Building and Environment 63 (2013) 134–144

Contents lists available at SciVerse ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Impact of perceived indoor environment quality on overall satisfaction in Swedish dwellings

Agnieszka Zalejska-Jonsson [a,*], Mats Wilhelmsson [b,c]

[a] KTH Royal Institute of Technology, School of Architecture and Built Environment, Real Estate and Construction Management, Brinelvägen 1, 100 44 Stockholm, Sweden
[b] KTH Royal Institute of Technology, Centre for Banking and Finance, Brinelvägen 1, 100 44 Stockholm, Sweden
[c] The Institute for Housing and Urban Research (IBF), Uppsala University, Sweden

ARTICLE INFO

Article history:
Received 23 November 2012
Received in revised form
5 February 2013
Accepted 9 February 2013

ABSTRACT

The aim of this paper is to contribute to the discussion on how satisfaction with different aspects of indoor environment contributes to occupants' overall satisfaction. The analysis is based on survey responses collected during a unique project commissioned by The Swedish National Board of Housing, Building and Planning. The results are representative of adults living in multi-family buildings in Sweden. The analysis shows that generally satisfaction with air quality has the highest impact on occupants' overall satisfaction. The occurrence of problems with indoor environment quality, particularly draught, dust and too low indoor temperature may affect occupants' overall satisfaction. However, it is demonstrated that the importance impact of perceived indoor environment quality on overall satisfaction is affected by individual and building characteristics.

1. Introduction

Building occupants are recognised more than ever as consumers, where building performance, comfort and usability are among the factors affecting customer satisfaction. Learning about and understanding occupants' needs is important for all actors involved in the building and operation process – from designers, engineers, and developers to facility managers. Their business goal is, after all, to provide customers extra value, which turns into profit. Hence, understanding what is included in occupants' satisfaction is an important issue.

Research has demonstrated that the quality of the indoor environment has considerable impact on human health, stress, productivity and wellbeing. Therefore, it is rational to conclude that the way in which occupants perceive indoor environment will impact their overall satisfaction. A large body of literature has shown that this hypothesis is correct, but it has proved to be a complex and difficult task to determine how important the measured aspects of indoor environment are to the occupants and how these aspects can be combined to produce overall satisfaction [22].

A few studies have approached the challenge and investigated the extend to which acceptance of indoor environment factors impact on occupants' overall satisfaction. Frontczak et al. [19] used panel data collected by the Center for Built Environment (CBE) through post-occupancy surveys sent to office buildings to investigate which indoor environment quality (IEQ) parameters affect occupants' satisfaction most. The results suggest that the three most important parameters for occupant satisfaction were space available for individual work, noise level and visual privacy. The impact of the main indoor environment parameters, i.e. thermal, visual, acoustic and air quality,[1] on office occupants' satisfaction was as follows: noise level, sound privacy, temperature, amount of light and air quality.

Kim and de Dear [27] distinguished between factors that have a linear and a non-linear relationship with overall satisfaction. Similarly to the Frontczak et al. [18] study, noise satisfaction was found to have the highest impact of the IEQ parameters on occupants' satisfaction. Temperature, followed by air and light quality was found to have negative impact on occupants' satisfaction. Kim and de Dear [27] used the Kano Model to differentiate between IEQ factors that impact overall satisfaction in negative, positive or in both directions. They concluded that 'temperature' and 'noise' had predominantly negative impact on occupants' overall satisfaction when expectations were not met; however, if the building

* Corresponding author. Tel.: +46761735889 (mobile).
E-mail address: agnes.jonsson@abe.kth.se (A. Zalejska-Jonsson).

[1] Literature survey conducted by Frontczak and Wargocki [20] shows that thermal, visual, acoustic and air quality are the main indoor environment parameters contributing to satisfactory indoor environment.

0360-1323/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.buildenv.2013.02.005

performed well, overall satisfaction was not impacted. On the other hand, 'air quality' and 'amount of light' were qualified as proportional factors and influenced overall satisfaction in both directions. It was found that occupant ratings were high when the building performed well and poor when it underperformed.

On the other hand, a study conducted on commercial spaces in Hong Kong [29,30] showed fairly different results, indicating that thermal comfort had the highest impact on overall IEQ acceptance, followed by air, noise and visual quality. An investigation conducted in China also suggests that thermal comfort has the highest impact on overall satisfaction [12].

The importance ranking of perception of IEQ may differ in residential buildings. An occupant survey conducted in Danish homes [19] showed that thermal, acoustic, air and visual quality are positively correlated with overall satisfaction with indoor environment, indicating that by a marginal difference, the relation between overall acceptability and air quality was the highest, followed by visual, acoustic and thermal quality.

However, studies based on indoor environment evaluation of occupants living in Hong Kong apartments indicate that thermal comfort has the highest importance impact on overall IEQ [28,30]. This was followed by noise and air quality.

Humphreys [22] deliberated whether overall satisfaction can be described by stable relative weights of different aspects of indoor environment and concluded that generally level of thermal and air quality is more important that lighting and humidity; however, relative weights can differ between occupants, depending on their requirements. The literature review showed that occupants ranked importance of satisfaction with IEQ was inconsistent.

It would be reasonable to state that if occupants experience problems with IEQ, the satisfaction decreases. Even though problems with IEQ have been discussed earlier in the literature [1,5,10,21,28,30,39], as far as the authors are aware, the impact of IEQ problems on occupants' overall satisfaction has not been explored by a quantitative model approach. Applying a quantitative model allows us to measure the extent to which the appearance of a particular IEQ problem affects overall satisfaction.

