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A Simple Interactive Design Tool for Sizing, Locating and determining Pollution Attenuation features, of Urban Air Inlets suitable for Office Buildings

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SYNOPSIS

This paper identifies successful ways of applying natural ventilation to non domestic buildings located in urban areas. Whilst noise and contaminant pollution sources are a problem methods of avoiding these emissions are discussed. A review of literature has established that pollution problems arise for buildings which are in close proximity to roads, railways, airports and local industries. Location of ventilation air inlets will affect the quality of indoor air, therefore it is essential that they are located in ways that minimise the ingress of external pollutants. Potential pollution avoidance strategies include, locating vents on sheltered facades and positioning central inlets at a sufficient height from emissions. Wind flows patterns around buildings have an important impact on air quality, and a simple model is discussed that determines the decrease in pollutant concentrations between emission sources and air intakes.

Adequate ventilation is required to limit the number of occasions when indoor temperatures are uncomfortable. A series of well established models are presented based on different natural ventilation concepts. These models can be used to size air inlets for any building, to provide specified ventilation rates on any floor. All issues discussed in the paper form part of an interactive design tool that provides best practice guidelines for minimising the impact of urban pollution, selecting suitable air inlets, and sizing them so as to provide adequate ventilation during the summer.

1. INTRODUCTION

The aim of this paper is to breakdown barriers to concepts of natural ventilation. The study is part of a Pan European project titled NatVent, that involves seven countries in the north of Europe. The project leaders are the UK Building Research establishment. Urban pollution is a major barrier to the adoption of natural ventilation, so successful ways of avoiding these problems need to be found.

The traditional approach to ventilating non domestic buildings located in urban areas is to specify mechanical ventilation. This strategy can seal buildings from pollution along facades, and where necessary draw air via cleaning filters to remove contaminants; the pressure drop associated with this process is not a practical option for passive ventilation. The draw back in relying upon air conditioning systems is in the amount of energy required to run them, hence the negative environmental impact. If natural ventilation systems are not adversely affected by external pollution then it offers an ideal alternative.

2. LIST OF SYMBOLS

NO_2	nitrogen dioxide.
NO	nitrogen monoxide.
CO	carbon monoxide.
SO_2	sulphur dioxide.
O_3	ozone.
D_{min}	minimum dilution factor at a fixed distance from an exhaust vent.
U_H	reference wind velocity (ms^{-1}) at height H.
Qe	volume flow rate of exhaust emissions (m^3s^{-1}).
r	distance between exhaust vent and air intake (m).
A	area of inlet (m^2).
Q	air flow rate (m^3s^{-1}).
C_d	discharge coefficient.
ρ_{ins}, ρ_{out}	air density inside and outside a building, respectively (kgm^{-3}).
g	acceleration due to gravity (ms^{-2}).
h, h_{NPL}	height of inlet and height of neutral pressure level, respectively (m).
T_{ins}, T_{out}	temperature inside and outside building, respectively (K).
v^2_{ref}	reference wind velocity (ms^{-1}).
$\triangle C_p$	difference in pressure coefficient between inlet and outlet.

3. SOURCES OF POLLUTION IN URBAN ENVIRONMENTS

Urban pollution arises from a range of sources, all of which should be considered when deciding upon the ventilation strategy for non domestic buildings. Pollution sources include local industries, cooling towers, building exhaust vents and traffic emissions arising from vehicles including aircraft and trains (1). Vehicles pollutants have the largest impact on ambient air quality. Particles (PM_{10}) and noise are the primary pollutants of concern, although other forms of pollution include the gases NO_2, NO, CO SO_2 and O_3. All sources should be identified prior to positioning air intakes on buildings.

Buildings in close proximity to busy roads are exposed to noise and contaminants. A recent investigation revealed that in one of two naturally ventilated buildings had 33% higher concentration of CO; this building was beside a busy road, whereas the 'cleaner' building was 400m away (2). Ambient pollution derived from vehicles emissions reflect traffic intensity and mobility, hence during rush hour periods when vehicles are stationary or congested, air quality will be at it poorest (3).

Aircraft and trains generate noise pollution, for buildings located near airports and railway stations. Emissions from building exhaust vents and industrial stacks may also negatively impact on air quality within buildings. Wind direction and speed are critical factors that will affect air quality at air intakes, (4).

