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REPORT

Adapting to Intensified Living
Task 3L Physical Environments
Submitted By:
CENTRE FOR BUILDING PERFORMANCE RESEARCH
To:
Opus International Consultants

1.0 Abstract

The aim of this project is to create an index of liveability for urban spaces, combining sun, wind and temperature data. As our cities undergo more intensified occupation, more needs to be done to increase human comfort in the public areas created between our buildings. The index would enable designers to take into account the comfort of users of the space and the priorities they have for that environment.

Based on a review of the relevant literature, potential "comfort descriptors" for combinations of physical measures of the environment (wind speed, temperature) were prepared. The result was a preliminary report on how a survey of people in public spaces might be constructed and the type of information needed from it.

From NIWA's National Climate Database, data was obtained of solar radiation, temperature and wind speed and directions recorded at Wellington Airport. The data was subject to a cross-tabulation analysis. The results were then displayed in graphs summarising for each dry bulb temperature band, the likely solar and Northerly and Southerly wind conditions. These graphs allowed for several climatic patterns to be identified.

From the beginning, it was assumed two existing techniques would be used to establish how to combine wind and solar data. Computer Aided Design (CAD) models would analyse hourly solar access, defining sunny and shady parts of urban environments. These results would be combined with existing wind tunnel test reports of specific areas within Wellington. An existing CAD model of the city (spanning from Te Aro through to Lambton Quay) was obtained from the Wellington City Council.

Grids of 1m, 2m, 5m and 10m were created at ground level in the case study urban areas to establish which size was the best method of quantifying the amount of sunlight/shade in the various spaces. The models were lit at 9am, 12pm and 5pm and the ratios of sun to shade were calculated for each grid size at the different times of the day. This method established the 1m grid as giving the most accurate results.

Bead erosion tests and single point speed measurements from existing wind tunnel test reports by Opus International were used for the purposes of constructing the index. The initial plan was to combine these two pieces of data into a comprehensive graphic. A similar grid system as used for solar data would then be used to quantify wind data, allowing wind and sun to be combined at the grid square level prior to constructing a summary index.

It has proved difficult to draw wind contour lines and thus produce a clear, legible map when a large range of wind data is concentrated within a small area. An index of liveability requires solar information to be combined with the wind data (and possibly temperature data as well). Due to the different types of information contained in the solar, wind and temperature data, the map needs further development if it is to display all of the data in an easily understandable manner.

2.0 Introduction

This project combines sun, wind and temperature data in an index of the liveability for public spaces. This index can be used and applied to a proposed change to an inner urban area. The index will take into account the comfort of users of the space and the priorities they have for that environment.

For this part of the project (Task 3L – Physical Environments), the main objective is to model wind speed and sunlight/shade over the seasons for the case study areas. Existing measures of sun and wind are used.

The rationale behind this project is that assessment of quality in urban environments will require more accurate measures of their suitability for human habitation as we move to more intensified occupation of the city. Each building may affect the quality of environment in adjacent buildings and in the spaces between. At ground level, we use these spaces for movement, relaxation and entertainment. Above ground level the air, light and heat within these spaces can be used to light, heat and ventilate our buildings.

With intensified living, it is increasingly likely that each building will influence the environment in and around adjacent buildings. Inner city areas are becoming areas where many people spend a much greater portion of their time for work, recreation, entertainment and residence. To better design our cities we need more sophisticated measures of the impact of buildings on the quality of these urban spaces than our current bulk and location measures provide.

3.0 Literature Study

Indicative "comfort descriptors" for combinations of physical measures of the environment (wind speed, temperature) were prepared based on a survey of the literature. (Refer to Appendices A to C). This lead to a preliminary report on how a survey may be constructed and what information is needed from the survey (See Appendix D).

Architecture: Comfort and Energy (1988)[1] notes that for humans to achieve thermal comfort, they need to maintain heat balance within the human body.[i] Cities have been built to provide choices to people about where they sit, walk or take shelter. However, not enough has been (or is being) done to increase human comfort in outdoor areas.

One of the barriers to increased comfort in urban spaces is, as seen by Ralph Knowles (1984)[2], government regulations and ordinances. Knowles states that access to direct sunshine enhances the quality of life and that guaranteeing solar access through modifying traditional zoning principles rather than through legal methods is preferable. This, he suggests, can be achieved by solar zoning being formulated as a relatively simple modification of present zoning ordinances governing building height and bulk.

An article in *Building and Environment* by Richard Aynsley (1989)[3], discusses current urban policies for wind control in several United States cities. Aynsley suggests that governments attempt to limit their legal liability by calling in specialists. The concern is mostly about the safety of people in the city rather than comfort. Specialists often create regulations and bylaws requiring wind tunnel studies of specified projects over a certain height. Some governments do nothing, losing an opportunity to develop well considered controls free from pressure group influences.[ii]

Following this same logic, it seems likely that in the future an index of liveability of a public space could be used by government authorities to reduce their legal liability in creating comfortable urban spaces.

Throughout the literature, constant reference was made not only to the need to examine the effects of buildings on wind conditions at street level, but also to the need to pay careful attention to the combined effects of sun and wind conditions on pedestrian comfort.

In his report *A Comfortable Wind Climate for Outdoor Relaxation in Urban Areas*[4], M. Tacken states that various combinations of temperature, sun and wind determine how pleasant outdoor relaxation will be for the individual. Armed with this knowledge, the Research Institution of Urban Planning and Architecture (OSPA) of Delft University of Technology in the Netherlands undertook a study to help determine norms for wind climate in urban areas suited to outdoor relaxation.

The environmental factors examined in the project method were temperature, solar irradiation, wind velocity and wind turbulence. Air humidity was not considered as due to the range of temperature being considered in the project (14-28ºC) it was believed that perspiration was sufficient for cooling the body during relaxation.

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[i] *"The job of our Thermoregulatory system is to maintain the heat balance, that is a fundamental condition for survival and necessary (but not sufficient) for our comfort."* **Gallo (et al), p. 39**.

[ii] *"City Governments typically respond in three ways. Firstly they attempt to limit their legal liability by using existing, often inappropriate, legislation to call for specialist wind consultants' reports at the developer's or building owner's expense. These reports are expected to advise on existing problems, or identify the probability of future pedestrian level wind problems. Legislation used in some cases does not include criteria for assessing such reports, leaving no legal basis for their acceptance or rejection. Developers often refuse to comply with controls that are not legally binding. Secondly, City Governments engage specialist wind engineering consultants to specify acceptable pedestrian level wind criteria and create regulations or by-laws requiring wind tunnel study reports on all new projects usually over a specified height. With appropriate legislation in place and assessment criteria clearly specified, there is little question of the legality of the controls. Further refinement may include specifications of wind tunnel test and data analysis procedures. Thirdly, having been fortunate in the past, City Governments sometimes do nothing, believing that their city does not and will not have pedestrian level wind problems."* **Aynsley, p. 921.**

Data from an anemometer was compared to the results from a questionnaire that human test subjects answered, regarding their perception of how comfortable they had been in exterior conditions. The study showed that in a temperate climate extra wind sheltering measures are often required to make urban areas suitable for outdoor relaxation.

Edward Arens and Peter Bosselmann (1989)[5] began tests to predict the thermal comfort of people in outdoor spaces using a computer model of the human thermoregulatory system, and data of a typical year's hourly climate. The computations produced the number of hours, by time of day and season of year that comfort and discomfort are to be expected. What Arens and Bosselmann neglected to include in the calculations was that the predictions must also incorporate the effects of prior environmental exposure and activity levels of people, in addition to the environmental conditions and activity levels in the space being considered. (ASHRAE Transactions, 1994).[6]

Sun and wind offset each other's effects during many hours of the year. The literature revealed that because human thermal balance is a complex function of several environmental variables, its evaluation in a given climate is best performed using the actual coincidences of environmental conditions expected throughout the year. It was also thought that a certain amount of unpredictability can occur when data is simplified, such as by using mean values.

As Arens and Bosselmann suggest, it is important that both comfortable and uncomfortable times of the year be predicted. This suggests that there needs to be further research done on the coincidence of wind speed and sun-cloud conditions, as separate sun and wind ordinances can only approximately assure the desired comfort levels in outdoor spaces. Both sun and wind occur concurrently. A greater understanding of comfort in an urban environment can be developed if environmental conditions are combined.

4.0 Analysis of Climatic Conditions Data

4.1 Obtaining the Data

Data for Solar Radiation, Temperature and Wind Speeds and Directions recorded at Wellington Airport over the past 30 years was obtained from NIWA's National Climate Database. The National Climate Database (CliDB) is New Zealand's national repository of high quality climate data. It comprises historical paper-based archives dating back to 1860. The program operates under ISO 9002 accreditation and includes "development efforts to respond to ever-changing user demands and the opportunities offered by new technology".[iii]

Investigation was done into the availability of data from the three New Zealand locations concerned, as some of the weather stations in New Zealand were either out of commission or had only being recording for a few years. The project called for 20-30 years of data, so that the averages concluded were a good indication of happenings in that area.

The data from CliDB comes in text format and was changed into a format readable by SPSS. SPSS provides a powerful set of sophisticated univariate and multivariate analytical techniques for real-world problems. It was used for its ability to deal with large volumes of information (the Wellington file comprises some 250,000 lines of data). By following a system of taking the raw data from CliDB into a text editing program (Kedit), the data was separated into columns which could then be imported directly into SPSS with little further formatting required. (Refer to Appendix A)

The data obtained at Auckland, Wellington and Christchurch is from the weather stations at their respective airports, and the frequency of the measurements was hourly. Early checks were made to ensure the accuracy of the data, and a cross tabulation was done comparing year/month, year/day and year/hour. These cross tabulations made it clear that data was missing. However, as less than 10% of the data was missing, it was determined to have a negligible effect on the outcome of the tests.

4.2 Sorting and Graphing of the Data

Following this, the data was divided into ranges describing the varying conditions of the data being considered. These bins will most likely change at a later date when the results of the Urban User Survey are completed and are taken into consideration.

