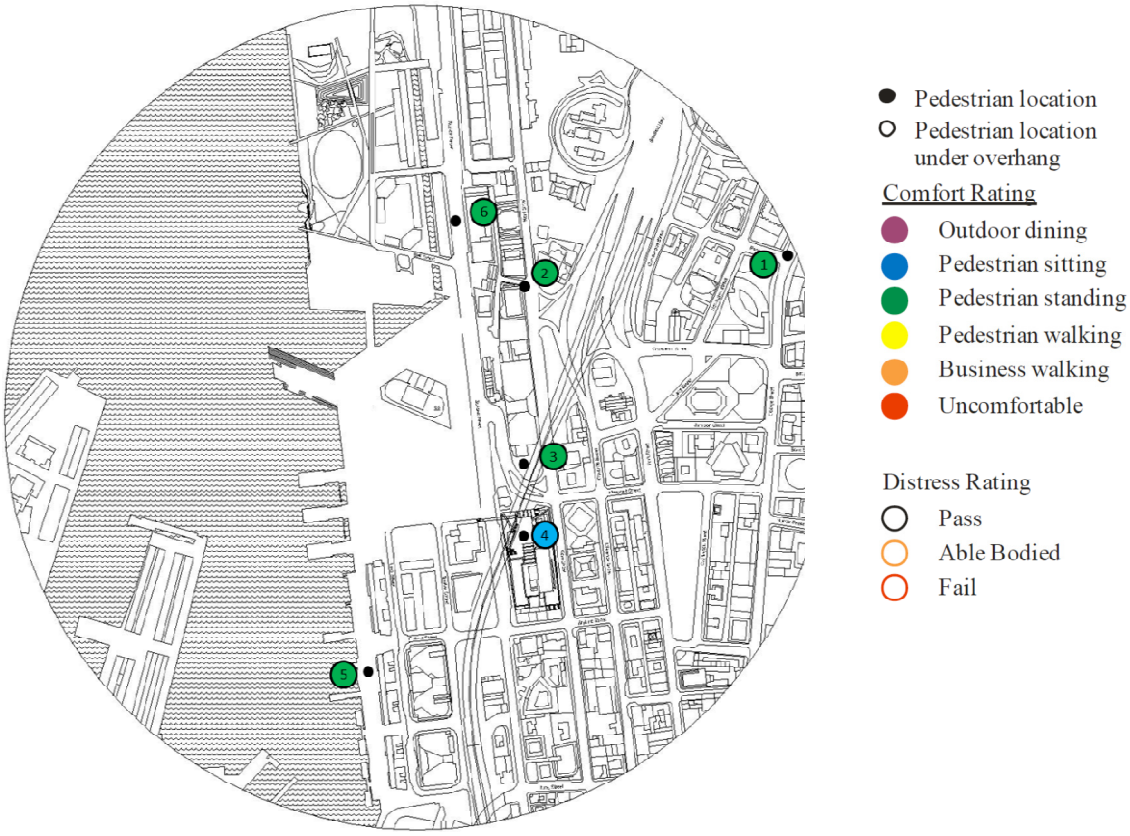

Figure 4: Remote pedestrian wind speed measurement locations with ratings for configuration A.0

The mean and gust equivalent mean velocities relative to the free stream wind tunnel reference velocity at a full-scale elevation of 200m are plotted in polar form in Appendix C. 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 is of greater importance.

To enable a quantitative assessment of the wind environment, the wind tunnel data were combined with wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10m at Sydney Airport from 1974 to 2008 as shown in Figure 6. From these data, directional criterion lines for the Lawson rating wind speeds have been calculated and included on the polar plots in Appendix C; this gives additional information regarding directional sensitivity at each location.

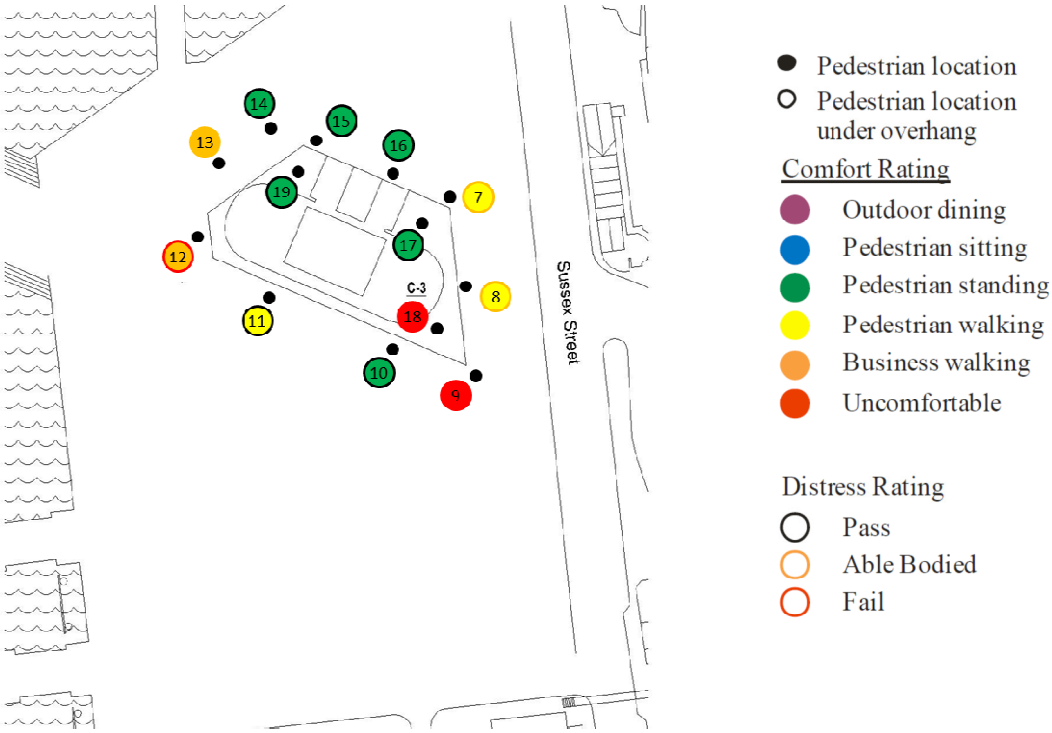

Figure 5: Pedestrian wind speed measurement locations with ratings for configuration A.0

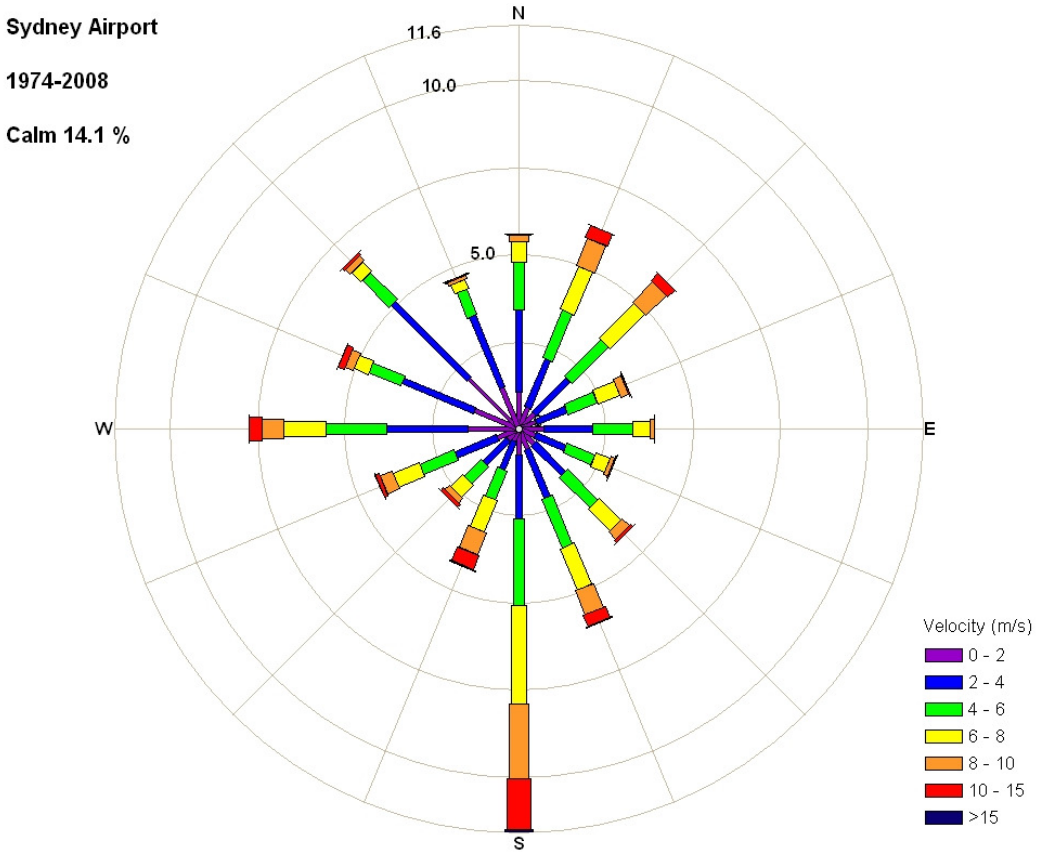

Figure 6: Wind rose of direction and speed for Sydney Airport

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarized in Figure 6 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 C 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 including qualitative descriptions of wind effects.

The tables in Appendix C additionally provide the wind speed exceeded 5% and 0.022% of the time for direct comparison with the Lawson criteria and the associated Lawson ratings for both mean and GEM wind speeds. A colour coded summary assessment of pedestrian comfort and safety with respect to the Lawson criteria is presented in Figure 4 and Figure 5 for each test location in configuration A.0, and Figure 7 and Figure 8 for Configurations B.1 and C.2 respectively. Data for remote Locations (1 to 6) in Configuration C.2, in which the layout of other buildings surrounding C3, C4, and C5 was the same for testing as per the November 2010 Masterplan, were sampled for a previous, similar tower design. However, as the geometric changes to the buildings are considered to have a negligible influence on these more distant locations, these readings remain valid for the current design. Because some pedestrian wind measurement positions are purposely chosen at sites where large velocities of small spatial extent may exist, the general wind environment about the structure may be less severe than one might infer from an analysis only of the plots. The implications of the results are discussed in Section 5.

Table 4: 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 6 indicates that the most frequent strong winds are from the south, and to a lesser extent, the west and north-east. The locations tested around the development site are susceptible to winds from different directions, depending on the relative location of the point tested to the geometry of development. However, in general terms winds from the south-west and west quadrants had the most pronounced effect on the site as higher level winds were brought to street level as downwash and channelled between the large buildings. The influence of wind direction on the suitability of a location for an intended purpose can be ascertained from the graphs in Appendix C

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of Figure 4, Figure 5, Figure 7, and Figure 8, which depict the locations selected for investigation of pedestrian wind comfort around the site along with the Lawson criteria rating for both comfort and distress. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes the distress criterion. Mitigation measures are likely to be required for red locations, orange locations on main pedestrian thoroughfares, and may be necessary for other locations depending on the intended use of the space. Although wind conditions may be classified acceptable there may be certain wind directions that cause regular strong events, these can be determined by an inspection of the plots in Appendix C. Note that testing was performed without planned trees or other plantings to provide a worst case assessment; heavy streetscape planting typically reduces the wind speeds by less than 10%.

It is evident from Figure 4 and Figure 5 that the wind environment for pedestrian comfort around the proposed development is quite variable. Wind conditions around the site are generally poorer than at locations 1 to 6, which are located in well-known areas remote from the site. These remote locations give a general indication of the surrounding wind climate and can be used for comparison to the wind environment in and around the development. A comparison between Figure 4, Figure 7, and Figure 8 indicates that as the development of Barangaroo progresses, wind conditions in and around the city remain very similar. Directional wind conditions change slightly, and an examination of Appendix C indicates that winds from the west quadrant are most affected as the massing of the development begins to influence the wind flow through the city. The wind conditions in Napoleon Street (location 3) slightly improve due to progressive shielding, and Gas Lane (location 2) slightly worsened due to the increase of diverted flow around the development.

The wind environment around the isolated Building C3 is primarily due to the isolated nature of the building. When wind impacts upon a relatively large isolated building, the wind is accelerated down the windward facades and then around the windward corners in a mechanism called downwash. Winds from the south-west, and to a lesser extent, north quadrants produce significant downwash from the exposed face of the building, resulting in strong mean wind conditions along the east and west sides of the building faces. Once the Barangaroo site is further developed with Buildings C4 and C5, the new surrounding buildings will provide significant shielding to winds from the south, generally improving wind conditions around the site at most locations, but Building C3 will remain exposed to the north and west. The additional large building C4 to the south channels the

flow for winds from the west quadrant causing windier conditions at some locations.

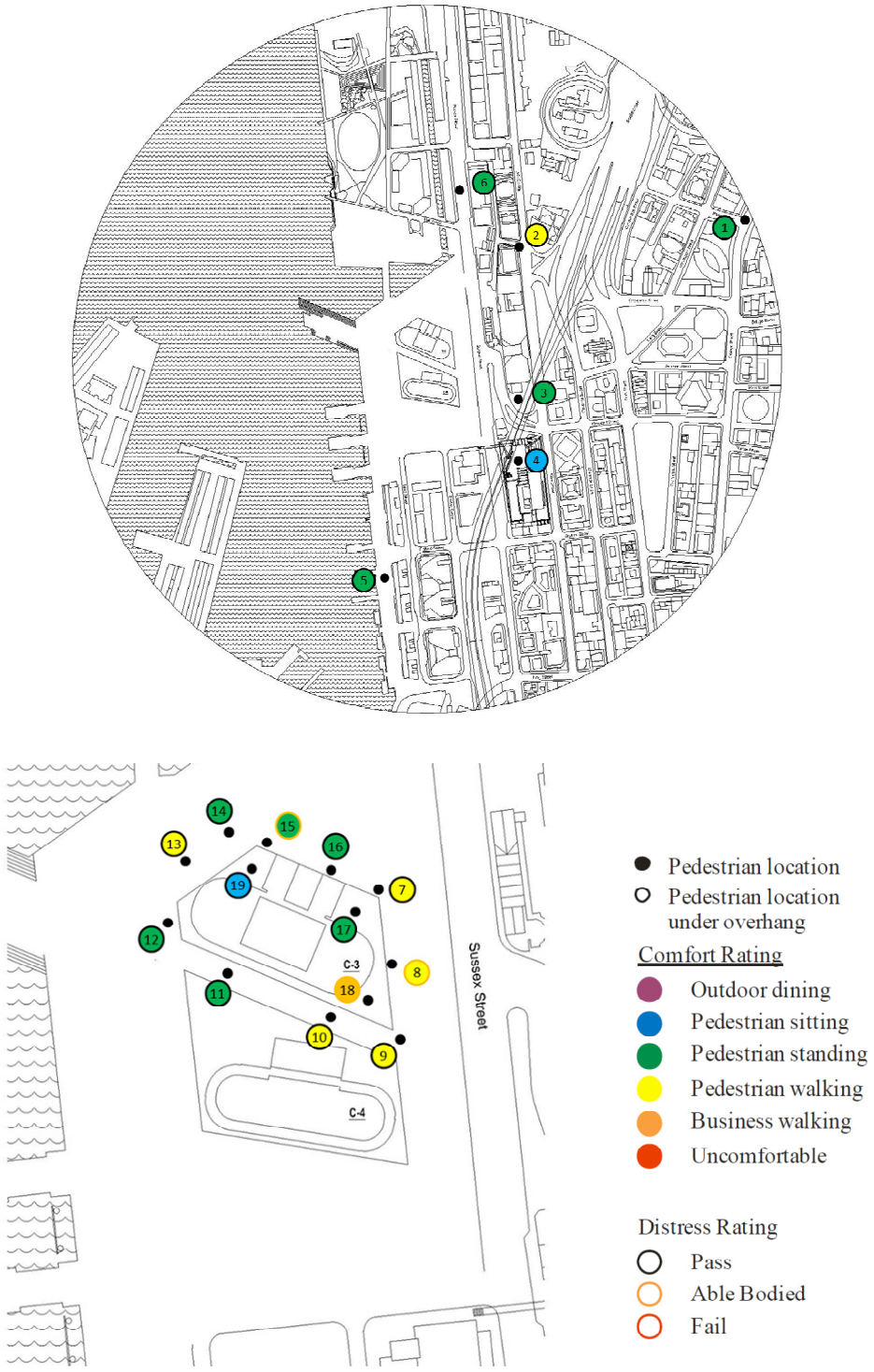

Figure 7: Pedestrian wind speed measurement locations with ratings for configuration B.1

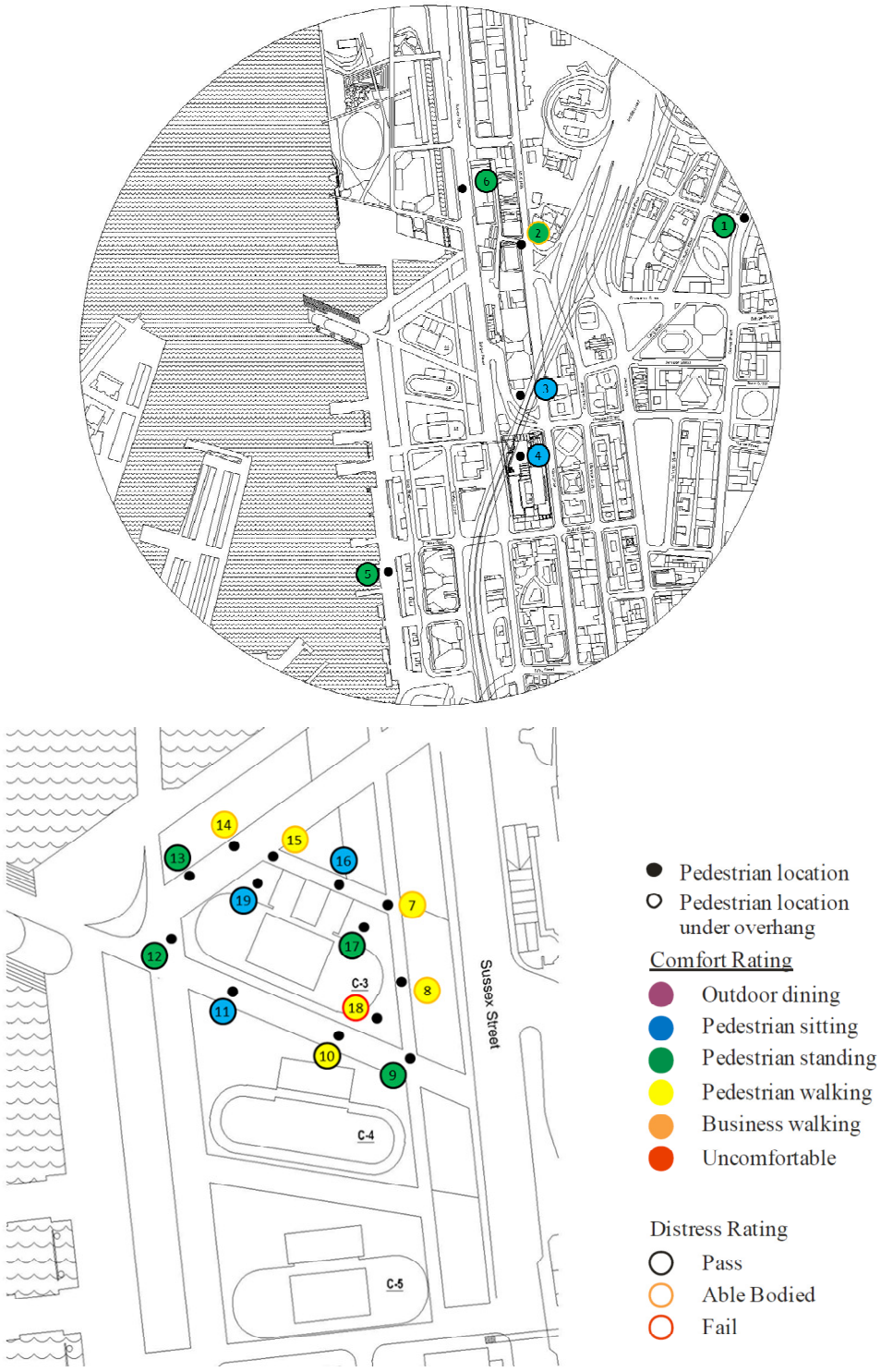

Figure 8: Pedestrian wind speed measurement locations with ratings for configuration C.2

Locations 7 and 8 are positioned along the east side of Building C3. These locations were suitable for pedestrian walking, and exceeded the general distress criterion, being suitable for able bodied patrons in Configuration A.0. Conditions at Location 7 and 8 are relatively consistent for all three configurations. In Configuration B.1, with Building C4 constructed, conditions at these two points are generally windy due to downwash during winds from the north and south quadrants being suitable for pedestrian walking. In this configuration, Location 7 passed the general distress criterion, and Location 8 was suitable for able bodied patrons. In Configuration C.2, both points were rated for pedestrian walking and suitable for able bodied patrons. The fastest winds at these locations are caused by downwash under winds from the north and the south quadrants, which is channelled along Shelley Lane. Locations on the east of Building C3 will be windy during winds from the south west quadrant, primarily due to downwash.

Location 9, positioned at the south-east corner of the podium was classified as uncomfortable and failed the distress criterion in the isolated configuration, but improved significantly for the more developed configurations tested. The addition of Building C4 and the remainder of the development improves the wind conditions at Location 9 by reducing downwash for winds from the south west, with Location 9 being suited to pedestrian walking and pedestrian standing for Configurations B.1 and C.2 respectively, and passing the general distress criterion in both instances.

As the majority of the flow causing exceedances along the eastern side of the building is caused by downwash, mitigation in the form of wide horizontal elements along the southern and eastern edge of the building, a large setback of the tower on the podium, or other low level mitigation measures along the east of the tower are required to disturb the downwash reaching ground level. Acceptable mitigation measures will be further developed during detailed design, but preliminary work has indicated that acceptable pedestrian walking conditions can be achieved through the use of appropriate amelioration devices.

Locations 10 and 11 are located along the southern face of Building C3. The wind comfort conditions at Location 10 straddled the criterion of pedestrian standing and walking for all configurations, as the addition of Building C4 provides shelter for some wind directions, but creates a channelling effect for winds from the south-west to west. Location 11 is rated for pedestrian walking in the isolated case, pedestrian standing for Configuration B.1, and pedestrian sitting for Configuration C.2. Both locations passed the distress criterion for all configurations. These points are in the vicinity of the main entrance to Building C3, and exhibit a wind climate that is acceptable for such an entrance.

Wind conditions along the west face of the building, Locations 12 to 13, are very windy in the isolated configuration. Both points are heavily affected by downwash during winds from the south-west quadrant, and two a lesser extent from the north quadrant. Both locations were rated as suitable for business walking. Location 12 failed the distress criterion, and Location 13 was rated for able bodied patrons. As with the east side of the building, a wide southern and western awning, and a setback of the tower on the podium would improve the wind conditions along the Globe Street side of the building. The addition of Building C4 alters the flow of

air around the building group, reducing the intensity of the downwash flows during winds from the south-west resulting in improved winds conditions to the north of Globe Street. For Configuration B.1, Locations 12 and 13 are rated for pedestrian standing and pedestrian walking, respectively. For configuration C.2, they were both suited to pedestrian standing. Both locations passed the distress criterion for both Configuration B.1 and C.2. Temporary measures to ameliorate the wind conditions at these locations would be required if the isolated condition were to proceed, and these would be determined during detailed design.

Wind conditions along the north face of the building (Locations 14, 15 and 16) for Configuration A.0 were suited to pedestrian standing, and passed the general distress criterion. The strongest winds at these locations are from the western quadrant, to which the site is exposed across Darling Harbour. In configuration B.1, these three points are also acceptable for pedestrian standing for the comfort criterion. However, in this configuration, Location 15 does not pass the general distress criterion and is rated for able bodied patrons, as the massing of Building C4 encourages slightly more flow around the north of Building C3 during winds from the western quadrant. In the configuration in which the site is fully developed (Configuration C.2), channelling effects between Building C3 and adjacent structures produce windier conditions at Locations 14 and 15 than the less developed stages of construction. In this final configuration, both Locations 14 and 15 are suited to pedestrian walking and both did not pass the general distress criterion, rating as suited to able bodied patrons. A combination of vertical and horizontal screening in the vicinity of these points, as well as dense planting to the west will ameliorate these strong winds. Amelioration measures will be developed during detailed design. Conditions at Location 16 for Configuration C.2 are calmer than the other two configurations, as it is acceptable for short term pedestrian sitting activities, and passes the distress criterion.

Locations 17, 18 and 19 are located on the podium roof of Building C3. These locations are exposed to downwash from specific wind directions. For all configurations, Location 17 is acceptable for pedestrian standing, and passes the general distress criterion. It is acceptable for outdoor dining between 55% to 75% of the time, depending on the level of surrounding future development on the site. In the isolated Building C3 configuration, Location 18 is subjected to strong winds resulting from downwash for winds from the south-west quadrant and is classified as uncomfortable and fails the Lawson distress criterion. In Configuration B.1, the conditions at this location are slightly improved although still windy, and exceed the general distress criterion, being suitable for able bodied patrons with a comfort criterion rating of business walking. In Configuration C.2, when the site is fully developed, it is suited to pedestrian walking, and fails the Lawson distress criterion as a combination of downwash and channelling effects cause strong winds at this location. In general, this location would be suited to outdoor dining less than 50% of the time. Location 19, which is situated on the north west side of the podium close to the tower is well sheltered under most conditions being suited to pedestrian standing or sitting and passing the distress criterion in all three configurations. The most favourably rated of the three podium locations investigated, Location 19 is still only suited to outdoor dining approximately 65% of the time. The podium is proposed for usage as part of a child care facility and consequently forms of amelioration against the environmental wind conditions will be required. The amelioration measures adopted will be developed under a separate Project Application for the fitout of this space.

Ground level retail entrances are generally located away from the building corners, which is favourable from a pedestrian access perspective. It would be recommended to move the entrances to the retail units on the south-east and south-west corners to the east and south faces respectively. Simultaneous opening of multiple entrances to the same retail unit will likely result in strong internal flows, although in smaller tenancies this can be regulated by controlling which doors are open at the same time. Revolving doors are shown on the entrance to the main lift lobby, which will help avoid internal flow issues.

6 Conclusion

In summary, wind conditions at certain locations around the building are not acceptable for general pedestrian access for some specific wind directions. The wind conditions around Building C3 generally improve with the construction of the other Barangaroo buildings; particularly Building C4 to the immediate south of the site. However, channelling effects associated with the layout of the fully developed site result in more windy conditions at a limited number of locations. Mitigation measures, such as awning extensions along the east, south and west faces and vertical screening elements will be considered to ameliorate the wind conditions. Remedies to solve these issues will be investigated in the wind tunnel during detailed design to ensure a suitable pedestrian environment around the development.

Preliminary work on the isolated Building C4 has indicated that an acceptable wind environment can be developed with temporary structures, so if Building C3 were to be constructed first these amelioration measures would be developed during detailed design.

Amelioration measures to address wind conditions on the podium will be developed as part of a separate Project Application for the tenancy fit out of that area.

