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Occupants' Behaviour with Respect to Window Opening: A Technical and Sociological Study.

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1.0   Synopsis

The occupant's behavior with respect to window opening may greatly affect the ventilation system, the energy consumption or/and the indoor air quality. In order to quantify the magnitude of opening times, many surveys have focused on climatic parameters and concluded to the temporal correlation between the timelength of opening and the outside temperature or the solar irradiation. In this paper, we study the influence of sociological and technical parameters on the average time of opening during the winter. The research is based on a sociological survey and a two year monitoring of thirty houses with recording sensors on every window.

The wife at home or not, the size and age distribution of the family are key variables in the kitchen, bathroom, children's bedroom. The orientation of the living room related to the sun explains the occupant's behavior in this room. For the parent's bedroom, none of the selected parameters emerges, the distribution and frequency of opening time are so erractic. The type of ventilation systems, natural versus mechanical, is not the main explainable variable, as well as the degree of equipment of the family.

2.0   Introduction

In the past years, research has focused on understanding air infiltration and improving ventilation systems. Building construction techniques and ventilation products have now reached a high quality standard. However, we still face some claims for a better indoor environment. Satisfying this demand implies a clear identification of occupants' wishes and behavior.
In this paper, we analyse the technical and sociological parameters impacting occupants' behavior with respect to window opening during winters. We will not present the influence of the weather data on their behavior.

3.0   Methods

Given the complexity of understanding the occupants' behavior with respect to window opening, we used different approaches to examine this issue :
    - a two year monitoring on 30 individual electrically heated houses, recording duration and number of openings on each window /1/
    - a questionnaire survey on 60 households including the 30 monitored one /2/
    - 3 household interviews.

3.1   Building group

The studies were conducted in the same geographical area near Lyon (France) with houses built between 1982 et 1985. In the measurement group, 10 dwellings were equipped with humidity controlled ventilation (numbered 1to 10), 5 with natural ventilation system (numbered 11 to 15) and 15 with mechanical exhaust ventilation systems (numbered 16 to 30).

3.2 Recorded parameters

Instead of an automatic monitoring of the entiere house, we decided to develop miniature sensors with an periodical inspection.
Every two or three weeks, the following data were recorded :
- duration of opening of each window
- number of opening of each window
- energy consumption (day and night)
- functionning time of the ventilation.

During the visit, the agent noted :
- temperature and humidity in the living-room
- flow rate in exhaust rooms
- angle of opening of opened windows if any
- cleanliness of exhaust valves
- temperature and humidity in the parents' bedroom.

At the local weather station, the following data were recorded :
- global solar irradiation (MJ/m2)   - diffuse solar irradiation (MJ/m2)
- number of hours of sun (h)   - water precipitation (mm)
- wind speed (m/s).

For analysis, all the previous data were converted to a daily basis.

3.3 Characteristics of the households

For each instrumented houses, we have identified :
- number of persons   - number of babies (not at school)
- number of children at school   - number of smokers,
- women at home   - men working during nights
- number and type of pets   - ventilation system,
- equipment of the house (diswasher,microwave,cooker hood,....),
- orientation of the living room window (north or other).

4.0 Results

4.1 Recorded duration of opening

Table 1 is the synthesis of two winters. Winter in 90 was more severe than in 89, (average temperature 2° C less). Consequently, the durations were slightly different but the same order of magnitude is respected.

If we compared with foreign experiences, the figures are different but the building techniques and HVAC systems also differ significantly. However, the parents' bedroom is also the room where the window is often opened.

	Present Experiment	Netherlands /3/	Belgium /4/
Kitchen	30 mn	1h45	1h
Living room	50 mn	1h	30 mn
Bathroom	45 mn		1h30
Parents' bedroom	2h30	5h	4h
Children's bedroom	1h	1h45	2h30

Table 1 : Duration of opening in every room

4.2 Estimated duration of opening

Table 2 compared the estimated duration of opening in each room with the recorded one. We notice that occupants underestimate this variable, especially in the bedrooms and living-room. At the opposite, the evaluation is quite accurate in the bathroom.