In order to obtain the desired results, the following values were of most importance from the data provided:

- Solar radiation levels, which were binned into three ranges: 0 W/m^2 (night), 1,001-20,000 W/m^2 (cloudy) and 20,001-80,000 W/m^2 (sunny).
- Air temperature, which was binned into: 0-10ºC (cold), 10.01-18ºC (cool), 18.01-26ºC (comfortable) and 26.01-99ºC (hot).
- Wind speed, which was binned into the ranges: 0-5m/s, 5.01-10m/s, 10.01-15m/s and 15.01-99m/s.
- Wind direction, which was binned as: Northerlies, Southerlies, Calm and Variable conditions. Of these, only Calm, Northerlies and Southerlies were considered important as they were by far the most prevalent conditions in Wellington.

[iii] http://www.niwa.co.nz/services/clidb/ Accessed 29 August 2002

The aim of this research was to understand how often Northerly and Southerly winds occurred in varying solar and temperature levels. The following cross-tabulations were produced to display the information in a usable format:

- ? Wellington Northerlies Wind Speed (m/s) * Solar Radiation (W/m^2) * Dry Bulb
- ? Wellington Southerlies Wind Speed (m/s) * Solar Radiation (W/m^2) * Dry Bulb

The raw data of these cross-tabulations can be seen in Appendix E.

For each cross-tabulation, a table was produced, which recorded the number of occurrences of each different climatic condition under Northerlies or Southerlies. These values were then converted into percentages of the number of occurrences under Northerly or Southerly conditions (Figure 1), both taking into account those that occurred at night (percentages shaded in pink) and excluding night time occurrences (percentages shaded in blue).

Figure 1 - Example of Frequency Analysis

Wellington Northerlies Wind Speed (m/s) * Solar Radiation (W/m2) * Dry Bulb Crosstabulation

			Solar Radiation (W/m2)							
Dry Bulb	Wind Speed (m/s)		0	0	1.001 - 20.000	1.001 - 20.000	1.001 - 20.000	20.001 - 80.000	20.001 - 80.000	20.001 - 80.000
0 - 10	0 - 5	Count	2632	3.96%	2032	3.05%	6.25%	1125	1.69%	3.46%
	5.01 - 10	Count	1867	2.81%	1617	2.43%	4.97%	1027	1.54%	3.16%
	10.01 - 15	Count	483	0.73%	472	0.71%	1.45%	315	0.47%	0.97%
	15.01 - 99	Count	40	0.06%	24	0.04%	0.07%	19	0.03%	0.06%
10.01 - 18	0 - 5	Count	9869	14.88%	4172	6.27%	12.82%	3398	5.11%	10.44%
	5.01 - 10	Count	10862	16.35%	6505	9.78%	19.99%	6458	9.70%	19.85%
	10.01 - 15	Count	3477	5.23%	2297	3.45%	7.06%	1758	2.64%	5.40%
	15.01 - 99	Count	300	0.45%	216	0.32%	0.66%	157	0.24%	0.48%
18.01 - 26	0 - 5	Count	2278	3.42%	249	0.37%	0.77%	166	0.25%	0.51%
	5.01 - 10	Count	1608	2.42%	218	0.33%	0.67%	222	0.33%	0.68%
	10.01 - 15	Count	413	0.62%	45	0.07%	0.14%	38	0.06%	0.12%
	15.01 - 99	Count	44	0.07%	3	0.00%	0.01%	5	0.01%	0.02%
26.01 - 99	0 - 5	Count	13	0.02%						
	5.01 - 10	Count	1	0.00%						
			Count All	66545		Count (no zero)	32538			
			Check %age	100.00%		Check %age	100.00%			

Further tables were produced that combined Northerly and Southerly data, describing the percentage frequency occurrence of the different conditions over **total time**.

The results were then summarised into tables and a surface graph was produced for each dry bulb temperature band, occurring under both Northerly and Southerly wind conditions (refer to Appendix F). Surface graphs were considered the best presentation method for the data as they are clear to read and allow for easy comparison of the results obtained in order to detect any recurring trends.

4.3 Climatic Trends Identified from the Graph

It was clear from the graphs that the most common temperature band occurrence in Northerly wind conditions is the 10-18ºC band.

In each Northerly graph, the occurrence percentages of the 10.01-18ºC band in Northerly conditions are similar during daylight hours (1,001-20,000 W/m^2 and 20,001-80,000 W/m^2), with a maximum difference in occurrence of 0.5%. This suggests that the occurrence of Northerlies has no correlation to level of solar radiation during the day.

In Southerly wind conditions, the 0-10ºC temperature band is more common and as wind speed increases, so do the occurrence percentages of the 0-10ºC band in relation to the 10.01-18ºC band. This

is due to Southerlies being more prevalent during the colder months of the year, leading to a significant wind chill effect.

The percentage occurrences of Southerly winds at any temperature band tend to drop as solar radiation levels increase from 1,001-20,000 W/m^2 to 20,001-80,000 W/m^2. This percentage drop becomes more obvious with increasing wind speed. This suggests that Southerlies, particularly strong ones, are less common on sunny days.

In order to account for all the dry bulb temperature values, the 26-99ºC temperature band was initially included in the analysis. However, after analysing the data and producing frequency tables, it was discovered that such conditions have only occurred on 14 occasions in thirty years (0.02% of total occurrences). Therefore it is clearly not a relevant category for an analysis of Wellington's climatic conditions.

5.0 Combining Solar and Wind Data

It was assumed from the outset that existing measures and techniques would be used to test experimentally how to combine wind and solar data. The two existing measures include: using Computer Aided Design (CAD) models to analyse hourly solar data and combining the results with existing wind reports of the specific areas: Courtenay Place; Cuba Street/Ghuznee Street; Midland Park/Lambton Quay; Lambton Quay/Willis Street Intersection Area; and Cable Street/Taranaki Street/Wharf Area.

Existing CAD models (as provided by the Wellington City Council) and wind tunnel tests were used to combine sun, wind and temperature data in an index of liveability of a public space. This reduced the time and cost as there was no need for new wind tunnel tests or CAD data. This ensured that the maximum time was available to examine the question of combining the individual measures.

CAD files were obtained from:
Mike Reed, Asset Information, Wellington City Council
Email: **Reed1M@wcc.govt.nz**
Phone: (04) 801-3637

The CAD files are accurate as of the late 1990's and consist of the building stock of Wellington City. The information included in the files is:

- Buildings – plans with building heights appended
- Kerb and Seal
- Fence
- 1m Contour Lines
- Aerial Photos (1:500 & 1:5000)

All data is provided on CD. Vector data is provided in dxf format and/or shape files. Image data is provided in tiff or jpg format. A world file is also provided; this contains the NZMG coordinates of the bottom left hand corner of the image so it is easily geo-referenced.

The wind data that was used was from wind reports completed at Opus Central Laboratories. These are referenced at the end of this report.

6.0 Construction of Index

6.1 Calculating Solar Access

The solar model was created in AutoCAD. This model includes data from the Te Aro area through to Lambton Quay.

In the CAD program, a single "distant" light simulates the sun. Although the sun radiates in all directions, because of its size and distance, by the time its rays reach the earth they are effectively parallel. Because a distant light is so frequently used to simulate the sun in this way, especially in architectural renderings, the photorealistic renderers provide a special sun angle calculator that calculates the sun's position based on both the hour of the day and geographic location.[7]

To obtain solar information from CAD, views were chosen giving a good perspective on the sites chosen for the project, for example Civic Square. In all cases these were plan views as these were determined the best for ascertaining the sunlight/shade ratio of a given space. Views from a more "realistic" ground level or human viewpoint were not normally sufficiently comprehensive in coverage to provide an adequate overview.

It was thought that a grid would allow the best form of quantification of the sunlight/shade ratio in the spaces. Four different grid sizes were chosen, 1m, 2m, 5m and 10m. This range of sizes would make sure that the grid could fit sensibly into any area necessary and still produce sensible results. The grid was constructed at ground level. The goal was to use a similar grid system to quantify the wind data and then to combine wind and sun at the grid square level prior to constructing a summary index.

The models needed to be lit at different times of the day and year. Tests have been carried out at 9am, 12pm and 5pm at four times of the year, the Solstices and Equinoxes. The selection of 3 times of the year reflects the convention in hard-generated assessments of solar access/solar shading. Since the sun follows the same path across the sky in Autumn and Spring (at the Equinoxes), this effectively requires 3 times of the day x 3 times of the year = 9 lighting conditions. It is anticipated that the times of the day are significant because they reflect the hours of the working day, and reflect three different climatic conditions throughout those days.

An AutoLISP[iv] function has been devised to automate the solar access 'tests'. The user inputs the dates and the time interval required and the Lisp function instructs the computer to carry out the renderings and produce images for each time of the day and time of the year. This makes it feasible to produce many more images for many more times than is conventionally possible with hand held calculators. Increasingly this type of automation is being provided as an in-built tool within the CAD program.

Figure 2 shows some examples of the images that were produced from CAD of the Civic Square.

[iv] **"Lisp is a programmable programming language." – John Foderaro**
LISP is an acronym for LISt Processing. Its development history has often been associated with symbolic processing and with both computer and human languages. A heterogeneous list data type has always been built into the language in order to efficiently deal with arbitrary and changing models.

