POTENTIAL FOR NATURAL VENTILATION IN URBAN CONTEXT: AN ASSESSMENT METHOD

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ABSTRACT

The natural ventilation potential (NVP) is the possibility, or probability, to ensure an acceptable indoor air quality by natural ventilation only. A passive cooling potential (PCP) can also be defined, as the possibility to ensure an acceptable indoor thermal comfort using natural ventilation. Ensuring an acceptable indoor air quality, or cooling down the building structure by natural ventilation hangs on many conditions depending on the site (outdoor air quality, outdoor air temperature and moisture, outdoor noise, local winds or global wind and urban structure, etc.) or on the building (indoor pollutant sources, indoor heat sources and stored heat, indoor air quality requirements, position and size of ventilation openings, indoor temperature, orientation of building, internal air path distribution, etc.)

The NVP cannot therefore be expressed as a single number. It is a multiple attribute variable, i.e. a list of quantitative and qualitative characteristics of the site or the building, based on available input data. It is nevertheless possible to decide, on the basis of these characteristics combined with the requirements, if a given building – or a room in a building – is likely to be well enough ventilated or not using natural ventilation. No detailed modeling is required for this assessment, which is based on existing experience.

The contribution presents the method developed to assess the NVP and PCP, and to represent it using geographically referenced information.

KEYWORDS

Natural ventilation, Potential, GIS, Multicriteria analysis, Morphological Indicators, ELECTRE.

INTRODUCTION

A large majority of the publications on natural ventilation deal with its behaviour within a *single* building, like single and multi-zone models, possibly coupled with thermal models (Orme, 1999). The aim of this contribution is to assist the designer in the early stages of design, if possible before the construction of a building. More precisely, it aims at providing information on the issue of 'where to build' more than on 'how to build'. This is why an entire part of the urban fabric, rather than a single edifice like in the mentioned publications, has to be considered. In fact, the current investigation studies natural ventilation at mesoscale, *i.e.* at the scale of the building-environment interaction in urban context : local heterogeneity is hence set aside. Moreover, it avoids too complex modelling such as CFD, because the boundary conditions are never known precisely, because of the chaotic nature of the urban flow, and because it resorts to pressure coefficients, which are seldom known and, if the case arises, are hardly usable to calculate infiltration or ventilation rate.

DEFINITION OF THE NATURAL VENTILATION POTENTIAL

The natural ventilation potential (NVP) is the possibility to ensure an acceptable indoor air quality by natural ventilation only. This definition assumes that *"acceptable indoor air quality"* is defined. There are many definitions available, issued either by institutions such as WHO or ISIAQ, or research programmes such as COST613 (COST 613, 1991).

The passive cooling potential (PCP) is the possibility to ensure an acceptable indoor thermal comfort using natural ventilation. The acceptable indoor thermal comfort is defined by international standards such as ISO 7730 (EN-ISO-7730, 1993).

DEFINITION OF THE *SITE* NATURAL VENTILATION POTENTIAL

We define the potential of the site as the potential of having good ventilation, provided that an appropriate building is or will be built on. In other words, it tells whether the site is suitable for the construction of a well naturally ventilated building.

SITE POTENTIAL AND MULTICRITERIA EVALUATION

The NVP of the site depends on several criteria. These are:

Meteorological criteria:
- macroscale wind speed distribution and orientation
- macroscale temperature distribution
- solar radiation
- outside air moisture

Urban criteria:
- microscale wind speed distribution and orientation
- microscale temperature distribution
- buildings layout
- buildings height
- morphological indicators of the urban context
- outdoor noise levels
- outdoor pollution
- land topology

The mentioned morphological indicators (ninth row) are a set of criteria introduced hereafter. As the enumerated criteria are of very different types, it would not be realistic to gather them in a single equation. This is why a multicriteria evaluation seems more relevant for the assessment of the NVP.

These criteria may be grouped and each of them associated with veto, indifference and preference thresholds and weights. This important point is where physics and physical values come into play.

METHOD

In order to have an assessment of the NVP of the site, one useful tool is geographic information systems (GIS) (Maguire, 1991), because the intention is to compare various geographical locations.

GIS will be used at two stages. First, the relevant data for the evaluation of NVP are chosen. Particularly, they comprehend weather data, the layout and the height of the buildings, the length and the width of the streets, and so on. At a second stage, once the multicriteria evaluation is processed, the NVP at each location can be represented as a new GIS layer. Between both stages, each GIS information layer is seen as a criterion and takes part in a multicriteria evaluation, whose outcome is the NVP.