The aim of this study was to contribute to the discussion of the impact of satisfaction from aspects of indoor environment on overall satisfaction and investigate how the occurrence of different problems with IEQ affects occupants' overall satisfaction. This paper investigates the effect that perception of indoor environment quality has on overall satisfaction of occupants in residential buildings in Sweden. The analysis is based on survey responses collected during a unique project commissioned by The Swedish National Board of Housing, Building and Planning (*Boverket*). The results provide insights into how occupants perceive indoor environment and into the set of problems appearing in dwellings in Sweden. The results are representative of adults living in multifamily buildings in Sweden and contribute to the existing knowledge about perceived comfort and occupants' satisfaction.

2. Literature review

Overall satisfaction and perception of indoor environment, being a subjective evaluation, can be impacted by various contextual factors. The literature provided evidence that individuals' characteristics and building characteristics contribute significantly to how occupants perceive their comfort.

2.1. Building characteristics

2.1.1. Location and climate differences

Outside conditions may have an impact on occupant perception of indoor environment and become a contributing factor to defining what constitute satisfactory indoor conditions. For example, cold climatic conditions may be an important factor in occupants' preference for higher indoor temperature [40]. Becker and Paciuk [3] also showed that thermal adaptation and perception of comfort may be impacted by contextual variables, such as local climate. Humphreys' [22] analysis of over 4600 responses from office occupants in five different countries showed that ranked importance of satisfaction factors for overall comfort varies between countries.

2.1.2. Building design and construction

Zhang and Altan [40] investigated the difference in perceived IEQ and occupants' overall satisfaction in conventional and environmentally concerned building and reported that occupants presented different satisfaction levels for their thermal and visual environment. A study of educational and office buildings in the UK and in India [37] showed that occupants' overall satisfaction varies depending on the ventilation mode applied in the buildings. Moreover, dwelling quality, size and design were also demonstrated to have significant impact on residents' satisfaction. [16,31,33].

2.2. Individuals' characteristics

2.2.1. Gender

Lai and Yik [29] investigated how perception and importance ranking of indoor environment differs depending on time spent in the building and depending on gender. It was concluded that both factors may have an impact on how occupants rate the importance of indoor environment aspects. It was found that female workers were slightly more sensitive to air quality than men, ranking odour and air cleanness before noise. Odour was also the most important factor for male workers; however, air cleanness was ranked as the third attribute after noise. Thermal comfort was ranked as least important by both groups.

Women were found to be relatively more sensitive to thermal sensation [4,15]; however, men were found to have a lower level of thermal acceptability than women [25]. It was suggested that the difference in tolerance for the thermal environment between men and women might be related to physiological characteristics but also to life style differences [25]. On the other hand, research conducted in 20 office buildings in the US showed that the mean level for thermal satisfaction was 30% lower for female than male occupants, indicating that women are less satisfied with thermal quality than men [14]. Other studies showed limited or no difference between women and men in relation to indoor environment perception [18] or sensitivity to sound level [21].

2.2.2. Age

Older respondents were found to be more satisfied with dwellings than younger ones [15,16,26], and age was found to have negative impact on overall satisfaction [33,38]. Research indicates that there is a difference in thermal sensation and thermal acceptance between age groups [14,25]. Age was also found to be significant and one of the more powerful predictors in investigations of the relationship between traffic noise exposure and self-reported health status [9]. Clearly, a fit between dwelling design and occupants expectations and requirements may affect how occupants perceive their housing. The elderly may require dwellings to be fitted with features that enable easier access (e.g. lifts) or that are easy to control but less technically advanced. Finally, occupant perception may vary depending on their housing career [32] and previous residence experience [33].

2.2.3. Lifestyle and health

The latest literature survey exploring the effects of IEQ on occupants shows that there is rather limited literature exploring how life style and health may impact occupant satisfaction with indoor environment

[20]. Life style and health were found to have no influence on satisfaction with IEQ. However, a more recent study conducted on public low-cost housing in Malaysia [33] showed negative correlation between residential satisfaction and family size and whether the wife stayed at home or was working, which would indicate that occupants' satisfaction may be impacted by life style. Lai and Yik [29] demonstrated that the importance of IEQ attributes differs depending on length and frequency of occupants' stay in the building.

The literature review indicates that occupants' satisfaction depends on satisfaction with indoor environment parameters but the perception can vary depending on individual and building characteristics. Therefore, in this paper we tested for the impact that individual and building characteristics have on occupants' overall satisfaction. The tested characteristics were based on a literature review but also depended on availability of data.

3. Data

A database was created using data collected during a unique project commissioned by the Swedish National Board of Housing, Building and Planning – *Boverket*. The particular focus of this project has been data collection on health, indoor environmental quality, energy performance, and the technical and maintenance status of Swedish building stock. The data was obtained by: inspections and measurements of buildings, and surveys addressed to residents of single houses and apartment buildings [8].

Defining the nationally representative sample required multistage sampling, clustering and stratification. The first three stages in the sample selection process were coordinated and the same was done for the whole project. In the first step, a sample of municipalities was selected, in the next stage, a sample of valuation units was made and in the third step, a building was selected. The fourth step of sampling was designed only for the particular leg of the project, i.e. for the indoor environment quality and health surveys or inspections and measurements. The fourth stage aimed at sampling households and individuals. Detailed information about the survey population design can be found in [8].

