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# Post Occupancy Evaluation of 23 Newly Renovated Apartments in Copenhagen

## Occupants' Perception

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### Abstract

*The present article is based on the post occupancy occupants' perception of indoor air quality of recently renovated 23 residential apartments in Copenhagen. The apartments are equipped with novel mechanical ventilation systems. The apartments can be categorised in four, according to the design of ventilation systems. The analysis in present article is based on occupants' perception of the temperature, indoor air quality and energy consumptions of their apartments. The study shows the perception of occupants of first six months of post occupancy. The study was carried out by conducting interviews with the tenants. 74% of the total occupants took part in the interviews. 83% of the interviewed occupants as an averaged spend more than 50% of their time inside their apartments. 37% of the total interviewed occupants were satisfied with the current performance of their apartments. Apparently the reason of dissatisfaction of occupants was the lack of maintenance of the HVAC systems. Another point raised by the occupants during the interviews was the missing provision of user control on ventilation system.*

***Keywords – post occupancy evaluation; occupants' perception; residential apartments; mechanical ventilation systems***

### 1. Introduction

According to the Energy performance of building directive (2002/91/EC) every member state has to reduce the primary energy demands for buildings. Majority of the buildings in Copenhagen are from 1970s or even older. These buildings consume approximately 40% of the total primary energy consumed by the whole Denmark. 75% of the energy consumed by buildings is the share of HVAC systems. Therefore there is a large energy saving potential in energy renovation of existing buildings (Tommerup, Svendsen 2006). In 2014 three adjacent apartment building from 1970s were renovated. There were 23 apartments in total. These building were located in Frederiksberg within Copenhagen. Before the renovation, apartments were naturally ventilated, whereas after the renovation mechanical ventilation systems were installed in each building. After renovation the buildings were occupied by the tenants in late 2014. The Danish

Building Research Institute (SBI) has carried out a follow up study based on post occupancy performance of the all renovated apartments.

The findings from the study were divided into two parts. Part one was the performance of the systems, which is documented in the article “Post Occupancy Evaluation of 23 Newly Renovated Apartments in Copenhagen - Performance of Ventilation Systems (Paper 41) in the same conference. Paper 41 encompasses the details regarding the design of the ventilation systems and the preliminary findings. Present article is part two of the study, which is occupants perception regarding the performance of the ventilation systems and the quality of indoor environment.

## 2. Aim of the study

Aim of the present study is to analyse how user perceive indoor environment in comparison with the findings from logging of indoor parameters such as temperature, relative humidity, ACH, CO<sub>2</sub> etc.

## 3. Methodology

The analyse the occupant’s perception regarding the ventilation systems, a questionnaire was made by SBI. The questionnaire was filled by interviewing all the available the tenants. There were several questions in the survey and the survey was conducted in the summer of 2015. Hence the survey is based on the perception of occupants that have been living in the apartments for around 6 months. The similar survey will be conducted in summer 2016 to know how occupants perceive regarding the system after almost 18 months. The asked questions and the statistics of answers are illustrated in the section 5 of the present article.

## 4. Description of buildings

As mentioned earlier, in 2014 three adjacent apartment buildings were renovated. After renovation, four different types of mechanical ventilation systems were installed in the buildings. The following diagram and table illustrates the building blocks and the associated ventilation systems.

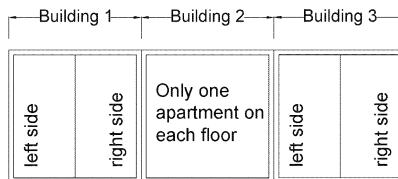


Figure 1 schematic plan of evaluated buildings

Table 1 details of the evaluated buildings

	<b>Building 1</b>		<b>Building 2</b>	<b>Building 3</b>	
	Left side	Right side		Left side	Right side
Area - m <sup>2</sup>	92	62	130	67	73
Height – m	2.7	2.7	2.7	2.7	2.7
No of apt.	5	4	4	5	5
Ventilation system	Type 1	Type 2	Type 3	Type 4	
	De-centralised	De-centralised	Centralised	Centralised	
Control strategy	Conventional with no user control	Variable speed system with limited user control	Variable speed system with limited user control	Variable speed system with no user control	

Type 1 ventilation systems are traditional decentralized ventilation systems which work only on two speeds i.e. high flowrates when kitchen exhaust is on otherwise lower flow rates. Type 2 ventilation systems are decentralized ventilation systems with motion sensors in hallways, humidity sensors in all the rooms and a kitchen hood sensor. Type 3 ventilation system is a centralized ventilation system with the motion sensors in hallways and toilets, humidity sensors in each room along, and kitchen exhaust hood sensors. Type 4 ventilation system is a centralized ventilation system with only kitchen exhaust hood sensor. Type 2, Type 3 and Type 4 systems are also equipped with a newly designed drop type dampers that has a very low pressure drop.