METEOROLOGICAL DATA

The meteorological data used are provided by Swiss Federal Office of Energy's work *METEONORM*.[1] It comprehends amongst others a piece of software and a data source on a vast number of meteorological data covering Switzerland and other locations around the world. The software provides an interpolation facility allowing to describe meteorological conditions between weather stations. Monthly GIS maps have been derived for wind speed, wind direction and air temperature. The choice of the wind is justified by the fact that wind pressure is one of the driving forces of natural ventilation. The other driving force is stack effect, resulting from air density differences, in their turn provoked by temperature differences and humidity differences. This is why air temperature was selected, too. Night cooling is considered as well.

MORPHOLOGICAL INDICATORS

If we intend not to work at a too close scale ant not to look at the urban fabric details, an idea is to assimilate the urban fabric to a porous medium with a rigid skeleton. This is a way to get rid of local heterogeneity. The so-called *morphological indicators* (Adolphe, 1999) fulfil this objective. They are helpful in the sense that they were designed to be compatible with several requirements that allow them to be used in practice, namely completeness, non-redundancy and operationability. As a matter of fact, the morphological indicators model was developed in order to assess NVP, while remaining compatible with the usual existing urban databases.[2]

Another advantage of these indicators is their help in deducting urban climate conditions from the conditions outside the city. Usually indeed the weather stations are located in the suburbs. The list of the morphological indicators is the following:

- absolute rugosity: *mean height of the building*
- relative rugosity: *mean square deviation of the canopy height*
- porosity: *ratio of the useful open volume to the total volume of the urban fabric*
- sinuosity: *mean orientation of the streets*
- occlusivity: *mean building perimeter for each horizontal cross section*
- compacity: *sum of the ratios of the building area to the building volume*

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[1] http://www.meteotest.ch/products/meteonorm/index.html

[2] The morphological indicators model is in the process of being validated on three sites in the South of France (Toulouse, Blagnac and Marseille) by comparisons with on-site measurements and with CFD.

- contiguity: *buildings adjacency with neighbours*
- solar admittance: *ability to capture the incoming solar radiation*
- mineralization: *useful area of water and vegetation*

These indicators – except solar admittance – have been implemented in MapBasic®, the programming language of the GIS software MapInfo Professional®.
Each of the indicators can be implemented over a city area.

MULTICRITERIA EVALUATION

The expected result of a multicriteria evaluation is a decision or a group of decisions to be taken (Schärlig, 1990ab). In our case, the decisions to be taken are 'where to build', which will be expressed here on a map by squares of different colours telling how good the potential for natural ventilation is. In other words, the decisions – or *actions* – of our multicriteria evaluation consist of the locations in the city.

As they are numerous, it makes it difficult to use the multicriteria method referred to as ELECTRE III (Maystre, Pictet and Simos, 1994) – one of the methods usually used for such an evaluation – because it proceeds to a classification of the entire set of decisions at the same time, implying too much calculation.

Another method, ELECTRE TRI (Yu, 1992ab; Maystre, Pictet and Simos, 1994) – also referred to as ELECTRE BETA –, seems more relevant because it proceeds to an assignment of the decisions to a category. Namely, two base decisions – or more – are chosen and the other decisions classified by comparison with them. Therefore, the number of decisions can be very high, because they are evaluated independently. This consists in the so-called _-methodology. The drawback of this method is the choice of the two base decisions. They can be chosen in accordance with the experience, *i.e.* with the knowledge of well-ventilated sites. Alternatively, a preliminary study can be done with ELECTRE III and a small number of locations to select two appropriate base decisions.

RESULTS

ELECTRE TRI has been implemented in MapBasic and can be run for the time being over the canton of Geneva area, in Switzerland. The user of the program has the possibility to choose the month of the evaluation, the region he intends to evaluate, the size of the squares delimiting each location-decision, the criteria to include in the evaluation and the two base locations-decisions.

The result is displayed on two maps. The first one is the outcome of the so-called *pessimistic assignment procedure* of ELECTRE TRI and the second one that of its *optimistic assignment procedure*. The pessimistic assignment procedure tries to assign each decision to the lowest category, in our case the category corresponding to the worst NVP, whereas the optimistic does the same towards the highest category.

In Figure 2, the two bold squares stand for the two base decisions, cross-hatched squares for the areas classified below the worst base decision, lined squares for these classified between the two base decisions and blank squares for these classified above the best base decision.

The map corresponding to the pessimistic assignment procedure (not shown here) is quite similar but exhibits a little less blank areas.

