# Criteria for Determining the Impact of Wind Climatology on Pedestrian Comfort in an Urban Setting

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## Abstract

Tall structures and the arrangements of tall structures have significant influence on the magnitude of wind velocities at the surface. Strong winds aloft can be brought down to the surface by their interaction with tall buildings. Channeling between large buildings can accelerate winds to high speeds. To the average person this may be only a nuisance, but to the frail or disabled this may be a real threat to health and safety. Therefore, environmental assessments of an existing or planned building or block of buildings should take into account the possibility of building influence on winds at the surface. Wind tunnel modeling using scale models has been the primary tool used to address these impacts for some time. Though proven to be accurate and reliable, this approach is not always feasible. Also, since measurements can only be taken at discrete points in the model, the more accuracy needed, the more expensive the modeling becomes. The advancements in computing power today have allowed for an alternative computational approach of wind tunnel modeling known as computational fluid dynamics (CFD). Though not as well-established as wind tunnel modeling, CFD offers a viable alternative that has advantages. CFD allows the investigator to analyze the full domain of modeling and present results in easy-to-understand graphics rather than several dozen discrete points, as with physical wind tunnel modeling. CFD modeling has been used by Envirometrics to assess comfort levels with respect to wind climate. This paper explores guidance criteria for evaluating pedestrian comfort in an urban setting.

## Introduction

We have all experienced it: you are walking downtown among the tall skyscrapers with flags shaking violently in the strong winds above the towers, but you notice only the occasional breeze at sidewalk level. Then suddenly, as you turn the corner a great gust of wind hits you and almost knocks you to your feet! Well, this may just be a minor nuisance to you as you brush your hair back and fix your inside-out umbrella but if you had perhaps been frail or of compromised strength, that gust of wind could have been dangerous. This is precisely what environmental planners are considering today when assisting architects, planners, and managers with pedestrian comfort. Safety is particularly a concern at hospitals and health facilities where a large portion of the population in the area may have compromised health and be prone to injury from an unexpected wind burst.

Microclimate studies are commonly required today for large construction projects to assess several forms of environmental impact that the project might have. The wind climate is of particular concern due to its potential impact on the safety and usefulness of the area surrounding the project buildings. For example, a planned green area may be rather useless if common winds make it too uncomfortable to enjoy a picnic or read a book.

Such studies have typically been performed using wind tunnels and scale models or qualitative techniques based on past experience. In these wind tunnel studies, scale models are exposed to winds at different angles and wind speeds at critical areas are recorded using hot-wire anemometers. These types of studies have been proven to be accurate and representative of the actual environment if the modeling technique is done correctly. However, wind tunnel modeling cannot return a full 3-dimensional view of the wind vectors and other flow features in the model. The more accuracy that is needed, the more sensors are needed. More sensors means added expense and more corruption of the flow itself from interaction of the sensors with the flow field.

In recent years, computational fluid dynamics (CFD), has shown promise to become a reliable alternative to wind tunnel modeling. CFD is essentially a computerized wind tunnel that solves the equations of motion to give a steady-state solution of the wind field in a model. Though the steady-state solution is directly not that useful in pedestrian wind evaluation (because wind gusts are the maxima of the wind speed deviation), estimates of gust speed can be calculated using the calculated values of turbulent kinetic energy (TKE) at locations in the model. CFD used for this type of study may be the "most promising area for the use of CFD in wind engineering for now." (Wright, 2004).

Here are the steps involved in conducting a CFD-based study of pedestrian winds in an urban landscape:

1. Criteria are selected to gauge what wind velocities and what frequencies of high velocity winds are acceptable.
2. A meteorological analysis of the wind climate is conducted.
3. A mathematical model of the site in question is built for computerized CFD modeling.
4. A proper method of simulating the atmosphere in the model is determined.
5. Modeling is performed at different wind speeds and directions, all determined from the climatology study of the area.
6. Wind velocities and levels of turbulence are measured in the model under the different scenarios.
7. Graphics and results are displayed showing the level of impact in different areas.
8. Mitigation efforts, if needed, are developed and tested in the model.
9. Risk management decisions are made to find the most economical solution that limits the risk of negative impacts.

**Criteria selection to gauge wind comfort levels.**

In an environmental review of wind climate effects, it must be learned if the project will make the climate more uncomfortable. If the situation is worsened more than an acceptable amount or promotes the possibility of dangerous wind velocities, mitigation must be formulated and tested in respect to the criteria.