4. MINIMISING THE IMPACT OF URBAN POLLUTION

A number of simple steps can be taken to reduce the impact of external pollution on air quality within non domestic buildings. These involve the intelligent location of air intakes to office blocks. Sheltered facades such as courtyards and enclosures are ideal for locating air inlets, as they are protected from pollutants derived from busy roads. Both contaminant pollutants and noise exposure are significantly reduced by this strategy (5). Buildings with central air inlets at high level are less exposed to pollutants generated at road level, particularly in the case of PM_{10} (6), and also in the case of gaseous pollutants such as CO and the oxides of N (7). Figure 1 is an example of the dilution of pollutants observed along a building facade situated besides a busy London road.

Roof level installation of central air inlets may have some drawbacks if noise from planes is a local problem. If exhaust vents from host or neighbouring buildings are close to air intakes problems will arise. A simple model has been developed to evaluate the effect of exhaust vent emissions on air quality at air intakes (8). The model is defined by equation 1.

$$D_{\min} = 0.11\left(\frac{U_H r^2}{Q_e}\right) \qquad 1$$

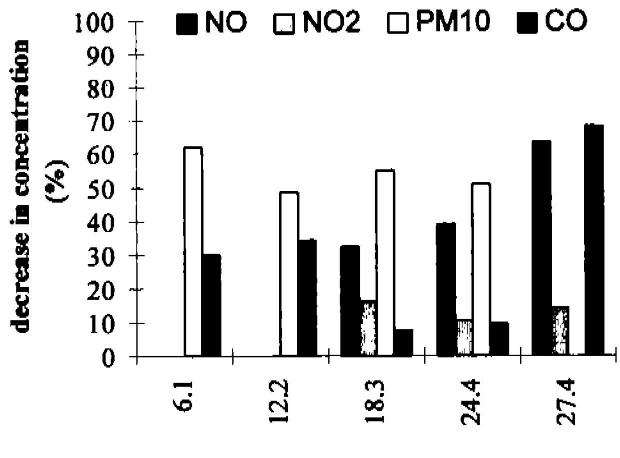

Figure 1. The effect of height on ambient concentrations of pollutants

Although wind direction is not important in the model wind speed is. The value of U_H should closely reflect typical local conditions. Figure 2 indicated minimum dilution factors that have been calculated for a range of conditions.

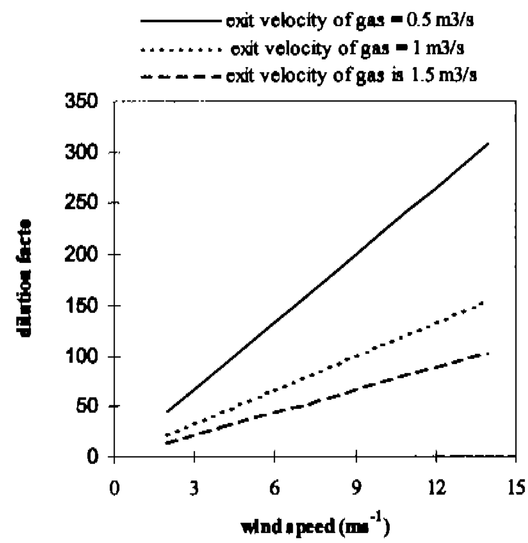

Figure 2. Dilution factors for gas emissions between exhaust vents and air intakes.

5. WIND FLOWS AROUND BUILDINGS

Buildings downwind of pollution sources are more exposed to contaminants than those upwind (4). However the situation is made complex by the way neighbouring buildings also affect air flow patterns. National meteorological wind flows are often not reflected on a local scale (9), so even buildings perceived to be downwind from pollution sources are subjected to re-ingestion of exhaust emissions. In a similar way relying on prevailing winds to avoid and / dilute exhaust emissions ignores the fact that significant sub prevailing winds may be derived from the opposite direction.

Wind forces acting on building generate leeward and windward facades as well as down-wash and up-wash zones (8). Air intakes and exhausts should be positioned on buildings so that are located in different zones. This will minimise the possibility of exhaust fumes re-entering the building. The size of the down-wash and up-wash zones depends on the size and shape of the building. A good design practice is to distance air intakes from exhaust vents by at least 1/3 rd the building height.

6. SUITABLE AIR INLETS FOR URBAN ENVIRONMENTS

It is not always possible to prevent outdoor pollution entering air inlets. To reduce the negative impact on indoor air quality air inlets will need to offer some means of attenuating pollution levels. A range of pollution attenuation strategies for air inlets is provided in Table 1. The aim of the design tool is to suggest suitable air inlets for buildings in relation to their environment. The tool is fully interactive, so allows the user to determine their inlet requirements.