7 References

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Appendix A

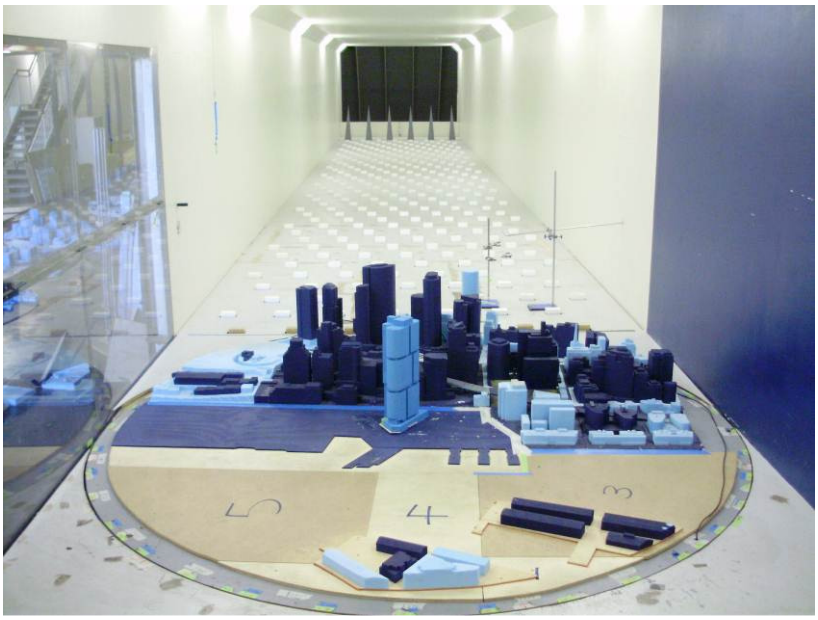
List of Symbols

A1 List of Symbols

D	Characteristic dimension (building height, width, etc.)
n	Mean velocity profile power law exponent
T_u	Turbulence intensity, U_{rms}/U
U	Local mean velocity
U_{ref}	Reference mean wind speed at reference height Z_{ref}
U_{pk}	Peak wind speed in pedestrian studies
U_{rms}	Root-mean-square of fluctuating velocity
z	Height above surface
ν	Kinematic viscosity of approach flow
σ ( )	Standard deviation of ( ), = ( )$'_{rms}$
ρ	Density of approach flow
( )$_{max}$	Maximum value during data record
( )$_{min}$	Minimum value during data record
( )$_{mean}$	Mean value during data record
( )$_{rms}$	Root mean square about the mean

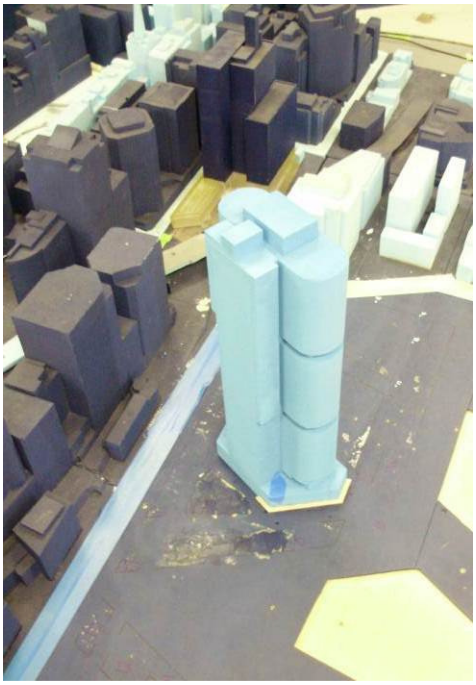
Appendix B

Additional Photographs of the CPP Wind Tunnel Model



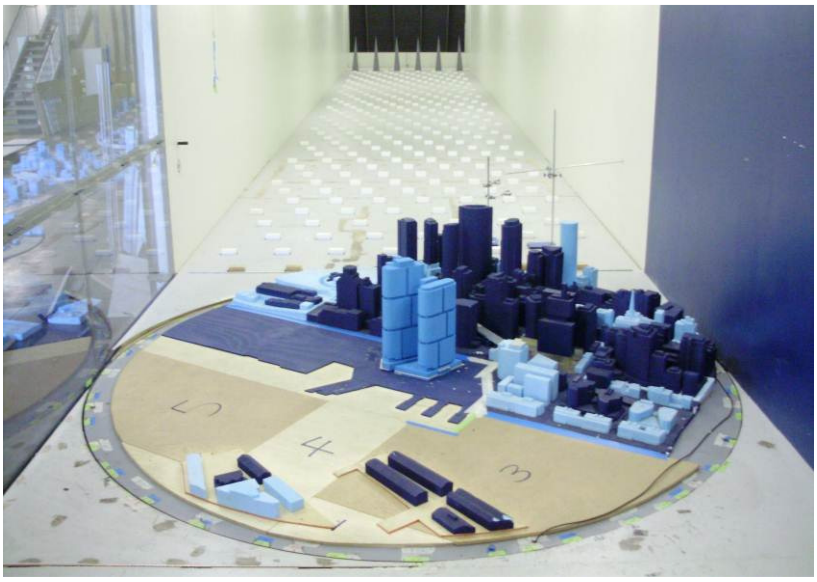
a)

b)

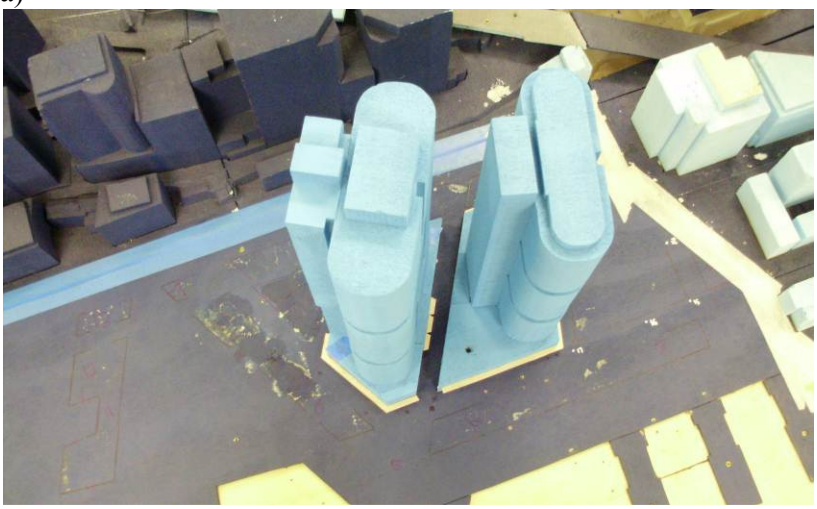


c)

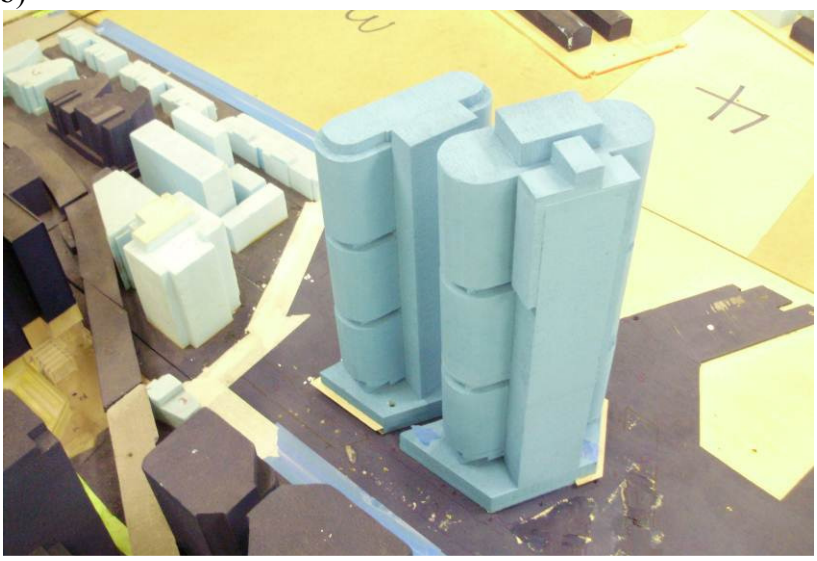
Figure 9: Configuration A.0 - Isolated Building C3 from a) west, b) south west, and c) north west



a)



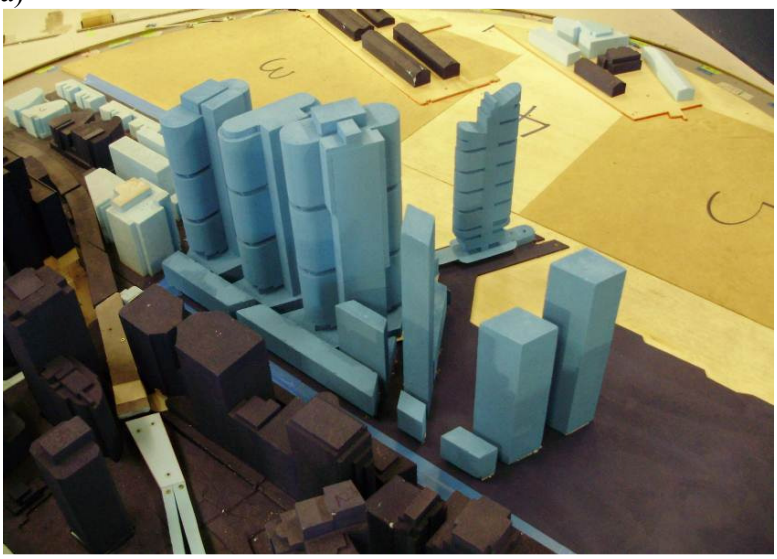
b)



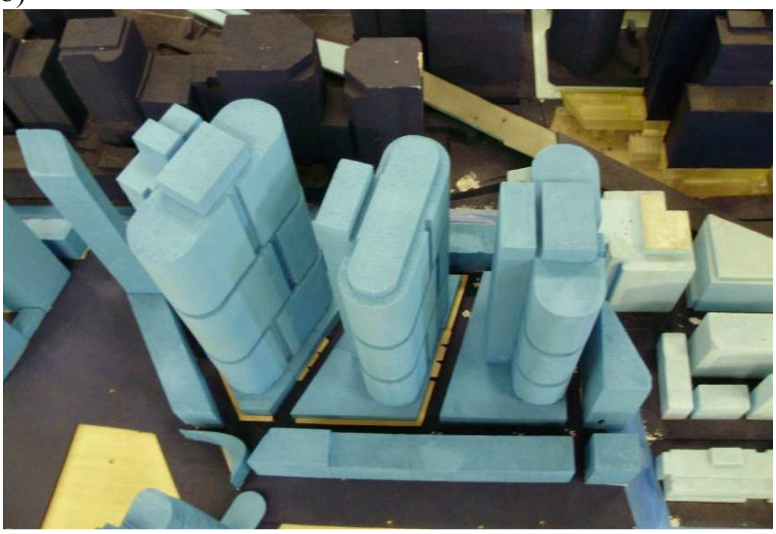
c)

Figure 10: Configuration B.1 – Building C3 with adjacent building C4 from the a) west, b) above, and c) north east

a)



b)

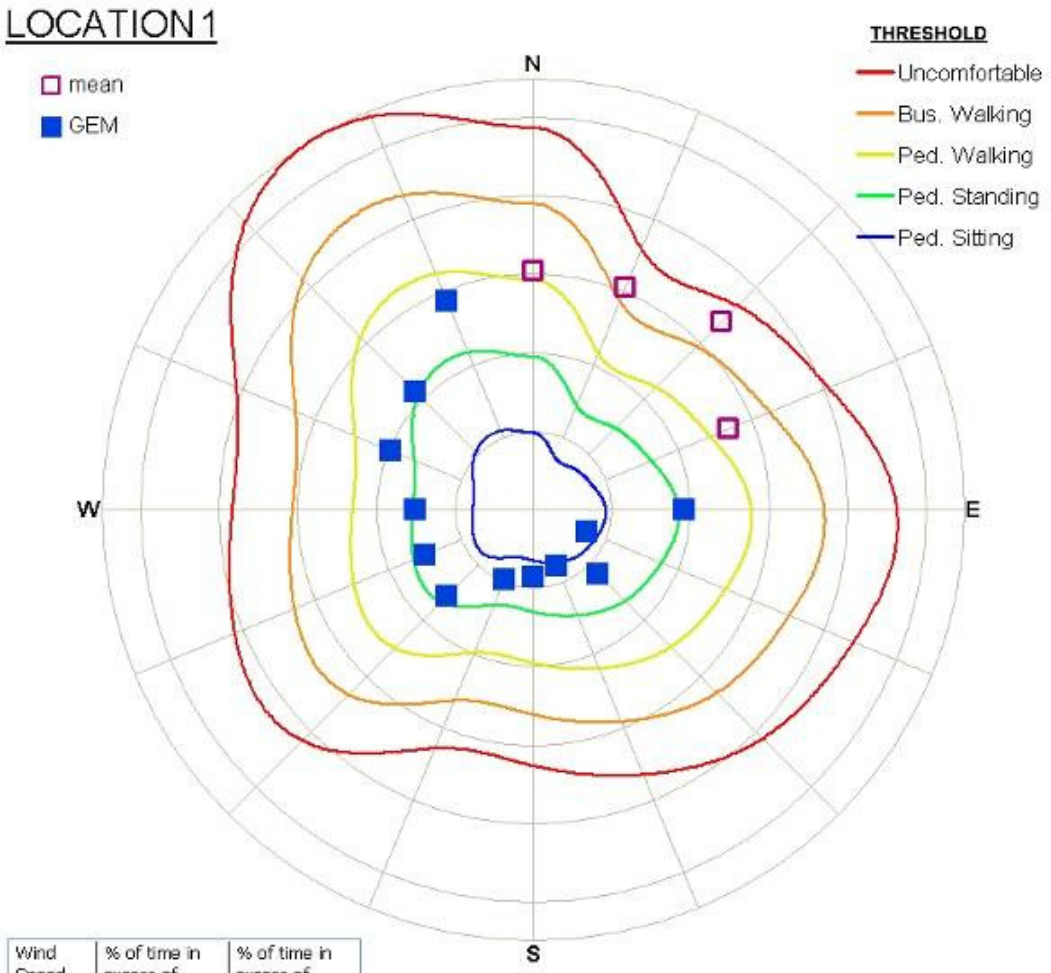


c)

Figure 11: Configuration C.2 – Building C3 with Masterplan from the a) west, b) north-east, and c) above.

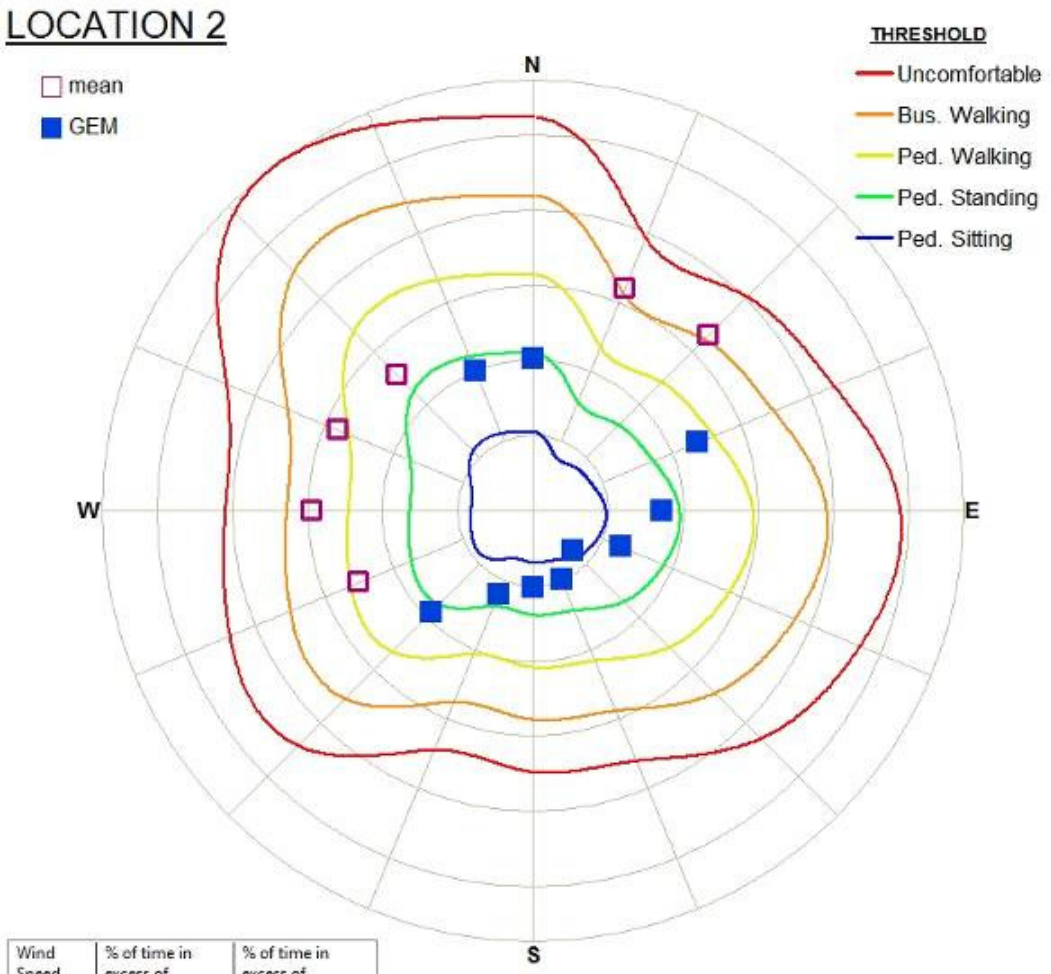
Appendix C

Directional Wind Results



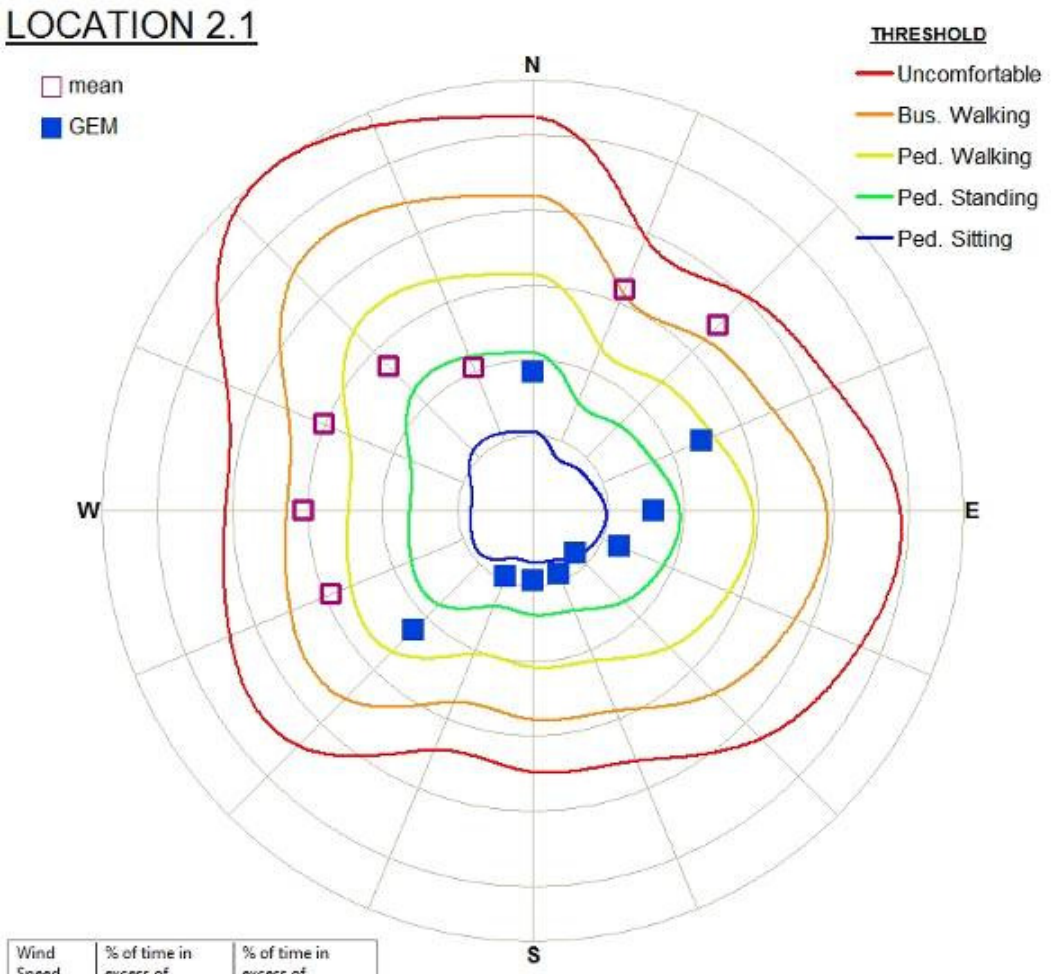
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	29.4	37.3
4.0	11.5	10.9
6.0	4.9	3.2
8.0	1.5	0.5
10.0	0.3	0.1
5.9	**5.0**	Ped Standing
12.1	**0.022**	Pass
5.3	Ped Standing	**5.0**
10.5	Pass	**0.022**

All



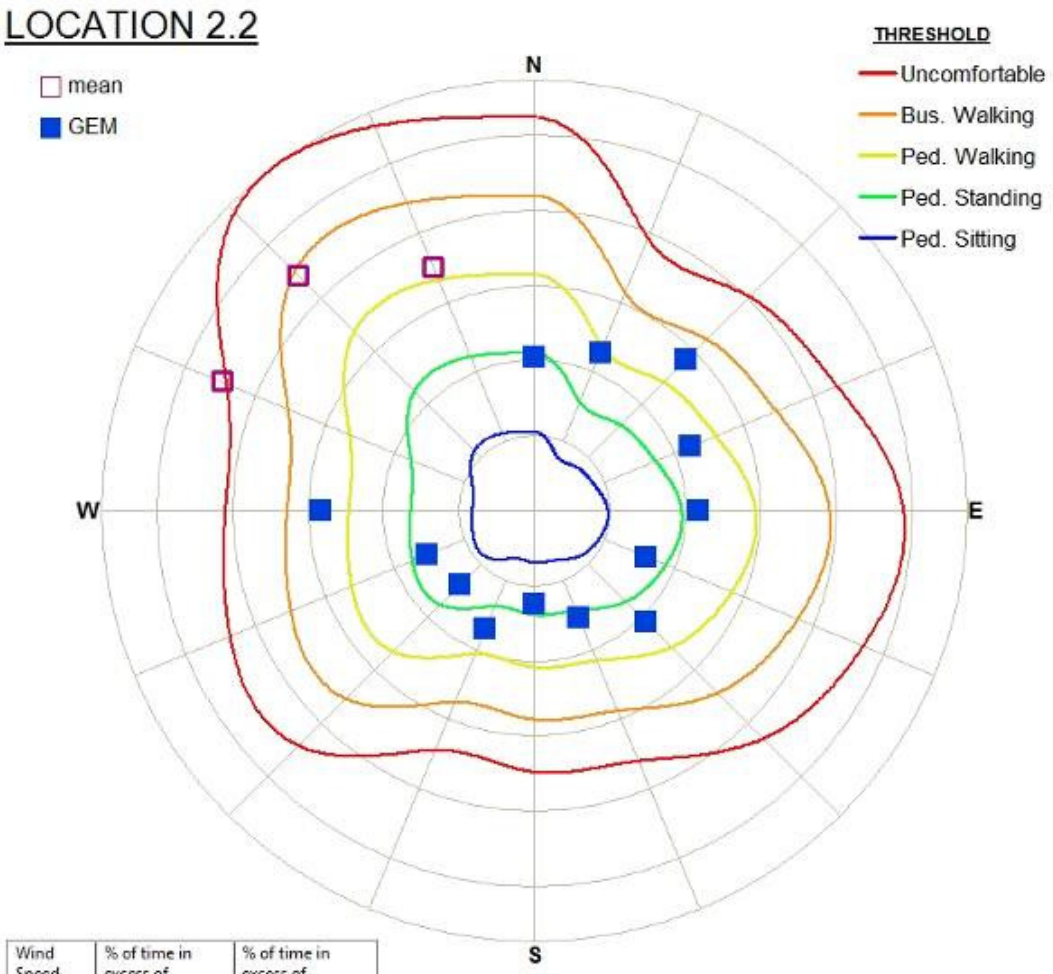
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	35.3	39.6
4.0	12.9	11.9
6.0	5.0	3.3
8.0	1.2	0.5
10.0	0.2	0.0
5.9	**5.0**	Ped Standing
11.6	**0.022**	Pass
5.4	Ped Standing	**5.0**
10.3	Pass	**0.022**

With Building C3



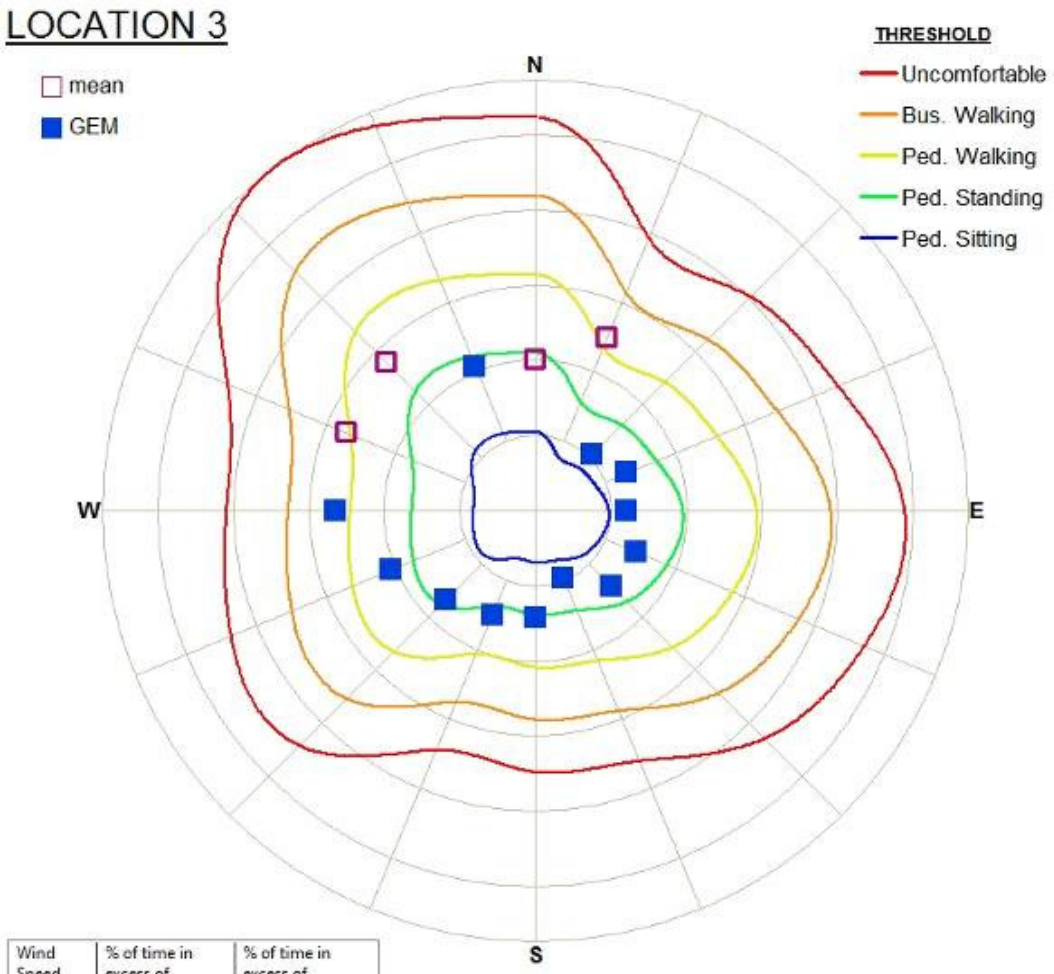
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	33.9	38.2
4.0	14.1	12.8
6.0	5.8	4.0
8.0	1.6	0.7
10.0	0.3	0.1
6.2	**5.0**	Ped Walking
12.2	**0.022**	Pass
5.6	Ped Standing	**5.0**
10.8	Pass	**0.022**

With Buildings C3 and C4



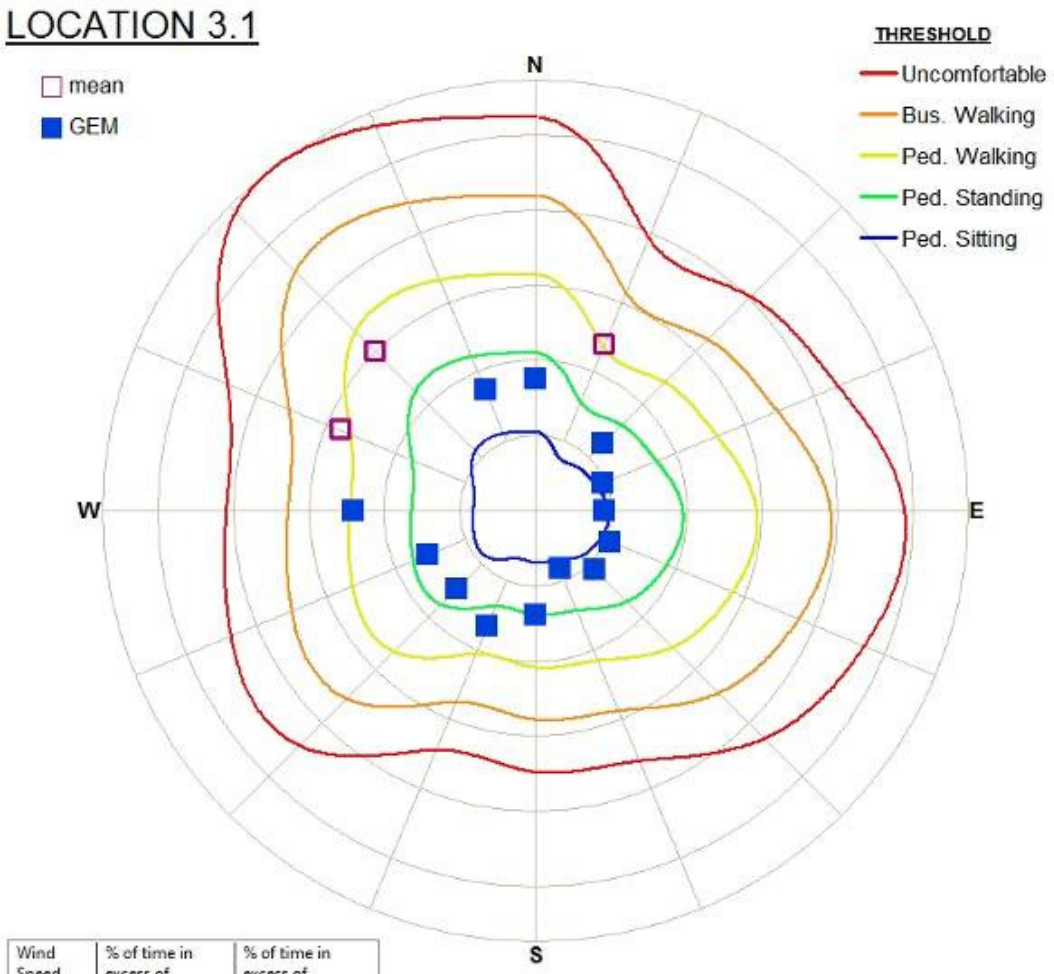
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	47.4	51.5
4.0	13.9	15.2
6.0	3.8	3.9
8.0	1.3	1.0
10.0	0.6	0.3
5.5	**5.0**	Ped Standing
17.0	**0.022**	Able Body
5.6	Ped Standing	**5.0**
14.2	Pass	**0.022**