Figure 2 - Example Images from CAD

1m Grid – 9am

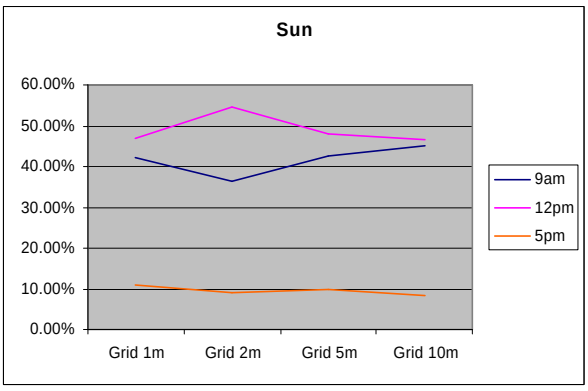
10m Grid – 9am

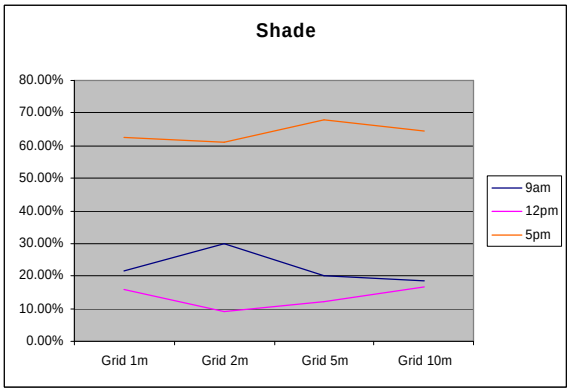
2m Grid – 5pm

5m Grid – 9am

In order to ascertain the most appropriate grid sizing, the ratios of sun to shade were calculated for each grid size for the three times of the day. The results are shown in Figure 3.

Figure 3 - Grid Values from Counting





The peaks and the troughs show inconsistencies in the values derived from the 2 and 5 metre girds. But the 1 and 10 metre grids produce relatively similar values. The smaller grid size (1 metre) is clearly more precise. At the same time the 10 metre grid would prove too large for many urban areas. This experiment demonstrates that 1, 5 and 10 agree and 2 is oddly at variance.

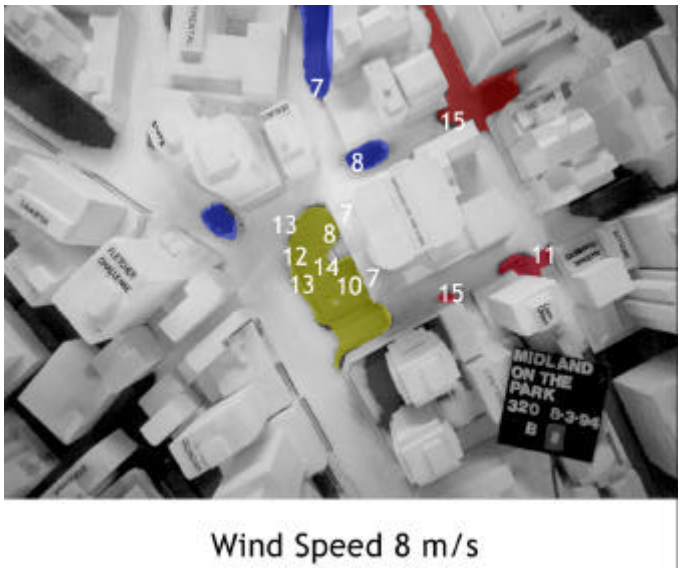
6.2 Calculating Wind Exposure

Existing wind tunnel test reports were used as sources of information for the purposes of constructing the index. The wind tunnel studies have been completed by Opus Central Laboratories.

These reports consist of flow visualization tests that use erosion of polystyrene beads to establish a relative degree of windiness in a proposed development area. Hot-film anemometers were used to obtain wind speeds at various locations around the site, particularly in areas where there are foreseeable problems.

The information used from within the reports completed by Opus Central Laboratories was the Bead Speed Tests and wind speed point measurements. The initial plan was to combine these two pieces of data together into one coherent graphic. The bead clearance is indicated by varying colours relating to the speed at which the beads cleared in that particular area, thus showing the areas most prone to uncomfortable wind disturbance. The point measurements which were gained from the hot-film anemometers are displayed with a number corresponding to the wind speed in that area. The result of this can be seen in graphic in Figure 4.

Figure 4 – Wind Speed Map



Locke tested the accuracy of bead speed tests, which have been used from the wind reports (See Appendix E). Locke drew contour maps in much the same way as above and found that the least accurate part of the analysis was assigning 'frequencies' to the locations where wind speeds were measured with the hot-film probe. Locke found that two problems arose here:

1. Identifying the location on the image.
2. Interpolating a frequency value from the contours. [8]

The map is not yet clear enough and needs further development. This could be achieved through the use of AutoCAD Surface and Map programs. Also by increasing the scale, the map could be much clearer.

7.0 Conclusions

The data on climatic conditions obtained from NIWA's National Climate Database has been of sufficient quantity and accuracy to allow for the data to be analysed through binning and cross-tabulation, and for the identification of distinct climatic trends that have occurred during the past 30 years. An understanding of these trends and what measures can be taken to temper the effects of these conditions so as to increase human comfort, are necessary for producing an index of liveability for our inner city areas.

The CAD model constructed of the city proved to be an effective method of analysing solar data for the selected inner city areas. Of the grids constructed at the ground level of the CAD model, it was concluded that the 1m grid was the most useful and accurate for quantifying the sun/shade ratio within urban spaces.

The goal to construct a similar grid system to quantify the wind data, so as to be able to combine sun and wind at grid square level is the next phase of the project. The concentration of large amounts of wind data in small areas of the map means that it has proved difficult to produce a clear, legible and accurate map of both wind and solar data.

8.0 Bibliography

AutoCAD Help: User Documentation

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Various Contributors, *The Transient Nature of Thermal Loads generated by People*, ASHRAE Transactions, Part 2, vol. 100, 1994

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2. *The Solar Envelope*, Ralph Knowles, UIA International Architect
3. 'Politics of Pedestrian Level Wind Control', article by Richard M. Aynsley, *Building & Environment*, 1989, Vol. 24, No. 4, pp. 291-295
4. 'A Comfortable Wind Climate for Outdoor Relaxation in Urban Areas', article by M. Tacken, *Building and Environment*, 1989, Vol. 24, No. 4, pp. 321-324
5. 'Wind Sun and Temperature – Predicting the Thermal Comfort of People in Outdoor Spaces', article by Edward Arens and Peter Bosselmann, *Building & Environment*, 1989, Vol. 24, No. 4, pp. 315-320
6. *The Transient Nature of Thermal Loads Generated by People*, Various Contributors, ASHRAE Transactions, 1994, Vol. 100, Part 2
7. AutoCAD Help: User Documentation
8. *Erosion Contour and Hotfilm Wind Speeds*, Nick Locke

10.0 Appendix A

Wind and Thermal Bibliography

A Comfortable Wind Climate for Outdoor Relaxation in Urban Areas
Article by M. Tacken
Building & Environment
vol. 24, no. 4, 1989, p. 321-324
Published 1989
TH1 B933
Summary:
This study shows that in a temperate climate, extra measures are often required for making urban areas suitable for outdoor relaxation and that these measures can be used to increase the number of hours during which people perceive the climate as comfortable.
Researches into wind, temperature, solar irradiation, wind velocity and wind turbulence (variations in velocity and direction), and air humidity. Conducts tests on people using anemometer and a solarimeter – measuring perception. Compares results from 105 tests of people's perceptions with climatic data from a meteorological station in the Netherlands, to assess how often favourable combinations of wind velocity, sun and temperature occur.
Project is trying to investigate possibilities for arriving at norms for the wind climate in urban areas suited to outdoor relaxation.

Airflow Around Buildings
Article by C.B. Wilson
E.A.R. (Edinburgh Architectural Research)
vol. 11, 1982, p. 18-25
Published 1982
NA1 E
Summary:
The main intention of the article is to expose the development of a research strategy aimed at providing information and techniques for use in design. Discusses different research projects:
An investigation of velocity profiles in an urban area using a captive balloon as a support for anemometers
A wind tunnel study of the flow between parallel rows of "houses" of different length and separation to display the systematic relationship between changes in form and changes in flow regime.
A parametric study of wind-flow in a rectangular walled enclosure, which showed that in such a form there exist optimum dimensionless geometries, which maximise shelter in the enclosure.
A general discussion paper on the simulation of airflow around buildings.

Architecture: Comfort and Energy
Edited by C. Gallo, M. Sala, A.M.M Sayigh
Published 1988, Elsevier Science Limited, Oxford
TH6021 A673
Summary:
Chapter 1: Thermal comfort and the development of the bioclimatic concept in building design. It is an attempt to adopt the building bioclimatic chart concept as well as Mahony tables to Qatar, which is used as an example, in order to determine the most appropriate design strategies.
Chapter 3: Principles of thermal comfort. Explains that providing and maintaining a heat balance within the human body, is a fundamental condition for survival and necessary (but not sufficient) for comfort.
Investigates: heat exchanges (man-environment), comfort indices, and the adaption model.

Building Aerodynamics and Pedestrian Comfort
Research Report, ARCH 389
By Jonathan Scholes
Published 1987
H AS741 VUW A16 S368 B 1
Summary:
Investigates the causes and limits of pedestrian discomfort around the bases of tall buildings, through a study of the aerodynamic performance of building forms and aerodynamic devices used to improve their wind performance.
Covers the influence and the requirements of wind-performance on the design of tall commercial buildings (in Wellington especially) concerning the wind conditions at ground level to which pedestrians are subjected. Investigates factors relating to pedestrian comfort. Also how best to improve the pedestrian environment by either modifying the shape and proportions of buildings; or by the use of aerodynamic devices that may either deflect or dissipate problem wind flows.

Buildings, Climate and Energy
By T.A. Markus and E.N. Morris
Published 1980, Pitman Publishing Limited, London
NA2541 M346 B
Summary:
Refer to photocopy for contents.
Chapter 3: Includes information on Thermal Comfort – comfort equation, Ole Fanger and Thermal Index – operative temperature and thermal comfort. Appendix has extensive operative temperature charts and thermal comfort charts.
Discusses assessment of discomfort – measuring discomfort, the number of people affected and the duration of the discomfort. General index of the environment – index of the thermal environment, which is valid throughout the building and all the space around it.
Good book for equations.