Table 1. Air inlet pollution control strategies, suitable for non domestic buildings

type	pollution control strategy
1	inlets without pollution control features
2	inlets that can be closed during peak traffic periods
3	inlets with noise attenuation features alone
4	inlets with particle attenuation features alone
5	inlets with both noise and particle attenuation features

7. SIZING AIR INLETS

A minimum ventilation rate of 5 air changes per hour should ensure "sensible cooling" for most of the summer, in temperate climates (10). This requirement partly influences the size of air inlets suitable for non domestic buildings, as will the natural ventilation strategy adopted. Three models have been developed based on three approaches to natural ventilation (11). The models are based upon stack, wind and combined stack-wind driven ventilation. Equations 2 and 3 describe the models available in the design tool.

STACK DRIVEN VENTILATION:

$$A = \left(\frac{Q}{C_d} \sqrt{\left(2/\rho_{ins} \right) \rho_{ins}\, g\, (h - h_{NPL}) \left(T_{ins} - T_{out}/T_{ins} \right)} \right) \qquad 2$$

WIND DRIVEN VENTILATION:

$$A = \frac{Q}{Cd \sqrt{\left(2/v^2_{ref} \Delta Cp \right)}} \qquad 3$$

where;

$$Cp = \left(Cp\left(0.5\rho_{out} v^2_{ref}\right)_{inlet} \right) - \left(Cp\left(0.5\rho_{out} v^2_{ref}\right)_{outlet} \right) \qquad 4$$

The combined stack-wind ventilation model draws on both equations 2 and 3. The models can be used for buildings of any number of floors and each can have different ventilation rates if so required. The design temperature can be selected to reflect local meteorological conditions, the same applies to the choice of reference wind speed. Other data inputs relate to the dimensions of a building.

8. CONCLUSIONS

All issues that have been raised in this review are contained within the interactive design tool. Information can be accessed as a simple summary schematic, or if more detail is required, as a series of tables that address the full range of pollution issues associated with urban environments. The goal is to suggest the most suitable type of air inlet given the environment surrounding a building, and then to size them in order to provide adequate ventilation for most of the year. In appendix 1 the start options of the design tool are shown. These amount to the option of entering the full checklist by table format, or referring to the schematics that summarise all noise and contaminant pollution issues. Appendix 2 summarises the air inlet pollution attenuating options that are available, whilst appendix 3 outlines data inputs and outputs relevant to sizing inlets.