Masterplan



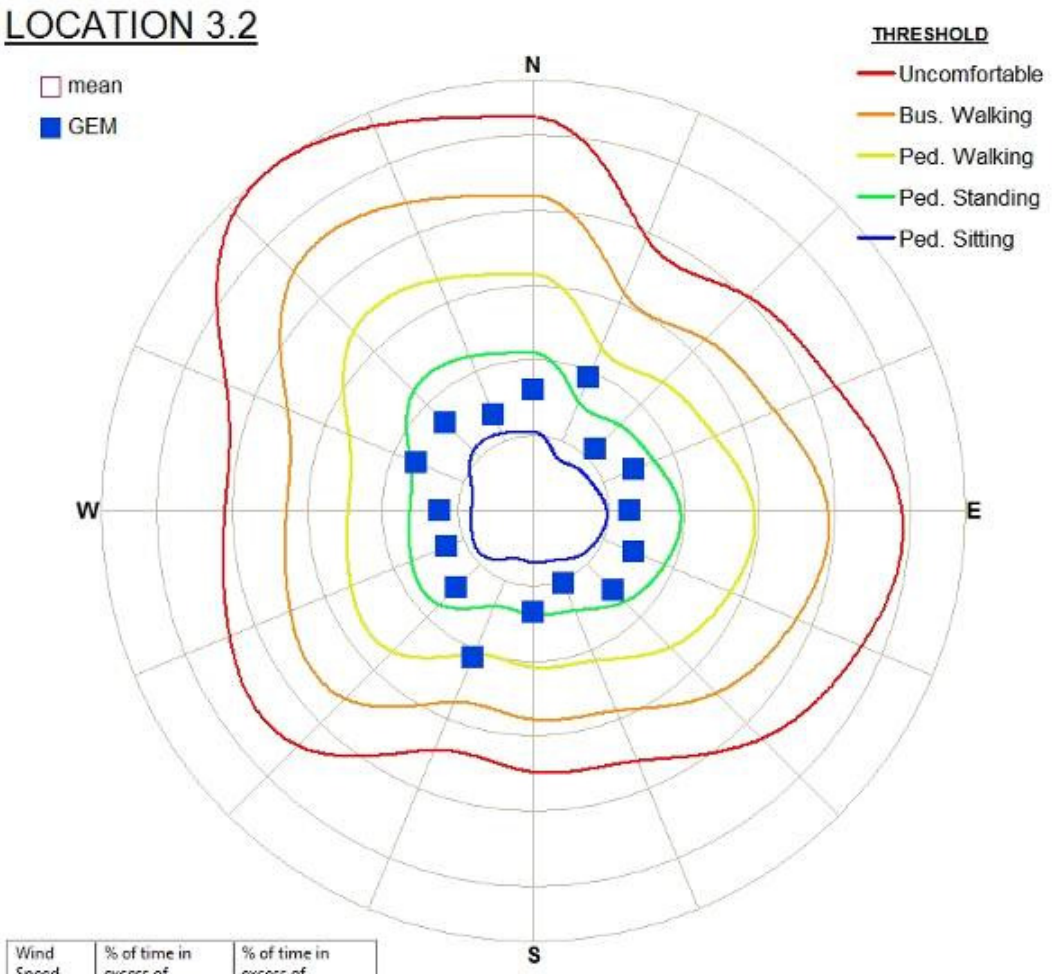
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	31.8	39.7
4.0	7.0	8.1
6.0	1.7	1.6
8.0	0.3	0.2
10.0	0.0	0.0
4.5	**5.0**	Ped Standing
10.7	**0.022**	Pass
4.6	Ped Standing	**5.0**
10.3	Pass	**0.022**

With Building C3



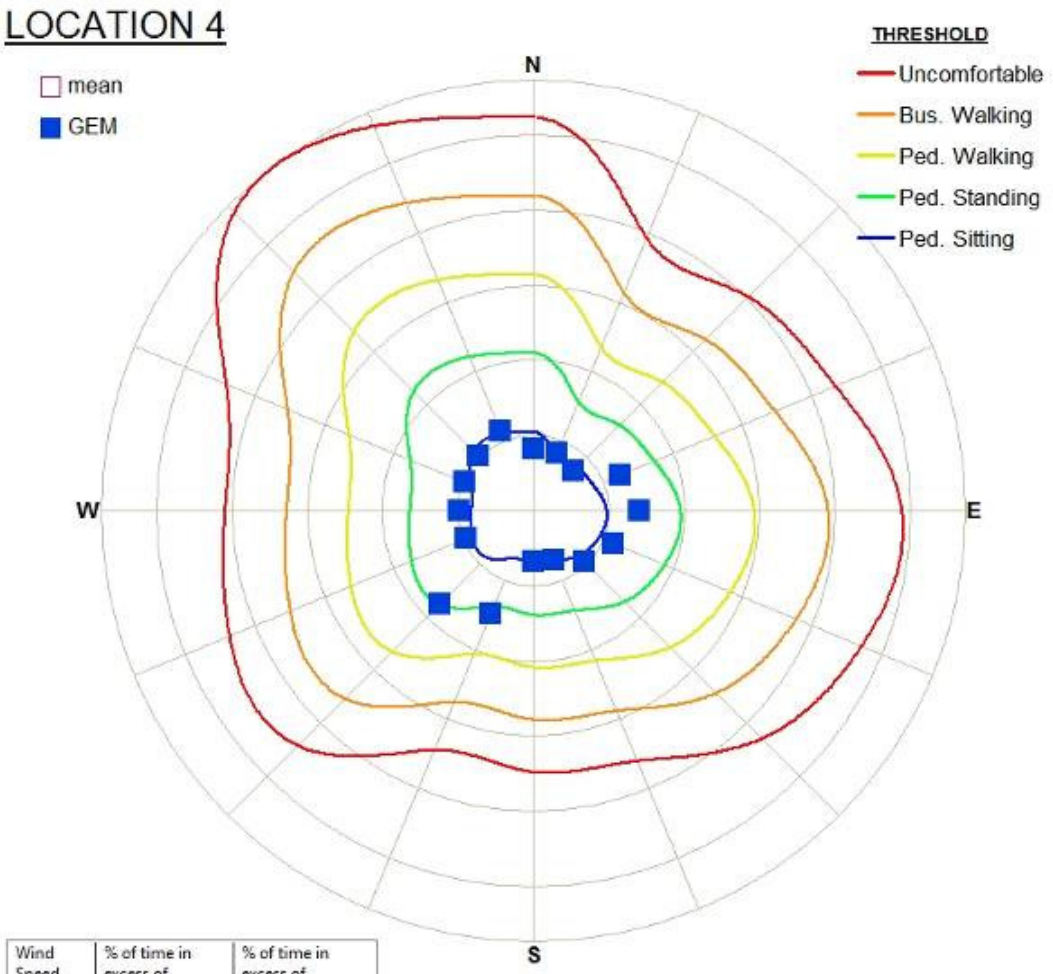
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	28.1	34.7
4.0	6.1	6.9
6.0	1.4	1.3
8.0	0.2	0.2
10.0	0.0	0.0
4.2	**5.0**	Ped Standing
10.9	**0.022**	Pass
4.3	Ped Standing	**5.0**
9.9	Pass	**0.022**

With Buildings C3 and C4



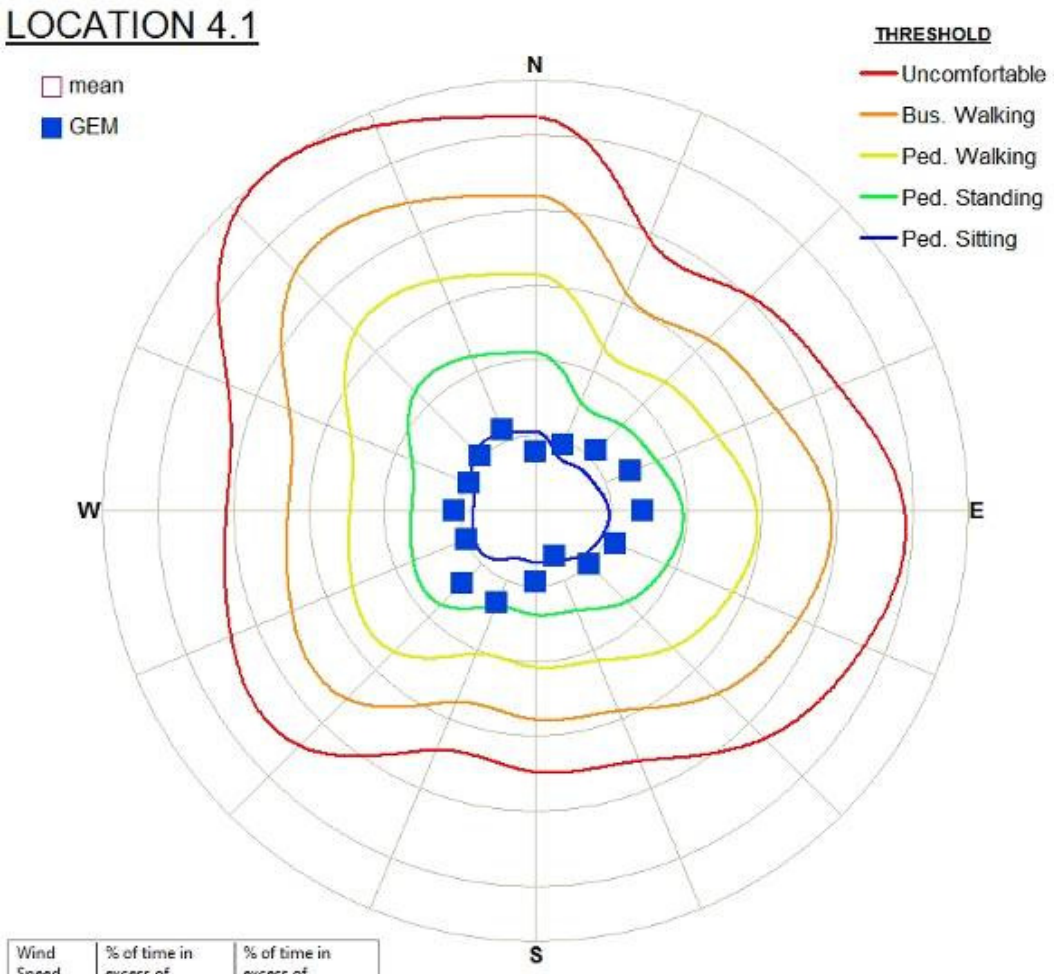
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	18.4	30.9
4.0	1.6	3.8
6.0	0.1	0.4
8.0	0.0	0.0
10.0	0.0	0.0
3.0	**5.0**	Ped Sitting
6.7	**0.022**	Pass
3.7	Ped Sitting	**5.0**
8.5	Pass	**0.022**

Masterplan



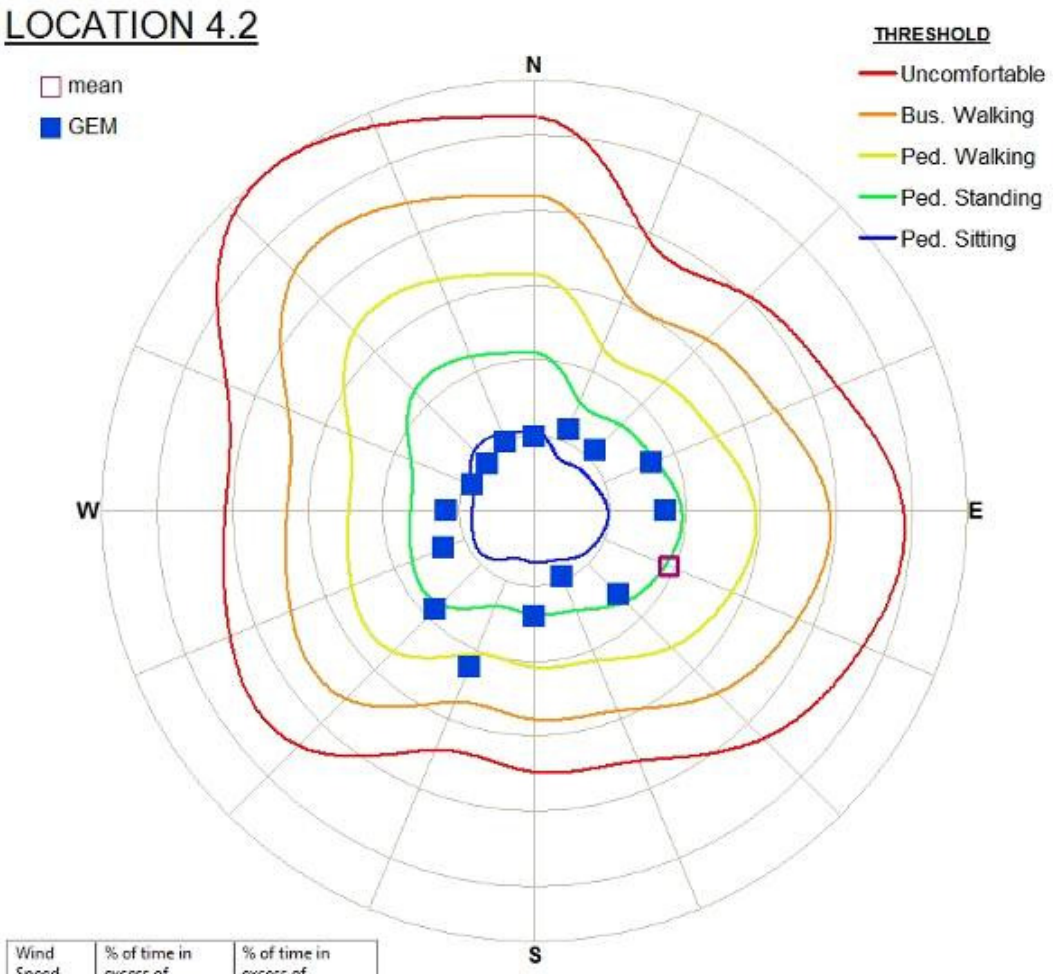
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	4.0	10.8
4.0	0.1	0.5
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
1.9	**5.0**	Outdoor Dining
4.7	**0.022**	Pass
2.5	Ped Sitting	**5.0**
6.2	Pass	**0.022**

With Building C3



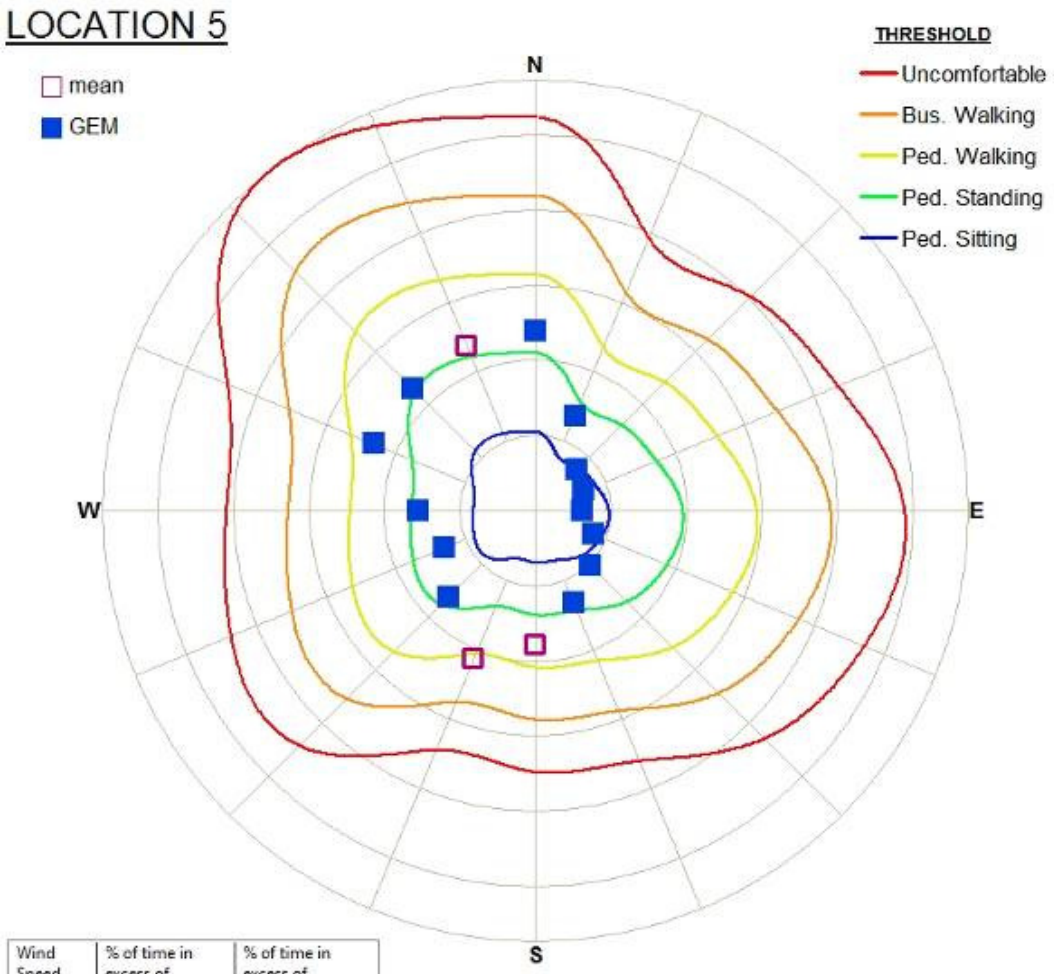
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	4.5	15.2
4.0	0.0	0.3
6.0	0.0	0.0
8.0	0.0	0.0
10.0	0.0	0.0
1.9	**5.0**	Outdoor Dining
3.9	**0.022**	Pass
2.6	Ped Sitting	**5.0**
5.4	Pass	**0.022**

With Buildings C3 and C4



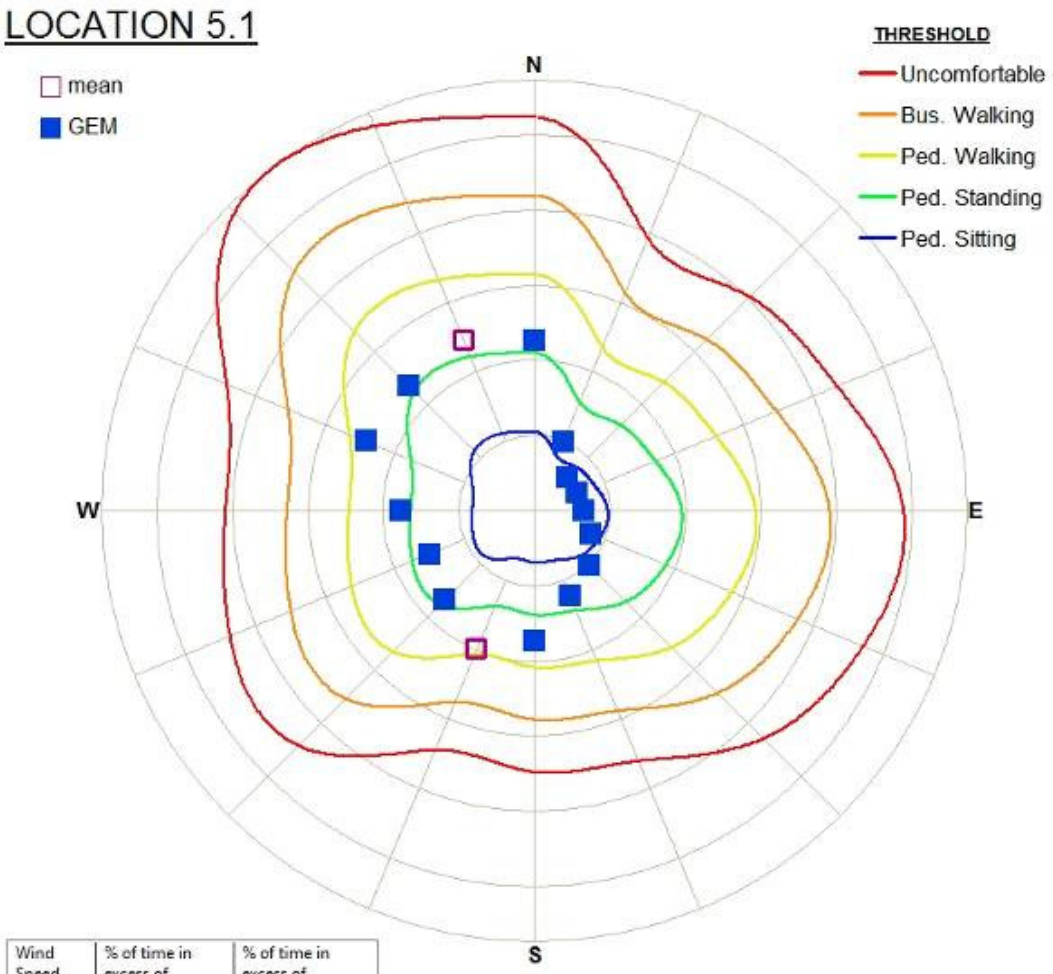
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	18.6	27.1
4.0	1.6	3.1
6.0	0.2	0.4
8.0	0.0	0.1
10.0	0.0	0.0
3.0	**5.0**	Ped Sitting
7.8	**0.022**	Pass
3.5	Ped Sitting	**5.0**
9.0	Pass	**0.022**

Masterplan



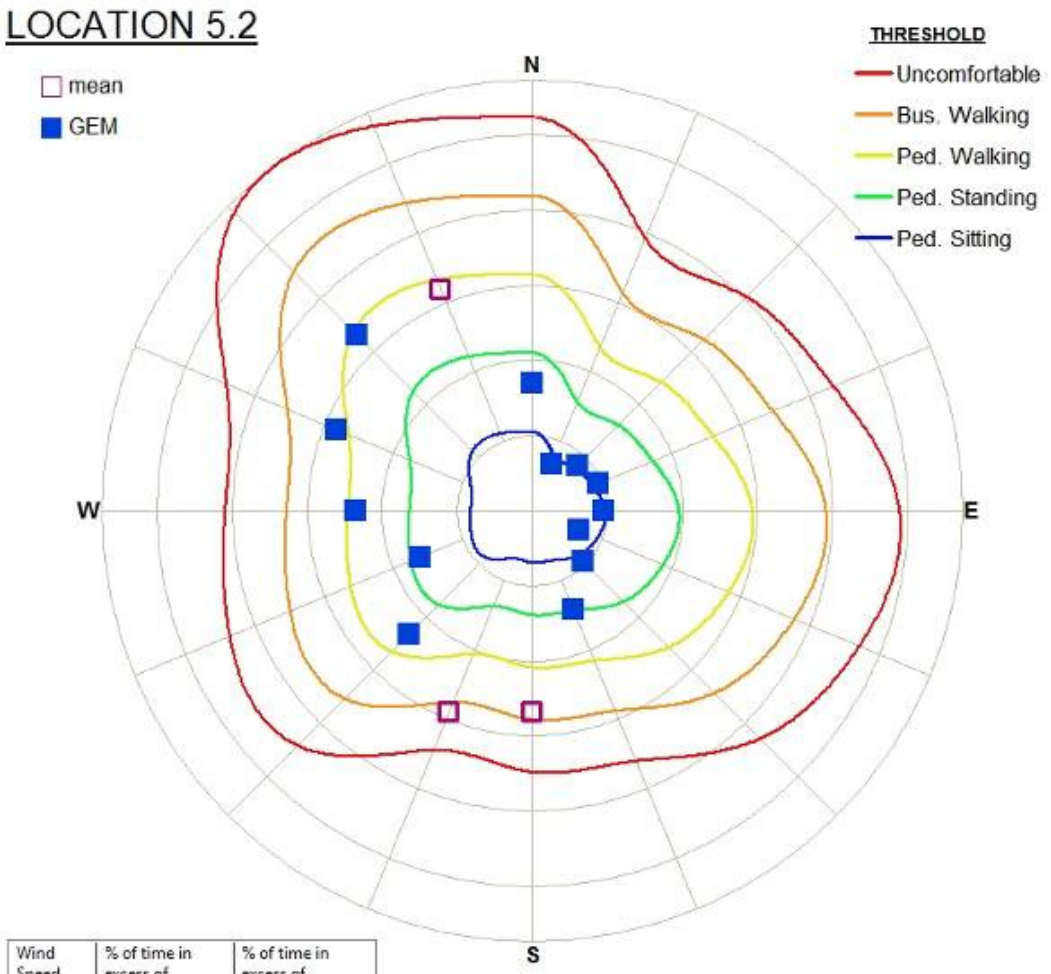
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	26.9	33.0
4.0	5.5	5.8
6.0	0.7	0.6
8.0	0.1	0.1
10.0	0.0	0.0
4.0	**5.0**	Ped Standing
9.0	**0.022**	Pass
4.1	Ped Standing	**5.0**
9.0	Pass	**0.022**

With Building C3



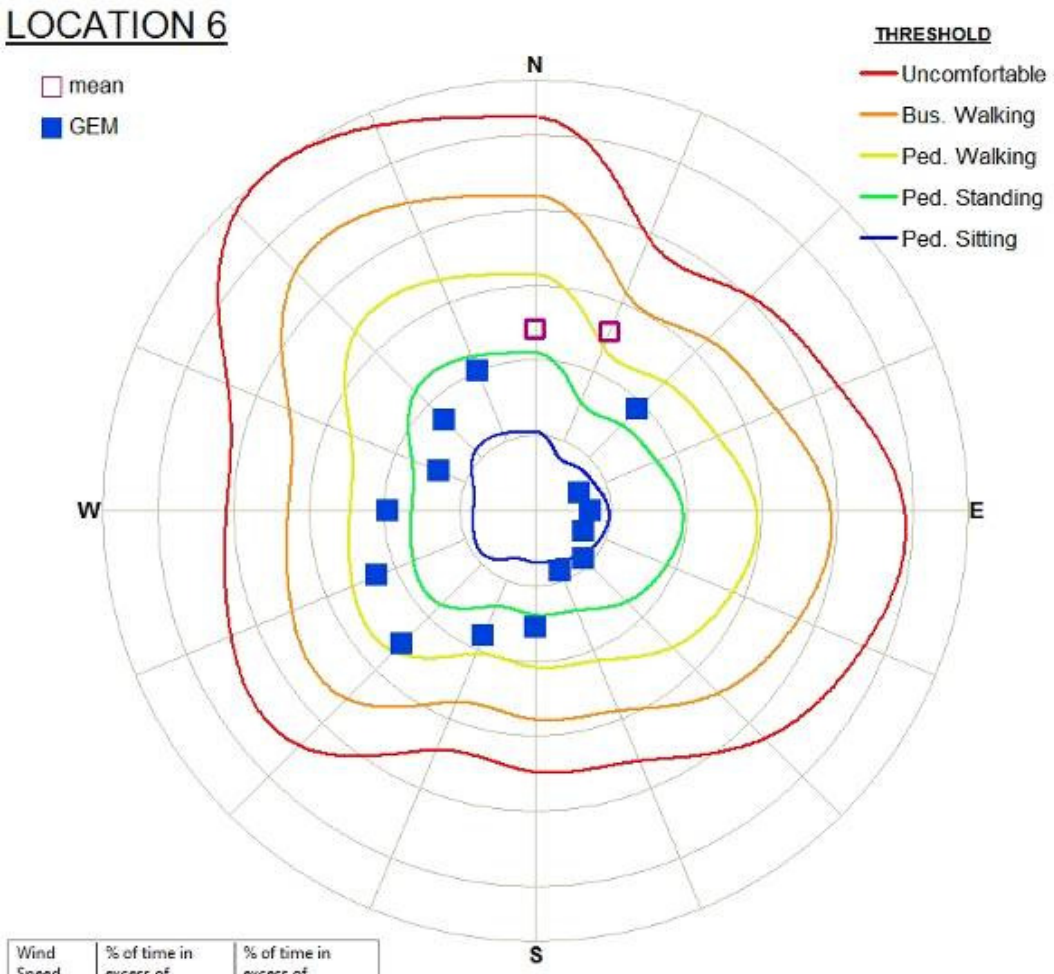
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	25.4	32.3
4.0	4.9	6.1
6.0	0.6	0.7
8.0	0.1	0.1
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
8.8	**0.022**	Pass
4.2	Ped Standing	**5.0**
9.3	Pass	**0.022**