## 5. Survey and the findings

The survey is based on the 60%, 50%, 100% and 80% participation of the tenants of the apartments with Type 1, Type 2, Type 3 and Type 4 systems respectively. The overall occupants participation was 74%. The interview was conducted with one person (interviewee) per apartment. It is assumed that each interviewee was describing the average perception of all the occupants living in that particular apartment. The followings are the findings from the interview. All the findings are illustrated in figures. In each figure, Type 1 means the occupants who are living in the apartments with Type 1 ventilation systems, Type 2 stand for the occupants who are living in the apartment with Type 2 ventilation systems and so on.

(i) *First of all, the occupants were asked regarding the time in hours they spent in their apartments per week:*

The Figure 2 shows the percentage of occupants that lives in the apartments for the particular range of hours. For instance all the occupants in apartments with Type 2 systems spend around 80 to 100 hours in their apartment during a week. In apartments with Type 4 systems, 13% of the occupants spend less than 60 hours in the apartment, 13% spend around 61 to 80 hours, 63% spend around 81 to 100 hours and 13% spend around 101 to 120 hours per week in their apartments. There were some occupants who were self-employed therefore a significant percentage of occupants in Type 1 and Type

2 spend most of their time in their apartments. From this question it was concluded that almost 83% of the total occupants in all three buildings spend more than 50% of their time in their apartments. 30% of the tenants spend more than 60% of their time inside their apartments.

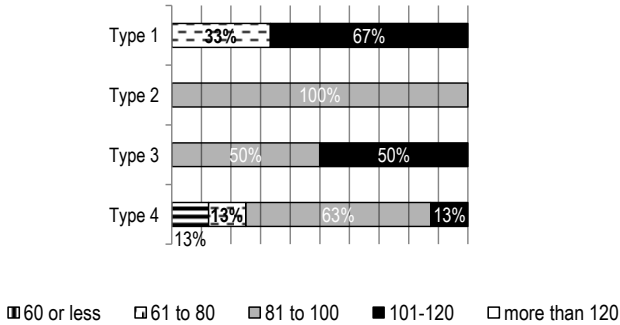


Figure 2 weekly hours spent by the occupants in their apartment

(ii) When occupants were asked regarding the energy performance of their apartments:

Many occupants were not aware of the energy performance of their apartments. For them the only parameter to judge the energy performance was their energy bills. Unfortunately the occupants pay their bills on yearly average values therefore the survey after 6 months was not enough to ask this question. Probably this question will be more significant for them in the upcoming interview session. Therefore, a significant percentage of occupants are not aware of the performance, few people were dissatisfied only because the system was not working so they answered as dissatisfied or very dissatisfied. Since the percentage of energy bills compared to the overall budget of the occupants were marginal, therefore many occupants said that they are satisfied. Figure 3 (a) represents the percentages of the occupants' perceptions regarding energy performance of their apartments.

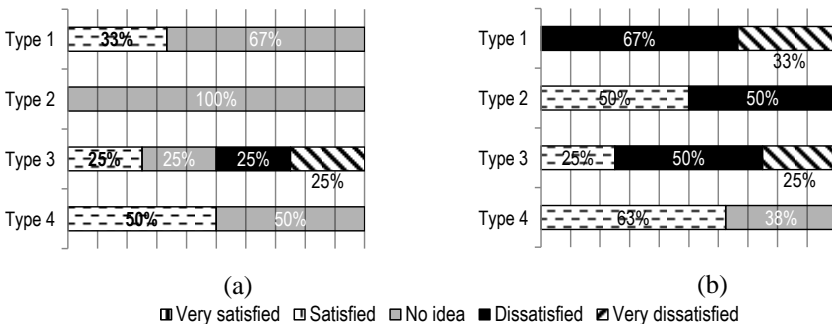


Figure 3 Occupants perceptions of (a) Energy performance of their apartments, (b) indoor temperatures in the apartments

(iii) When the occupants were asked, if they are satisfied with the temperatures in their apartments:

The perception of occupants of individual category of apartments regarding the temperatures in their apartments is illustrated in Figure 3 (b). Overall 42% of all the occupants were satisfied, same percentage of occupants were dissatisfied and the remaining had no idea whether the temperature was ok or not.