Pedestrian wind acceptability criteria are not established in any set of guidelines or standards adopted by a professional association. Different researchers and wind engineering firms have adopted their own criteria based on experience and usefulness.

Envirometrics has extracted several sets of criteria from the literature to deveop a set of guidelines for use in CFD modeling.

A recent study compared 9 building projects with 5 different sets of criteria (Ratcliff, 1990) to determine which set of criteria fared best when compared to measured results after project completion. This study observed that none of the criteria were particularly suited to be used for a wind analysis individually, but recommended that several sets of criteria be used simultaneously. One set of criteria which performed well based on actual experience from architects was the Isyumov and Davenport criteria, which consisted of an extensive set of limits for magnitude and frequency of winds for various uses of each point of analysis. However, the study recommended that this set of criteria not be used on its own because the criteria did not take into account wind gusts, only the mean wind. As a result of this, only 4.5% of the test points in the study test project were unacceptable, which was believed to be too low. The alternative Penwarden and Wise criteria fared better with a result of 7.3% of test points showing unacceptable wind speeds with respect to frequency of impact.

Based on this study, we reviewed the better performing Penwarden and Wise criteria, but determined this criteria to be too simplified to answer the questions that a pedestrian comfort study should answer. The criteria do not take into account site use or danger levels of wind velocities. The Isyumov and Davenport criteria does take into account various increment levels of Beufort scale winds. Therefore, a modified Isyumov and Davenport criteria scheme is used by Envirometrics that takes into account the values of turbulence at points of interest to factor wind gusts into the criteria.

The Isyumov and Davenport criteria have been altered to conform better to the Beaufort wind scale. The descriptions of activities have been altered to better apply to site planning review. The frequency of impacts for each category were chosen based on an estimate of the number of wind events in a given time period. The criteria are given in the following Table.

**Table I. Criteria for Acceptable Winds for Pedestrian Comfort**

| Activity | Average wind speed | Beaufort scale | % of time | High wind speed | Beaufort scale | % of time |
|---|---|---|---|---|---|---|
| **Long stationary** | > 7 mph | >2 | < 1.5% | >12 mph | >3 | < 0.3% |
| **Short stationary** | > 12 mph | >3 | < 1.5% | > 18 mph | >4 | < 0.3% |
| **Recreational motion** | > 18 mph | >4 | < 1.5% | > 24 mph | >5 | < 0.3% |
| **Transitory motion** | > 24 mph | >5 | < 1.5% | > 31 mph | >6 | < 0.3% |
| **Dangerous** | > 31 mph | >6 | < 0.02% | > 46 mph | >8 | any occurrence |

The criteria include both an average wind speed and a high wind speed category. This takes into account that there will always be some days with high winds at virtually any location. The high wind speed category restricts the time in which these speeds occur to a lower amount of time than the average. It is important to note that these wind speeds are measured at approximately 1.5 meters and not at the conventional 10 meters of a met tower.

For each category, a location is fit for the listed activity if the indicated wind speed limit is exceeded only for a limited amount of time. The type of activities that coincide with each category are defined here:

*Long stationary*: regions where persons will spend more than 10 minutes involved in the outdoor activity. Examples include: picnic areas, outdoor seating areas (for stationary activities such as eating a meal, reading, writing, etc.)

*Short stationary*: regions where persons will spend up to 10 minutes standing or sitting in an outdoor environment. Examples include: entrances to buildings, bus stops, smoking areas, vendor area and areas where a queue could form.

*Recreational motion*: regions where the average person will be walking at slower speeds or involved in physical activities such as frisbee. Examples include: recreational walkways, open play fields and parks.

*Transitory motion*: regions where the average person will be walking briskly to get from one place to another. Examples include: sidewalks, walkways and city streets.

The wind speeds measured at the points of interest will take into account the average wind gust at each location by using a measure of the turbulent kinetic energy.

**Meteorological analysis of the wind climate.**

Selection of a proper meteorological data set is the key for any study involving wind data. The dataset should be from a site as near to the study location as possible. The site should also have similar surrounding topography and land features to properly account for local wind features. A 5-10 year dataset is sufficient to demonstrate the climatology of an area. A 1-year dataset may not be sufficient due to the possibility of anomalies from rare wind-storm events or seasonal events such as El Nino/Southern Oscillation.

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