With Buildings C3 and C4



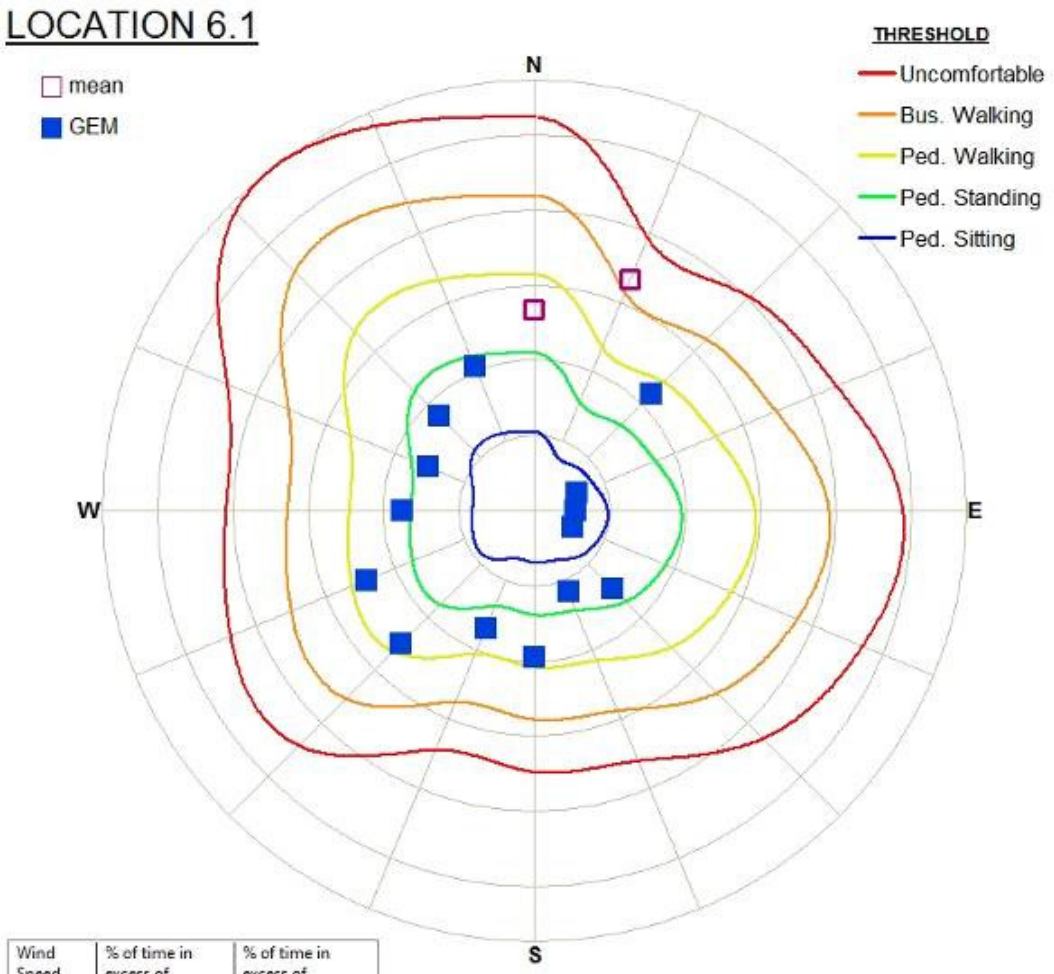
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	32.2	38.2
4.0	12.6	13.8
6.0	4.5	4.1
8.0	1.1	0.8
10.0	0.2	0.1
5.8	**5.0**	Ped Standing
12.7	**0.022**	Pass
5.6	Ped Standing	**5.0**
12.1	Pass	**0.022**

Masterplan



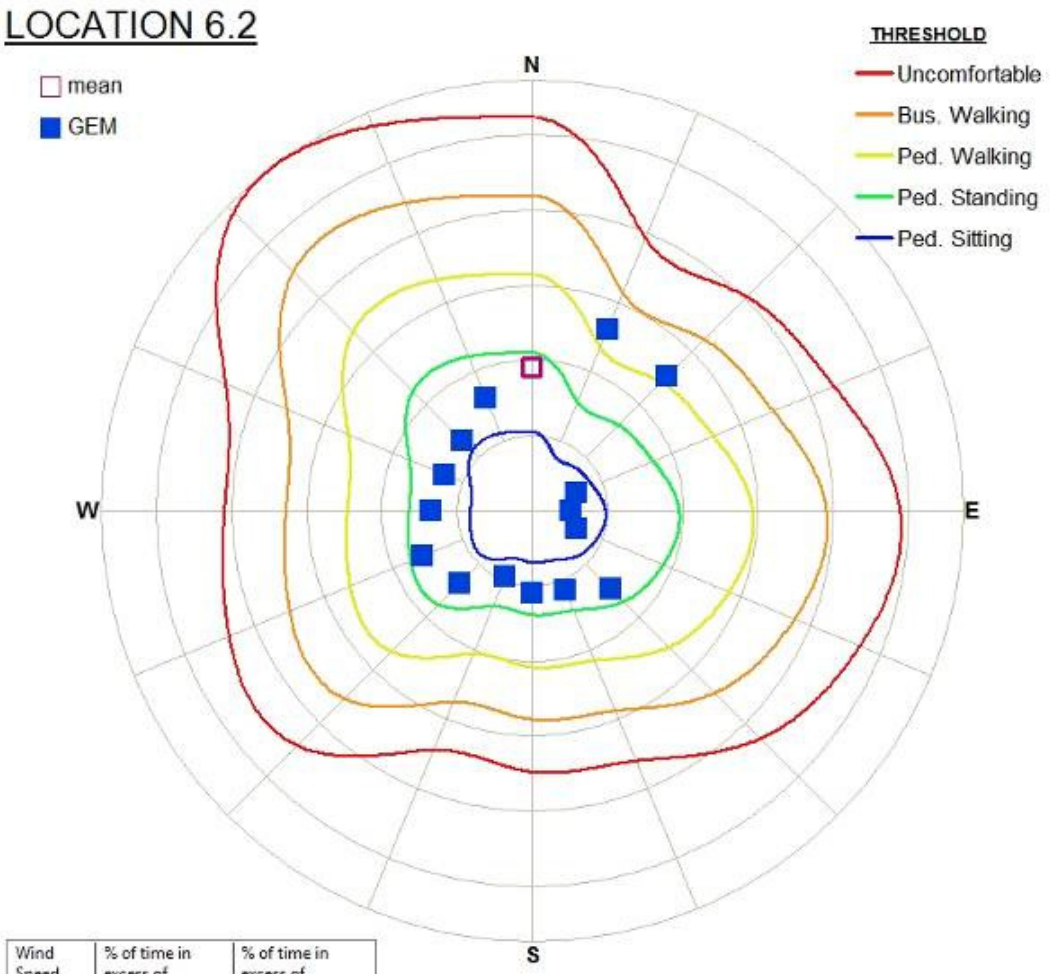
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	26.4	34.9
4.0	4.6	8.5
6.0	0.7	0.9
8.0	0.1	0.1
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
8.5	**0.022**	Pass
4.5	Ped Standing	**5.0**
8.7	Pass	**0.022**

With Building C3



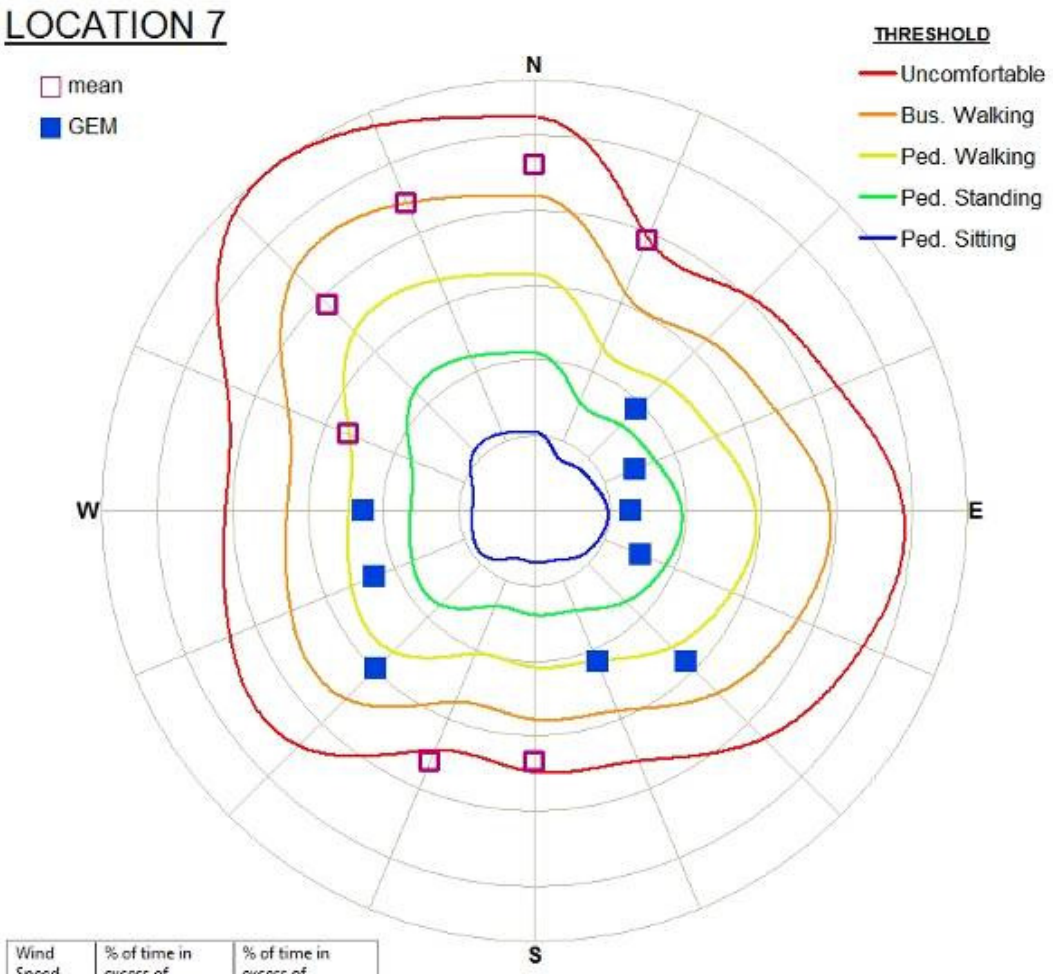
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	32.9	40.1
4.0	7.7	12.0
6.0	2.0	2.0
8.0	0.5	0.2
10.0	0.1	0.0
4.5	**5.0**	Ped Standing
10.8	**0.022**	Pass
5.0	Ped Standing	**5.0**
9.7	Pass	**0.022**

With Buildings C3 and C4



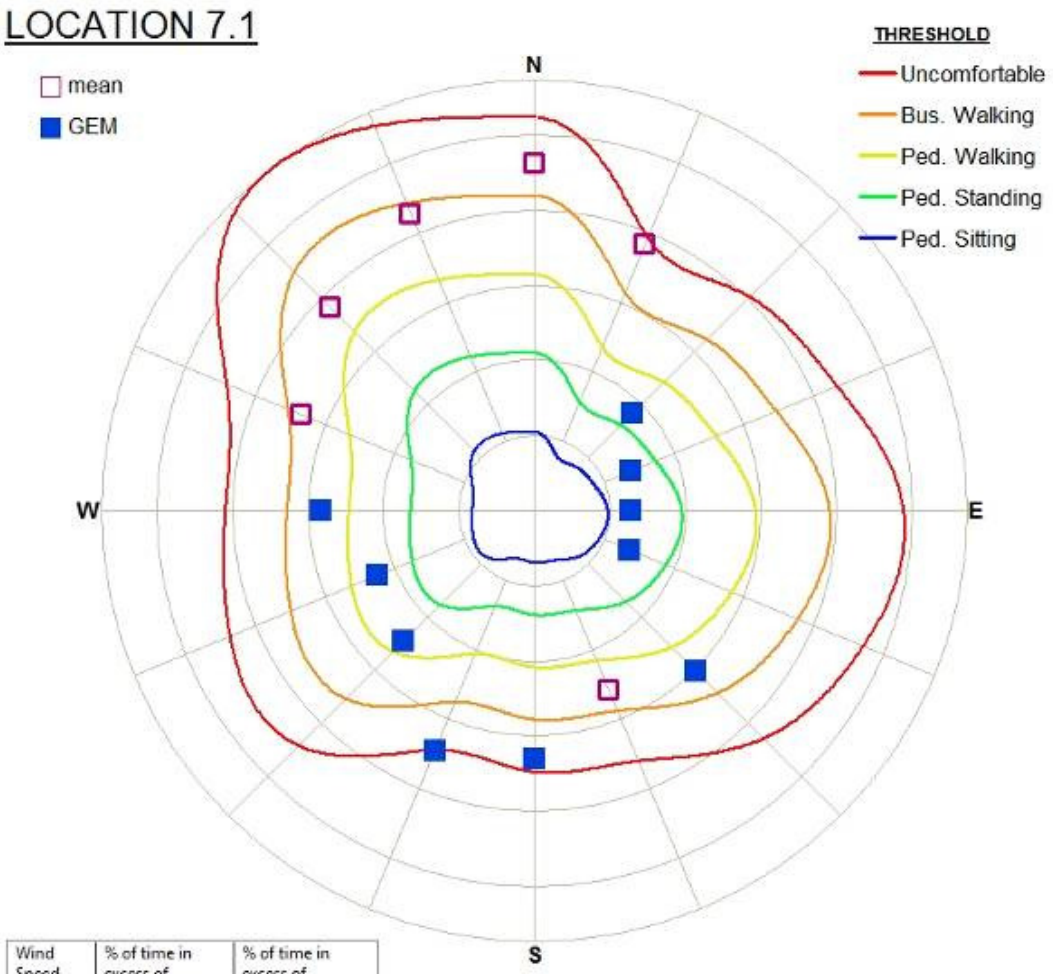
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	17.0	28.2
4.0	3.8	5.7
6.0	0.5	1.1
8.0	0.0	0.1
10.0	0.0	0.0
3.5	**5.0**	Ped Sitting
7.8	**0.022**	Pass
4.1	Ped Standing	**5.0**
8.8	Pass	**0.022**

Masterplan



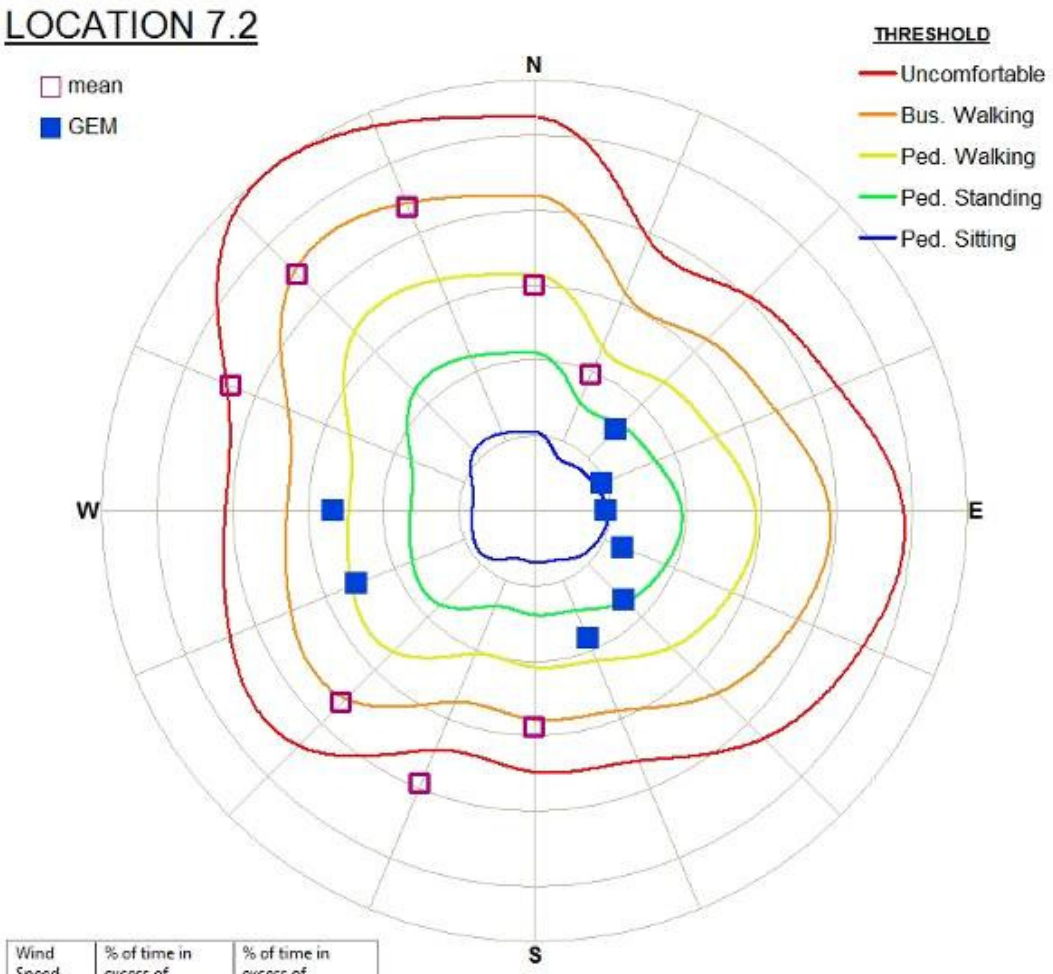
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	54.0	57.9
4.0	25.6	26.3
6.0	12.2	10.5
8.0	4.9	3.1
10.0	1.5	0.7
7.9	**5.0**	Ped Walking
15.8	**0.022**	Able Body
7.2	Ped Walking	**5.0**
14.7	Pass	**0.022**

With Building C3



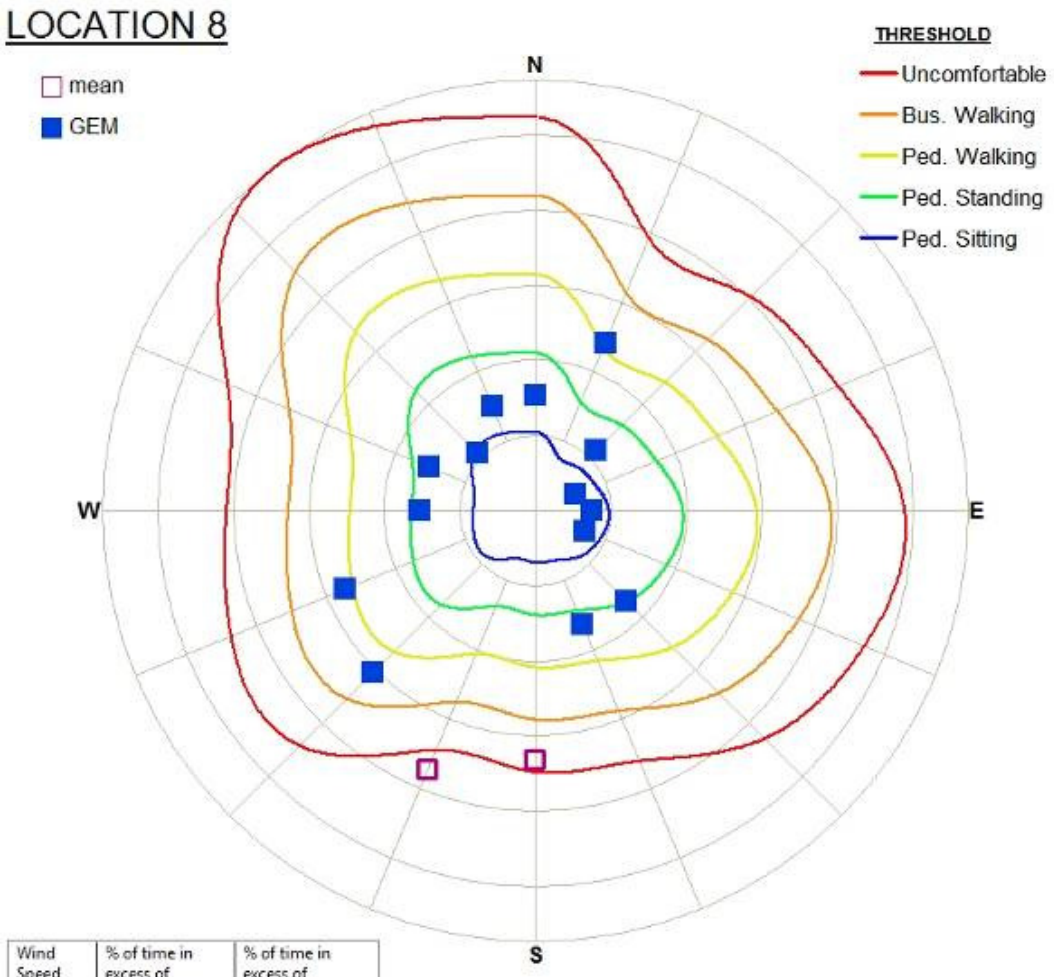
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	56.9	58.2
4.0	28.5	27.3
6.0	11.9	11.5
8.0	3.9	3.5
10.0	1.0	0.8
7.5	**5.0**	Ped Walking
14.7	**0.022**	Pass
7.4	Ped Walking	**5.0**
14.8	Pass	**0.022**

With Buildings C3 and C4



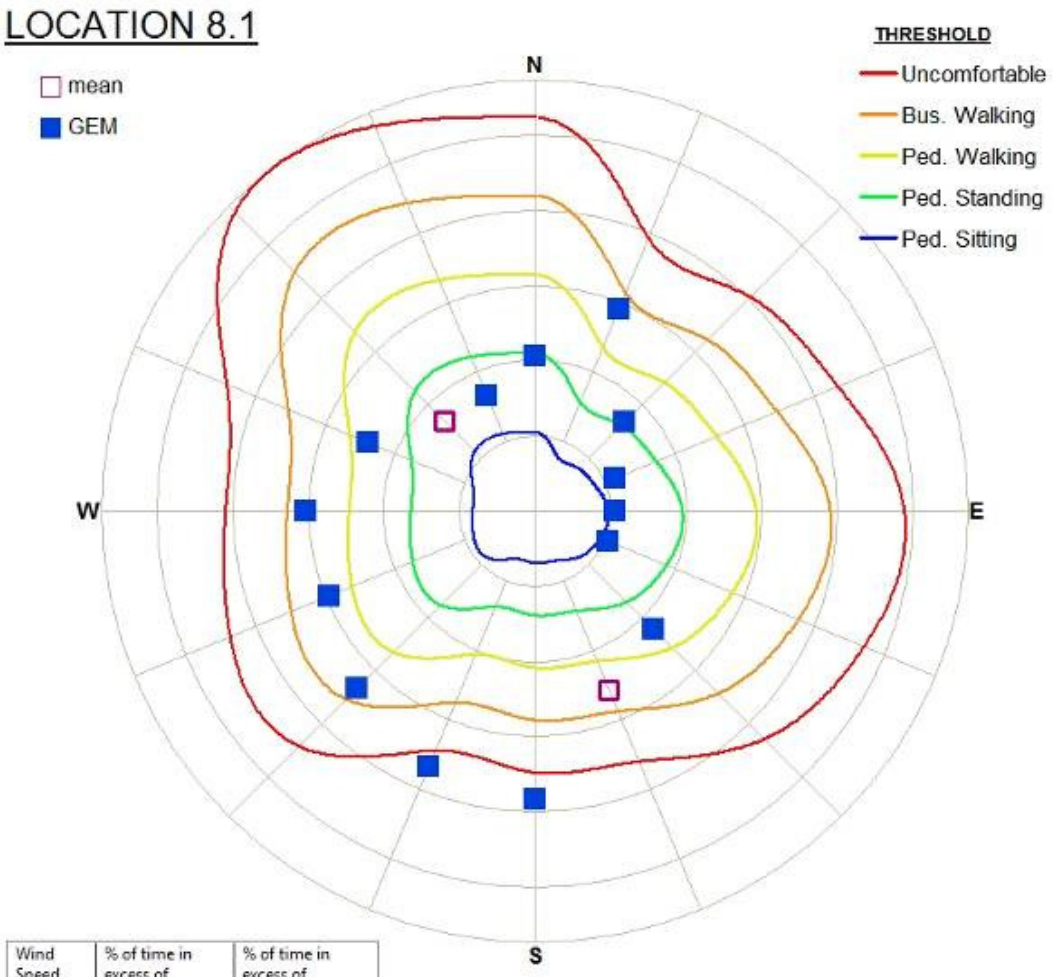
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	51.4	52.5
4.0	22.4	20.0
6.0	8.9	6.2
8.0	3.5	1.5
10.0	1.3	0.3
7.2	**5.0**	Ped Walking
17.5	**0.022**	Able Body
6.3	Ped Walking	**5.0**
13.4	Pass	**0.022**

Masterplan



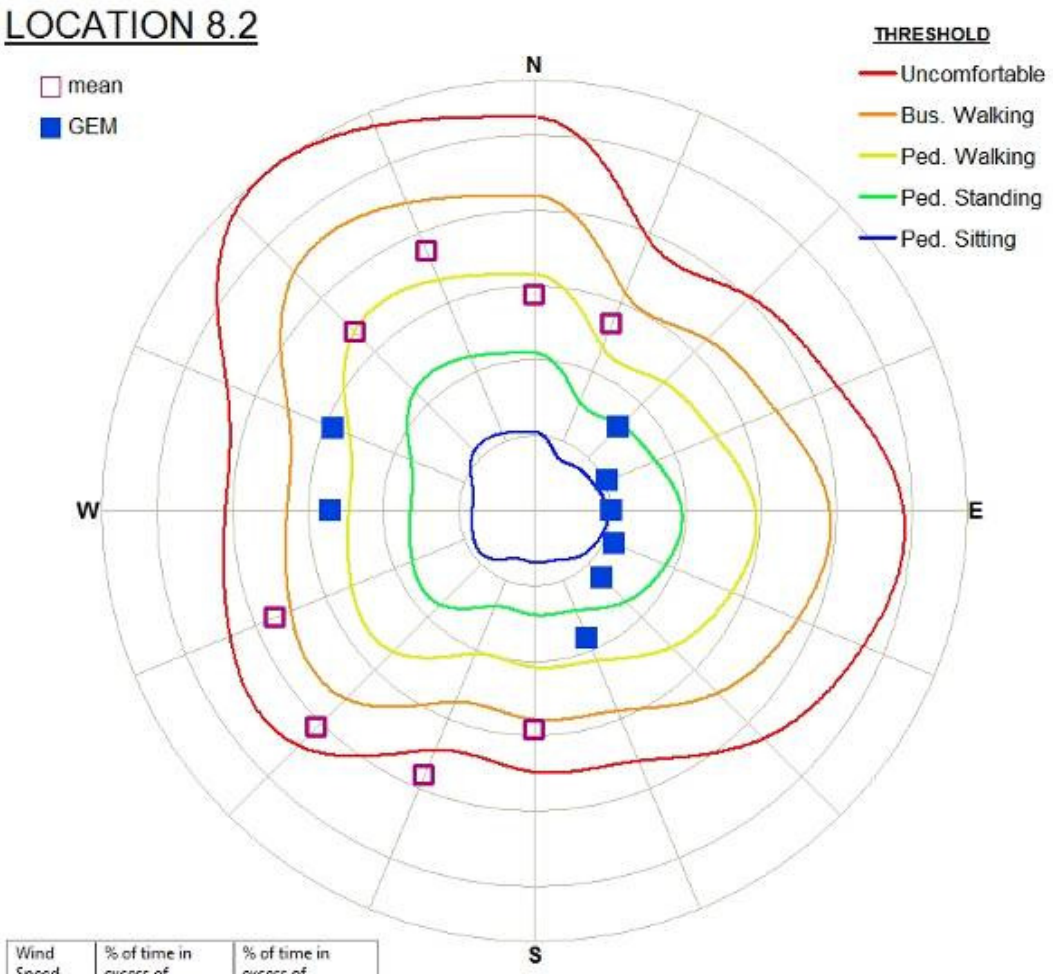
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	31.5	37.9
4.0	13.7	15.8
6.0	7.0	5.9
8.0	2.8	1.5
10.0	0.8	0.3
6.7	**5.0**	Ped Walking
15.4	**0.022**	Able Body
6.2	Ped Walking	**5.0**
13.4	Pass	**0.022**