	Kitchen	Living room	Bathroom	Parents' bedroom	Children's bedroom
Overestimation	26	13	10	7	14
Underestimation	43	57	35	73	57
Rigth estimation	30	30	55	20	29

Table 2 : % of people under, over or correctly (+/- 10 mn) estimating the duration of opening

4.3 Multivariable analysis

4.3.1 Method

The sociological survey identified explanatory parameters of the occupants' behavior and a kind of hierarchy. Using the Morgan and Sonquist method, we have tried to identify the main explanatory variables of the recorded duration of window opening.
The segmentation criteria is based on the variable which is going to maximize :

$$W = \sum Pj \; (Mj - M)$$

Where M is the average of the duration of opening
         Mj is the average of the duration of opening of the state of the explanatory variable
         Pj is a weighting values.
Repeating the segmentation criteria at different levels, we can build a segmentation tree with a hierarchy for the explanatory variables. This method is really attractive but presents some risks. When no variable

represents a strong segmentation criteria, the segmentation tree can be irrealistic because a bifurcation was not pertinent. This fact should lead to a comparative analysis of W for the various explanatory variable.

Because of the limited number in the sample, we will consider only the first levels of the segmentation tree.

4.3.2 Kitchen

The wife working full time, part-time or at home is the main variable for the kitchen. The time available for cooking activityies explains the difference between the various households. As we will notice for other rooms, the larger the family is, the less the window is opened. Finally, we notice a shorter duration of opening in a house equipped with a mechanical exhaust ventilation system. In a naturally ventilated house, the wife may need to open the window to exhaust the pollutions.

4.3.3 Living-room

The orientation of the living-room is the key variable: occupants open widely their windows by sunny days. The presence of smokers induces a longer duration of opening, babies within the family lead to the opposite.

4.3.4 Bathroom

The households without children leave the window open for a long time. The presence of babies in the family leads a short duration of opening.

4.3.5 Children's bedroom

When the bedroom is occasionnaly used, the window is opened for large period of time. In fact, this room can be used for other activities and is largely ventilated before the welcome of a guess. When the wife is working full time, this room is rarely opened.

4.3.6 Parents' bedroom

No explanatory variable emerges from the statistical analysis. None of the listed parameters can correlate the opening. In fact, we notice a difference behavior in any class. From a few minutes to hours, the entiere spectrum was recorded.

4.3.7 Conclusions

The wife working or not, the presence and the age of children are the key variables explaining the occupants' behavior. However, usually another specific variable emerges in any room. The type of ventilation systems is not fundamental in the occupants' behavior except in the kitchen where the natural ventilation system is not sufficient to exhaust pollutions.

These results are in agreement with the sociological survey and illustrate the major role of the household with respect to the window opening and the ventilation system.

4.4 Energy consumption

This study has identified a large spectrum of behavior with respect to window opening. The act of opening is usually combined with the switch of the electric radiator and we did not point out a correlation between the time of opening and the energy consumption.

5.0 Conclusions

This study illustrates the crucial role of sociological parameters regarding to the occupants' behavior with respect to window opening. Even if the conclusions are limited to this reduced sample, this research points out that the specifications and the operation of a HVAC system should better integrate the occupants' behavior. An excellent system from a theoritical and technical approach can be a failure if it does not include, in the design approach, the occupants.