Computer Modelling of Wind-Flow around more than one building
Article by David Summers and others
E.A.R. (Edinburgh Architectural Research)
vol. 11, 1984, p. 90-103
Published 1984
NA1 E
Summary:
Trying to analyse full flow fields using computer modelling instead of a wind tunnel. Interested in long time averages over all statistical fluctuations, assuming that the mean flow field will correspond to the solution of a time steady equation.
Includes: streaklines, speed contours.
Developed a numerical program that can treat more complex shapes. More work on the computer validation to be done.

Concepts in Thermal Comfort
By M. David Egan
Published 1975, Prentice-Hall Inc. New Jersey
TH6021 E28 C
Summary:
Refer to photocopy for contents.

This book presents the basics of thermal comfort in a graphical format. The verbal descriptions are few, emphasis being on graphical displays to illustrate the significance of climate, materials, and mechanical systems in the design of buildings.

Courtenay Place Wind Environment
By Michael Donn and Kathryn Davies
Published 1989, School of Architecture, Victoria University of Wellington
NA12 V645 P 51
Summary:
Refer to photocopy for contents.
Analyses the results of 104 wind tunnel tests of Courtenay Place and 42 types of wind gates. Aim to assess the impact on the wind environment of the changes described in the Courtenay Place Precinct Design Guide.
The guide proposed adding entry gates at each end of the precinct to provide wind shelter. This in response to newspaper reports of the Taranaki Street Courtenay Place intersection being a "danger spot".
A simple pictorial system of analysis was used to examine the impact on the wind environment of placement of wind gates in Courtenay Place and of the increase in height of buildings allowed by the Precinct Ordinance.

Effects of Air Temperature, Humidity, and Air Movement on Thermal Comfort under Hot and Humid Conditions
By Shin-ichi Tanabe and Ken-ichi Kimura
ASHRAE Transactions
1994, Part 2, vol. 100
TH7005 A512 A5
Summary:
The purpose of this paper is to review and summarize the effects of air temperature, humidity, and air movement on thermal comfort under hot and humid conditions with a view toward energy conservation. Recently ASHRAE published a new comfort envelope in Standard 55-1992. In that standard, the upper limit of relative humidity was set at 60%. In hot and humid regions, humidity levels higher than 60% may often be observed.
This upper limit of humidity is discussed based on their subjective data. In addition, the results show that under hot and humid conditions, air movement may be one of the least expensive methods of providing thermal comfort. The effect of air movement is also described in this paper.

Energy & Form: An Ecological Approach to Urban Growth
By Ralph Knowles
Published 1981, The MIT Press, Cambridge, Massachusetts
NA2750 K73 E
Summary:
Looks at energy conservation through design. Scope is the form of our built environment. Its method is deductive and rests on the premise that human survival depends on our willingness to consciously direct urban growth.
Book advocates three new purposes for design:
An economic purpose for urban growth that stresses the long-term costs of maintaining equilibrium in the built environment over the short-term costs of development.
Large-scale view of a community as a set of associations in which the diversity of community needs is met not by supplying ever-increased mobility but by building closer contact diversity into the arrangement.
An aesthetic based on form as a natural adaptation for survival.

Energy in Architecture: The European Passive Solar Handbook
Edited by John R. Goulding, J. Owen Lewis, Theo C. Steemers
Published 1993, B.T. Batsford Limited, London
TH7413 E56
Summary:
Refer to photocopy for contents.
This book attempts to demonstrate the benefits of an approach to the design of buildings and their immediate surroundings which takes advantage of natural phenomena instead of fighting the influences of nature with expensive and often environmentally-destructive heating, cooling or lighting equipment and the energy they consume.
The overall goals to which the book is directed are improved thermal and visual comfort in more environmentally benign buildings, and the synthesis of these objectives in good architectural design.

Evaluating Thermal Environments by using a Thermal Manikin with Controlled Skin Surface Temperature
Various Contributors
ASHRAE Transactions
1994, Part 1, vol. 100
TH7005 A512 A5
Summary:
This paper describes a method for measuring non-uniform thermal environments using a new thermal manikin with controlled skin surface temperature. The manikin and its control logic are described, and an equivalent temperature based on the thermal manikin (teq) is proposed and discussed. A method to calculate the PMV index from manikin heat loss is also given.

Games That Buildings Play With Winds: wind flow patterns created by some buildings put pedestrian comfort and safety at stake
Article by Ralph W. Crummy
Journal of the American Institute of Architects
vol. 61, no. 3, p. 38-40
Published 1974
NA1 A512 A
Summary:
Short article explaining the problems that occur with buildings and their effect on the wind.
Includes:
Explanation of how the wind-flow over and around a building.
Description of the effects of winds at ground level and possible mitigation techniques.
Discussion on wind tunnels as the best tool for obtaining data on winds around buildings.
Explains solutions to dangerous levels of wind around buildings.

Generic Models for Pedestrian-Level Winds in Built-up Regions
By Theodore Stathpoulos and Hanqing Wu
Journal of Wind Engineering and Industrial Aerodynamics
1995, vol. 54/55, p. 515-525
TA654.5 J86
Summary:
Wind conditions over streets in built-up cities were examined in a boundary-layer wind tunnel model study. Presented in this paper are results of wind speeds affected by a number of parameters such as the special density of street blocks, the building height over surroundings, the relative location of buildings, and the direction of the approaching wind.

Introduction to Building
By Derek Osbourn
Published 1985, B.T. Batsford, London
TH145 081 I 2ed
Summary:
Refer to photocopy for contents.
This volume is intended for those who are commencing a serious study of the various mental and physical processes, which are involved during the creation of a building. Divided up into the following parts:
Part A is an analysis of a building in terms of what is expected to do: its function and performance.
Part B is an analysis of a building in terms of the processes required, the Building Team which implements them, and the methods used for communicating information.
Part C is an analysis of a building in terms of construction methods.

Investigation of Measures Available for Improving Ground Level Wind Conditions around Buildings
By N. Jamieson and D. Brown
1989, Aerodynamics Section, Central Laboratories, Works & Development Services Corporation, New Zealand Limited
TA654.5 J32 1
Summary:
Refer to photocopy for contents.

Laboratory Studies of the effect of Air Movement on Thermal Comfort: a comparison and discussion of methods
By M.E. Fountain
ASHRAE Transactions
1991, Part 1, vol. 97
TH7005 A512 A5
Summary:
This paper compares and contrasts methods used in laboratory studies of thermal comfort that focus on the effect of air movement. In laboratory studies, subjects typically wear standardised or similar clothing, are pre-screened for healthy body temperature, are restricted in activity, and are exposed to a set of environmental variables that remain constant for a specific period of time. Three broad methodological categories are compared: experiments in which subjects have control of (1) air velocity or (2) air temperature or (3) neither. Specific experimental practices that may confound results are discussed.

Literature Review on Thermal Comfort in Transient Conditions
Article by J.L.M. Hensen
Building and Environment
Vol. 25, no. 4, 1990, p. 309-316
TH1 B933
Summary:
This is the background to the present literature study on thermal comfort in transient conditions. This study focused mainly on the effects of changes in temperature and mainly in homes, offices, etc.
In section 2 man's thermoregulatory system is discussed so as to show the interaction between man, building and HVAC system. Work on cyclically varying temperatures are present in Section 3.1 and on other types of changes in the following sections. Finally in Section 4 some conclusions towards practical applications are made.

Living with Wind – an introduction to the problems caused by wind, and some solutions
By P. Carpenter
1989, Aerodynamics Section, Central Laboratories, Works & Development Services Corporation, New Zealand Limited
TH891 C296 L
Summary:
Refer to photocopy for contents.
Particular interest is Chapter 11 – wind effects on people, which includes discussion on wind speed and wind chill.
Also Chapter 13 is of interest – guidelines for avoiding high wind speeds at pedestrian level in city streets.

Locally Controlled Air Movement Preferred in Warm Isothermal Environments
Various Contributors
1994, Part 2, vol. 100
TH7005 A512 A5
Summary:
While air movement can provide desirable cooling in "warm" conditions, it can also increase the risk of unacceptably cool drafts. The transition zone from desirable cooling to uncomfortable draft is a complicated function of physics, physiology, and human expectation. This work focuses on air movement for cooling in the expected temperature range, 25.5?C to 28.5?C of this transition zone.
Fifty-four human subjects were used, physical measurements of the environment and subjective votes collected. A model that predicts the percentage of satisfied people (the PS model) as a function of air temperature and air movement in warm conditions is proposed.

Multi-Source Synthesis: Shape, Texture and Flow
Article by Guy Battle and Christopher McCarthy
Architectural Design
vol. 65, no. 7/8, 1995 July/August, p. ii-iii
Published 1995
NA1 A3
Summary:
Presents some insights concerning the flow of fluids around objects streamlined and non-streamlined, rough and smooth, through a series of experiments.
Explains how order may be brought out of what seems to be chaos through the grasp of a relatively small number of fundamental concepts and governing physical principles, in order to begin a discussion of the fundamentals of shape, texture and air flow for high-rise towers.

New Metric Handbook
London: Butterworth Architecture
Published 1990
Reference
Summary:
- Planning and design data.
- Topics include:
- Heat Transfer Mechanisms
- Thermal Comfort
- Site and Climate
- Building Fabric
- Condensation

- Infiltration and Ventilation
- Heating and Cooling Systems
- Prediction and Measurement

New Solution to Tower Block Turbulence – by means of podia and perforated screens; proposals developed by: Gerry & Harvey Archtl Aerodynamics
Architects Journal
vol. 178, no.33, 1983 August 17, p. 22
Published 1983
NA1 A661
Summary:
Small article read…….

Pedestrian Level Wind Studies at the Wright Brothers Facility
By Frank H. Durgin
Journal of Wind Engineering and Industrial Aerodynamics
1992, vol. 41-44, p. 2253-2264
TA654.5 J86
Summary:
A careful re-examination of the work of Hunt is performed and the use of hot wire anemometers as well as the erosion of particles method are evaluated. A new particle is proposed and the Methods of pedestrian level wind testing at the Wright Brothers facility are reviewed.