With Building C3



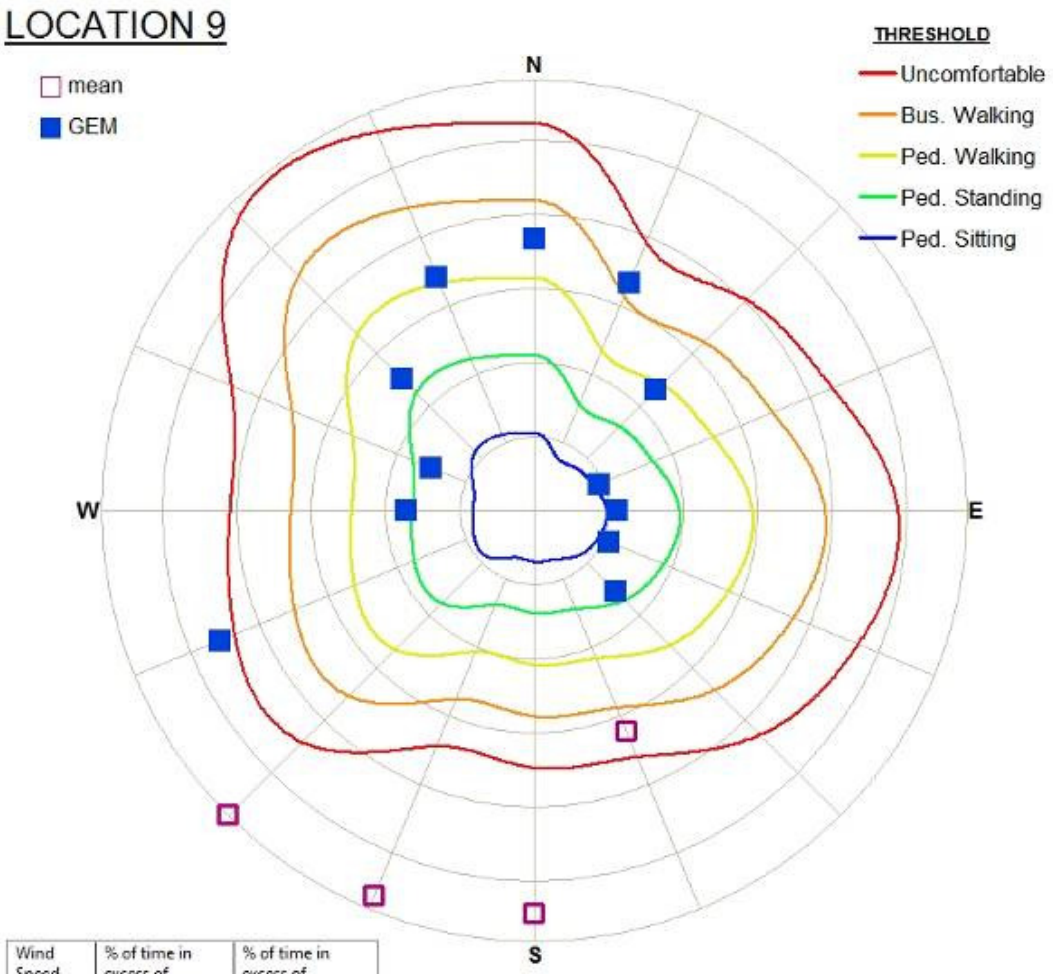
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	44.3	50.4
4.0	20.0	25.3
6.0	8.7	12.2
8.0	3.0	4.8
10.0	0.8	1.6
7.0	**5.0**	Ped Walking
15.0	**0.022**	Able Body
7.8	Ped Walking	**5.0**
16.5	Able Body	**0.022**

With Buildings C3 and C4



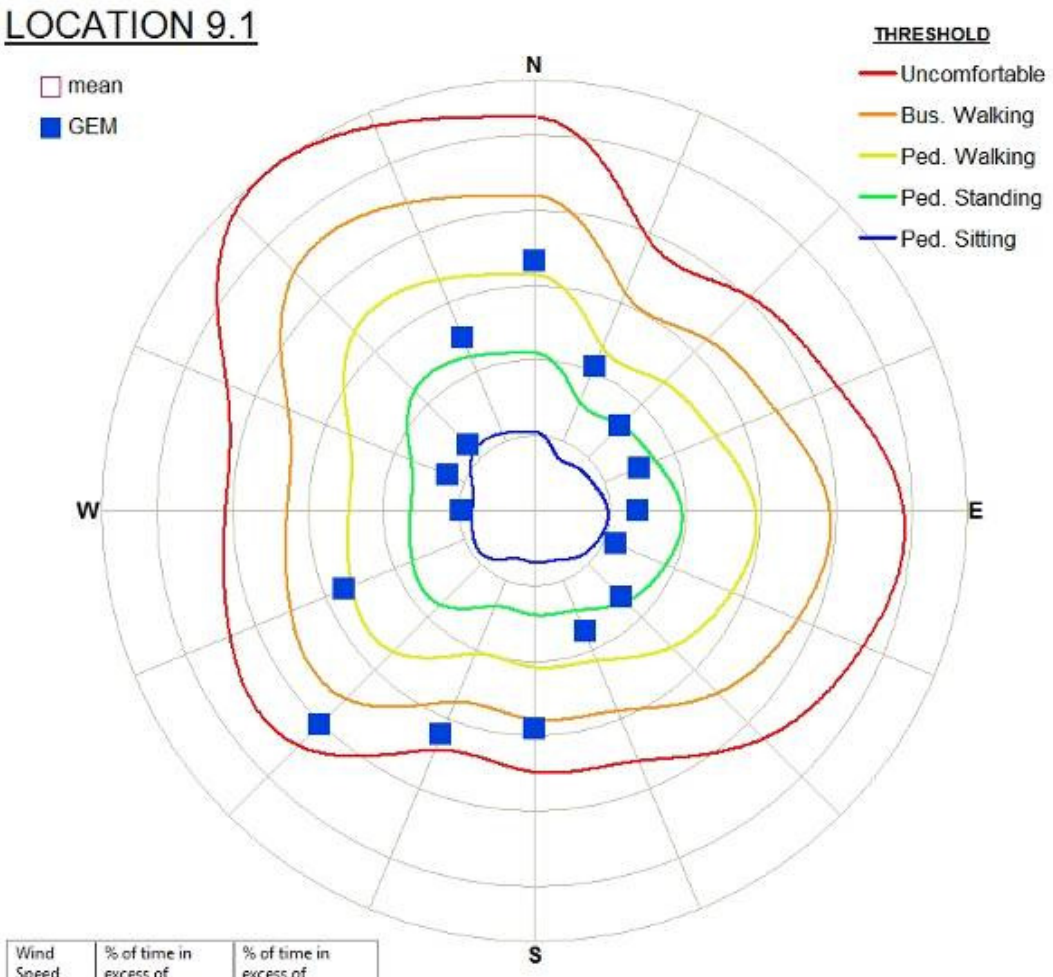
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	51.2	51.6
4.0	23.5	20.4
6.0	9.8	6.2
8.0	3.1	1.3
10.0	0.8	0.2
7.2	**5.0**	Ped Walking
15.8	**0.022**	Able Body
6.2	Ped Walking	**5.0**
12.6	Pass	**0.022**

Masterplan



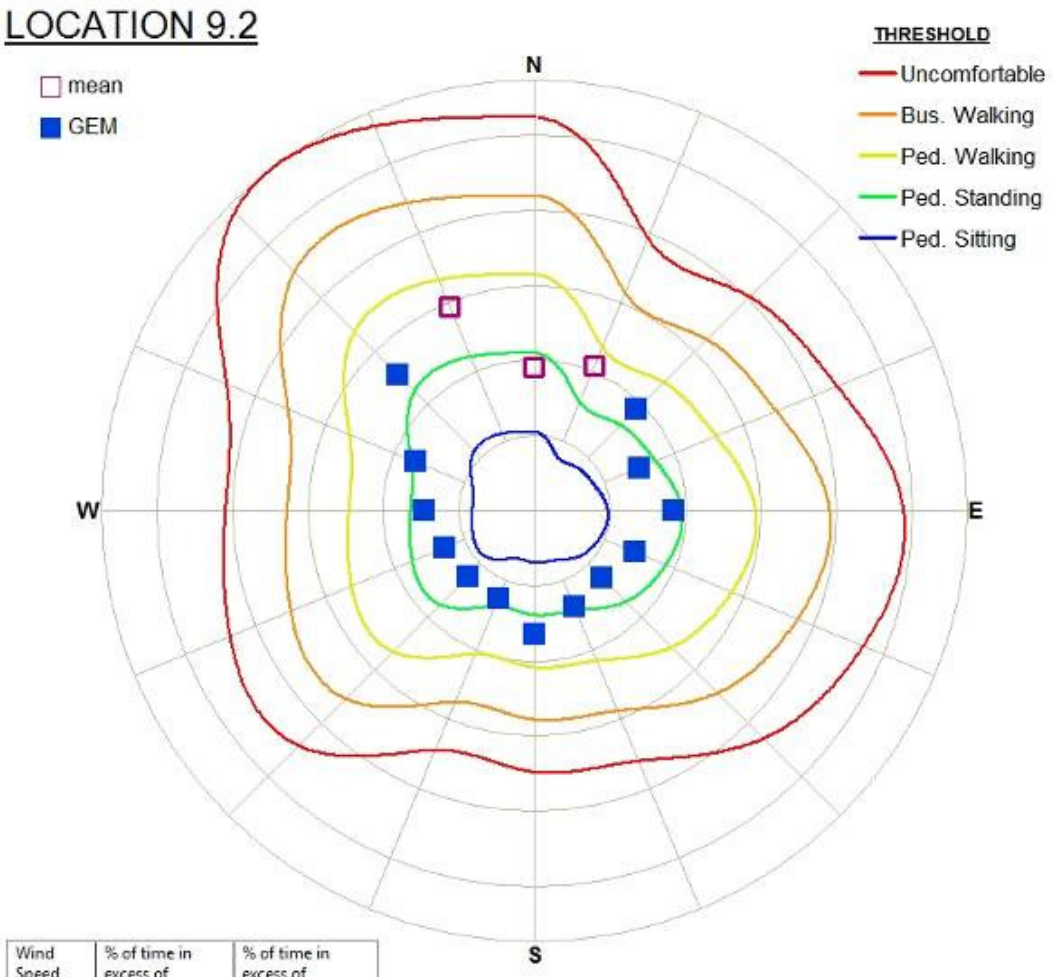
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	46.4	54.4
4.0	28.3	29.9
6.0	18.3	16.9
8.0	11.6	8.6
10.0	7.1	3.6
11.1	**5.0**	Uncomfortable
24.3	**0.022**	Fail
9.2	Bus Walking	**5.0**
19.3	Able Body	**0.022**

With Building C3



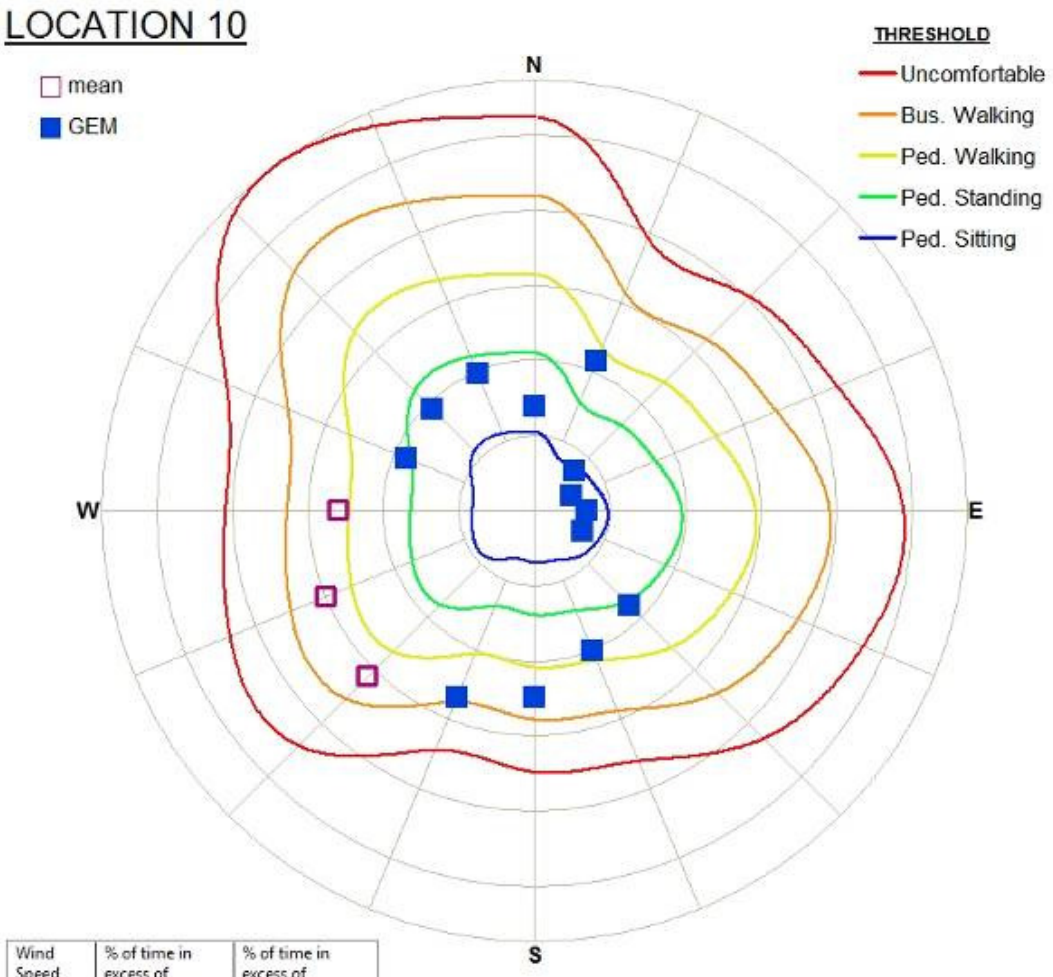
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	35.7	44.4
4.0	11.9	17.4
6.0	3.5	6.4
8.0	0.8	1.8
10.0	0.2	0.4
5.4	**5.0**	Ped Standing
13.0	**0.022**	Pass
6.3	Ped Walking	**5.0**
14.0	Pass	**0.022**

With Buildings C3 and C4



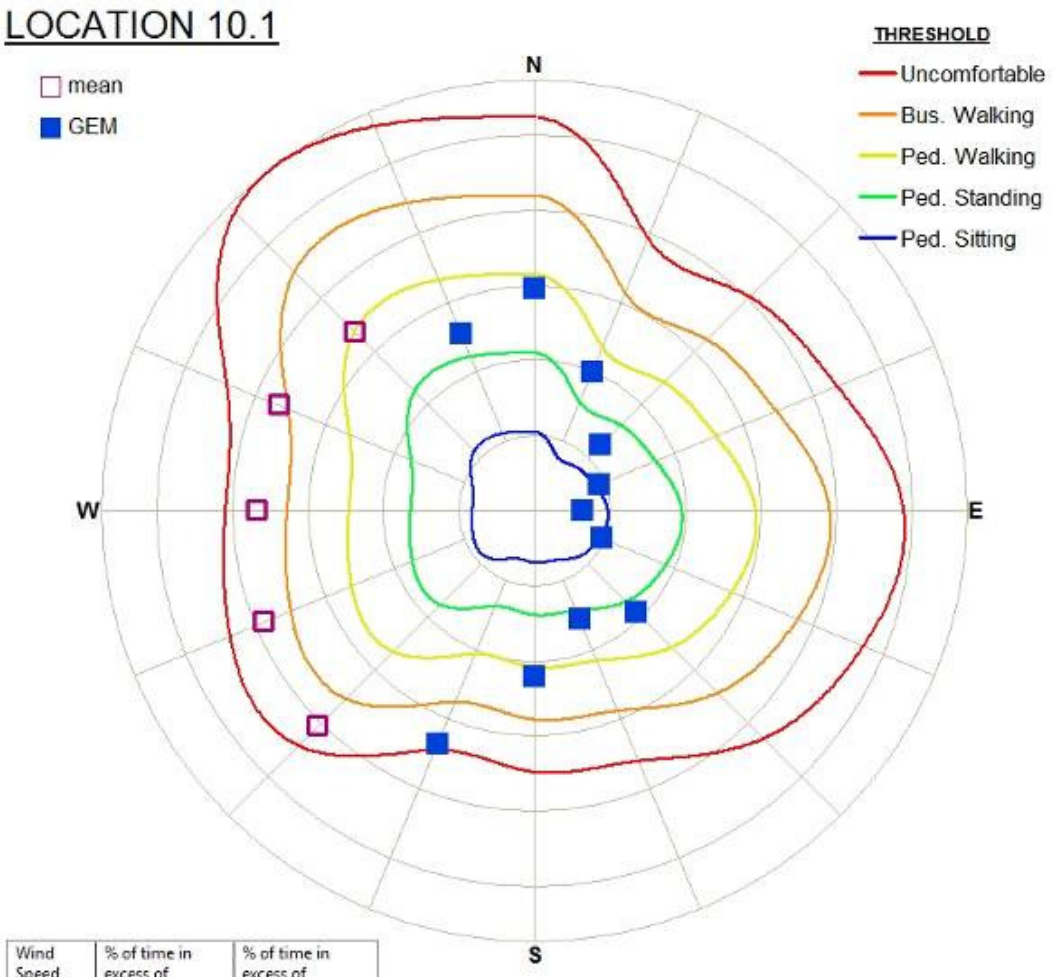
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	32.8	39.9
4.0	4.7	6.3
6.0	0.5	0.5
8.0	0.1	0.1
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
9.3	**0.022**	Pass
4.2	Ped Standing	**5.0**
8.7	Pass	**0.022**

Masterplan



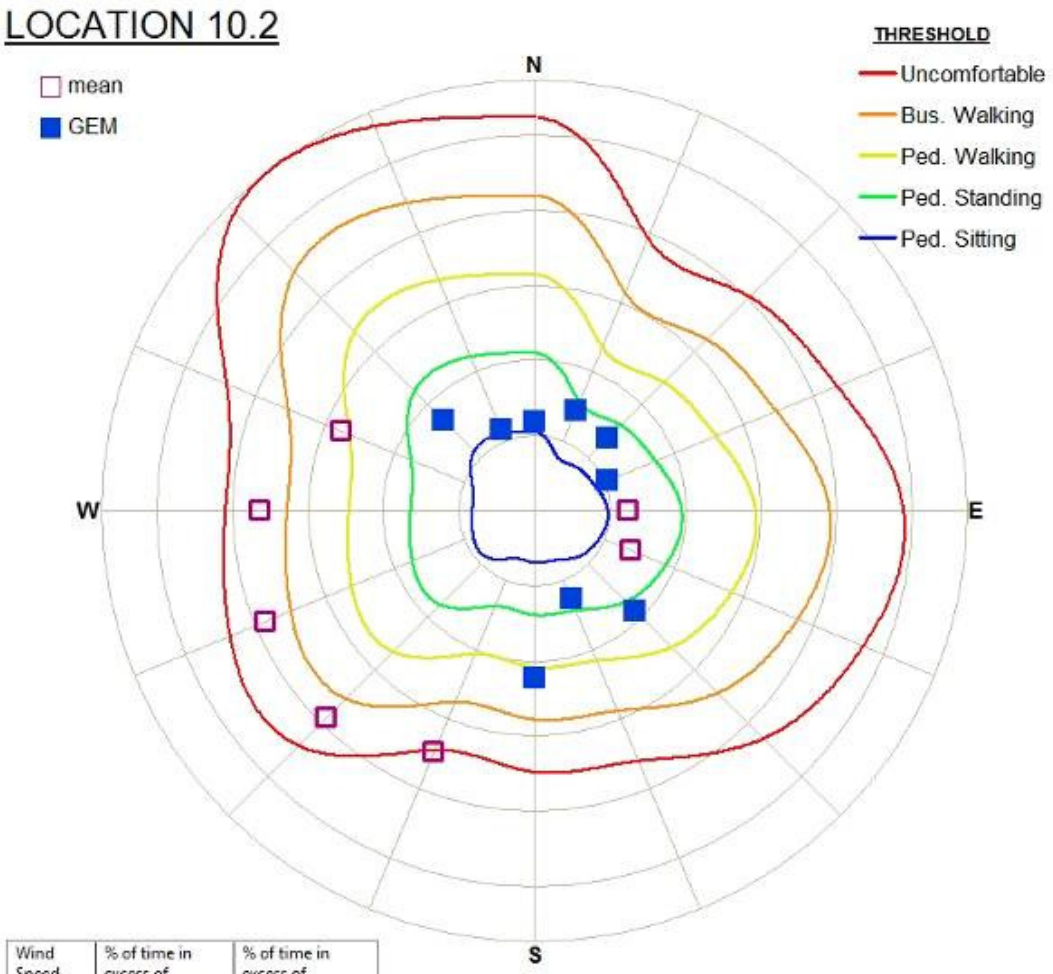
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	33.0	40.4
4.0	13.7	16.7
6.0	3.9	4.2
8.0	0.7	0.7
10.0	0.1	0.1
5.6	**5.0**	Ped Standing
11.7	**0.022**	Pass
5.7	Ped Standing	**5.0**
11.5	Pass	**0.022**

With Building C3



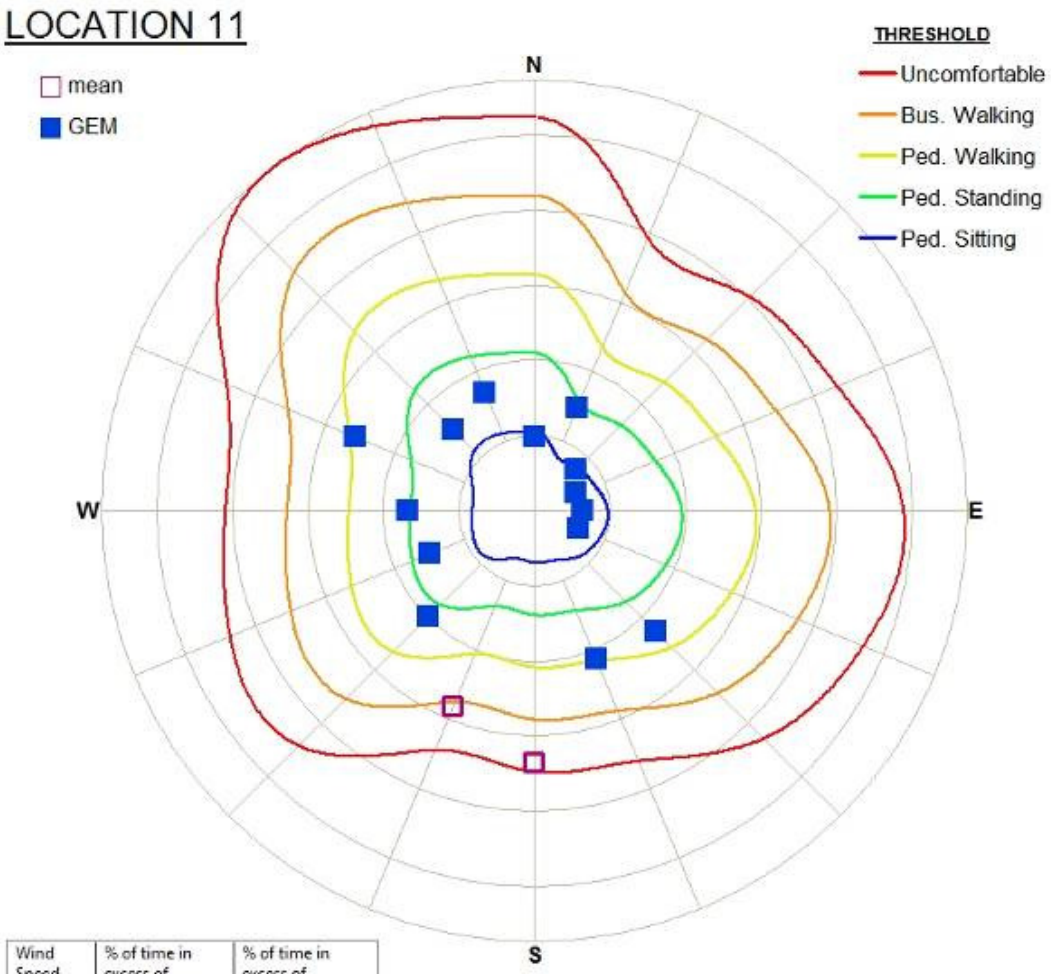
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	46.0	50.3
4.0	16.3	19.2
6.0	6.1	6.2
8.0	2.3	1.7
10.0	0.7	0.4
6.4	**5.0**	Ped Walking
14.8	**0.022**	Pass
6.3	Ped Walking	**5.0**
13.9	Pass	**0.022**

With Buildings C3 and C4



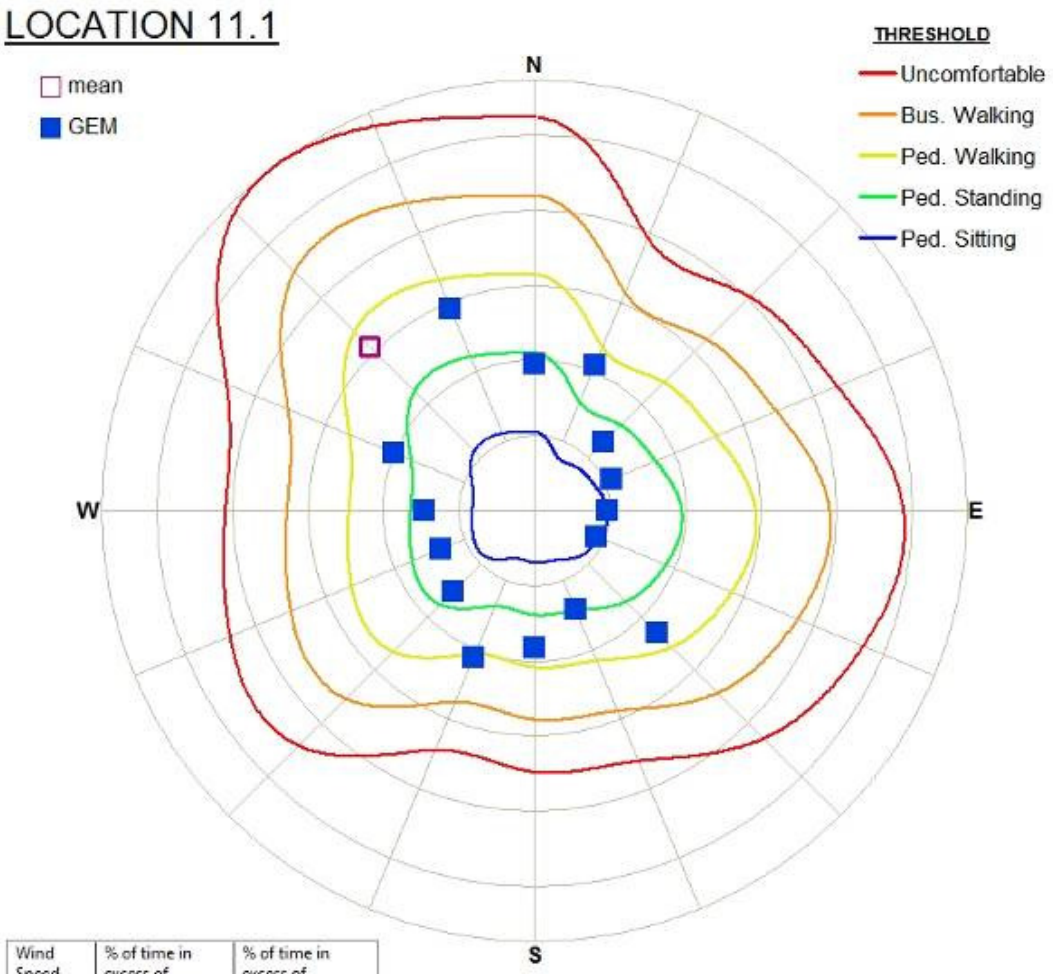
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	37.4	41.2
4.0	13.9	13.8
6.0	6.1	3.8
8.0	2.3	0.7
10.0	0.7	0.1
6.4	**5.0**	Ped Walking
15.0	**0.022**	Pass
5.6	Ped Standing	**5.0**
11.9	Pass	**0.022**

Masterplan



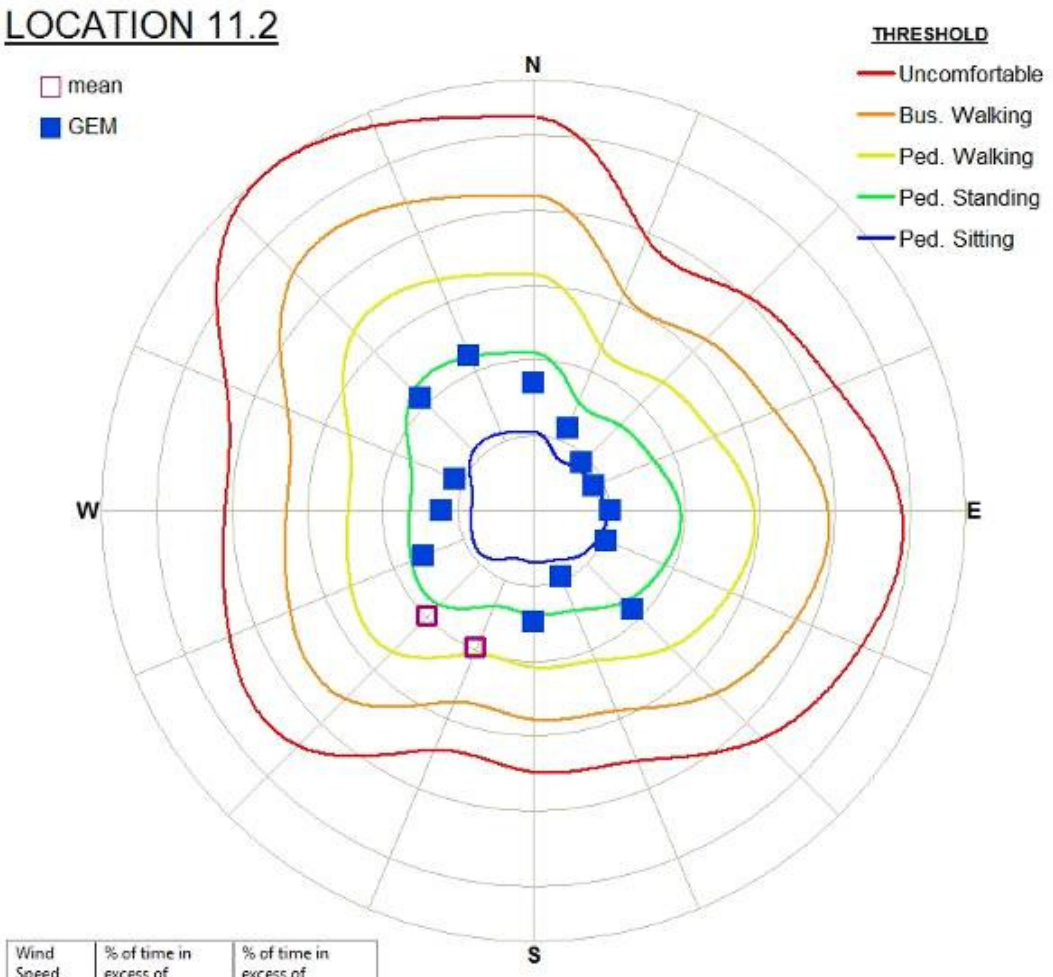
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	28.3	35.8
4.0	13.1	14.5
6.0	6.0	5.1
8.0	2.1	1.3
10.0	0.5	0.2
6.3	**5.0**	Ped Walking
13.7	**0.022**	Pass
6.0	Ped Standing	**5.0**
12.7	Pass	**0.022**