Everyone who lived in Sweden and was over one year of age was included in the definition of target population. The population was divided in three groups: young children (1–12 years old), teenagers (13–17 years old) and adults (18 years old and older). For each group, a separate questionnaire was distributed. This paper focuses only on adult occupants of multi-family apartment buildings.

In order to conduct the analysis and present results which are representative for the whole country, analytical weights were used. The data set and final analysis weights were received from the data producer (*Boverket*, Swedish National Board of Housing, Building and Planning). The analysis weights are the final value which was estimated by including a sample selection and non-response adjustment factor and post-stratification factor [23]

3.1. Questionnaire design

The questionnaire was addressed to all selected residents in May–June 2008 and posted by ordinary mail. The inhabitants were asked to fill in a survey questionnaire that included 35 questions divided into six parts.

Questions in the first part asked respondents for their general opinion about the indoor environment and if certain problems appeared in their apartment. The following three parts asked more detailed questions about the thermal comfort, air quality and sound quality, particularly about experience of different problems with indoor environment quality. The fifth part included questions about the respondent's health and the last part gathered background data about the respondents. The questions about general satisfaction rated the respondent's perception on a five-point ordinal scale from "very satisfied" (1) to "very dissatisfied" (5). Questions which asked the respondent to evaluate the indoor environment parameter (thermal comfort, air and sound quality) gave the respondent a choice from a five-point ordinal scale from "very good (1)" to "very bad (5)". In the case of questions referring to potential problems, a respondent could choose one of three answers: "yes, the problem occurs often (approximately once a week), "yes, the problem occurs sometimes" or "no, never happens". With reference to sound quality, additional frequency questions were included, but responses to those are not analysed here.

3.2. The data used and its limitations

The paper presents results based on total responses ($N = 5756$) from questions regarding overall satisfaction, general satisfaction with air quality and general satisfaction with sound quality, and experience of indoor environment quality problems as well as the background questions. The analysis of responses regarding more detailed problems with thermal comfort, air quality and sound quality is not presented in this paper.

Including physical measurements in the statistical analysis would allow the subjective responses to be related to objective measurements; however, even though data from measurements and on-site investigations was available, it was a conscious decision not to include those indicators in the model. When the objective indicators were introduced, the responses from the survey had to be matched with measurements and many observations had to be excluded. Introduction of physical values also required adjustment and substantial increase of weights needed for data analysis. This added complexity to the analysis and difficulty in interpreting the results.

4. Statistics analysis

Ordinal logistic regression was chosen due to the nature of the data; that is, variables are in ordered categories, measuring opinion and frequency using a rated scale so that responses are ordered [6]. Results are reported in the form of odds ratios and interpreted in this paper as likelihood of decreasing overall satisfaction if the predictor variable is increased by one unit while other variables are kept constant [18]. Odds ratios were used to rank the impact of variables on overall [19].

$$\text{Overall satisfaction} = ß_1\text{TC} + ß_2\text{AirQ} + ß_3\text{SoundQ} \quad \text{model 1}$$

β – odds ratios are interpreted as the likelihood of decreasing overall satisfaction if satisfaction with thermal or air or sound quality decreases by one unit while other variables are kept constant.

Likewise, overall satisfaction may be impacted by the appearance of problems with IEQ.

$$\begin{aligned}\text{Overall satisfaction} = {} & \alpha_1(\text{too high temperature}) \\ & + \alpha_2(\text{too low temperature}) \\ & + \alpha_3(\text{unstable temperature}) + \alpha_4(\text{draft}) \\ & + \alpha_5(\text{stuffy air}) + \alpha_6(\text{dry air}) \\ & + \alpha_7(\text{unpleasant smell}) + \alpha_8(\text{dust}) \\ & + \alpha_9(\text{static electricity}) \\ & + \alpha_{10}(\text{cigarette smell}) \\ & + \alpha_{11}(\text{noise}) \quad \text{model 2}\end{aligned}$$

α – odds ratios interpreted as likelihood of decreasing overall satisfaction if a particular problem with IEQ appears.

Table 1
Building characteristics.

Location	Binary variables	Per cent in sample
	North	11%
	Central	58%
	South	31%
Construction year		
	<1960	46%
	1961–1975	32%
	1976–1985	7%
	1986–1995	10%
	1995–2005	5%

Table 2
Residents' characteristics.

Individuals characteristics	Binary variables	Per cent in sample
Gender	Male	47%
	Female	53%
Life style[a]	Away 0–4 h	32%
	Away 5–9 h	45%
	Away >10 h	23%
Health[b]	Smoker	14%
	Non-smoker	86%
Age	≤35 years	34%
	36–50 years	22%
	51–65 years	22%
	≥66 years	23%

[a] Represented by time spent away from the apartment on weekdays.
[b] Represented by the fact that the occupant was or was not a smoker.

The statistics analysis was conducted in four stages:

In the first stage, the main models (model 1 and model 2) were applied to the data. Model 1 aimed to test whether occupants' satisfaction with thermal comfort, air and sound has a significant impact on overall satisfaction. The second model aimed to estimate the impact which potential problems with IEQ may have on occupants' overall satisfaction. Odds ratios were used to rank the impact of predictor variables on the response variable. The second stage of the analysis tested whether individual and building characteristics have significant impact on perception of indoor air quality and overall satisfaction. This was achieved by including controlling binary variables in both models (model 1a and model 2a).
In the third stage, main regression modes were applied (model 1b and model 2b) to separate sub-groups in order to estimate what impact individual and building characteristic have on overall satisfaction. Odds ratios were used to rank the impact of predictor variables on the response variable. The order was compared with results from the main model.
Finally, to test if and which variables have a significant effect on a particular sub-group, interactive variables were included in the main models (model 1c and model 2c). Interactive variables measured the effect which the predictor variable may have on a particular sub-group. The interaction effect between variables is interpreted in multiplicative terms [11].