9. ACKNOWLEDGEMENTS

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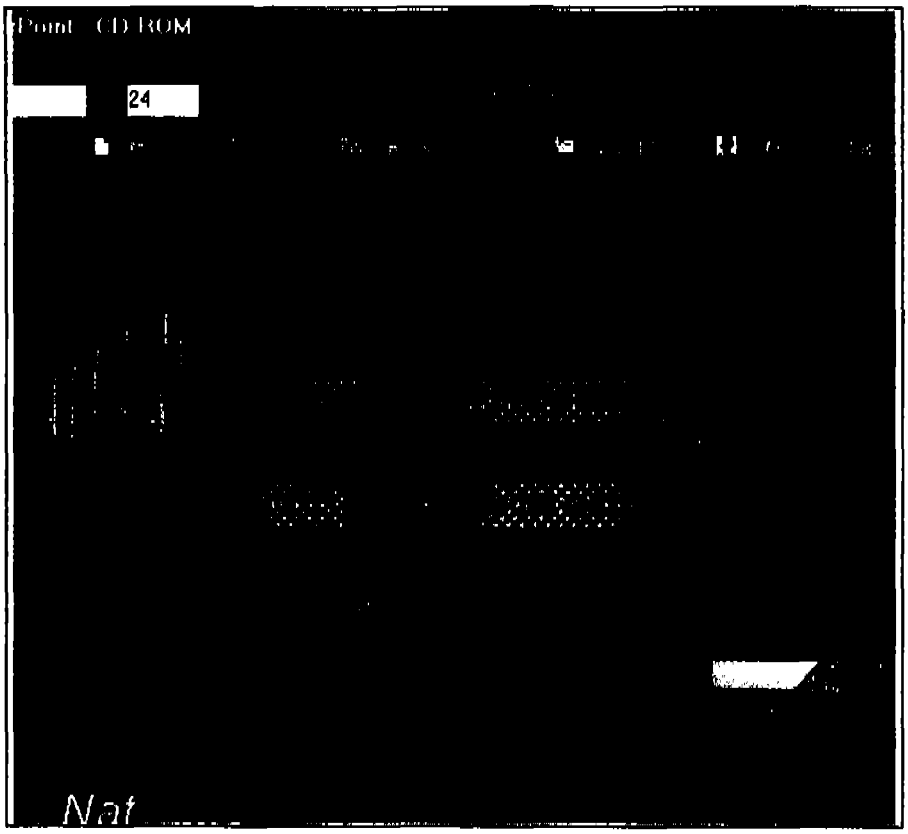
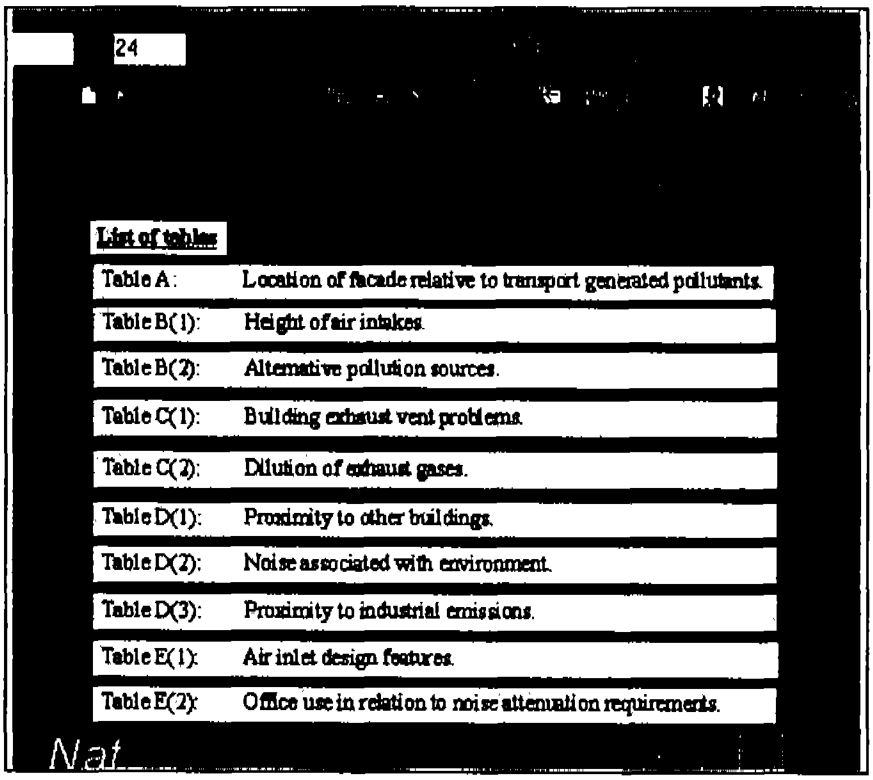
(10) **Irving, S.**, (1996); '*The Role of Ventilation in Cooling Non-Domestic Buildings*', Technical Note 48, AIVC, p.1.

(11) **Irving, S., et al.**, (1997); '*Natural Ventilation in Non-Domestic Buildings*', CIBSE Design and Applications Manual, pp. 55-57.