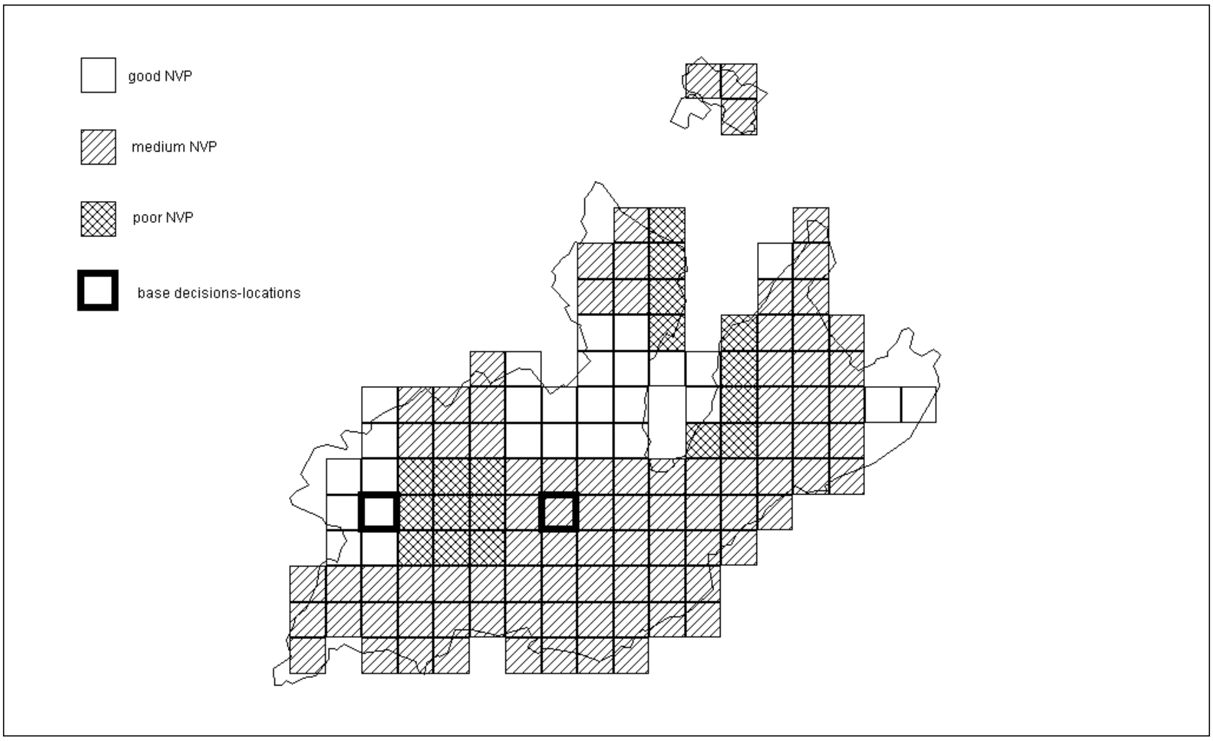

Figure 1 : Map of the site natural ventilation potential, optimistic assignment procedure : canton of Geneva, Switzerland

DISCUSSION

It has to be made clear that the current work is a first step in the assessment of the natural ventilation potential and that it concerns only the *site* NVP as it is defined in the fifth section. It does not tell whether an edifice in the area of concern is well ventilated or not, but rather whether it is possible or not to build a well ventilated building there or whether an existing building of this area can be well ventilated at the expense of possible modifications.

The multicriteria analysis ELECTRE TRI gives several sets of indices (in our software in the message window of MapInfo) – concordance indices, global concordance indices, discordance indices and credibility degrees – that should tell the user which of the criteria tipped the scales in favour or against a good NVP. The designer should then be able to choose the appropriate ventilation strategy – *e.g.* stack effect use – for the erection of a new building or for the refurbishment of an old one. Note that, up to the end of 2001, no validation has been undergone by comparison with on-site measurements.

A domain of applicability has to be defined for the scales that can be used: the morphological indicators model imply that the squares of assessment (Figure 2) must not be too small because it does not make sense to calculate these indicators – *i.e.* working out a sort of average on the urban fabric – in such a case. On the other hand, they must not be too large because this would generate a loss of the local information of the site.

CONCLUSION AND IMPLICATIONS

The presently proposed methodology and software should be able to help the designer to select the appropriate location to erect a subsequently well ventilated building or the location of an old building having the possibility, after refurbishment, to be well ventilated. It should be kept in mind that a new construction can itself affect the ventilation properties of an area.

However, one of the main drawbacks of this methodology is the lack of GIS data currently available around the world. The case of Geneva was chosen on the grounds of the existence of the required data for this town. Nevertheless, we know that the same type of data as Geneva will soon be available for the whole Switzerland and there is good hope that it will for the main European cities. Even if the case does not arise, there is still the possibility to generate the relevant data manually.

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