As discussed before, overall satisfaction may be impacted by different factors and therefore control variables and sub-groups were created according to the following characteristics.

4.1. Building characteristics

- Location

Sweden's geographical location, extending from latitudes 55° to 70°N, contributes to the fact that local climate in Sweden may differ significantly. This variation is recognised in Swedish Building Regulations, in which building requirements are adjusted depending on climate zone. Swedish Building Regulations specify three climate zones: north, central and south. Taking this and previous research into consideration, the database was divided into three sub-groups, depending on building location and control variables for north, central or south location; these sub-groups were included in the models.

- Building construction year

The literature research indicates that building characteristics such as design, building heating or ventilation system may impact on occupants' satisfaction. Taking into account all of this information was not feasible; however, by including a variable describing building construction year, we were able to group buildings that present similar technical standards.

4.2. Individuals' characteristics

- Gender

The literature review indicates that previous studies fail to give consistent results regarding the impact of gender on perception of IEQ and overall satisfaction. The aim of this paper is to contribute to this discussion by including gender as a control variable and by testing whether IEQ weighting into overall satisfaction differs between female and male occupants in dwellings in Sweden.

- Age

It is expected that occupants overall satisfaction and IEQ perception differs depending on for example housing career, previous housing experience, expectations and requirements. Therefore, we expect that age, being the best available proxy for the above mentioned factors, has a significant impact on occupant satisfaction.

- Life style and health

There is a fairly limited amount of research into how life style and health choices impact occupants' overall satisfaction. The goal is to add to existing knowledge, and therefore the following control variables were included in the analysis: a smoking habit and the time the occupant spends away from the apartment on weekdays. It is expected that a smoking habit can affect people's perception of indoor environment and therefore impact overall satisfaction. It is also expected that an occupant's absence from a dwelling impacts the interaction between occupant and dwelling. On the other hand, longer presence in the apartment may relate to exposing occupant to potential problems for a longer time, and consequently making the occupant more sensitive to specific problems, for example, unstable temperature or noise.

A Brant test for parallel regression assumption was conducted for each regression. The proportional odds assumption was satisfied in both models and the use of ordinal logistic models was justified. The results are reported with Confidence Intervals that present reliability of estimates at 95%. Generally, the results were considered statistically significant when $p < 0.05$.

5. Sample characteristics

A summary of individual and building characteristics is presented in Tables 2 and 3 respectively. The responses received from

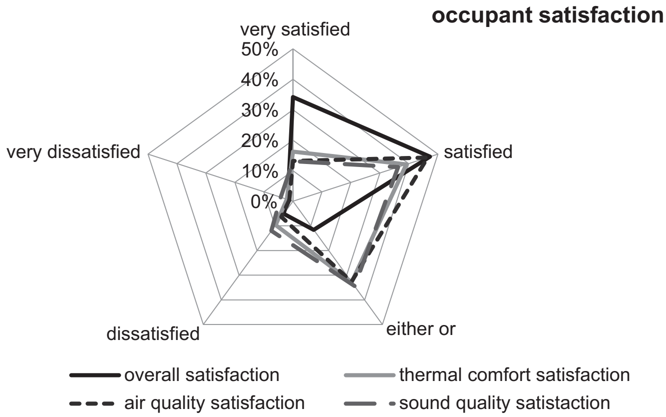

Fig. 1. Overall satisfaction and satisfaction with thermal comfort, air and sound quality in residential apartments in Sweden.

the north part of the country represent 11% of all responses, the central 57% and south 32%, which reflects population distribution in Sweden (Table 1). An almost equal quantity of responses was received from male and female occupants (Table 2).

6. Results

6.1. Overall satisfaction and satisfaction with thermal, air and sound quality

Generally, occupants are very satisfied with their apartments (mean 1.93, where 1 = very satisfied and 5 = very dissatisfied; see Table 4), though satisfaction with IEQ is relatively lower. Fig. 1 visualises the level of satisfaction with IEQ and compared to overall satisfaction. This difference might indicate that even though satisfaction with indoor environment parameters has an impact on overall satisfaction, there are other factors affecting occupants' general satisfaction.

Sound quality is the parameter that occupants are least satisfied with (Table 3), however, it is the air quality that has the highest impact on overall satisfaction (Table 4). The results indicate that if the occupant is dissatisfied with air quality, there is a 2.65 times likelihood that the overall satisfaction decreases (Table 4).

6.2. Overall satisfaction and problems with IEQ

The problem experienced most often by the occupants is related to dust and outside noise. The mean for variables has been ordered from the largest to the smallest, showing problems which are observed most frequently in Swedish apartments (Table 5). The hypothesis is that overall satisfaction will decrease if a specific indoor environmental quality (IEQ) problem appears. The proportional ordinal logistic model describes the relationship between overall satisfaction and problems that an occupant may experience in the building. The impact of the following IEQ problems was investigated: too high temperature, too low temperature, unstable temperature, draught, stuffy air, dry air, unpleasant smell, dust, static electricity, cigarette smell and noise (model 2). Odds ratios were used to rank the IEQ problems regarding their importance for overall satisfaction (Table 6).