11. APPENDIX 1: Front end of interactive design tool, for locating and sizing air inlets





List of tables

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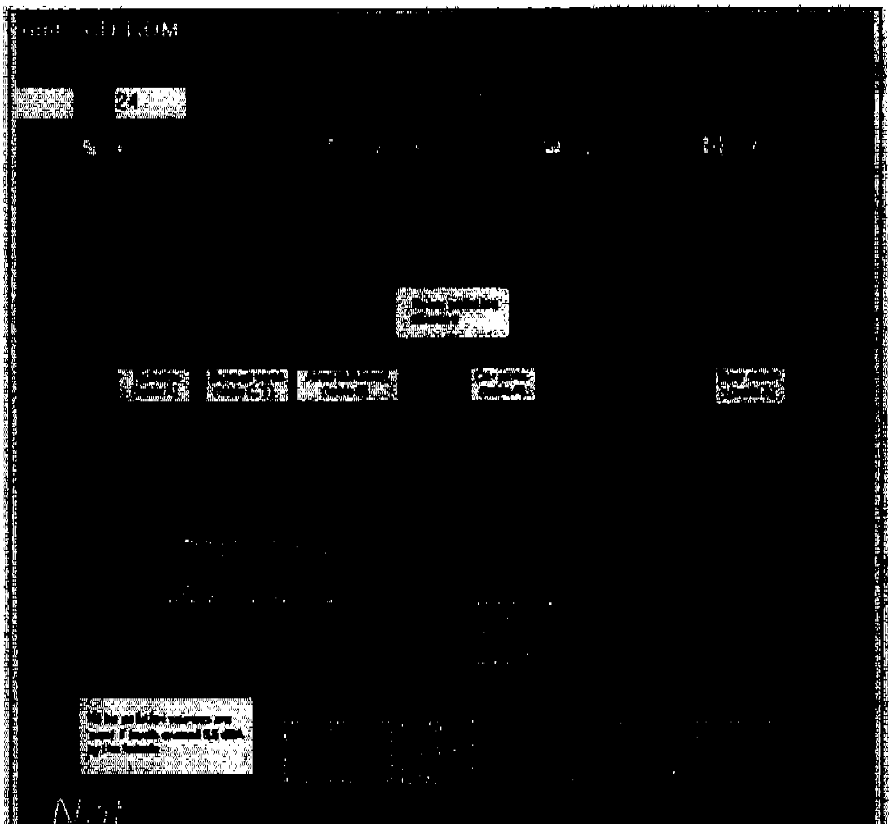
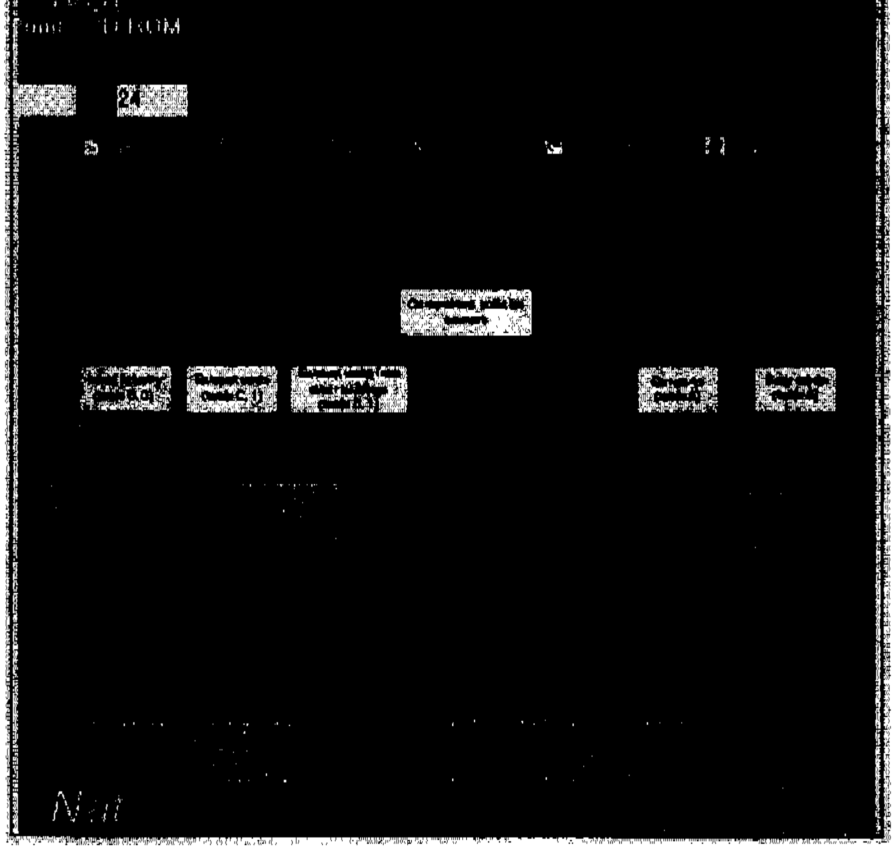
Table B(1):	Height of air intakes.
Table B(2):	Alternative pollution sources.
Table C(1):	Building exhaust vent problems.
Table C(2):	Dilution of exhaust gases.
Table D(1):	Proximity to other buildings.
Table D(2):	Noise associated with environment.
Table D(3):	Proximity to industrial emissions.
Table E(1):	Air inlet design features.
Table E(2):	Office use in relation to noise attenuation requirements.





APPENDIX 2: Air inlet options suitable for naturally ventilated buildings in urban areas

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Table E1

Air inlet design features		
number	features	move to table
1.	inlet without pollution controls.	
2.	inlets that can be throttled back during peak traffic flows.	E(2)
3.	inlets with excellent noise attenuation.	E(2)
4.	inlets with excellent particle attenuation.	
5.	inlets with both excellent noise & particle attenuation	E(2)

table list

skip to summary of noise pollution concerns

skip to summary of contaminant pollution concern

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Table E (2)

Nature of office on noise attenuation requirements :	
description of room	noise attenuation features desired
Noise sensitive offices.	- locate rooms on sheltered facades if possible. - locate rooms near ground level where aircraft noise is a problem.
Open plan offices.	- additional air inlet noise attenuation required to account for reduction in partition area.
Cellular offices.	- comparatively less noise attenuation required for air inlet due to greater room absorption.

table list

skip to summary of noise pollution concerns

skip to summary of contaminant pollution concern

APPENDIX 3: Data inputs and outputs of the combined wind-stack ventilation model