People and the Man-made Environment
Edited by Ross Thorne & Stuart Arden
Published 1980, Department of Architecture, University of Sydney, Sydney
NA2542.4 P419
Summary:
Deals with airflow and its effect on the environment and thermal comfort. Outlines the typical environmental wind problems, these are indications of the principle areas in which problems could be expected. Also outlines examples of environmental factors, which should be taken into consideration when considering wind: downwash, vortices, channelling
Other topics include:

- local air pollution
- motion sickness in tall buildings
- weatherproofing
- windborne spray from fountains
- deterioration of plants in windy conditions
- windborne dust and debris
- erosion near buildings
- snowdrifts around buildings and cooling effects in cold and warm climates
- wind generated noise
- ventilation of indoor spaces using wind-forces
- design criteria for wind in pedestrian areas

Politics of Pedestrian Level Wind Control
Article by Richard M. Aynsley
Building & Environment
vol. 24, no. 4, 1989, p. 291-295
Published 1989

TH1 B933
Summary:
This paper discusses current urban policies for wind control in several US cities.
Makes short discussion on how city governments respond to undesirable pedestrian level winds, outlining the following three main ways:

1. Attempting to limit their legal liability by using existing, often inappropriate, legislation to call for specialist wind consultants reports.
2. Engage specialist wind engineering consultants to specify acceptable pedestrian level wind criteria and to create regulations or bylaws requiring wind study reports on specified projects over a certain height.
3. City governments do nothing.

Topics include:

- ? objectives for urban pedestrian level wind control
- ? liability aspects
- ? existing city government urban wind controls (in the US)
- ? reducing costs of mandatory wind tunnel studies

Proposed Guidelines for Pedestrian Level Wind Studies for Boston – Comparison of Results from 12 Studies
Article by Frank H. Durgin
Building & Environment
vol. 24, no. 4, 1989
Published 1989
TH1 B933 24
Summary:
Reviews different approaches taken by wind consultants to proposed buildings in Boston, and assess the reasons for differences in results. It shows the importance that consultants use consistent weather data for a given city.
The Boston Redevelopment Authority (BRA), the Massachusetts Environmental Protection Agency (MEPA), and other regulatory agencies now require that the developer of each new large building or project in Boston assess the effect of the proposed project on pedestrian level winds in the vicinity of the project.
However, examination of many of the resulting reports disclosed problems with the types of data presented, the criteria used to evaluate the data, and the repeatability between results from different laboratories for the same conditions. As a result, the BRA has sponsored two programs at the Wright Brothers Facility (WBA) at the Massachusetts Institute of Technology to examine some of the reasons for those differences. This paper summarises the results of the efforts to date.

Site Layout Planning for Daylight
By P.J. Littlefair
IP 5/92, March 1992
Published 1992
TH1 B828
Summary:
This paper outlines new BRE guidance on site layout planning to achieve good daylighting, both within buildings and in the open spaces between them. It deals with daylighting within new developments, in existing buildings nearby, and on adjoining land for future development.
The guidelines developed for diffuse daylight within site layouts are intended to form part of a coherent design strategy along with new recommendations on interior daylighting.

Solar Access and Urban Form
Article by Ralph Knowles

Journal of the American Institute of Architects
vol. 69, no. 2, 1980 February, p. 42-49
Published 1980
NA1 A512 A
Summary:
A discussion paper, topics include:

- ? the impact of street patterns on the solar envelope
- ? urban design impacts of the solar envelope
- ? realisations
- ? the construction of the solar envelope

Special Issue. Proceedings of the Fourth International Conference on 'Urban Climate, Planning and Building', Kyoto, Japan, November 6-11, 1989: Part ii
Article by A. B. Barlag and others
Energy & Buildings
vol. 15, no. ¾, 1990/1991, p.i-iv, 289-514
Published 1990
NA2542.5 E56
Summary:
Very large publication, need to look at Contents page provided within photocopies.

Sun and Light for Downtown San Francisco
Environmental Simulation Laboratory
College of Environmental Design, Institute of Urban and Regional Development, University of California, Berkeley
April 1983
Summary:
This report recognises the variety of urban character and scale extent in downtown San Francisco as an important frame of reference for the way in which the city is seen and experienced both culturally and historically.
The report provides analysis of sun access criteria for down town streets and public open space and develops recommendations designed to protect and maintain the city's unique character.

Sun, Light and Wind in Central Wellington: Practical Barriers and Solutions
By Michael Donn, Werner Osterhaus and Andrew Bluck
Paper from ASCA in Paris
Summary:
Paper examines the application of wind tunnel testing and solar access assessment in the Central Business District of Wellington. It also examines the application in the Central Business District, of two architectural science techniques for the assessment of the performance of a building. It identifies the practical barriers that impede the full achievement of the potential promised by these techniques.
Includes discussion on:

- ? wind ordinances in Wellington
- ? daylight and solar access ordinances
- ? Wellington's Te Aro basin
- ? solutions for Wellington

Sun, Rhythm and Form
By Ralph Knowles
Published 1981, The MIT Press, Cambridge, Massachusetts
TJ810 K73 S

Summary:
Useful as general information.
Discusses Solar Access:
Sun - significance of solar access
- means of solar access
Rhythm - rhythm and perception
- rhythm and ritual
Form - natural variation and buildings
- the non-image of the city
- the transformation of cities
- street orientation
- the influence of street orientation on the solar envelope
- form in time

Sun, Shade and Shelter near Buildings: the forgotten art of planning with the microenvironment in mind – part IV
Article by Elisabeth Beazley
Landscape Design
no. 197, p- 46-50
Published 1991
SB469 L263
Summary:
Notes the importance of shelter and discusses the more general attitude to planning. Discussion on high-rise buildings on wind and the resulting ground level conditions, also deals with low-rise buildings. Shelter is discussed in depth, with rules of thumb, semi-permeable wind barriers – with pertinence to brick etc, but also goes into shelterbelts of trees.
Looks at the habitability of spaces near buildings, some points to consider at the outset of a project:

- ? siting of the proposed building
- ? functions of the spaces near the building and their relationship with that of those spaces within it
- ? access
- ? sun and shade
- ? rain and rain shadow
- ? details to consider as the design process

Sun, Wind and Comfort: A Study of Open Spaces and Sidewalks in Four Downtown Areas
Environmental Simulation Laboratory
Institute of Urban and Regional Development, College of Environmental Design, University of California, Berkeley
Summary:
This report describes a study of development in downtown San Francisco and its consequences for street level sun, wind, and thermal comfort conditions.
This research considers the effects of buildings on both sun and wind conditions at street level and evaluating the combined effects of these conditions on pedestrian comfort.

Sun, Wind and Light: Architectural Design Strategies
By G.Z. Brown
Published 1985, John Wiley & Sons
NA2542.3 B877 S
Summary:

Deals primarily with temperate climates like those within the United States – ie: sun position to south of the building that stays low in the winter sky, therefore inappropriate for Southern Hemisphere and equatorial regions.
Organised in thee parts:

1. Analysis techniques – help the designer define the context of the problem, by understanding the sun, wind, and light resources of a particular site and climate.
2. Design strategies – organised in terms of scale, building groups, buildings and building parts. This helps the designer understand a particular principle.
3. Supplements to passive systems – how passive design strategies should be integrated with more conventional electrical and mechanical systems in buildings.

Tempering Cold Winds
Article by Jeremy Dodd
Architects Journal
vol. 189, 1989 May-June, p.61-65
Published 1989
NA1 A661 189

Summary:
The main objective of this article is to outline some of the landscape planning techniques for moderating wind speeds before the wind-flow makes much impact on building surfaces, on people at ground level and on the air mass in the vicinity defined by the surrounding buildings, walls or other elements of the urban landscape.
It investigates strategies that are needed to improve indoor and outdoor comfort, to reduce loading on the structure and on relatively delicate parts of the fabric such as opening windows, and to minimise running costs of space heating, wind damage and surface erosion.

The Abatement of Wind Nuisance in the Vicinity of Tower Blocks
By U. Keith Gerry and G.P. Harvey
Published 1983, Greater London Council
TH891 G379 A
Summary:
The report begins by rating the various effects of the wind shed from tall buildings. Then, to provide a wider background, some aspects of the wind from global to local scale are reviewed. The extensive study of urban thermal effects of a single tower block is reviewed, with particular reference to Canada Estate, Rotherhithe.
The proposed means of relief are then explained and criteria for their effectiveness examined. Tests programmes are discussed and the report ends with a recommendation for wind tunnel tests to be made.
Of the two appendices, one covers tree planting and the other planning and architectural factors.

The Effect of Architectural Detailing on Pedestrian Level Wind Speeds
By N.J. Jamieson, P. Carpenter and P.D. Cenek
Journal of Wind Engineering and Industrial Aerodynamics
1992, vol. 41-44, p. 2301-2312
TA654.5 J86
Summary:
This paper presents results from a wind tunnel study on the effects of architectural detailing on pedestrian level wind speeds around city buildings. Mean and gust speeds were measured in the streets around a range of different building designs placed within a representative city model. The designs included different building shapes, towers with and without podiums, car parking buildings, and the use of fences at street level.

The Transient Nature of Thermal Loads generated by People
Various Contributors
ASHRAE Transactions
1994, Part 2, vol.100
TH7005 A512 A5
Summary:
This paper reports the results of ASHRAE research project 619-RP. The goal of the project was to provide a computer simulation model that could accurately predict the total thermal load generated by people and also predict the sensible and latent portions of this load. The predictions must also incorporate the effects of prior environmental exposure and activity levels of occupants in addition to the environmental conditions and activity levels in the vehicle.
The objectives required experimental measurements to determine the transient nature of human-generated thermal loads and to validate the model.