As shown in Table 6, the problem with draught in the apartment is the most important factor that can influence general satisfaction and should that problem appear, there is a 1.60 times likelihood that the overall satisfaction decreases. Interestingly, draught is not the issue that occurs most often in the apartments in Sweden. The problems of dust and too low temperature seem to occur in apartments most frequently and the analysis indicates that if this happens, the general satisfaction decreases (odds ratio 1.56 and 1.49).

On the other hand, the problems related to too high temperature, unstable temperature in the apartment, sensing cigarette smell and experiencing static electricity were found to be not statistically significant.

6.3. Overall satisfaction and building characteristics

6.3.1. Location

6.3.1.1. Satisfaction with IEQ. The analysis indicates that there is a significant difference in overall satisfaction depending on location. The results (model 1a) suggest that adults who live in apartments in the north and central part of Sweden are less likely to be dissatisfied than those living in the south of Sweden (Table 7).

In order to test the effect of particular variables, the model with interactive variables (model 1c) was applied to the data. The results suggest that dissatisfaction might be related to the thermal comfort; the effect of *thermal comfort* for adults who live in apartment blocks in southern parts is 1.44 (CI(95%) 1.24–1.67) times the effect of *thermal comfort* for those who live in the rest of the country. Occupants living in the central part of Sweden seem to be more sensitive to sound quality, as the effect of sound quality on residents in central Sweden was found to be 1.31 (CI(95%) 1.16–1.49) times the effect for those who live in the rest of Sweden. This has

Table 3
Overall satisfaction mean values.

	Mean	Standard error	Confidence intervals (95%)	*N*
General satisfaction	1.93	0.12	1.90–1.95	5570
Air quality satisfaction	2.35	0.11	2.33–2.38	5660
Thermal comfort satisfaction	2.42	0.12	2.39–2.44	5585
Sound quality satisfaction	2.58	0.13	2.55–2.60	5623

1, Very satisfied; 2, satisfied; 3, either or; 4, dissatisfied; 5, very dissatisfied.

Table 4
Satisfaction thermal comfort, air and sound quality impact on overall satisfaction, $p < 0.001$; (model 1).

	Odds ratios	Confidence intervals (95%)	
Air quality satisfaction	2.651	2.436	2.885
Thermal comfort satisfaction	1.814	1.691	1.946
Sound quality satisfaction	1.560	1.463	1.663

N, 5339; pseudo-R2, 0.179.

Table 5
Problems experienced in residential apartments in Sweden, depending on location ("problem does not occur" = 0, "problem occurs sometimes" = 1, "problem occurs often" = 2).

Experienced problem	Mean	Standard error	Confidence intervals (95%)	*N*
Dust	0.657	0.009	0.63–0.67	5547
Outdoor noise	0.649	0.009	0.63–0.66	5530
Too low temperature	0.549	0.008	0.53–0.56	5564
Unstable temperature	0.527	0.008	0.51–0.54	5479
Stuffy air	0.471	0.008	0.45–0.48	5542
Too high temperature	0.430	0.008	0.41–0.44	5543
Cigarette smell	0.409	0.008	0.39–0.42	5559
Dry air	0.399	0.008	0.38–0.41	5534
Draught	0.391	0.008	0.37–0.40	5561
Unpleasant smell	0.362	0.008	0.34–0.37	5560
Electric stat	0.148	0.005	0.13–0.15	5531

Table 6
Impact on overall satisfaction ranked according to odds ratios, *$p < 0.001$; (n) not significant, (model 2).

Experienced problem	Odds ratio	CI (95%)	
Draught	1.602*	1.442	1.780
Dust	1.560*	1.426	1.707
Too low temperature	1.490*	1.338	1.661
Unpleasant smell	1.486*	1.331	1.659
Dry air	1.433*	1.290	1.592
Stuffy air	1.389*	1.245	1.551
Outdoor noise	1.171*	1.074	1.277
Cigarette smell	0.952(n)	869	1.043
Electric stat	0.940(n)	0.814	1.085
Too high temperature	1.035(n)	0.937	1.144
Unstable temperature	1.070(n)	0.961	1.206

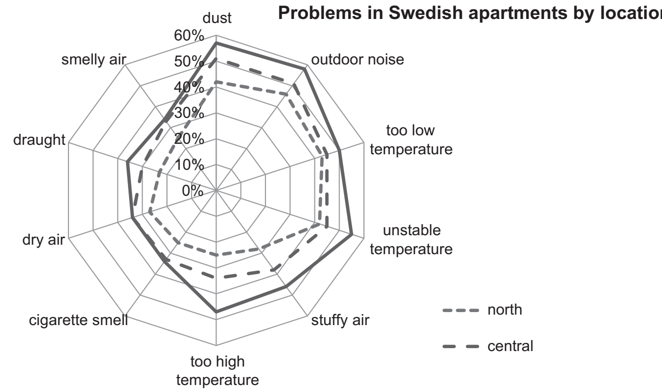

Fig. 2. Problems experienced in apartments in Sweden, presented by location.

been confirmed in the third step of analysis, when main model 1 was applied only to sub-groups created according to location of the building (model 1b). A certain alteration in ranking order was found for buildings located in the central and north parts of Sweden (Table 10). The results suggest that satisfaction with sound quality has higher importance impact for occupants in central and north than it has for those who live in the south part of Sweden.

Problems with IEQ. Interestingly, occupants living in the south of Sweden most frequently experience problems with IEQ, particularly problems related to thermal comfort (Fig. 2).

The analysis indicates that there is a significant difference in how the occurrence of a particular problem influences general satisfaction depending on location in Sweden.