With Building C3



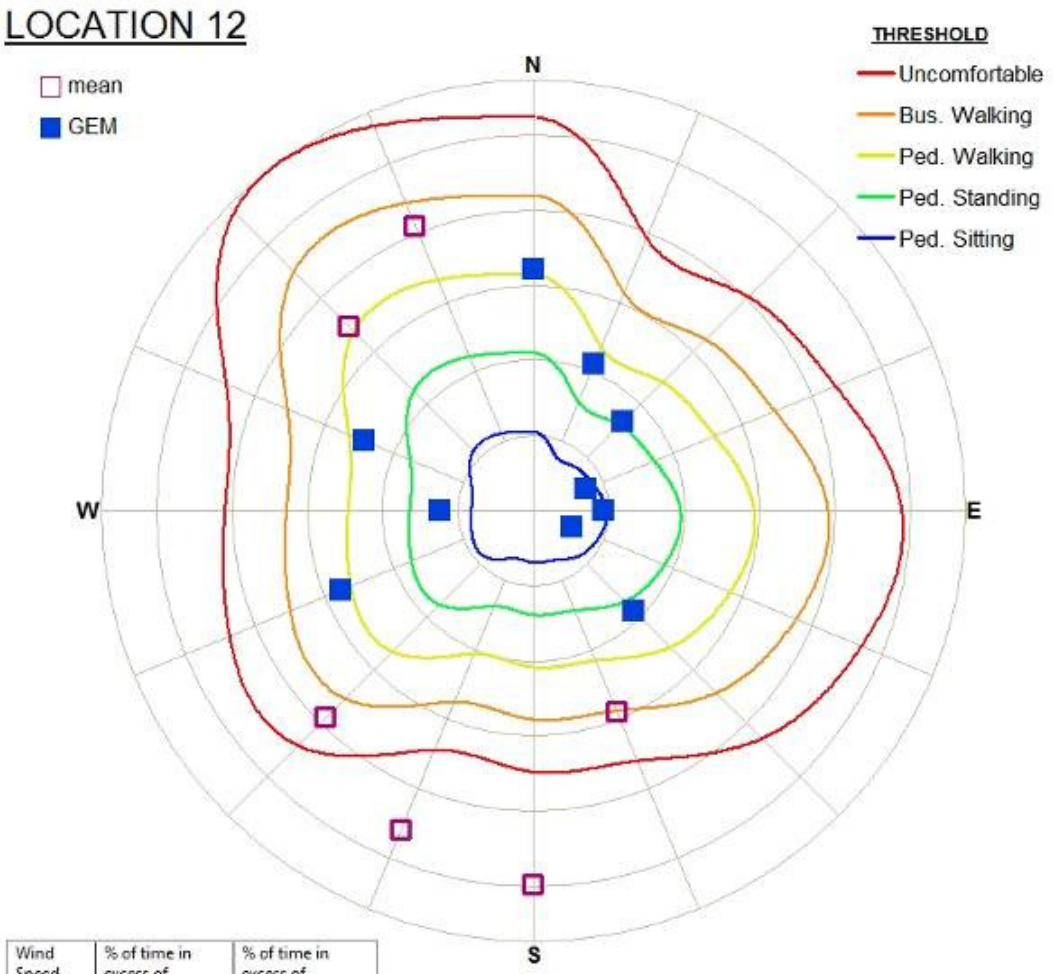
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	30.5	40.8
4.0	4.8	9.2
6.0	0.7	1.2
8.0	0.1	0.2
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
10.2	**0.022**	Pass
4.6	Ped Standing	**5.0**
9.9	Pass	**0.022**

With Buildings C3 and C4



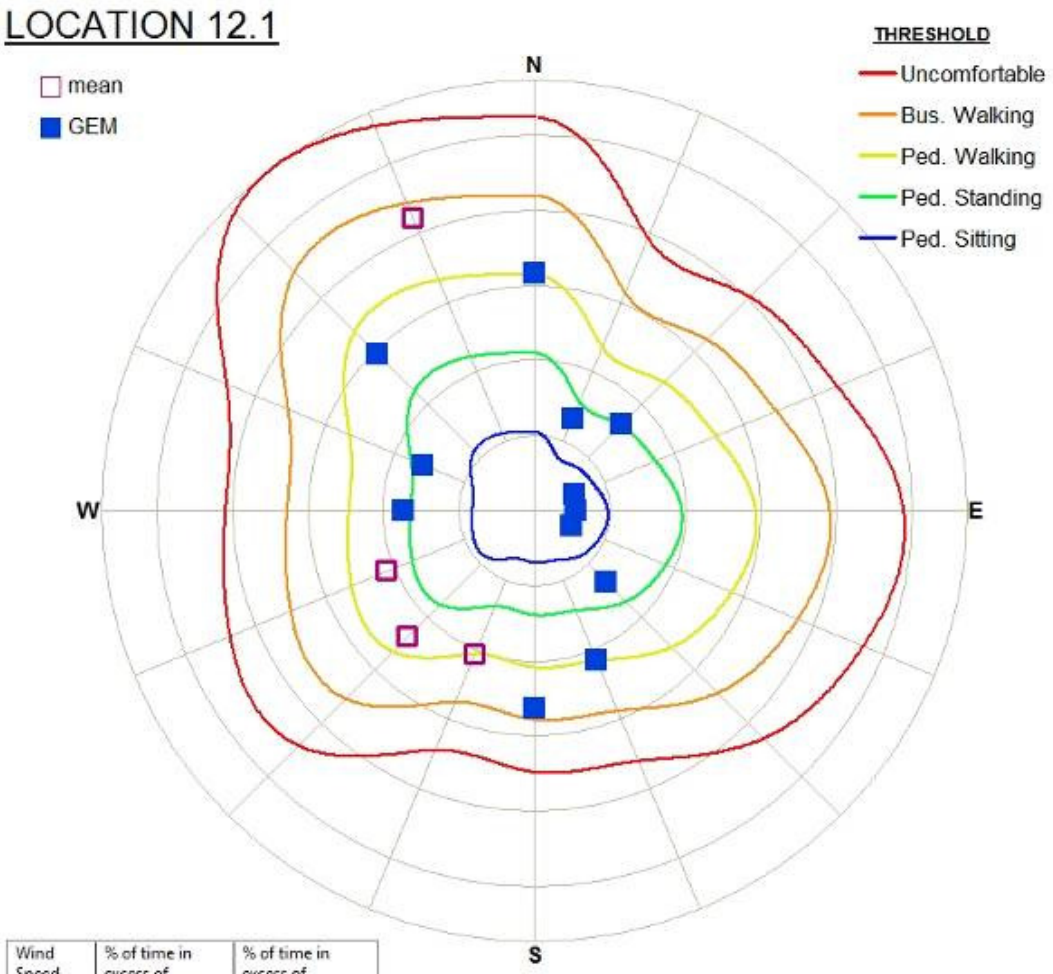
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	20.7	29.0
4.0	2.7	3.5
6.0	0.3	0.3
8.0	0.0	0.0
10.0	0.0	0.0
3.4	**5.0**	Ped Sitting
8.3	**0.022**	Pass
3.7	Ped Sitting	**5.0**
8.1	Pass	**0.022**

Masterplan



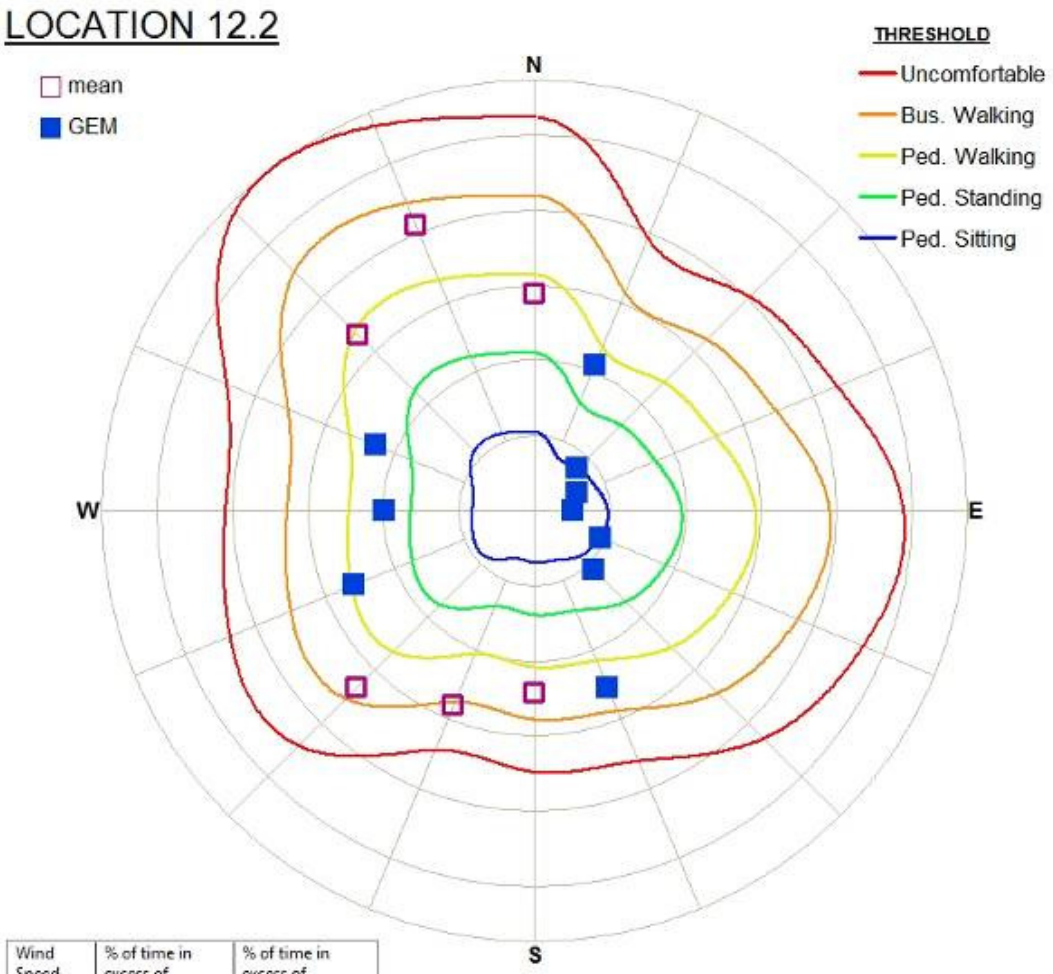
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	43.1	51.7
4.0	22.6	24.5
6.0	13.9	11.7
8.0	8.6	4.9
10.0	4.7	1.7
9.6	**5.0**	Bus Walking
21.1	**0.022**	Fail
7.9	Ped Walking	**5.0**
16.8	Able Body	**0.022**

With Building C3



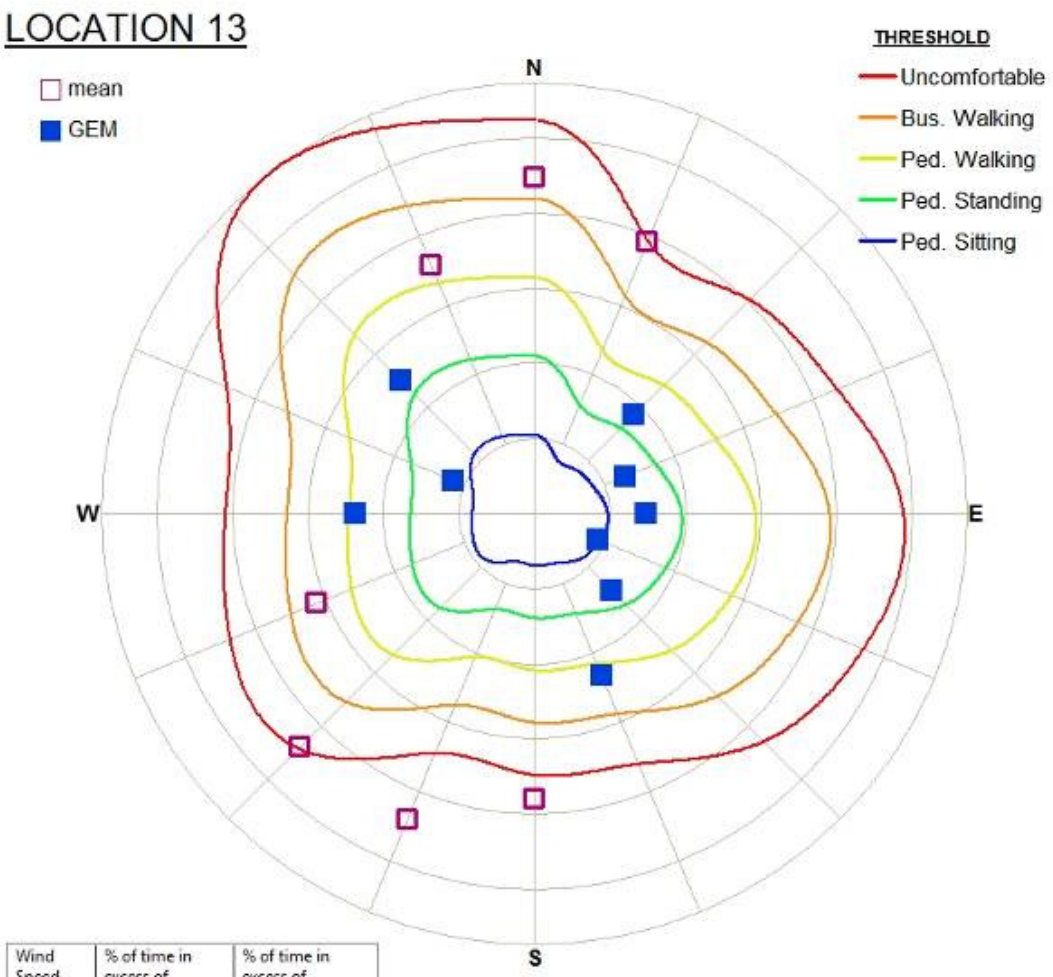
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	36.2	44.8
4.0	12.5	15.1
6.0	2.7	3.9
8.0	0.5	0.7
10.0	0.1	0.1
5.2	**5.0**	Ped Standing
12.6	**0.022**	Pass
5.6	Ped Standing	**5.0**
12.0	Pass	**0.022**

With Buildings C3 and C4



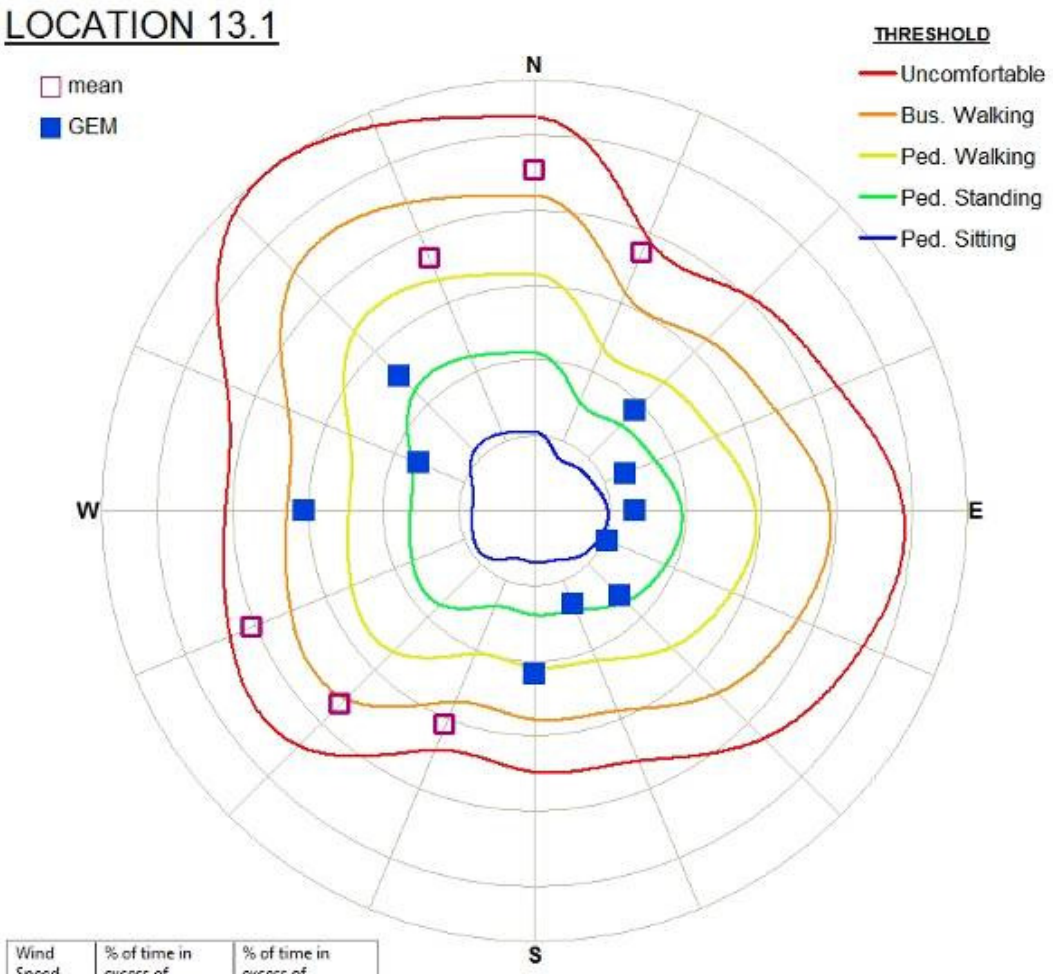
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	41.9	45.2
4.0	17.2	17.8
6.0	5.0	4.4
8.0	1.1	0.7
10.0	0.2	0.1
5.9	**5.0**	Ped Standing
13.3	**0.022**	Pass
5.8	Ped Standing	**5.0**
11.8	Pass	**0.022**

Masterplan



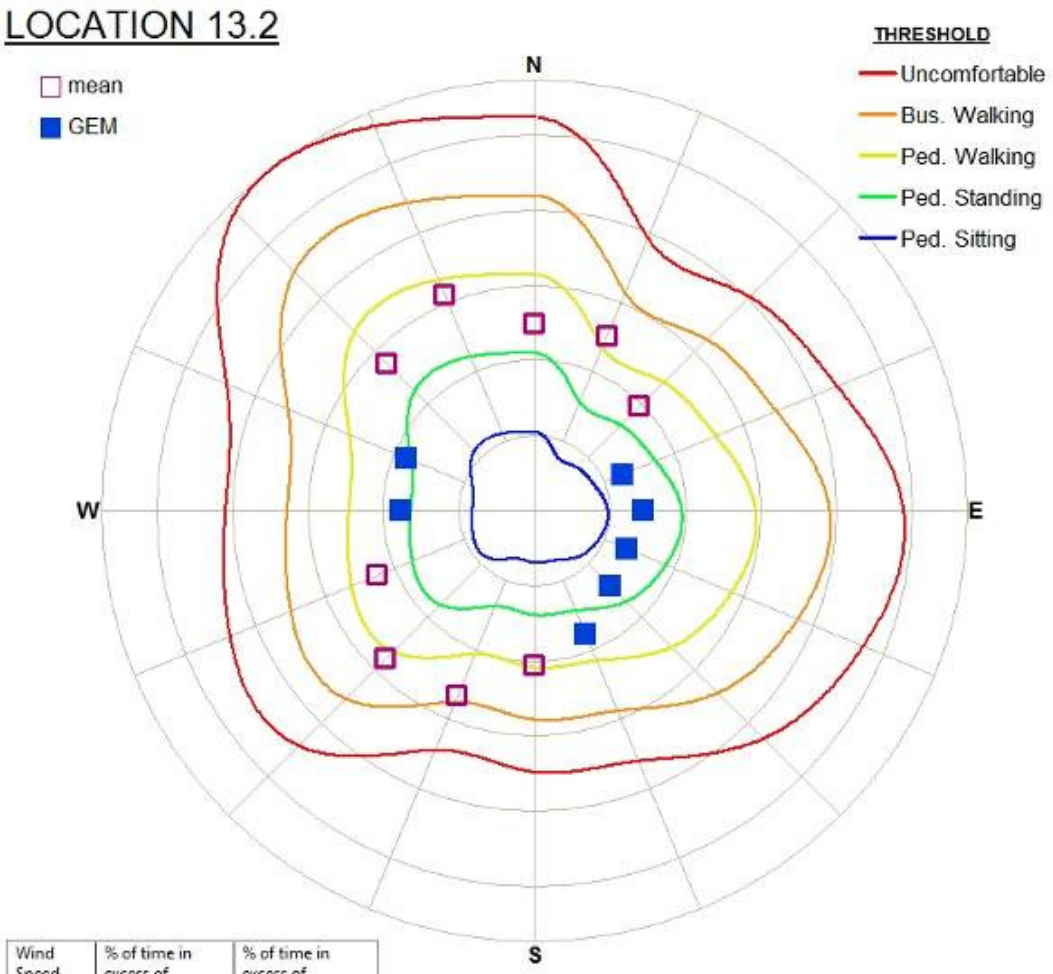
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	48.9	53.2
4.0	25.7	24.8
6.0	14.2	11.0
8.0	6.8	3.5
10.0	2.5	0.9
8.6	**5.0**	Bus Walking
18.2	**0.022**	Able Body
7.4	Ped Walking	**5.0**
15.2	Able Body	**0.022**

With Building C3



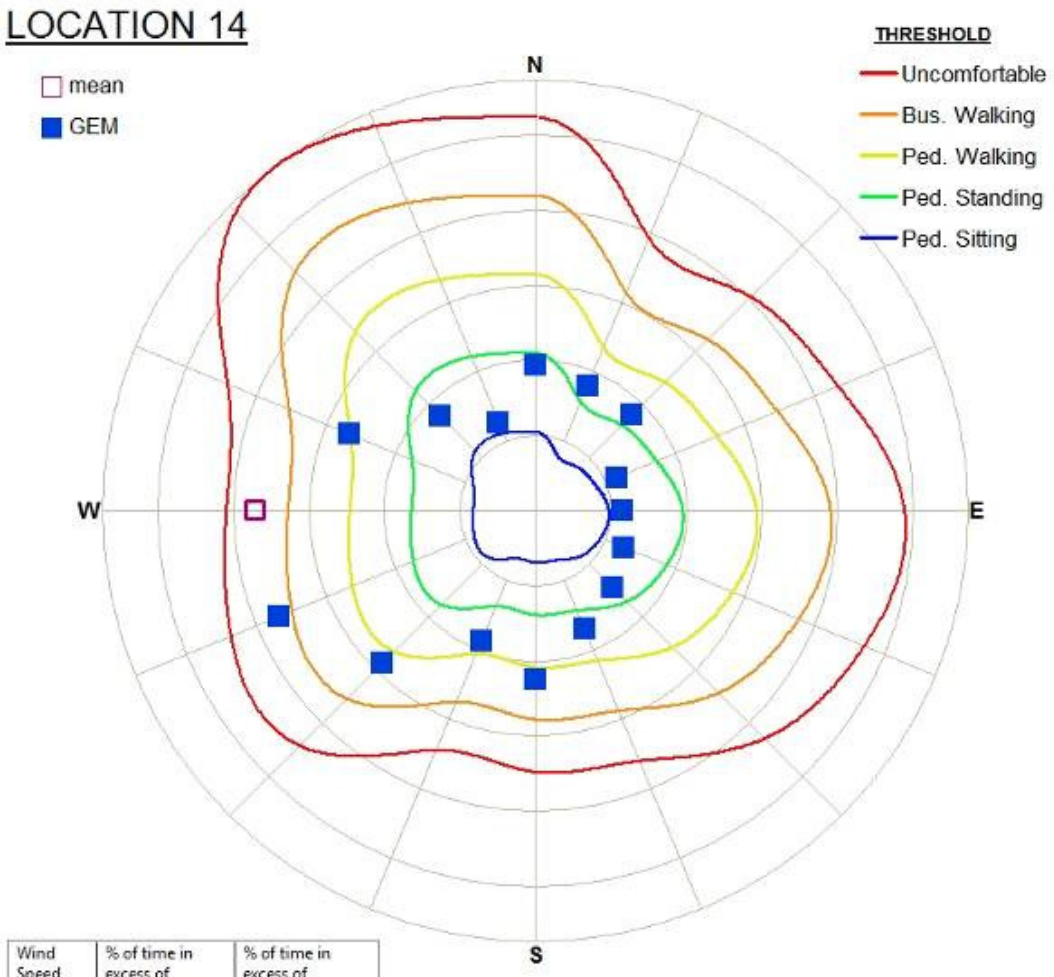
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	46.3	52.1
4.0	19.4	20.4
6.0	8.2	6.5
8.0	2.9	1.5
10.0	0.8	0.2
7.0	**5.0**	Ped Walking
14.3	**0.022**	Pass
6.3	Ped Walking	**5.0**
12.6	Pass	**0.022**

With Buildings C3 and C4



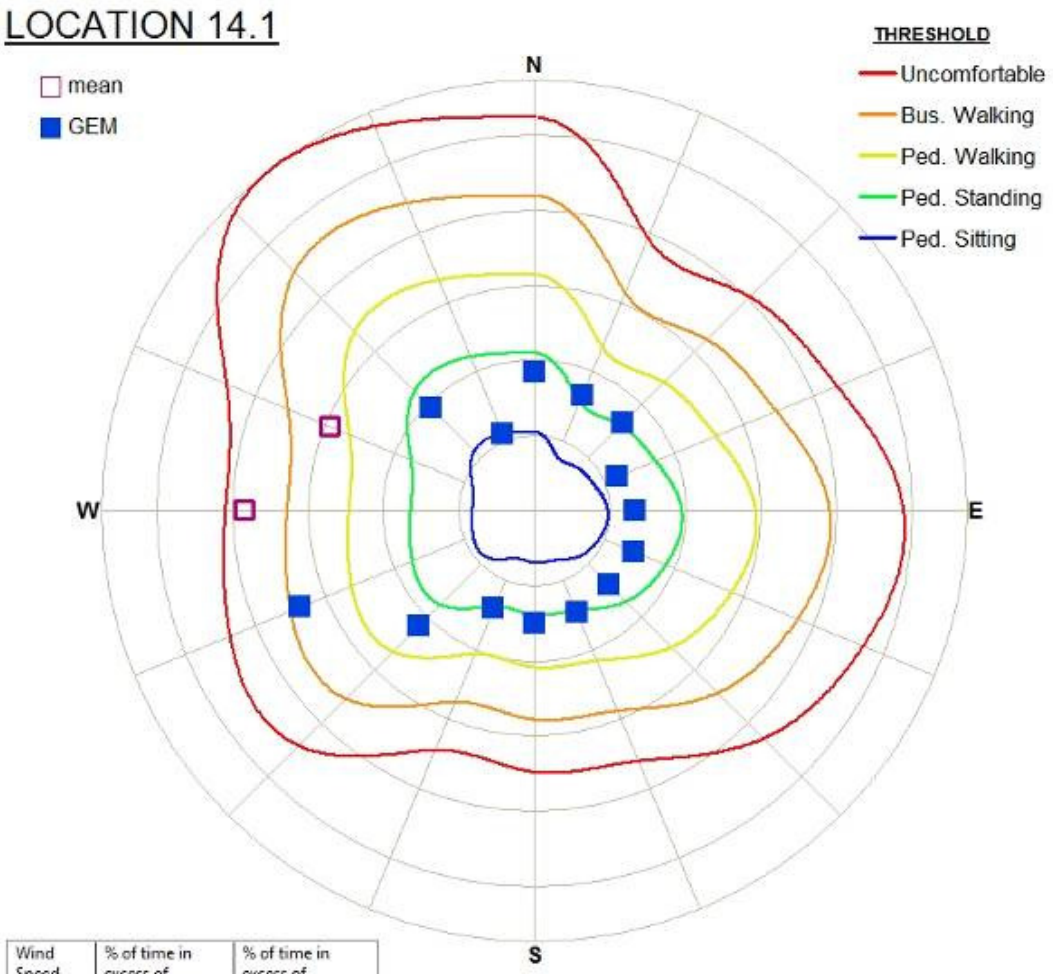
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	44.3	46.7
4.0	14.1	12.8
6.0	2.8	1.8
8.0	0.4	0.2
10.0	0.1	0.0
5.3	**5.0**	Ped Standing
11.3	**0.022**	Pass
5.0	Ped Standing	**5.0**
9.9	Pass	**0.022**