Thermal Comfort
By Andris Auliciems and Steven V. Szokolay
Published 1997, Department of Architecture, The University of Queensland, Brisbane
TH7222 A924 C
Summary:
Part 1: examines the physical and physiological basics
Part 2: detailed account of comfort studies and description of a range of comfort indices
Part 3: discusses recent developments: the present day broadening of views
Part 4: practical (architectural) applications
(refer to photocopy for Contents page)

Thermal Comfort
Article by Roderic Burn and N.A. Oseland
Building Services
Vol. 15, no. 6, 1993 June, p. 25-29
TH6014 C486
Summary:
Professor Ole Fanger's methods for assessing human thermal comfort are accepted by ASHRAE. Now that revised Section A1 of the CIBSE Guide will be acknowledging his work, Roderic Bunn travelled to Denmark to interview the maverick scientist.

Thermal Comfort and Moderate Heat Stress
Building Research Establishment Report 2
Published 1973, Crown
TH7005 T411
Summary:
Refer to photocopy for contents.
Proceedings of the CIB Commission W45 (Human Requirements) Symposium held at the Building Research Station 13-15 September 1972.

Thermal Comfort Studies Since 1958
Article by W.V. Macfarlane
Architectural Science Review
Vol. 21, no. 4, 1978 December, p. 86-92
TH1 A673
Summary:

This article reviews not only the change in definitions of comfort and newer methods of assessing comfort in buildings, but also to look again at increases in physiological understanding and at new findings on human indoor comfort. In addition some of the incursions of energy conservation into architectural design is noted.

The Solar Envelope
Ralph Knowles
UIA International Architect
vol. 5, 1984, p. 36
Published 1984
NA1 I61

Summary:
Discusses the theory that access to direct sunshine enhances the quality of life, and that guaranteeing solar access through modifying traditional zoning principles rather than through legal methods is preferable. Looks at solar zoning being formulated as a relatively simple modification of present zoning ordinances governing building height and bulk. Defines the solar envelope – being a formal expression of the sun's relative motion, defined by the passage of time as well as by the more traditional constraints of property.
Also discusses that the size, shape and orientation of the solar envelope depending on the patterns of urban settlement, with structural orientations determining solar envelope size and shape. Finally, it looks at how growth is dynamically controlled by the solar envelope. The solar envelope has impact on the size, shape and structure of buildings within it.

Urban Design in Different Climates
By Baruch Givoni
1989, World Meteorological Organisation
HT169.9 C6 G539 U
Summary:
Discusses the following topics:

- ? wind speed along streets and between buildings of about the same height
- ? mathematical representation of the effects of building height and spacing width with uniform buildings
- ? air flow patterns around high-rise buildings
- ? wind speeds around high-rise buildings located among lower buildings
- ? quantitative effects of high-rise buildings on air speeds around them
- ? effect of high-rise buildings placed upwind of the lower buildings
- ? mathematical modelling of the effect of high towers on urban ventilation
- ? pedestrian reactions to excessively windy environments
- ? width and orientation of streets and buildings
- ? impact of street layout on urban ventilation
- ? impact of street orientation, Lot's Subdivision and set-backs, on solar exposure
- ? special design details of buildings affecting the outdoor climates
- ? sun and rain protection
- ? urban glare protection
- ? façade treatments
- ? vegetation as glare control

Urban Form and Climate: Case Study, Toronto
Article by Peter Bosselmann and others
American Planning Association Journal

vol. 61, no. 2, 1995 Spring, p. 226-239
Published 1995
NA9000 A513 J
Summary:
This article describes a joint urban design study by the Berkeley Environmental Simulation Laboratory and the Centre for Landscape Research at the University of Toronto. The study analyses the effect of future development in Toronto's Central Area on street-level conditions of sun, wind and thermal comfort. The study originated in response to public concern about the quality of the downtown.

Using a Thermal Manikin
Laszlo Banhidi
Building Research and Practise
1998, vol. 16, no. 1, p. 14-17
TH1 B937
Summary:
At the time of publishing there were reputed to be only ten examples of the thermal manikin (a computerised doll) in the world at present. The author discusses their potential in microclimate research, and describes experiments with a thermal manikin at the Hungarian Institute fro Building Science (ET) to identify the quality of indoor comfort conditions. One study revealed that the correct heating system would yield better results than extra thermal insulation.

Walking Around Town – Planning for Pedestrians in New Zealand
Town & Country Planning Division, Ministry of Works & Development
Published 1995
TE279.5 M153 W
Summary:
Refer to photocopy for contents.
Of particular interest is page 22-23, which discusses building forms and the airflow around buildings both in built up areas and in isolation.

Wellington City District Plan
Summary:
Refer to photocopy for contents.
Design guide for wind – outlines in non-scientific terms the basics of wind effects caused by buildings and shows how particular relationships can cause or alleviate problems.
Also contains Central Area rules.
Appendix 1: remedial treatment for existing situations including:

- ? vegetation
- ? structures
- ? verandas
- ? enclosed walkways
- ? roofing over open spaces
- ? pedestrial corridors and foyers

Appendix 7: details the form and content of reports on wind tunnel tests.

Wind: A Design Guide for the Wellington City Centre
Prepared and Published by the Town Planning Department of the Wellington City Council
Published 1984
NA9282 W4 W763
Summary:

The design guide is to help designers, developers and decision-maker to become aware of what adverse affects proposed buildings, large or small, which are likely to have an affect on wind conditions in the City Centre. It also gives a general indication of how adverse wind effects can be reduced.
The following issues are addressed:

- ? safety and comfort aspects
- ? the basics of the interaction between individual buildings and wind
- ? interaction between groups, buildings and wind
- ? architectural detailing
- ? site exposure
- ? remedial treatment for existing situations

The guide introduces in non-scientific terms the basics of wind effects caused by buildings and shows how particular relationships can cause or alleviate problems, to varying degrees.

Wind around Tall Buildings
BRE Digest
No. 390, 1994, January, p. 1-12
Published 1994
TH1 B938
Summary:
This digest describes the process of wind flow around tall buildings, it shows how to decide at an early design stage whether a building is likely to give a satisfactory environment, and suggests measures which can be taken to achieve good conditions.
It explains the three steps to assess the environmental wind effects around proposed building development:

1. determine the wind flow patterns around buildings and measure, or predict, wind speeds at vulnerable locations
2. combine these local speeds with wind statistics from a nearby meteorological station and assess how often certain wind speeds will be exceeded
3. combine this data with established criteria for acceptable wind speeds, taking into account discussing people's activities around the buildings

It then goes into discussing, in detail, these three steps.

Wind around Tall Buildings
Building Research and Information
vol. 22, no. 3, 1994 May/June, p. 134-136
Published 1994
TH1 B937
Summary:
Is a review of the previous resource.

Wind as an Influential Factor in the orientation of the Orthogonal Street Grid
Article by A.T. Kenworthy
Building & Environment
vol. 20, no. 1, 1985, p. 33-38
Published 1985
TH1 B933
Summary:
This paper deals, in the main, with model investigations into the effects of directionally variable winds on a range of orthogonally gridded block and street arrangements for which air velocity ratios have been established. These ratios have been established by comparing averaged velocities along streets in the

direction of both grid axes. Block geometry is seen to have an important effect on air speeds producing large differences with the larger block ratios.
Topics include:

- ? street orientation and the sun
- ? the influence of wind on town planning
- ? model investigation
- ? wind direction and block geometry

Wind Effects on Buildings: Volume 1 Design Applications
By T.V. Lawson
Published 1980, Applied Science Publishers, England
TA654.5 L425 W 1
Summary:
Lawson deals with the mechanical effects of the wind on buildings as well as the wind and cooling effects on people that must inhabit the spaces around buildings. He discusses some of the ideas expressed by Gandemer about the effects of certain types of construction and also some of the thermal considerations raised by Penwarden.

Wind Environment around Buildings
By A.D. Penwarden and A.F.E. Wise
Published 1975, Building Research Establishment
TH891 P419 W
Summary:
Brings together, for designers, information and to make design recommendations, with particular reference to tall buildings. Some general principles of air movement around buildings are stated, indicating where windy areas are likely to occur. Includes detailed case studies. Descriptions of wind tunnel measurements around simple model buildings are followed by accounts of the use of meteorological wind data and the effects of wind on people.
Provides a method of predicting the wind conditions around a proposed development at an early design stage.

Wind Sun and Temperature – Predicting the Thermal Comfort of People in Outdoor Spaces
Article by Edward Arens and Peter Bosselmann
Building & Environment
vol. 24, no. 4, 1989, p. 315-320
Published 1989
TH1 B933
Summary:
This paper describes a procedure to predict the thermal comfort of people in outdoor spaces, and shows its application in determining the effects of urban height and bulk regulations around public open space in downtown San Francisco. The procedure is based on a computer model of the thermoregulatory system, run on a typical year's hourly climate data, to produce the number of hours, by time of day and season of year, that comfort and discomfort are to be expected. The climate data are synthesised to take into account the city's influence on wind and sunlight, and are distinct from wind tunnel tests, and the sunlight availability from one of several types of shading analysis.

Wind Tunnel Modelling of the Pedestrian Wind Environment: Modelling the Built Environment
By K.J. Davies
Published 1992, School of Architecture, Victoria University of Wellington
H AS741 VUW TBSc 1

Summary:
Examining the way the built environment is modelled in a wind tunnel.
Begins with an investigation of the context for a study into the use of models in wind tunnel testing of the pedestrian wind environment (see photocopies).
10 factors that influence wind tunnel; testing were identified. A general process for evaluating the influence of these factors was also investigated – looks more into modelling detail. Rest of the thesis looks at tests and experiments and the theories that come from them with relation to wind tunnels.