The effect of a specific IEQ problem for different zones has been tested (model 2c) and the results demonstrate that inhabitants who live in apartments in southern Sweden are more sensitive to thermal comfort problems related to unstable and too low temperature, as the effect of *unstable temperature* for the south was 1.62 (CI(95%) 1.26–2.08) times that for the rest of the country and the effect of *too low temperature* for the south was 1.52 (CI(95%)1.20–1.92) times that for the rest of the country.

The results also show that importance ranking of IEQ problems for overall satisfaction was altered when model 2b showed that *problems with too low temperature* (odds ratio 2.01) and *unstable temperature* (odds ratio 1.51) had the highest importance for overall satisfaction for occupants living in southern Sweden (Table 12). This means that, should the occupant encounter problems with too low temperature indoors, the likelihood of overall satisfaction decreasing would be 2.01. For buildings located in the north of Sweden, problems with air quality may have the highest impact on overall satisfaction, i.e. *dust* and *unpleasant smell*. Problems with *outdoor noise* have a higher importance ranking for occupants living in the north of Sweden.

Table 7
Relationship between overall satisfaction and satisfaction with IEQ, model 1 and model 1a (including control variables).

	Main model 1	Model 1a and dummy variables
Satisfaction with air quality	2.651* [2.43–2.88]	2.742* [2.51–2.99]
Satisfaction with thermal comfort	1.814* [1.69–1.94]	1.746* [1.62–1.87]
Satisfaction with sound quality	1.560* [1.46–1.66]	1.515* [1.41–1.62]
Zone north		0.702* [0.57–0.86]
Zone central		0.736* [0.65–0.83]
Woman		0.918(n) [0.82–1.02]
Smoker		1.011(n) [0.86–1.18]
<1960		1.396*** [1.06–1.82]
1960–1975		1.149(n) [0.87–1.51]
1976–1985		1.318(n) [0.94–1.83]
1986–1995		1.096(n) [0.80–1.49]
Away 5–9 h		0.823*** [0.70–0.96]
Away >10 h		0.837*** [0.70–1.00]
≤35 years		2.109* [1.74–2.55]
36–50 Years		1.970* [1.60–2.41]
51–65 Years		1.700* [1.40–2.06]
R2	0.184	0.189
N	5175	5175

*$p \leq 0.001$; **$p \leq 0.01$; ***$p \leq 0.05$; (*n*) $p > 0.05$.

6.3.2. Construction year

6.3.2.1. Satisfaction with IEQ. A significant difference in general satisfaction was found depending on building construction year. Results (model 1a) indicate that occupants in buildings constructed before 1960 are more likely to be less satisfied than occupants living in recently constructed dwellings (Table 7). The results show (model 1b) that satisfaction with air quality has the highest ranking importance for overall satisfaction regardless of building construction year, yet satisfaction with sound quality has increased its impact in ranking for buildings constructed between 1976 and 1985 and 1986 and 1995 (Table 10). For buildings constructed between 1961 and 1975, odds ratio for thermal comfort increased to 2.06 compared with the main model. This could mean that should occupants be less satisfied with thermal quality, there is a 2.06 times likelihood that the overall satisfaction decreases. Even though this increase did not have an impact on ranking, it is interesting when comparing it with further results.

Analysis with interactive variables (model 1c) indicates that occupants in buildings constructed between 1976 and 1985 (odds

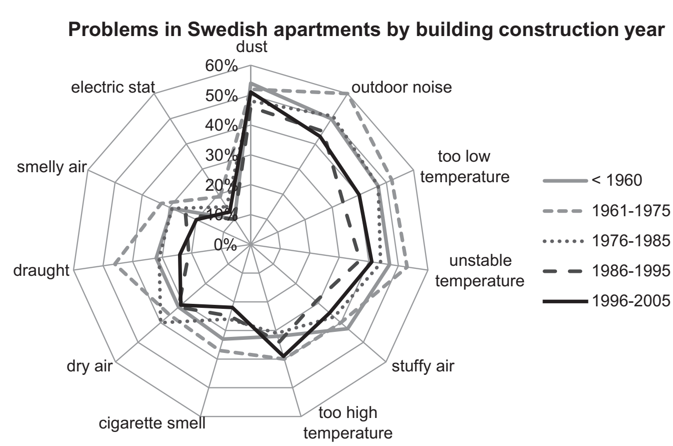

Fig. 3. Observed problems with IEQ in apartments in Sweden.

Table 8
Relationship between overall satisfaction and problems with IEQ, model 2 and model 2a (including control variables).

Variables	Main model 2	Model 2a (with dummy variables)
Draught	1.602* [1.44–1.78]	1.624* [1.45–1.81]
Dust	1.560* [1.42–1.70]	1.543* [1.40–1.69]
Too low temperature	1.490* [1.33–1.66]	1.382* [1.23–1.54]
Unpleasant smell	1.486* [1.33–1.65]	1.536* [1.37–1.71]
Dry air	1.433* [1.29–1.59]	1.591* [1.42–1.77]
Stuffy air	1.389* [1.24–1.55]	1.261* [1.12–1.41]
Outdoor noise	1.171* [1.07–1.27]	1.126** [1.02–1.23]
Unstable temperature	1.076(n) [0.96–1.20]	1.048(n) [0.932–1.17]
Too high temperature	1.035(n) [0.93–1.14]	0.915(n) [0.82–1.01]
Electric stat	0.940(n) [0.81–1.08]	0.945(n) [0.81–1.09]
Cigarette smell	0.952(n) [0.86–1.04]	0.918(n) [0.83–1.01]
Zone north		0.939(n) [0.76–1.15]
Zone central		0.812* [0.71–0.92]
Woman		0.849** [0.75–0.95]
Smoker		1.036(n) [0.88–1.21]
<1960		1.597* [1.23–2.07]
1960–1975		1.850* [1.41–2.41]
1976–1985		1.825* [1.31–2.53]
1986–1995		1.175(n) [0.86–1.59]
Away 5–9 h		1.032(n) [0.87–1.21]
Away >10 h		1.071(n) [0.89–1.28]
≤35 Years		2.027* [1.65–2.48]
36–50 Years		2.178* [1.76–2.68]
51–65 Years		1.322** [1.08–1.61]
R2	0.110	0.12
N	5054	5023