Masterplan



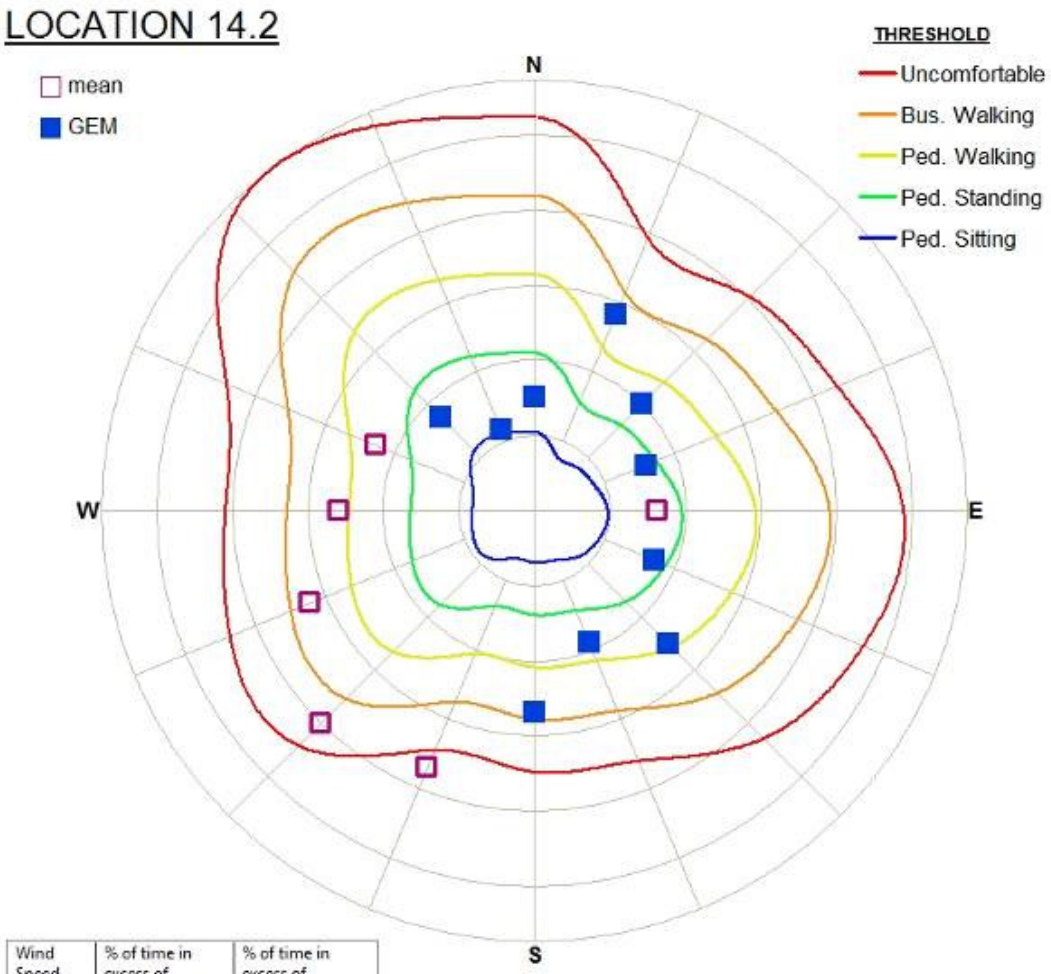
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	37.8	45.7
4.0	10.3	15.7
6.0	3.0	4.3
8.0	1.0	1.1
10.0	0.3	0.2
5.0	**5.0**	Ped Standing
13.3	**0.022**	Pass
5.7	Ped Standing	**5.0**
12.7	Pass	**0.022**

With Building C3



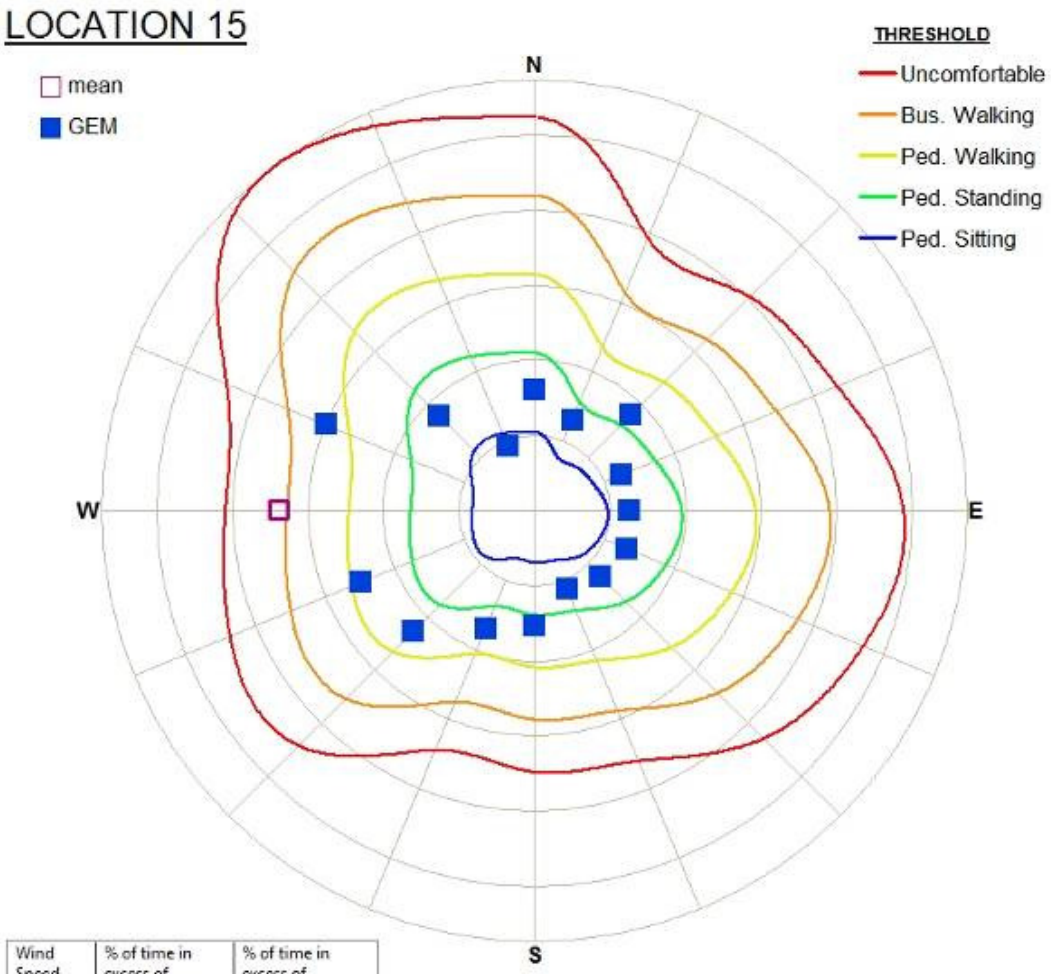
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	31.1	41.8
4.0	7.1	9.5
6.0	3.0	2.7
8.0	1.1	0.7
10.0	0.4	0.2
4.7	**5.0**	Ped Standing
13.8	**0.022**	Pass
4.9	Ped Standing	**5.0**
12.1	Pass	**0.022**

With Buildings C3 and C4



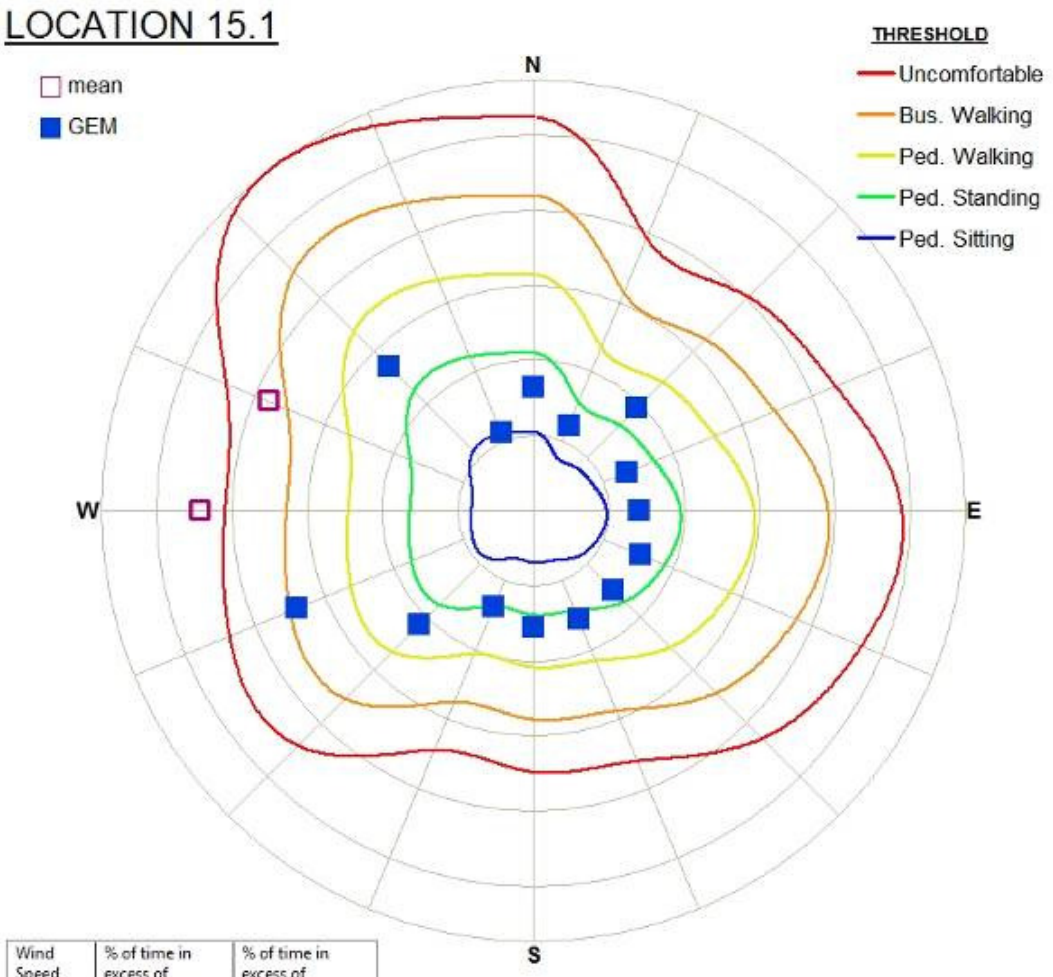
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	47.1	48.9
4.0	20.1	20.3
6.0	6.9	6.0
8.0	1.9	1.2
10.0	0.5	0.2
6.5	**5.0**	Ped Walking
15.2	**0.022**	Able Body
6.2	Ped Walking	**5.0**
12.7	Pass	**0.022**

Masterplan



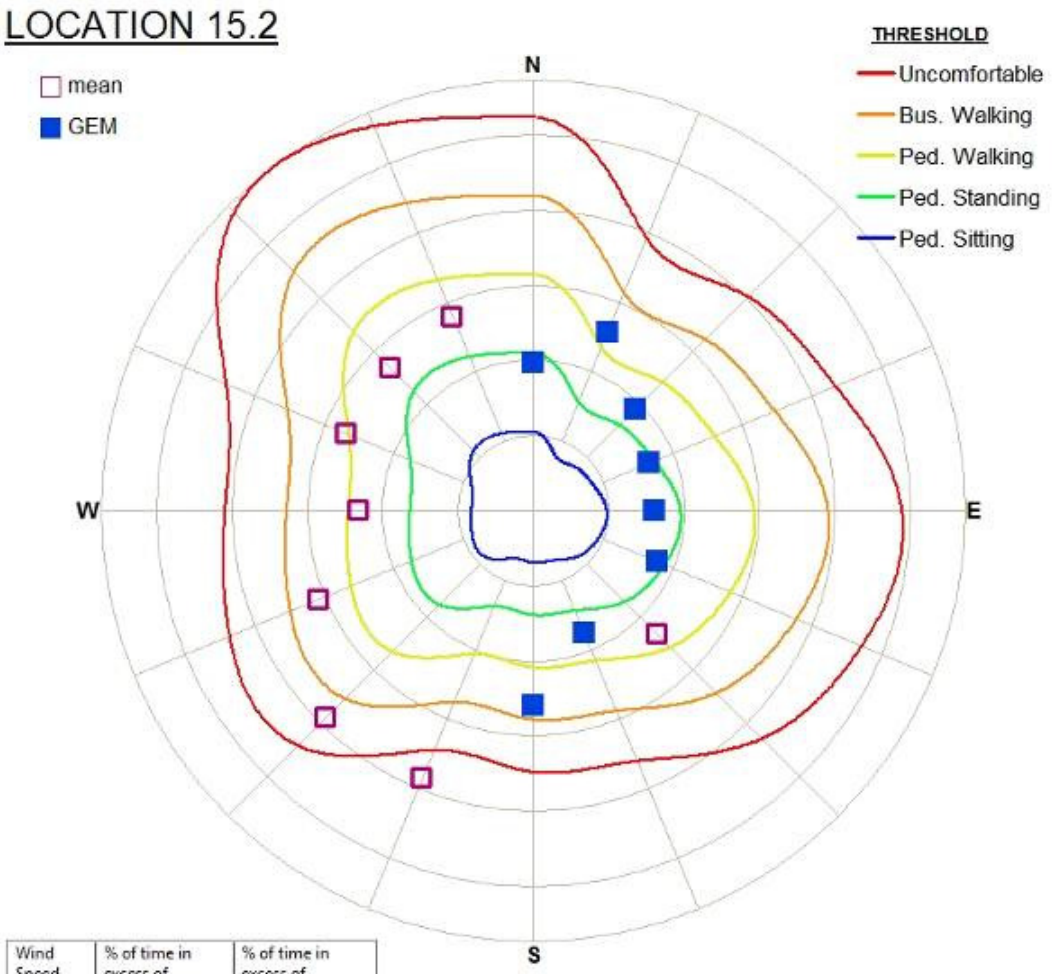
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	26.1	38.5
4.0	5.2	8.2
6.0	2.0	1.7
8.0	0.7	0.4
10.0	0.2	0.1
4.0	**5.0**	Ped Sitting
12.1	**0.022**	Pass
4.5	Ped Standing	**5.0**
11.3	Pass	**0.022**

With Building C3



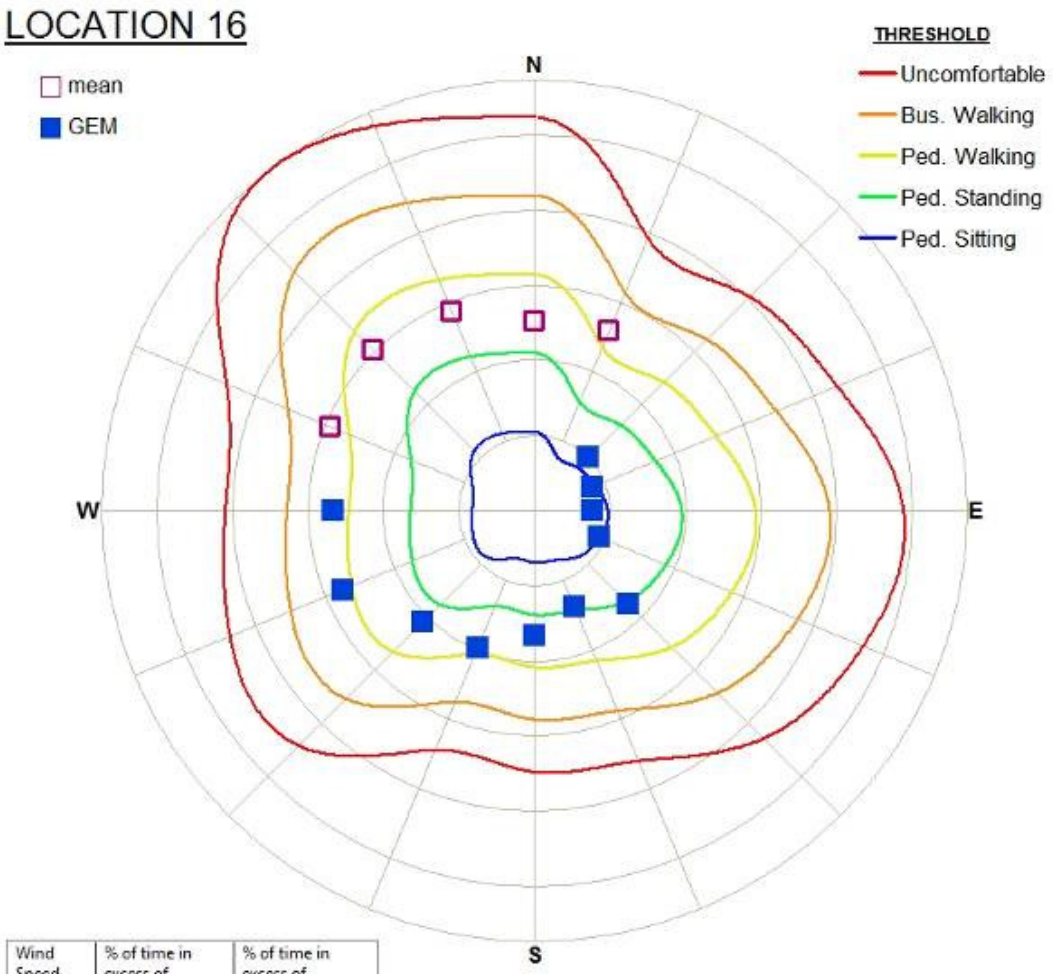
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	31.9	44.7
4.0	8.4	11.5
6.0	3.9	3.7
8.0	1.9	1.3
10.0	0.8	0.4
5.2	**5.0**	Ped Standing
16.1	**0.022**	Able Body
5.3	Ped Standing	**5.0**
14.0	Pass	**0.022**

With Buildings C3 and C4



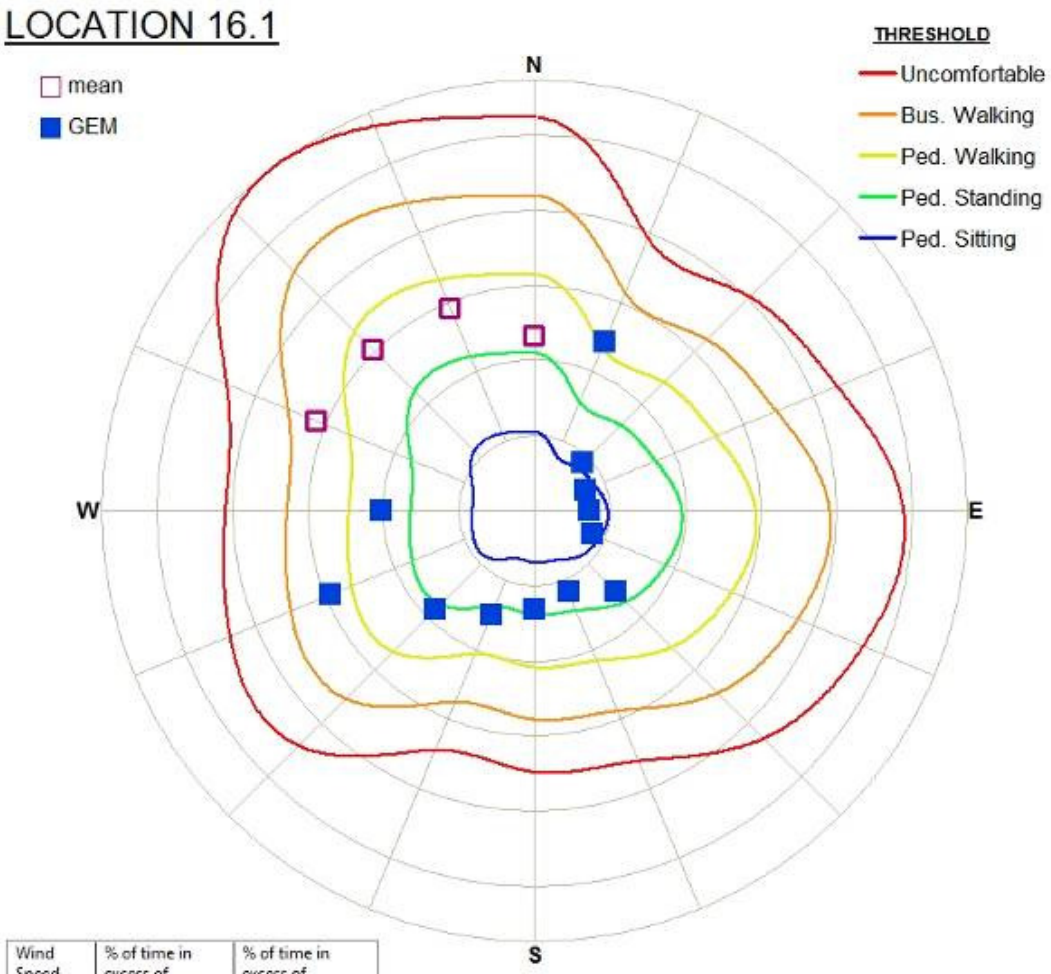
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	51.0	52.2
4.0	18.2	19.7
6.0	5.7	5.8
8.0	1.8	1.3
10.0	0.6	0.3
6.1	**5.0**	Ped Walking
15.6	**0.022**	Able Body
6.2	Ped Walking	**5.0**
13.7	Pass	**0.022**

Masterplan



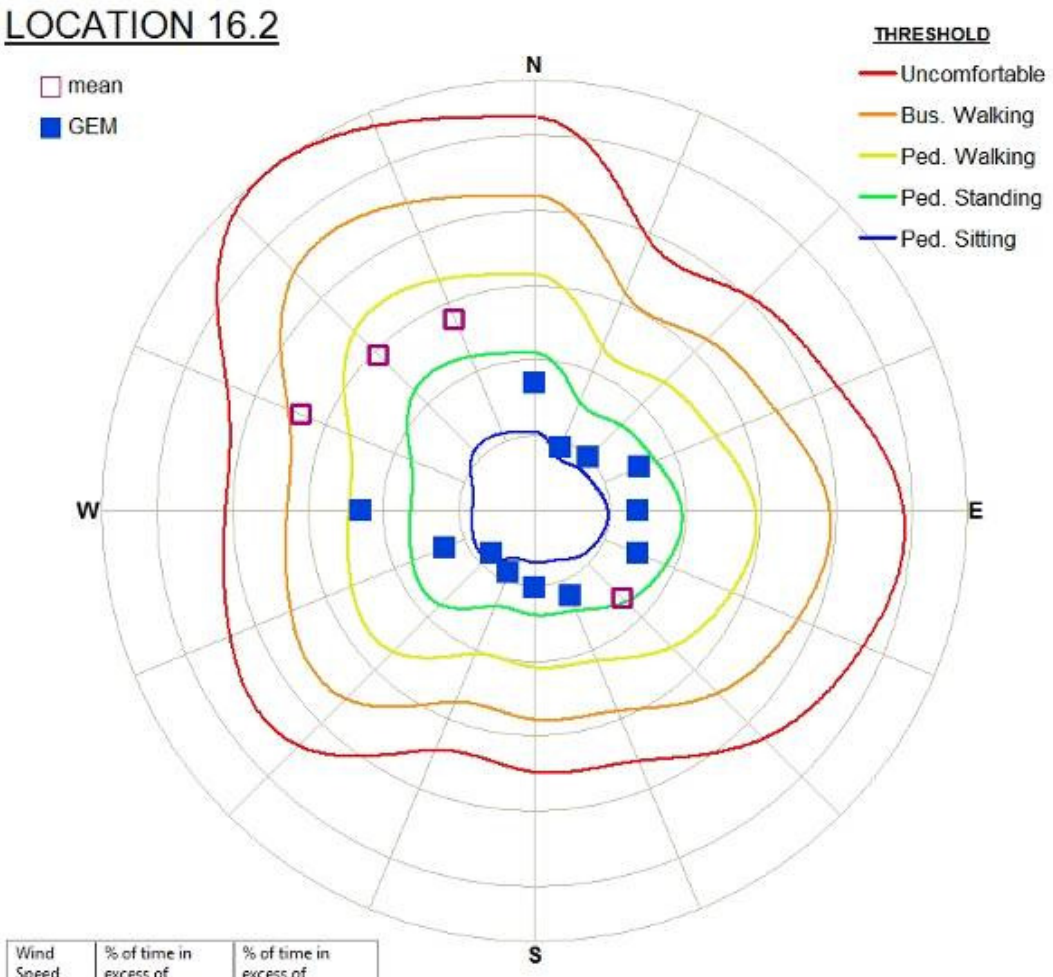
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	35.5	43.7
4.0	8.3	12.1
6.0	2.0	2.4
8.0	0.4	0.4
10.0	0.1	0.1
4.7	**5.0**	Ped Standing
11.4	**0.022**	Pass
5.1	Ped Standing	**5.0**
10.7	Pass	**0.022**

With Building C3



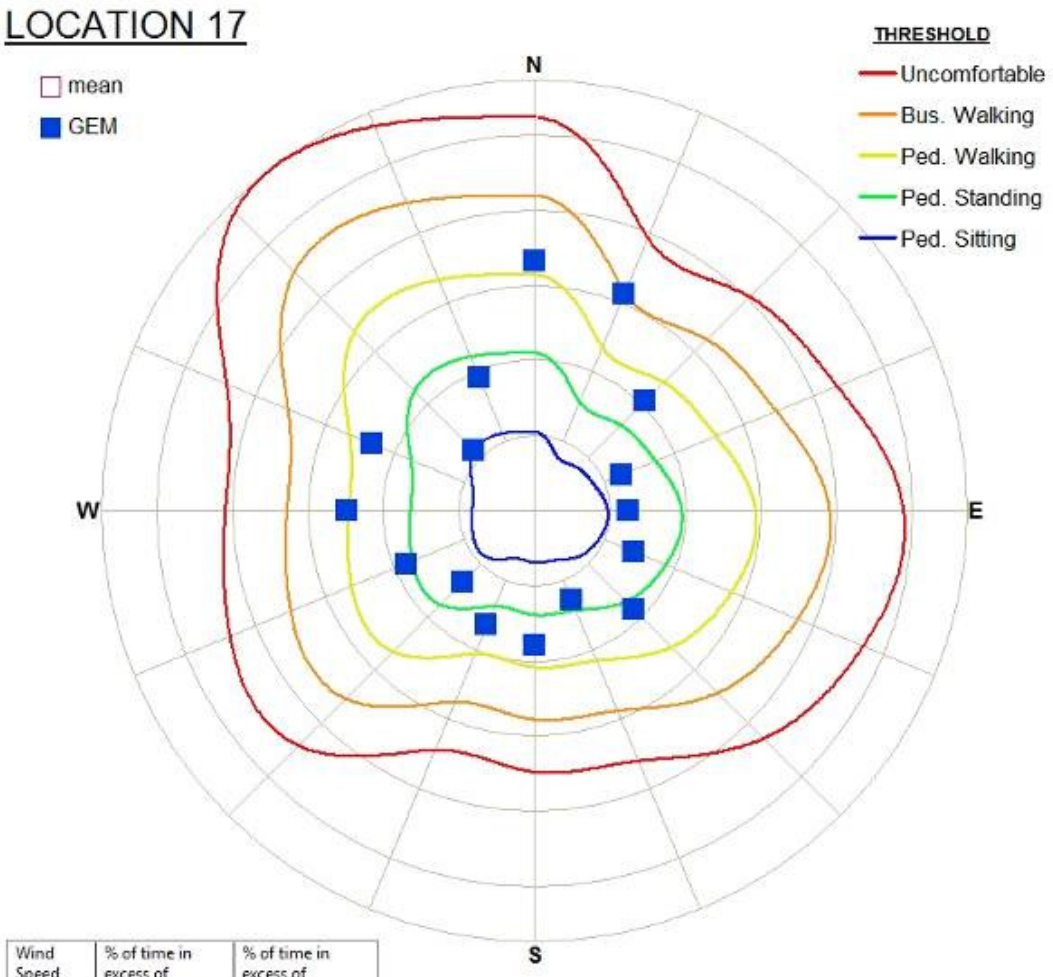
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	28.6	38.5
4.0	6.5	8.7
6.0	1.5	1.8
8.0	0.4	0.3
10.0	0.1	0.0
4.3	**5.0**	Ped Standing
11.8	**0.022**	Pass
4.7	Ped Standing	**5.0**
11.0	Pass	**0.022**