6.0 References

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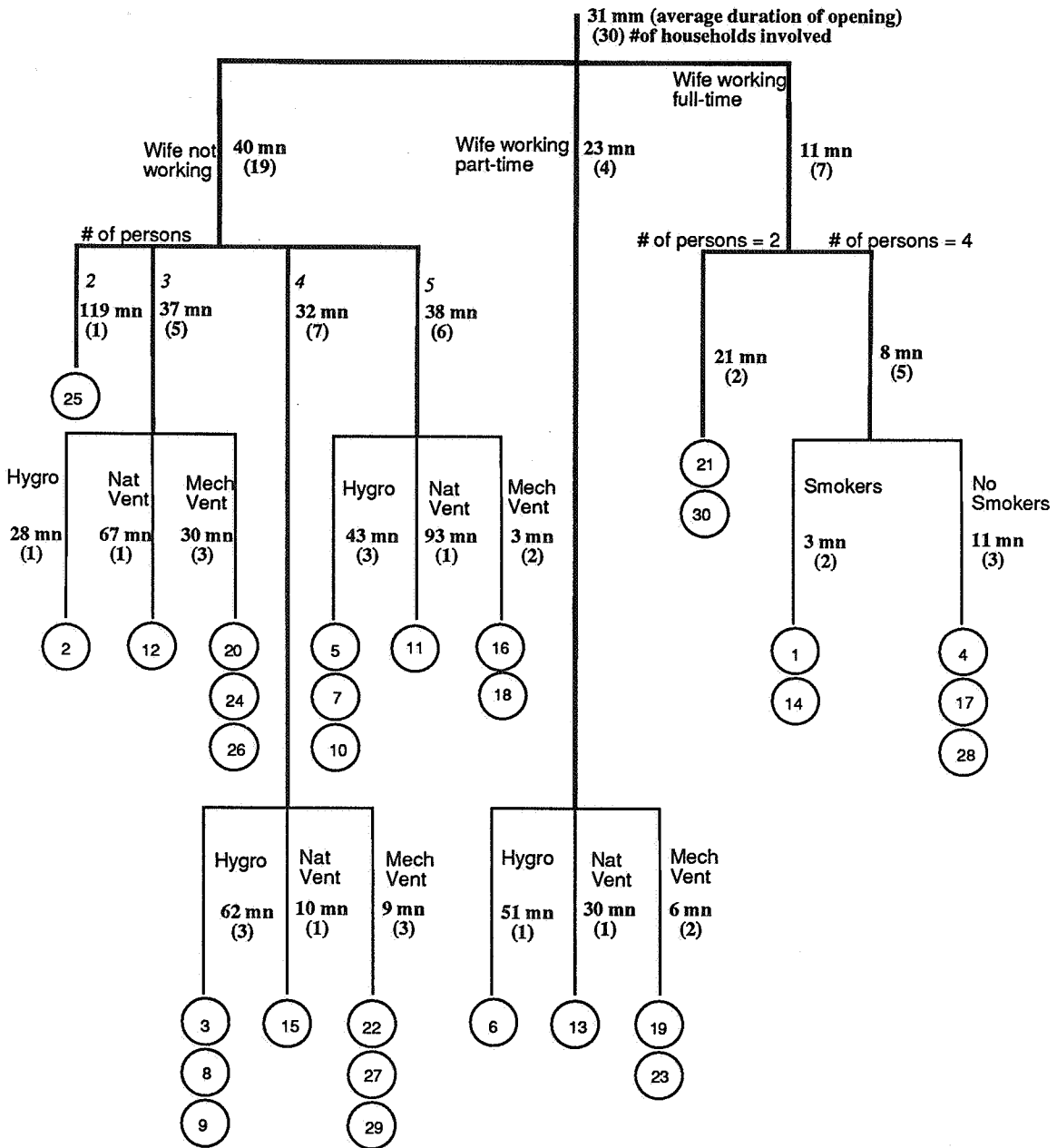
31 mm (average duration of opening)
(30) #of households involved

Wife working
full-time

Wife not | 40 mn   Wife working | 23 mn   11 mn
working | (19)   part-time | (4)   (7)

# of persons   # of persons = 2   # of persons = 4

2   3   4   5
119 mn   37 mn   32 mn   38 mn   21 mn   8 mn
(1)   (5)   (7)   (6)   (2)   (5)

(25)

Hygro   Nat   Mech   Hygro   Nat   Mech   21   Smokers   No
         Vent   Vent   Vent   Vent   Smokers
28 mn   67 mn   30 mn   43 mn   93 mn   3 mn   30   3 mn   11 mn
(1)   (1)   (3)   (3)   (1)   (2)   (2)   (3)