*$p \le 0.001$; **$p \le 0.01$; ***$p \le 0.05$; (n) $p > 0.05$.

ratio 1.48, CI (95%) 1.17–1.88) and 1986 and 1995 (odds ratio 1.24, CI (95%) 1.01–1.54) are more sensitive to *sound quality* than occupants of other buildings. The effect on *satisfaction with thermal comfort* for buildings constructed between 1961 and 1975 was 1.18 times the *satisfaction with thermal comfort* for other buildings, meaning that occupants living in apartment buildings constructed between 1961 and 1975 are marginally more sensitive to thermal comfort.

6.3.2.2. Problems with IEQ. The figure shows most problems with IEQ were observed in buildings built in Sweden in the mid-sixties to mid-seventies (Fig. 3).

The influence of building construction year on overall satisfaction was tested (model 2b). The results showed that the importance impact of IEQ problems varied depending on building construction year (Table 12). Model 2c, with interactive variables was applied to data to test which problem affects a particular sub-group.

6.3.2.3. Buildings constructed before 1960. For building constructed before 1960, *problems with draught* (odds ratio 1.76) *and problems with dust* (odds ratio 1.60) were found to have the highest impact on overall satisfaction, which was in line with the main model (Table 12). Analysis with interactive variables indicates that the effect of *problems with unstable temperature* was 1.37 times that for other buildings (CI (95%) 1.07–1.73).

6.3.2.4. Buildings constructed between 1961 and 1975. For buildings constructed between 1961 and 1975, rating importance has changed if compared to the main model; the highest impact on occupants' overall satisfaction seems to be from problems related to thermal comfort (*problems with too low temperature* – odds ratio 2.11 and *problems with draught* – odds ratio 1.75). Analysis with interactive variables confirms that the effect of *problems with too low temperature* for buildings constructed between 1961 and 1975 was 1.64 (CI(95%) 1.26–2.00) times that of *too low temperature* for other buildings. Interestingly, the effect of *problems with outdoor noise* was found to be statistically significant and was 1.26 times

Table 9
Relationship between overall satisfaction and satisfaction with IEQ applied to sub-groups, model 1b (individuals characteristics).

Variables	Main	Age				Life style			Gender		Health	
sub-groups	model 1	Under 35 years	36–50 Years	51–65 Years	More than 66 years	Away for less than 4 h on weekday	Away for 5–9 h on weekday	Away for more than 10 h on weekday	Woman	Man	Smoker	Non-smoker
Satisfaction with air quality	2.651* [2.43–2.88]	2.425* [2.02–2.88]	2.789* [2.36–3.34]	2.886* [2.39–3.47]	2.839* [2.30–3.37]	2.322* [2.053–2.65]	2.548* [2.21–2.92]	3.151* [2.65–3.74]	2.780* [2.47–3.11]	2.588* [2.27–2.94]	4.786* [3.61–6.33]	2.438* [2.22–2.66]
Satisfaction with thermal comfort	1.814* [1.69–1.94]	1.779* [1.51–2.08]	1.738* [1.50–2.01]	1.810* [1.54–2.11]	1.537* [1.33–1.76]	1.94* [1.74–2.16]	1.930* [1.71–2.16]	1.434* [1.23–1.66]	1.989* [1.81–2.18]	1.626* [1.45–1.81]	1.544* [1.26–1.88]	1.881* [1.74–2.03]
Satisfaction with sound quality	1.560* [1.46–1.66]	1.317* [1.14–1.51]	1.729* [1.49–1.99]	1.912* [1.66–2.19]	1.483* [1.32–1.66]	1.732* [1.56–1.92]	1.507* [1.36–1.66]	1.546* [1.34–1.77]	1.551* [1.42–1.69]	1.549* [1.402–1.71]	1.684* [1.42–1.99]	1.522* [1.41–1.63]
R2	0.179	0.114	0.213	0.235	0.160	0.201	0.164	0.179	0.194	0.162	0.255	0.166
N	5339	1015	1034	1429	1861	2145	2169	1195	2952	2338	628	4639

*$p \le 0.001$; **$p \le 0.01$; ***$p \le 0.05$; (n) $p > 0.05$.

Table 10
Relationship between overall satisfaction and satisfaction with IEQ applied to sub-groups, model 1b.

