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# Multicriteria assessment of natural ventilation potential

M. Germano *, C.-A. Roulet

*École polytechnique fédérale de Lausanne (EPFL), Laboratoire d'énergie solaire et de physique du bâtiment, CH-1015 Lausanne, Switzerland*

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**Abstract**

A method is proposed to assess the natural ventilation potential by taking into account the most comprehensive set of factors involved in natural ventilation. These factors are either driving forces, such as wind pressure and stack effect, or constraints, like noise pollution and atmospheric pollution. The process considers these factors in an ordinal qualitative scale and gives its result in that scale.

This bypasses the problem of the inaccuracy of some parameters, which can be very high, especially in urban environment and in the pre-design phase of a construction project. Actually, the method is particularly suitable for designers intending to take early-stage decisions.


*Keywords:* Natural ventilation potential; Multicriteria analysis; Wind; Stack effect; Noise; Pollution

## 1. Introduction

Factors involved in natural ventilation are *incommensurable*. This means that, if all are considered, they cannot relate or be reduced to another single criterion. Moreover, these factors can in most of the cases not be evaluated easily with a good accuracy. Both these reasons led to the choice of multicriteria analysis as a tool for evaluating the potential for natural ventilation. This approach will help to cope with the incommensurability and the uncertainty of the problem, by using *ordinal* scales for each criterion as well as for the final evaluation.

Problems of natural and hybrid ventilation are usually solved by means of airflow simulation tools. These tools are either computational fluid dynamics, zonal, nodal, or empirical models. They solve the equations of fluid dynamics or simplified equations to compute for instance the airflows in the building or parts of it. However, they do not take into account all factors involved in natural ventilation, like external noise, external pollution or safety compromising. Furthermore, they tend to propagate and to increase the uncertainty of the input parameters, which is for some parameters, like pressure coefficients, already high, especially in the early phases of a project. It has been proven (Fürbringer, 1994) that the higher the complexity of the simulation tool the higher this uncertainty increases.

* Corresponding author. Fax: +41 21 693 2722.
*E-mail address:* mario.germano@epfl.ch (M. Germano).

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## 2. Criteria involved in natural ventilation

### 2.1. Driving forces

The two driving forces of natural ventilation are wind pressure and stack effect. These forces induce a pressure difference on the building, which in turn generates airflows in the building. The wind-induced pressure difference is given by

$$\Delta p_w = \frac{1}{2} C_p \rho v^2, \tag{1}$$

with

$\Delta p_w$ difference between the static pressure on a given spot on the building envelope and the upstream reference static pressure (in an undisturbed zone),

$C_p$ pressure coefficient for a given spot on the building and a given wind direction,

$\rho$ air density,

$v$ upstream reference wind speed.

Pressure coefficients are determined either experimentally in a wind tunnel or numerically using computational fluid dynamics.

The other driving force of natural ventilation is stack pressure, or pressure due to buoyancy. It is induced by density differences between the indoor and outdoor air. The Bernoulli equation, combined with the ideal gas equation of state, leads to the stack pressure difference between two openings separated by a vertical distance $h$

$$\Delta p_s = \rho_i g h \frac{T_i - T_e}{T_e}, \tag{2}$$

where $\rho_i$ is the internal air density, $g$ is the acceleration of gravity, $T_i$ and $T_e$ are the internal and external air temperatures, respectively. In the absence of wind, when $T_i > T_e$, the air enters through the lower openings and goes out through the upper ones (upward flow). A downward flow takes place when $T_i < T_e$.

### 2.2. Constraints

The two constraints to natural ventilation retained here are noise and pollution. Others exist, such as compromising the safety of the building while leaving windows open, or the fact that the occupants do not interact in a proper way, but they are only briefly mentioned.

Noise is a constraint to natural ventilation when the building is occupied. The definition of the acceptability of noise used in the current methodology is inspired by the Swiss federal regulation, which resorts to degrees of sensitivity:

- high: zones requiring an increased protection against noise, such as relaxation areas;
- medium: zones where no disturbing company is allowed, such as residential areas and areas restricted to public facilities;
- low: zones where disturbing companies are allowed, such as industrial, agricultural and craft areas.

In order to assess the outdoor air quality, the following pollutants are usually considered:

- nitrogen dioxide ($NO_2$),
- sulphur dioxide ($SO_2$),
- carbon monoxide (CO),
- ozone ($O_3$),
- volatile organic components (VOC).

These pollutants each have long-term, short-term limiting values or both. For instance, the Swiss environment protection law (LPE) imposes for nitrogen dioxide a daily limiting value of 80 $\mu g/m^3$, whereas the annual limiting value is 30 $\mu g/m^3$.

## 3. Method

### 3.1. Assumptions of the method

The first assumption made in the current methodology is that the building will be built in a way that gets the most out of the potential for natural ventilation. The same goes in case of refurbishment.

In addition, it is supposed that the building occupants are aware of natural ventilation and open the windows or *ad hoc* openings accordingly.

The third assumption is that, given two city locations with different *local*[1] wind speeds, *wind-driven natural ventilation will be more effective at the location having the highest wind speed* (provided that natural ventilation is assessed in the same type of building in both locations).

This assumption on wind will also be valid in the present method for the three last criteria, which are stack effect, noise and pollution (obviously in a reverse way for the last two, since they are constraints instead of driving forces).

Finally, it is assumed that wind and buoyancy will never counteract each other. (It is always possible to configure openings in such a way.)

### 3.2. Justification of the method

Multicriteria analysis is a technique devoted to lighten a decision problem and to help solve it. This problem is made up of several possibly conflicting objec-

[1] Local wind speeds result from the influence of the building surroundings.