(2)   (12)   (20)   (5)   (11)   (16)   (1)   (4)
                 (24)   (7)   (18)   (14)   (17)
                 (26)   (10)   (28)

                 Hygro   Nat   Mech   Hygro   Nat   Mech
                          Vent   Vent   Vent   Vent
                 62 mn   10 mn   9 mn   51 mn   30 mn   6 mn
                 (3)   (1)   (3)   (1)   (1)   (2)

                 (3)   (15)   (22)   (6)   (13)   (19)
                 (8)   (27)   (23)
                 (9)   (29)

Figure 1 : Duration of opening for the window of the kitchen

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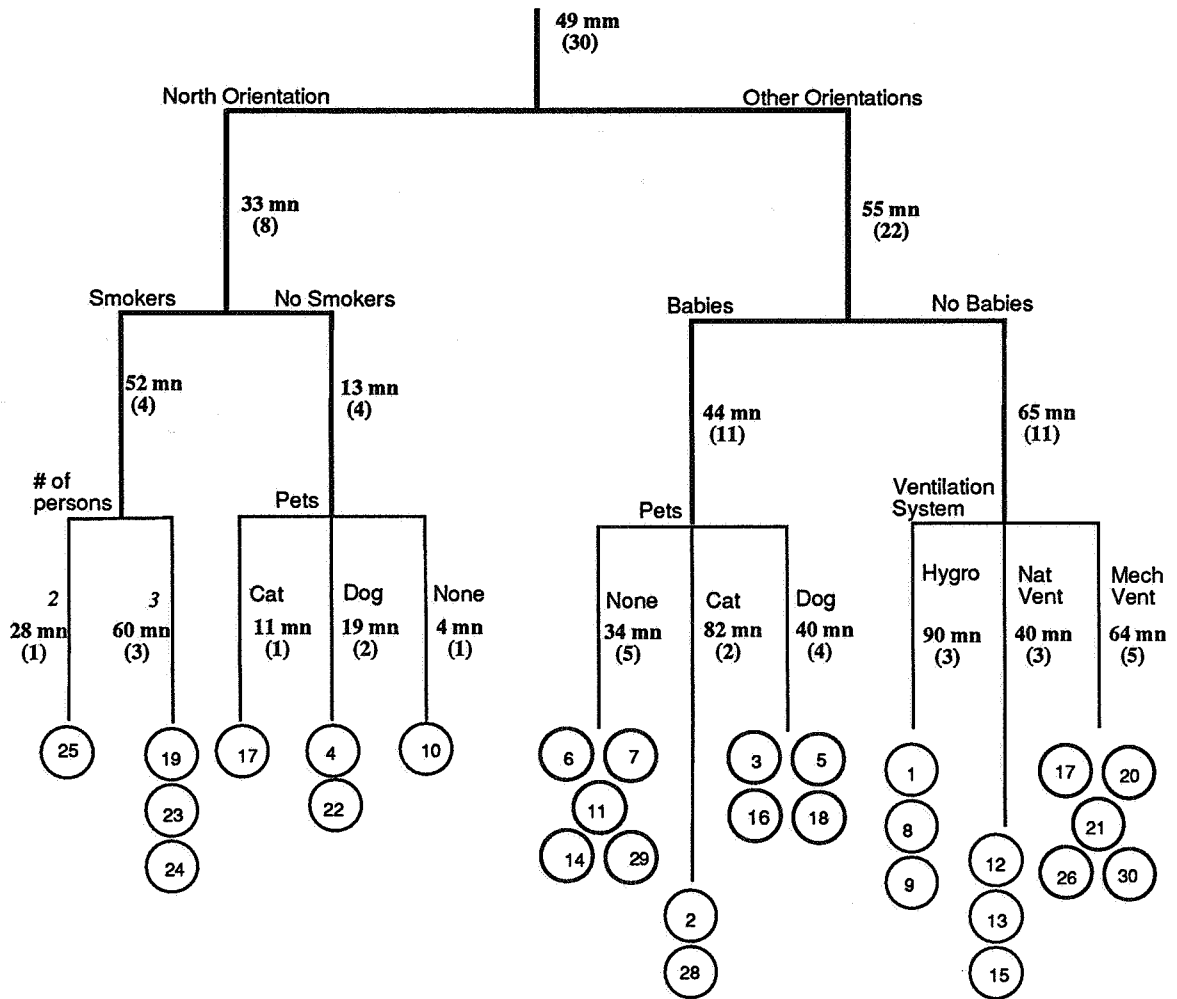
Figure 2 : Duration of opening for the window in the living room