Wind Tunnel Model Study of Environmental Wind Conditions around Buildings
Article by K.C.S. Kwok and H.A. Bridgman
Architectural Science Review
vol. 23, no. 3, 1980 September, p. 57-62
Published 1980
TH1 A673
Summary:
Presentation of results ad recommendations of NEWMED 1 (Royal Newcastle Hospital in Newcastle, NSW, Australia) – a major study in 1978 of the environmental wind conditions for the proposed Clinical Services Building. Article makes suggestions to minimise the effect of strong winds to maximise human comfort.
Covers:

- ? analysis of the wind in the area of NEWMED 1
- ? environmental wind speed criteria
- ? experimental procedures
- ? makes comments on the site after measurements have been taken and analysed

11.0 Appendix B

Wind Chill

Living with Wind – an introduction to the problems caused by wind, and some solutions
By P. Carpenter
1989, Aerodynamics Section, Central Laboratories, Works & Development Services Corporation, New Zealand Limited
TH891 C296 L

The effects of high wind speeds and shading caused by tall buildings can combine to produce excessive cooling. The heat loss from a person depends not only on air movement but also on air temperature, solar radiation and clothing, and must be balanced by the metabolic heat generated in the body by muscular activity. Figure 11-1 gives examples of the effects of wind chill.

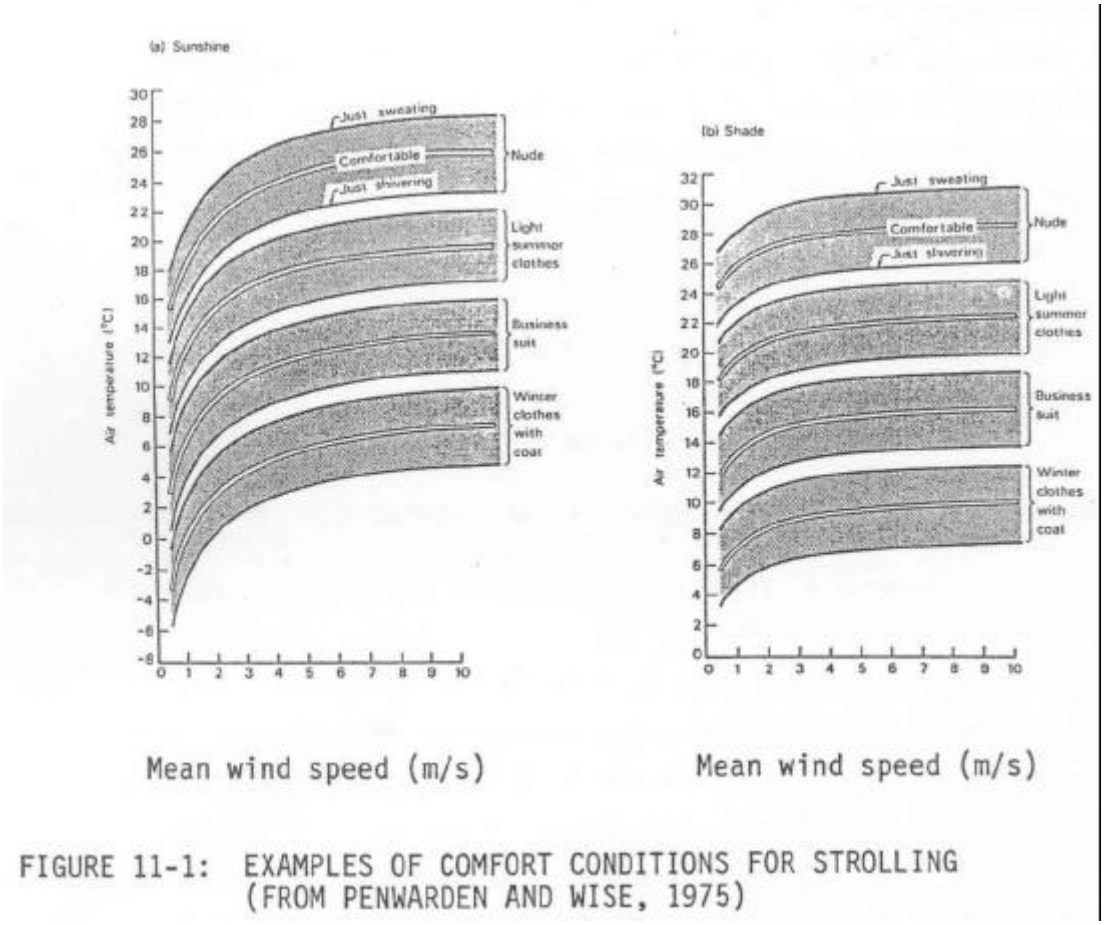
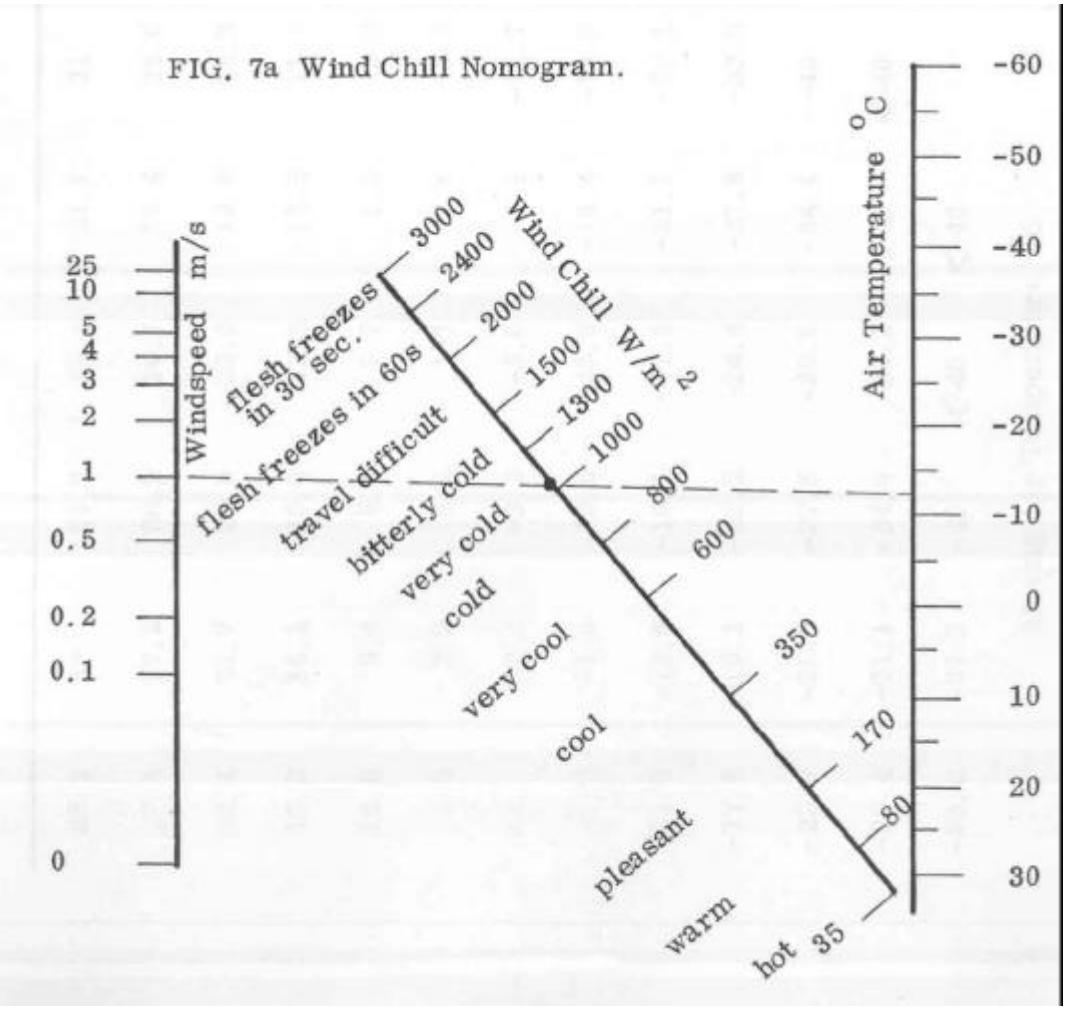


FIGURE 11-1: EXAMPLES OF COMFORT CONDITIONS FOR STROLLING (FROM PENWARDEN AND WISE, 1975)

It can be seen that, particularly in sunshine, the difference between flat calm and light breeze is substantial, but as wind speed increases the effect of variation in wind speed becomes less (IE: the curves become flat at high wind speeds.

People and the Man-made Environment
Edited by Ross Thorne & Stuart Arden
Published 1980, Department of Architecture, University of Sydney, Sydney
NA2542.4 P419

In this research report studies were done of the thermal comfort of people in pedestrian areas. Of interest was how heat transfer was measured. Heat transfer indicated by the "chill effect" was determined by heat loss from a plastic cylinder exposed above a research hut in Antarctica. This was related to separate comfort studies to indicate a relative comfort scale. (Figure 7) For this reason the wind chill monogram should only be used as a means of comparative comfort.



12.0 Appendix C

A Wind Map of Central Wellington

Kevin Russ 1986

Flow visualisation tests (beads):
- indication of relative degree of windiness adjacent to the building and surrounding streets.
- clearance of beads - magnitude etc., indicates a windy area
- wind speed measurements made at points indicated by the bead clearance
- done in both a Northerly and a Southerly