With Buildings C3 and C4



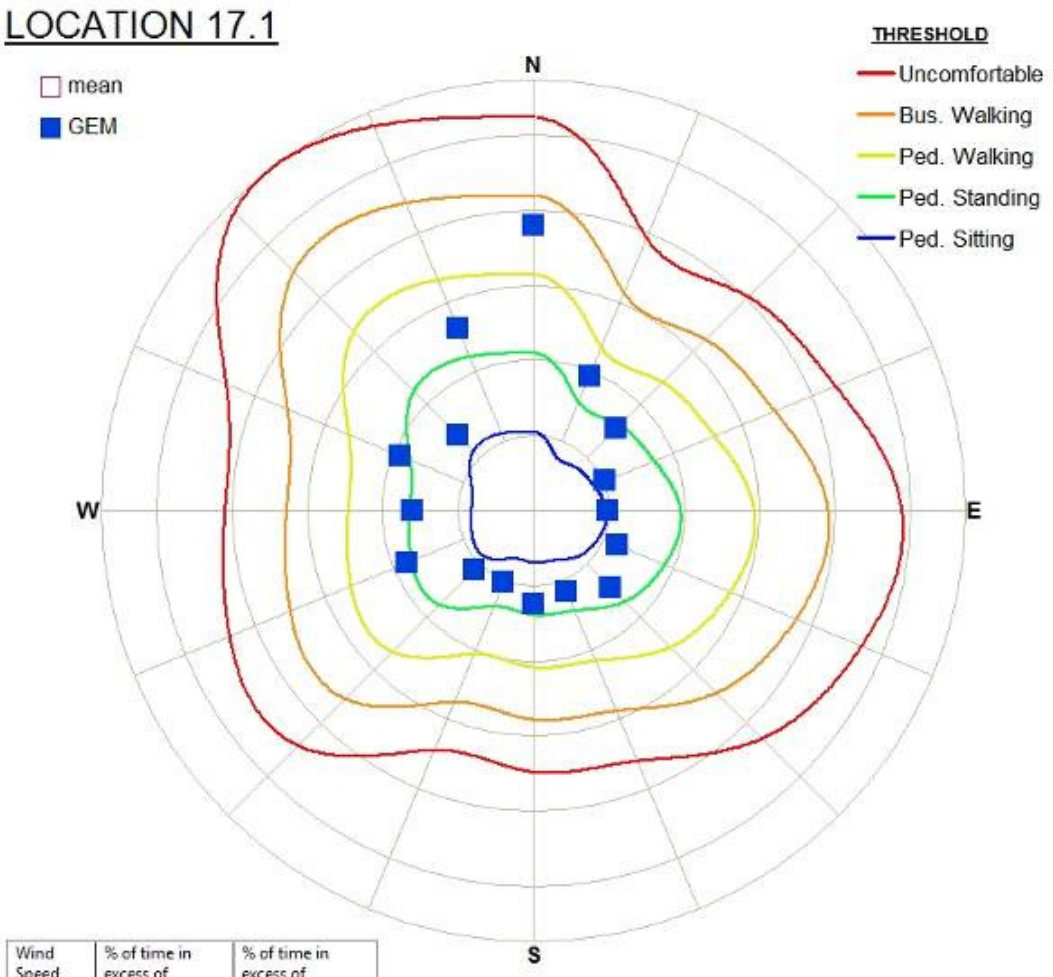
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	23.8	30.5
4.0	4.6	4.2
6.0	1.4	1.0
8.0	0.4	0.2
10.0	0.1	0.0
3.8	**5.0**	Ped Sitting
12.2	**0.022**	Pass
3.7	Ped Sitting	**5.0**
10.5	Pass	**0.022**

Masterplan



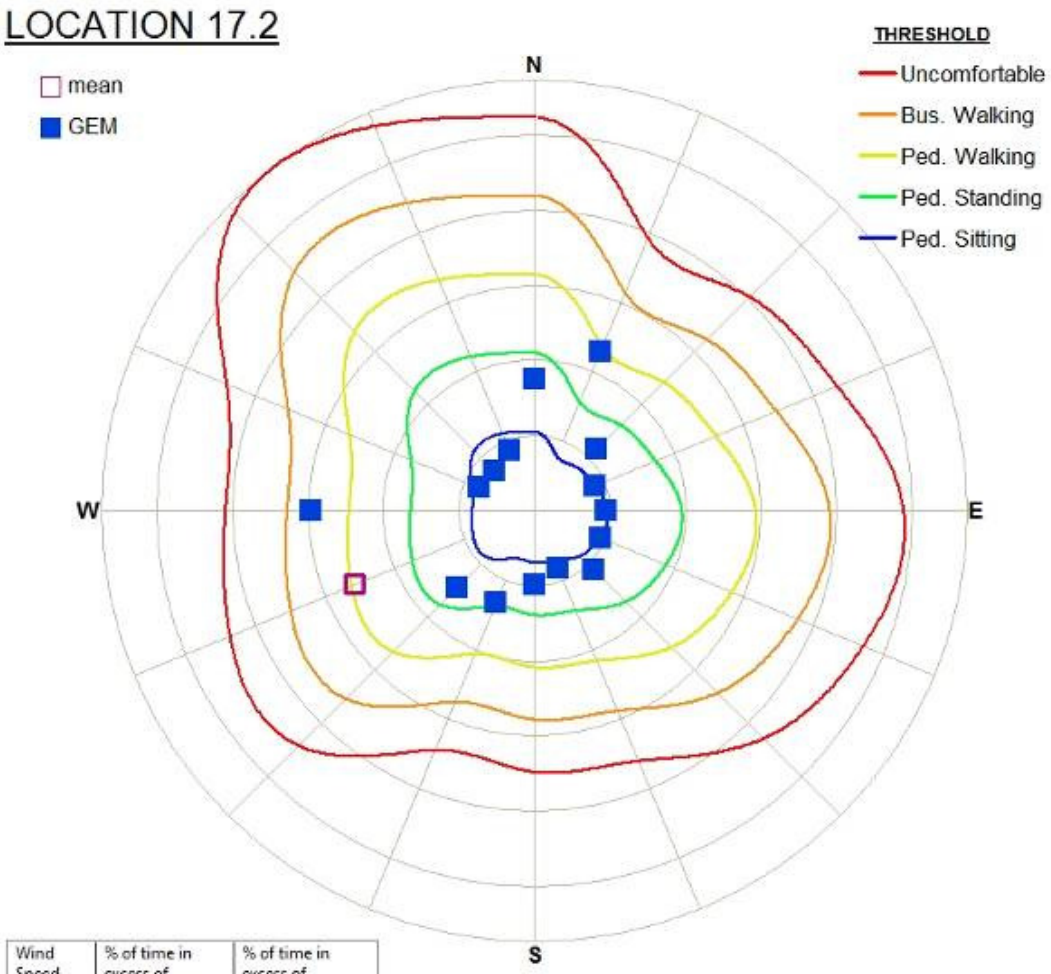
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	32.0	44.4
4.0	4.8	12.8
6.0	0.3	2.9
8.0	0.0	0.5
10.0	0.0	0.0
3.9	**5.0**	Ped Sitting
7.6	**0.022**	Pass
5.2	Ped Standing	**5.0**
10.5	Pass	**0.022**

With Building C3



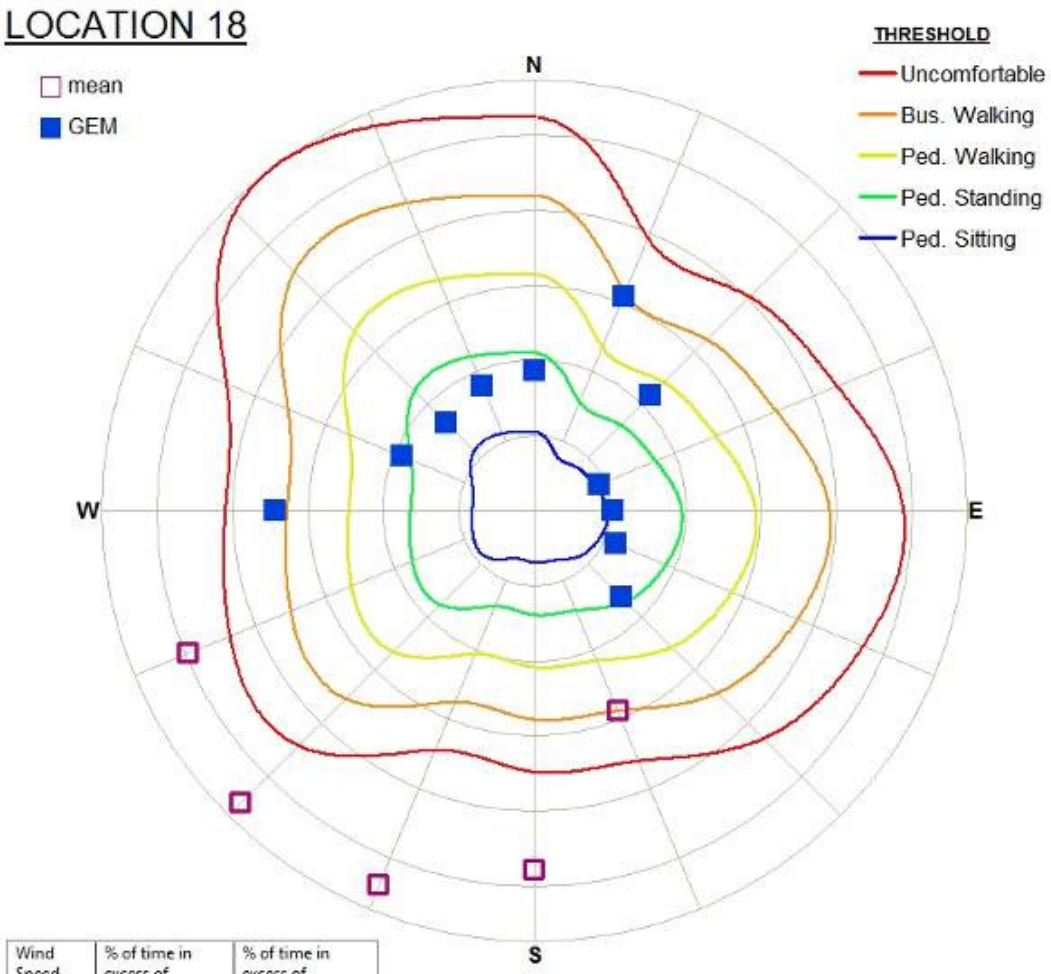
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	20.8	34.9
4.0	2.3	5.5
6.0	0.5	1.0
8.0	0.1	0.2
10.0	0.0	0.0
3.2	**5.0**	Ped Sitting
9.3	**0.022**	Pass
4.1	Ped Standing	**5.0**
10.4	Pass	**0.022**

With Buildings C3 and C4



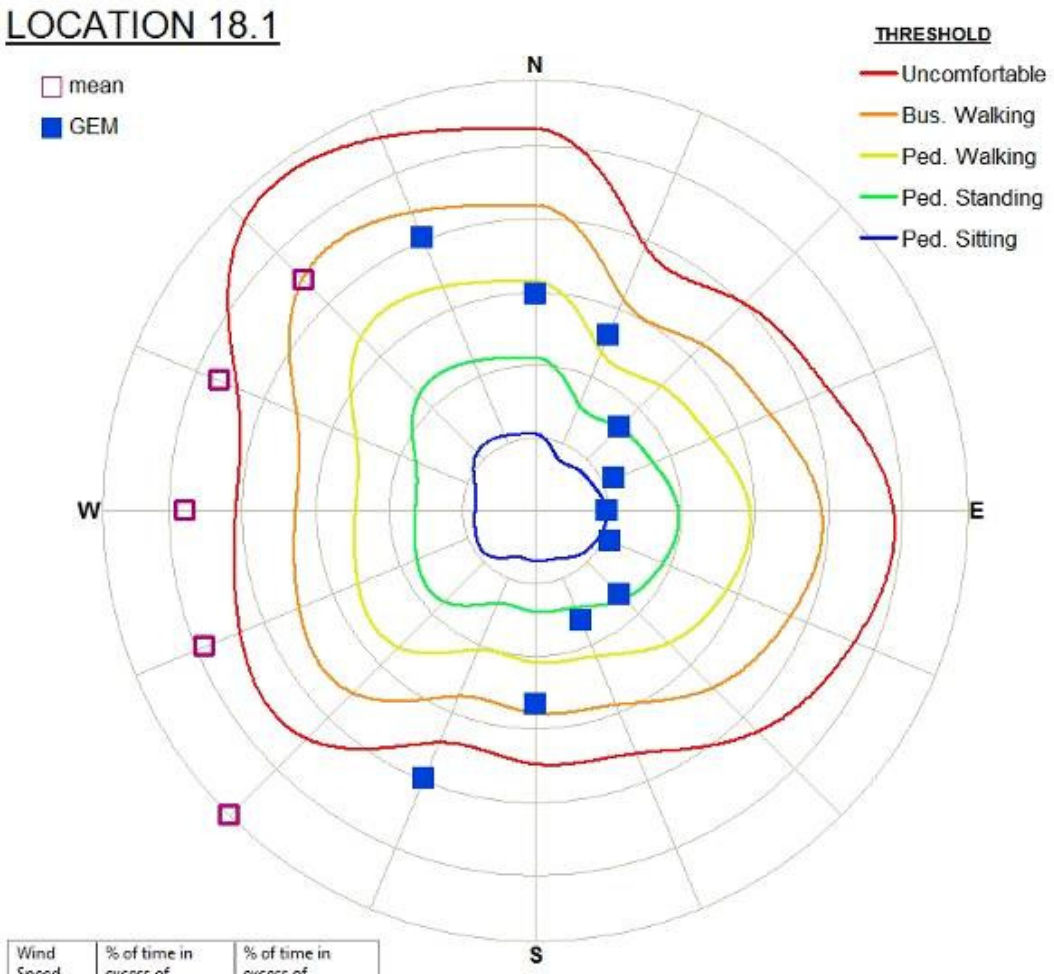
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	15.4	25.6
4.0	3.8	6.1
6.0	0.6	1.5
8.0	0.1	0.3
10.0	0.0	0.0
3.6	**5.0**	Ped Sitting
8.7	**0.022**	Pass
4.2	Ped Standing	**5.0**
10.6	Pass	**0.022**

Masterplan



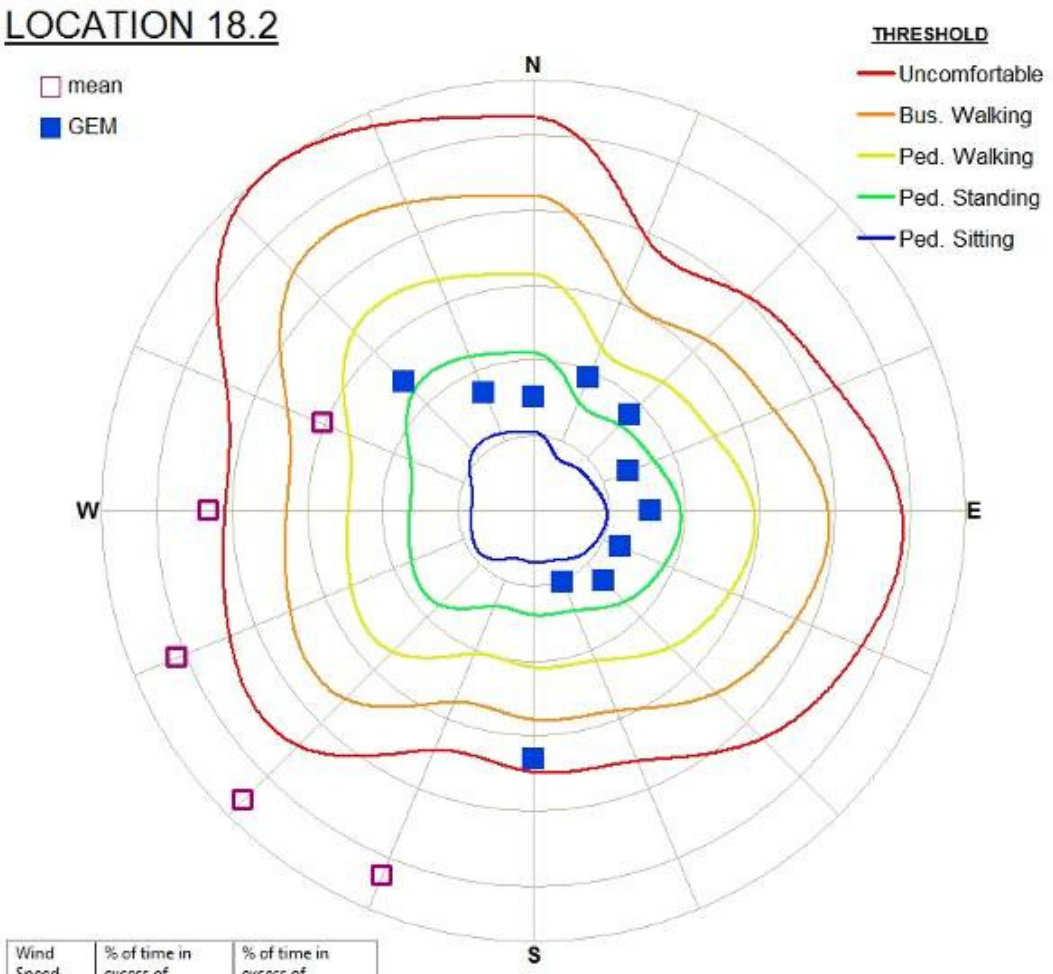
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	44.4	50.5
4.0	26.9	28.0
6.0	16.8	14.9
8.0	10.4	6.5
10.0	5.6	2.2
10.2	**5.0**	Uncomfortable
22.4	**0.022**	Fail
8.4	Bus Walking	**5.0**
17.4	Able Body	**0.022**

With Building C3



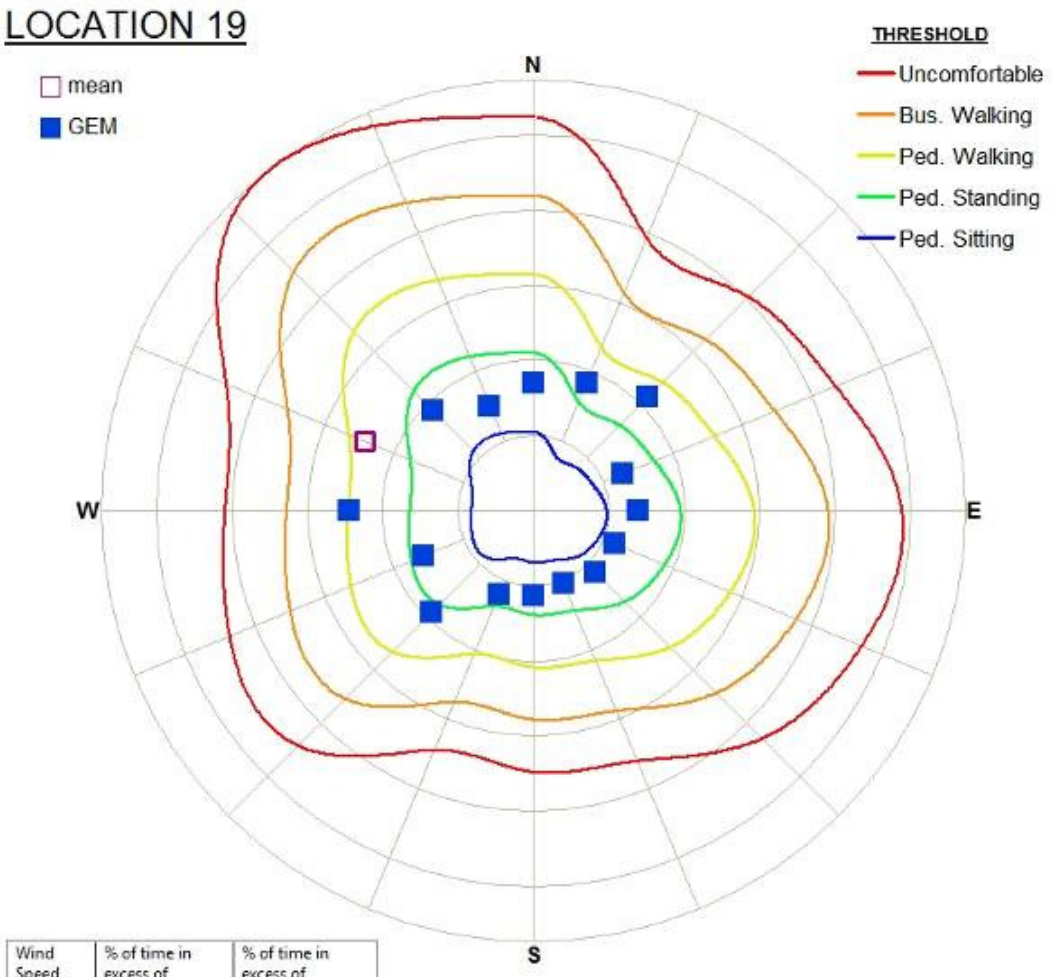
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	53.1	58.0
4.0	24.5	27.7
6.0	10.7	12.2
8.0	5.4	5.0
10.0	2.6	1.8
8.1	**5.0**	Bus Walking
19.8	**0.022**	Able Body
7.9	Ped Walking	**5.0**
17.4	Able Body	**0.022**

With Buildings C3 and C4



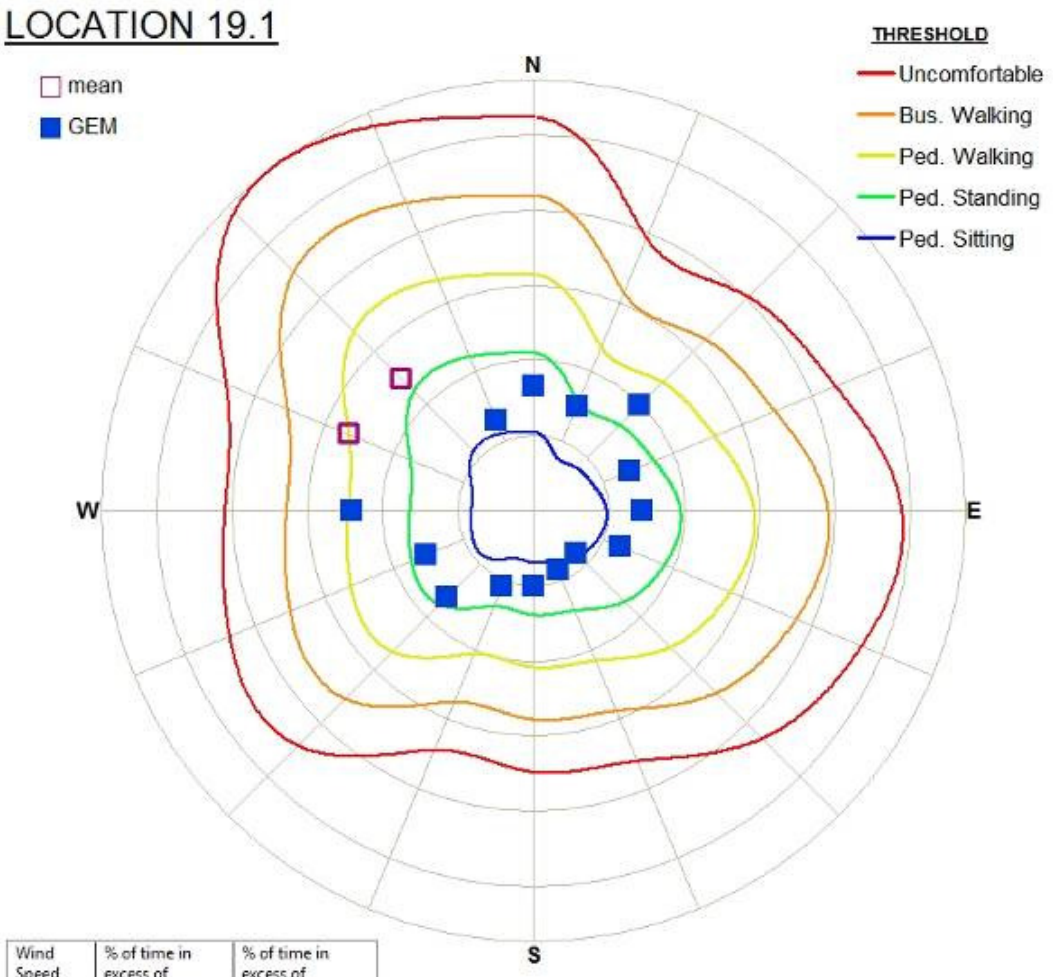
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	44.1	48.7
4.0	22.5	21.8
6.0	12.5	11.0
8.0	6.5	4.4
10.0	3.2	1.4
8.6	**5.0**	Bus Walking
21.4	**0.022**	Fail
7.7	Ped Walking	**5.0**
16.4	Able Body	**0.022**

Masterplan



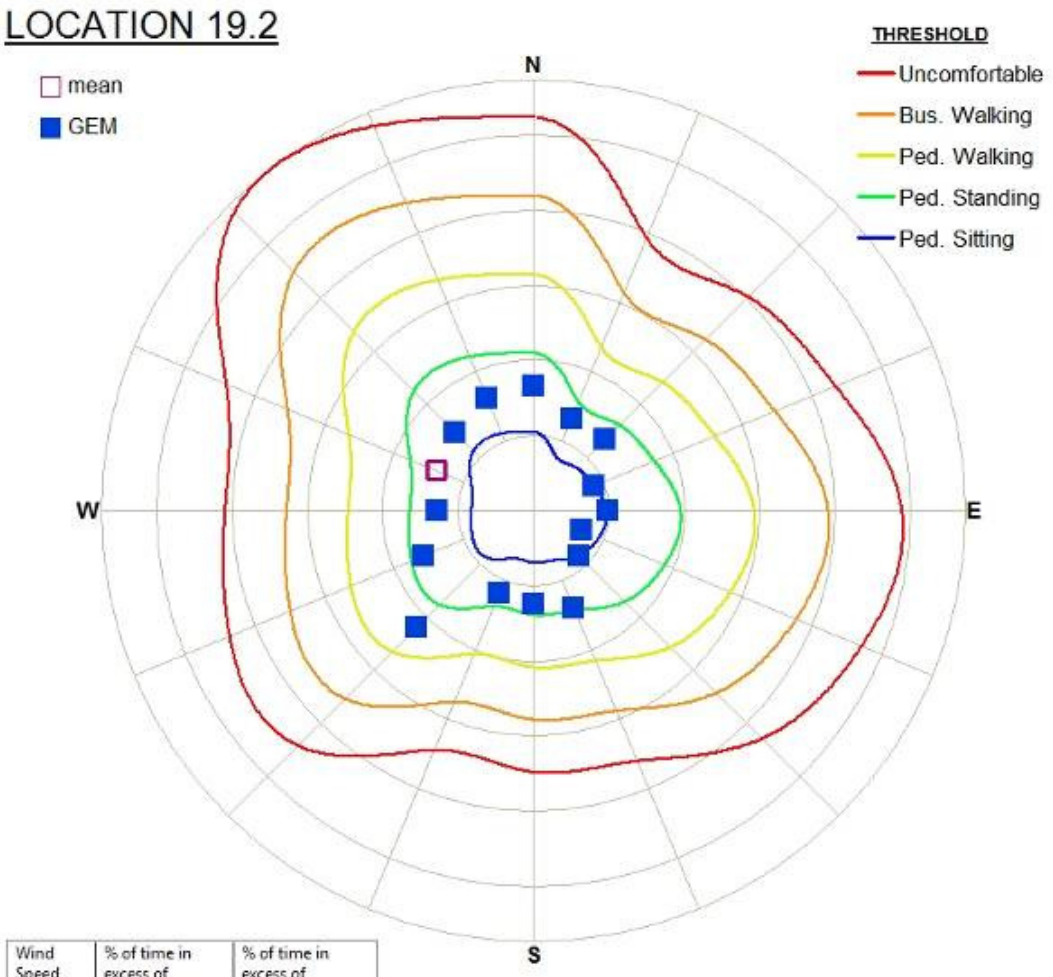
Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	21.0	34.6
4.0	3.4	6.0
6.0	0.6	0.9
8.0	0.1	0.1
10.0	0.0	0.0
3.5	**5.0**	Ped Sitting
9.3	**0.022**	Pass
4.2	Ped Standing	**5.0**
9.3	Pass	**0.022**

With Building C3



Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	19.4	31.6
4.0	3.2	5.1
6.0	0.8	0.9
8.0	0.1	0.1
10.0	0.0	0.0
3.4	**5.0**	Ped Sitting
10.0	**0.022**	Pass
4.0	Ped Sitting	**5.0**
9.8	Pass	**0.022**

With Buildings C3 and C4



Wind Speed (m/s)	% of time in excess of Mean	% of time in excess of GEM
2.0	15.0	26.0
4.0	0.5	1.7
6.0	0.0	0.1
8.0	0.0	0.0
10.0	0.0	0.0
2.6	**5.0**	Ped Sitting
5.7	**0.022**	Pass
3.3	Ped Sitting	**5.0**
7.0	Pass	**0.022**

Masterplan