(iv) When occupants were asked if they are satisfied with the indoor temperature during summer:

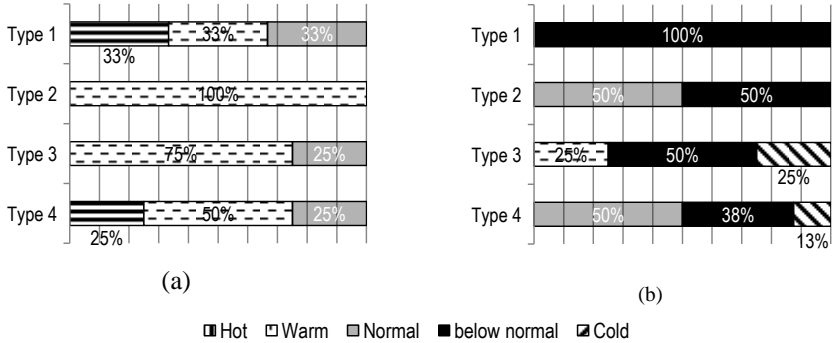


Figure 4 occupants' perception regarding indoor temperatures in (a) summer, (b) winter

Figure 4 (a) represents the percentages of occupants' perception on indoor temperatures in summer for each type of the apartments. However, 76% of the total occupants were feeling warm or even worse and only 24% were feeling normal room temperatures during summer season.

(v) When the occupants were asked if they are satisfied with the indoor temperatures during winter:

Figure 4 (b) represents the percentages of occupants' perception on indoor temperatures in winter for each type of the apartments. 64 % of the total occupants were feeling below normal or cold temperatures, 30% were feeling normal temperatures and 6% were feeling warm temperatures during the winter season in their apartments.

(vi) When the occupants were asked, if they are not satisfied with temperatures in their apartments, when (during a typical day) they feel that the system is not fulfilling their expectations:

During this particular question, many occupants were unsatisfied with the temperatures at different times of the day. Therefore they had a choice to select as many options as possible. The results are illustrated in Figure 5. 17 % of the total occupants were not satisfied with the indoor temperatures before noon, 17% were not satisfied with the afternoon temperatures, 41% were not satisfied with the evening temperatures, and 47% were not satisfying with the temperature at all.

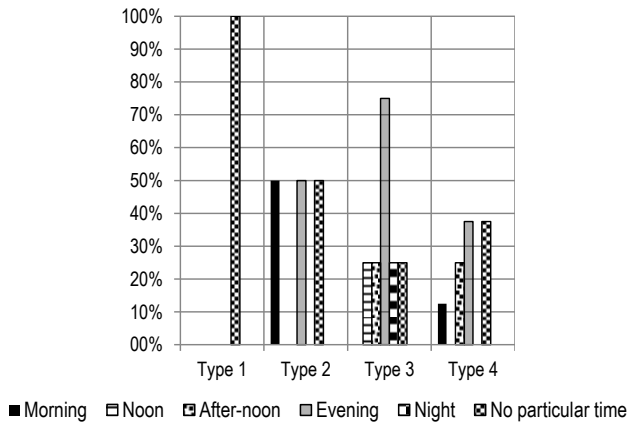


Figure 5 occupants perception regarding the day time when the temperatures are inappropriate

(vii) *When the occupants were asked if they perceive any discomfort other than temperatures:*

The answers of the occupants of individual type of apartments are illustrated in Figure 6. Overall 30% were not satisfied with the humidity levels in the apartments. Likewise overall 30 % were not satisfied with the air movements in the apartments. Overall 17 % were feeling cold or warm floors and walls and 30 % were having draught problems. Around 5% had a problem with noise from the ventilation units and 12% were not satisfied because of the inaccessibility of the ventilation control. However, 42 % of the overall occupants were not feeling any other discomfort.