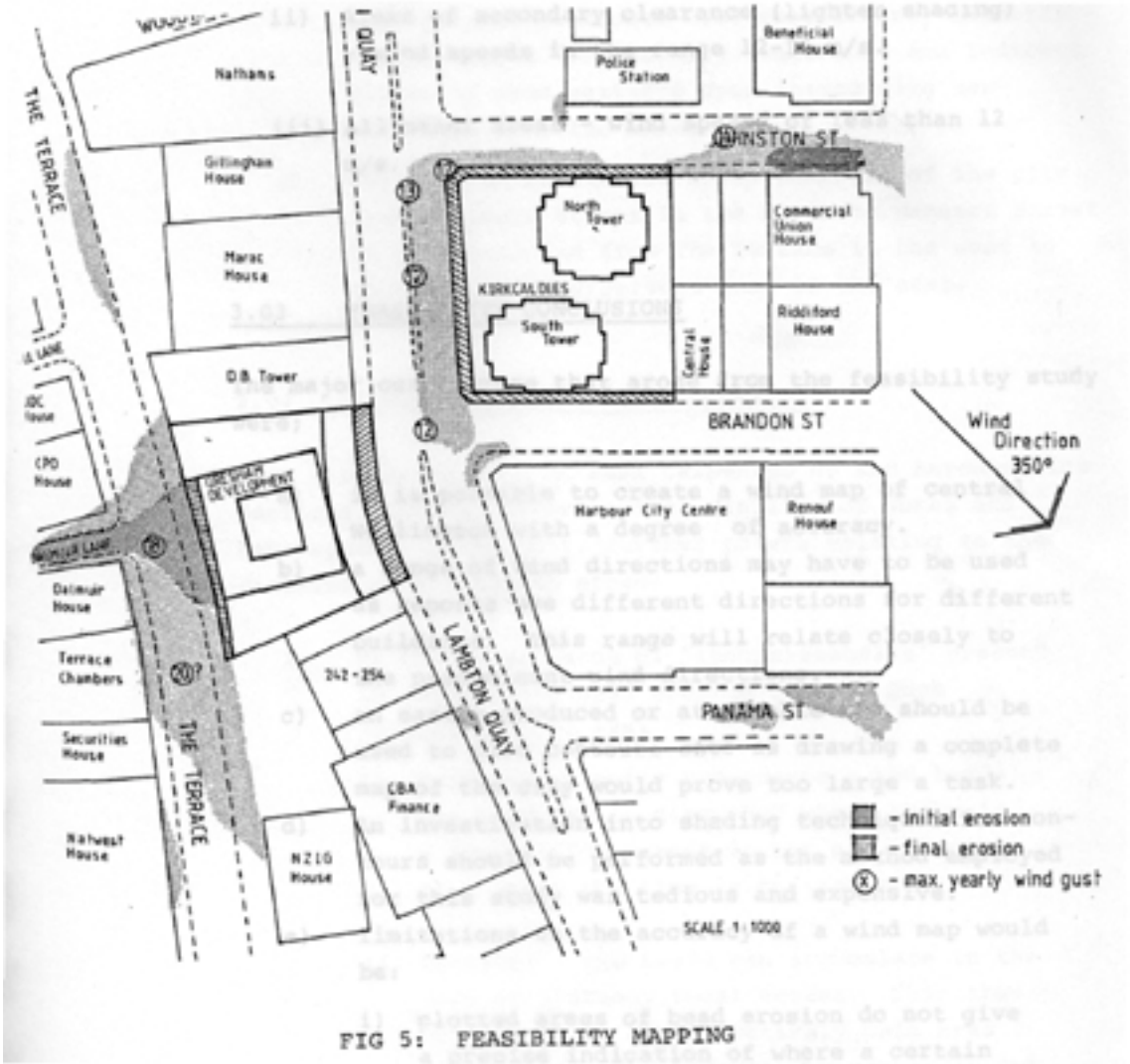


FIG 5: FEASIBILITY MAPPING

- Areas of initial bead clearance (darkest shading) wind speeds in excess of 18m/s
- Areas of secondary bead clearance (lighter shading) wind speeds of between 12-16m/s
- All other areas - less than 12m/s

Limitations of the bead erosion plots:
(Paul Carpenter, Aerodynamics Section, Central Labs, Ministry of Works and Development, Lower Hutt)

1. Vertical Velocity Components - beads more easily distributed where there is a downward component in the air velocity, than where the flow is horizontal.
2. Vortices - beads can accumulate in the core of a steady vortex. This area can be seen to be relatively calm, because the vortex is not visible.
3. Bead Mounds - beads tend to accumulate in mounds as each test proceeds, mounds subsequently modify the flow conditions in their vicinity.

Maps have the potential to sustain conditions indicated. Hence, speeds indicated are not necessarily a constant occurrence.

Photos taken during wind speed tests are taken at the same time.

Wind and the Building Entrance
Stephanie Whibley 1985

Civic Square Analysis:
Contains analysis done by Mike Donn in 1988 on the Civic Centre in the pre-design stage.

Does surveys on people in and around the civic centre.

Literature Survey on general wind effects.

As seen by the title of the report, mainly looks at entrances to buildings. The buildings considered are: Library, Administration Building, City Gallery & Square Affair Cafe.

13.0 Appendix D

Preliminary Survey Report

- ? temperature every 10 minutes
- ? sun average every 1 minute
- ? wind and gust measurements
- ? humidity every hour

What people like/dislike about the space in terms of thermal comfort.
Types of questions – scales 1-5 or 1-7
General questions:

- ? What information are we trying to gather?
- ? Wind and sun factors of person being in the space – how much wind, how much space?
- ? Do they affect our idea of thermal comfort?
- ? What type of space does the person like?
- ? clothing, where, preferences

If there is a group of people concerned, then there is no condition, which can be optimal for every member of the group, due to individual variation. So one must have some measure of discomfort, which involves determining the degree of discomfort, the number of people affected, and the duration of the discomfort. In survey, based on semantic techniques, people are asked to express their feelings about the environment in words. These expressions are quantified by scaling and then correlated to variations in the environment and in clothing and activity levels.

Information can also be gathered from words used naturally, in unsolicited situations, such as daily conversations or newspaper articles. In either case, solicited or not, peoples comments can only be usefully analysed by grouping them into categories or classes and recording the frequency of items occurring in the different groups. Further analysis may enable the categories to be arranged in some sort of continuum, or, dimension. There are usually several underlying dimensions beneath the concepts people have about environment or, for that matter, any other complex and rich experience.

In thermal comfort work a commonly used semantic approach is to ask people to express their impressions of the environment on a linear scale in which numbers are fitted to phrases. One such scale is that used of Bedford.

Thermal sensation scales:

Bedford		ASHRAE	
Much too warm	1	Cold	1
Too warm	2	Cool	2
Comfortably warm	3	Slightly cool	3
Comfortable	4	Neutral	4
Comfortably cool	5	Slightly warm	5
Too cool	6	Warm	6
Much too cool	7	Hot	7

Fanger		Rohles and Nevins	
Cold	-3	Very cold	-4
Cool	-2	Cold	-3

Slightly cool	-1	Cool	-2
Neutral	0	Slightly cool	-1
Slightly warm	+1	Neutral	0
Warm	+2	Slightly warm	+1
Hot	+3	Warm	+2
		Hot	+3
		Very hot	+4
		Painful	+5

A study already made by the Research Institute of Urban Planning and Architecture of Delft University of Technology in Netherlands was trying to arrive at norms for the wind climate in urban areas suited to outdoor relaxation. In this context, they defined relaxation as; very tranquil behaviour, such as sitting quietly outside, sunbathing, standing chatting, looking into shop windows, supervising children at play etc.

The study decided to include temperature, solar irradiation, wind velocity and wind turbulence (variations in velocity and direction). The humidity of the air is an important factor in the regulation of body temperature – in this case the temperature range was high (14 to 28?C), hence it was disregarded. At these temperatures, in view of the tranquil behaviour under consideration, perspiration is sufficient for cooling the body.
The most important instruments for measuring perception were found to be:

- ? A series of pairs of contradictory concepts from which subjects can make a choice (semantic difference).
- ? Willingness to remain outside longer.

The subject was required to choose 3 out of series of 16 concepts which best fitted his/her perception of the climate. On the basis of the results, a rating scale was developed. This scale consisted of 6 contradictory concepts:

warm	cold
windless	draughty
comfortable	uncomfortable
pleasant	unpleasant
comfortable temperature	uncomfortable temperature
calm	windy

Six variables affect thermal comfort outdoors. Solar radiation provides warmth for the human thermoregulatory system, and can compensate for the body's heat loss on cold and windy days. A human body exposed to wind exchanges body heat through convection. Two other climate variables, humidity and ambient air temperature, also affect thermal comfort. Additional factors are people's activity levels and their clothing.

Depending on local climate and seasonable weather conditions, a person may prefer to sit or walk in warm sunlight or in the cool shadow of buildings, may enjoy a cool breeze on his/her face and body, or may take shelter in buildings, or inside arcades. Cities have been and can be built to provide these choices.

Not only should the effects of buildings on wind conditions at street level be examined, but also the combined effect of sun and wind conditions on pedestrian comfort needs to be considered carefully. Also as well as focussing on individual buildings, one should evaluate the cumulative effects of area-wide development.

In reality, comfort is affected by the combined influences of the above variables. We know intuitively that when conditions are hot, sun can be unwanted and even fairly strong wind can be desirable. Sun and

wind offset each other's effects during many hours of the year. So below the level of wind speed where mechanical buffeting becomes the primary case of discomfort, it should be possible to evaluate environmental acceptability based on thermal comfort criteria. If a person's thermal comfort represents a zone of environmental conditions within which the person is able to maintain thermal equilibrium, then sun and wind codes could be based on a model, or index, of the human thermal balance.

Because human thermal balance is a complex function of several environmental variables, its evaluation in a given climate is best performed using the actual coincidences of environmental conditions expected throughout the year. Any simplification of the climate data, such as in using mean values or in treating the climate elements independently, introduces an unpredictable but usually significant error.

Separate sun and wind ordinances can only approximately assure the desired comfort levels in outdoor spaces. The sun ordinance is particularly simplistic, stating that the diminution of possible direct sunlight is bad. The wind ordinance is based on the mechanical effects of wind on people, with an underlying assumption that air temperatures are cool and that strong wind causes unwanted cooling.

Some preliminary questions and ideas for survey:

Regularity of surveyee – leads to reliability of selection and how random that selection of candidates is. Use semantic techniques to gain an idea of what description best suits the candidate – this technique makes it easy for analysis later. Scales discussed earlier by ASHRAE, Bedford, Fanger, Rohles and Nevins are some examples of the types of scales that can be used. Careful consideration needs to be made of the scale (1-5 or 1-7), a 1-7 scale allows for a more defined response from the candidates, and allows people to express themselves more. It is also important that when giving the survey that the scales orientation is changed so as the urge to just tick a column is averted.

Some of the questions in the scales can include such things as:

- ? more sunlight - less sunlight
- ? more shade - less shade

Need to gain a reaction from people to change in wind direction and the effects of gusts upon them.