44 mn
(29)

# of persons = 2   # of persons > 2

168 mn   **29 mn**
(3)   **(26)**

Children at school   No children at school

(21)(25)
(30)

33 mn   **5 mn**
(21)   **(5)**

Wife not   Wife   Wife working full-time
working   working   (2)(6)(15)
                  part-time   (24)(26)

35 mn   **24 mn**   **39 mn**
(13)   **(3)**   **(5)**

(3)(5)(7)(8)   (13)(19)   (1)(4)(14)
(9)(10)(11)   (23)   (17)(28)
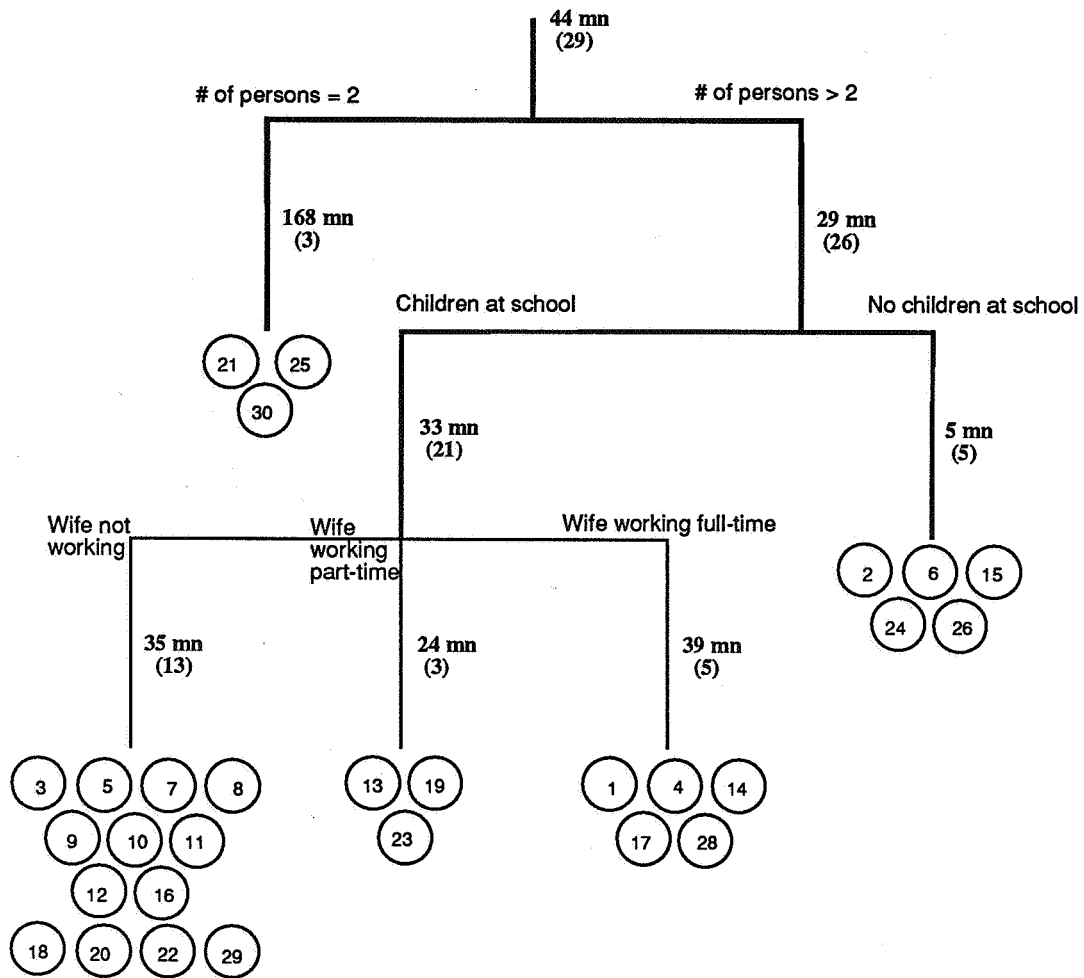(12)(16)
(18)(20)(22)(29)
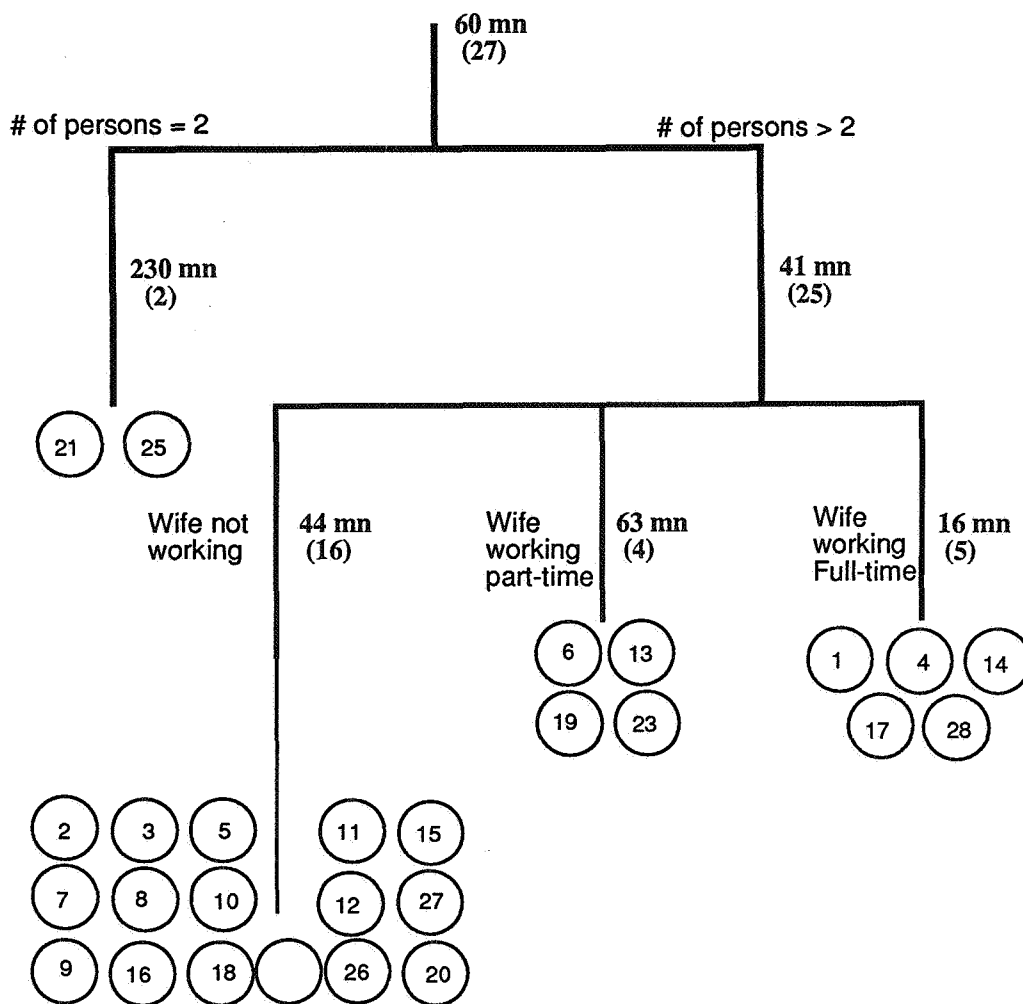
Figure 3 : Duration of opening for the window of the bathroom

Figure 4 : Duration of opening for the window of the children's bedroom