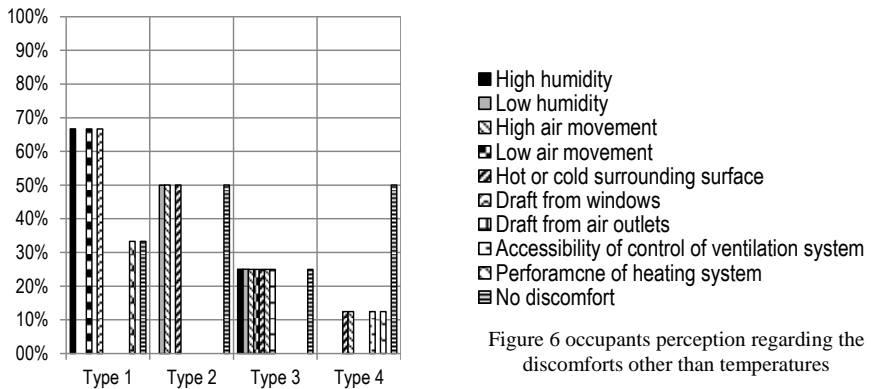


Figure 6 occupants perception regarding the discomforts other than temperatures

(viii) When the occupants were asked, if they are satisfied with the temperatures and indoor air quality of their kitchen:

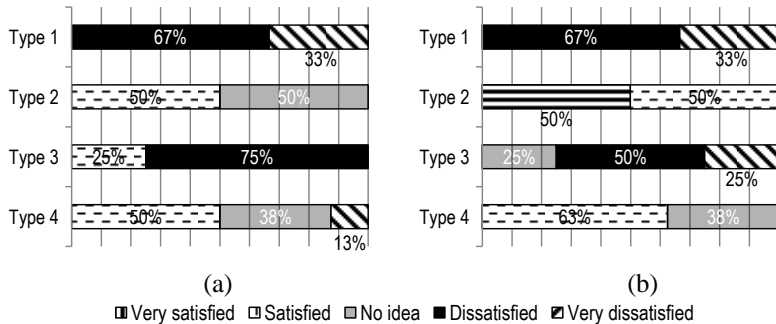


Figure 7 occupants perception of (a) temperatures and (b) air quality in their kitchens

Occupants' perceptions regarding temperatures and air quality in their kitchen are illustrated in Figure 7. In Figure 7 perceptions of occupants are categorized according to the type of ventilation system in their apartments. However 35% of the overall occupants were satisfied with the temperatures in the kitchen and the associated areas. 42% of the occupants were satisfied with the air quality in the kitchen areas. 23% of the occupants had no idea regarding the temperature and air quality as they spend very little time in their kitchens.

(ix) When the occupants were asked, if they are satisfied with the temperature and indoor air quality of their living rooms:

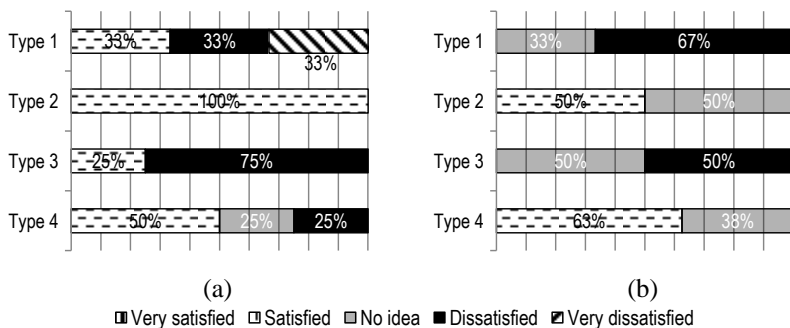


Figure 8 occupants perception of (a) temperatures and (b) air quality in their living rooms



Occupants' perception regarding temperatures and air quality in their living rooms is illustrated in Figure 8. In Figure 8 perceptions of occupants are categorized according to the type of ventilation system in their apartments. However, 47% of the total occupants were satisfied with the temperatures in their living rooms, whereas 35% were satisfied with the indoor air quality of their living rooms. 12% of the occupants had no idea regarding the temperatures and 42% had no idea regarding air quality of the living room(s).

(x) *When the occupants were asked, if they are satisfied with the temperature and indoor air quality of their bed rooms:*

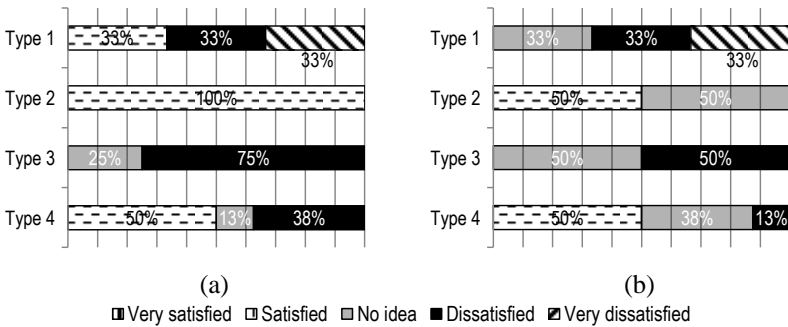


Figure 9 occupants perception of (a) temperatures and (b) air quality in their bed rooms

Occupants' perception regarding temperatures and air quality in their bedrooms is illustrated in Figure 9. In Figure 9 perceptions of occupants are categorized according to the type of ventilation system in their apartments. However, 42% of the total occupants were satisfied with the temperature and 30% were satisfied with the air quality in their bed room(s). 12% of the occupants had no idea regarding temperatures and 42% had no idea regarding the air quality of their bed room(s).

(xi) *When the occupants were asked, how satisfied are they with the temperature, indoor air quality and energy efficiency of their apartments in comparison with their previous apartments?*

Occupants' perception regarding temperatures, air quality and energy efficiency of the renovated apartments compared with their previous apartments/residence is illustrated in Figure 10. In Figure 10 perceptions of occupants are categorized according to the type of ventilation system in their apartments. 30% of the total occupants perceive that the temperatures in the renovated apartments are either better than the temperatures of the same apartment before the renovation or better than their previous apartments. 35% of the total occupants perceive better indoor air quality and 30% thinks that the energy efficiency of their new apartments is better than their previous apartments.

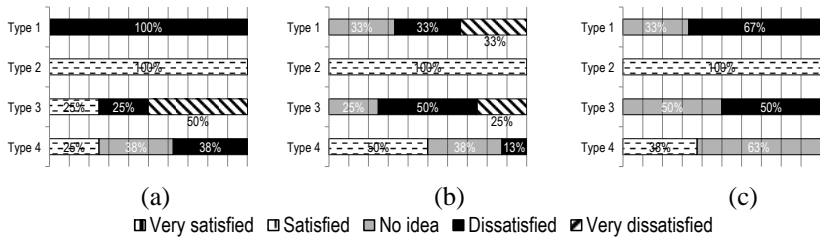


Figure 10 occupants perception of performance of the new apartment compared with their previous apartment/residence (a) temperatures, (b) air quality and (c) energy efficiency

## 6. Discussion

In the present study survey regarding the occupants' perception was carried out by conducting interviews with the tenants. There are many factors that may influence the occupants' perceptions for instant maintenance issues of the HVAC system. Another factor other than technical issues was the age group. 75% of the interviewed occupants of apartments with Type 3 systems were in their 60s whereas all of the interviewed occupants of the apartments with Type 4 systems were 35 or younger.

From the survey it was concluded that 37% of the occupants are satisfied with the overall performance of their apartments. 38% and 32% of the occupants of apartments with Type 4 and Type 2 respectively are satisfied with the performance of their apartments. Only 10% and 12% of the occupants the apartments with Type 1 and Type 3 respectively are satisfied with the performance of their apartments. Surprisingly the Type 1 ventilation units consume much less energy, in comparison with the remaining 3 types – see Paper 41 for details, on the contrary the occupants are least satisfied. This is primarily due to the fact that the ventilation units were not running continuously.

It is also observed that some findings from logging of indoor climate parameters are supporting the perceptions of the occupants. For instance the 50% of occupants of the apartments with Type 2 systems perceive high air movements in their apartments which is true as the overall measured average air change rates in those apartments are higher than 0.5 – for details see Figure 5 of Paper 41. On the contrary, many occupants perception are in contrast with the logged technical data. However, these findings are from their initial perception i.e. after 6 months. The occupants' perception after 18 months will also be conducted and will be published soon in a peer reviewed journal that will give more insight of the occupants' perception regarding the performance of their apartments.

## 7. Conclusion

In the present study, traditional method of post occupancy evaluation of occupants' perception was evaluated. The study was carried out by surveying through interviews. 74% of the occupants out of 23 apartments have participated in the interviews. Among the interviewed occupants, 37% were satisfied with the overall performance of their

apartments. Occupants of the apartments with Type 4 ventilation systems were the most satisfied occupants, whereas occupants of the apartments with Type 1 were the least satisfied occupants.

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