Variables sub-groups	Main model 1	Location			Construction year				
		North	Central	South	<1960	1961–1975	1976–1985	1986–1995	1996–2005
Satisfaction with air quality	2.651* [2.43–2.88]	1.442* [1.15–1.80]	2.755* [2.44–3.10]	3.026* [2.61–3.49]	2.755* [2.17–3.48]	2.471* [2.12–2.86]	2.435* [199–2.97]	3.207* [2.48–4.14]	2.454* [2.04–2.94]
Satisfaction with thermal comfort	1.814* [1.69–1.94]	1.486** [1.22–1–81]	1.565* [1.422–1.72]	2.369* [2.08–2.68]	1.840* [1.50–2.24]	2.067* [1.81–2.35]	1.376* [1.16–1.61]	1.436* [1.20–1.71]	2.151* [1.84–2.50]
Satisfaction with sound quality	1.560* [1.46–1.66]	1.529* [1.29–1.86]	1.719* [1.56–1.88]	1.346* [1.20–1.50]	1.504* [1.25–1.80]	1.401* [1.24–1.57]	2.376* [2.03–2.78]	1.956* [1.65–2.31]	1.698* [1.49–1.91]
R2	0.179	0.084	0.180	0.208	0.163	0.178	0.210	0.214	0.210
N	5339	714	2786	1839	664	1754	940	851	2145

*$p \le 0.001$; **$p \le 0.01$; ***$p \le 0.05$; (n) $p > 0.05$.

that of *problems with outdoor noise* for other buildings (CI (95%) 1.04–1.52).

6.3.2.5. Buildings constructed between 1976 and 1985. For buildings constructed between 1976 and 1985, the importance ranking has also changed and variables with the highest importance are problems related to air quality (*problems with unpleasant smell* (odds ratio 2.74), *stuffy air* (odds ratio 1.70)). Interactive variables confirm that occupants living in buildings constructed between 1976 and 1985 are more sensitive to problems with air quality. The effect of *unpleasant smell* for this building group was 1.82 (CI (95%) 1.18–2.79) times the effect of *unpleasant smell* for other buildings.

6.3.2.6. Buildings constructed between 1986 and 1995. Results show that for buildings constructed between 1986 and 1995, the variables describing problems with air quality were placed first in the importance ranking. They also showed that *problems with stuffy air* (odds ratio 1.82) and *problems with unpleasant smell* (odds ratio 1.82) and *problems with dust* (odds ratio 1.58) had the highest impact on overall satisfaction for these buildings. Sensitivity to air quality problems was indicated by the analysis with interactive variables, where *problems with cigarette smell* were found to have a statistically significant effect for buildings constructed between 1986 and 1995 (odds ratio 1.55, CI (95%) 1.11–2.18).

6.3.2.7. Buildings constructed between 1996 and 2005. Interestingly, the highest impact on overall satisfaction for occupants living in the most recently constructed buildings (1996–2005) came from *problems with too low temperature* (odds ratio 2.11). This was followed by issues related to air quality: *problems with unpleasant smell* and *problems with stuffy air*. Interactive variables were found to be statistically not significant.

6.4. Overall satisfaction and individuals' characteristics

6.4.1. Gender

6.4.1.1. Satisfaction with IEQ. The analysis indicates that gender does not have a statistically significant impact on how occupants perceive overall satisfaction. The effect of satisfaction with thermal comfort, air and sound quality was tested (model 1c) and results show that the effect of thermal comfort is statistically significant, being 1.24 times the effect for women than the effect of *thermal comfort* on men, indicating that women are more sensitive to thermal discomfort.

6.4.1.2. Problems with IEQ. Results generated from the second model (model 2c) show that problems with *stuffy air* (odds ratio 1.49(CI(95%) 1.19–1.85)), *draught* (odds ratio 1.25(CI(95%) 1.01–1.55)), and *dust* (odds ratio 1.25(CI(95%) 1.04–1.50)) have a greater effect on women than on men. This was confirmed in the importance ranking in the female sub-group (Table 9). The results show that *problems with draught* (odds ratio 1.73), *problems with dust* (odds ratio 1.72) and *problems with stuffy air* (odds ratio 1.66) have the highest impact on women's overall satisfaction. This implies that if the problem with draught appears, there is a 1.73 times likelihood that women's overall satisfaction would decrease, if other variables were kept unchanged.

6.4.2. Age

6.4.2.1. Satisfaction with IEQ. Results from model 1a show (Table 7) that occupants' age has significant impact on overall satisfaction and that younger occupants are more likely to be dissatisfied (odds ratio 2.10) Interestingly, the importance of satisfaction with noise increased for occupants between 36 and 65 years; for group 51–65 this IEQ aspect was ranked higher than thermal comfort (Table 9), which is different if compared to results from the main model and to results from the model 1 if applied to other age sub-groups (model 1b).

6.4.2.2. Problems with IEQ. Should the problems with IEQ appear, it is most likely that younger occupants will be dissatisfied (Table 8). It can be noticed that the impact of IEQ problems on overall satisfaction varies depending on age group.

Analysis with interactive variables (model 2c) suggests that the youngest group, occupants of 35 years and below, are affected by *problems with unpleasant smell* (odds ratio 1.44, CI (95%) 1.15–1.81) and *problems with high temperature* (odds ratio 1.29, CI (95%)1.04–1.59). The age group between 51 and 65 was found to be affected most by *problems with unstable temperature* (odds ratio 2.17, CI (95%) 1.59–2.95), whereas the effect of *problems with noise* is statistically significant and has 1.38 (CI (95%) 1.09–1.74) times the effect on the oldest group (over 66 years).

This was reflected in this sub-group's importance ranking, where *problems with unpleasant smell* were found to have the highest impact on overall satisfaction for the youngest respondents' group and *problems with unstable temperature* for age group 50–65 (Table 11).

6.4.3. Life style

6.4.3.1. Satisfaction with IEQ. The analysis indicates that life style has a statistically significant impact on occupants' overall satisfaction (Table 7). It was found that occupants who are absent from the apartment for more than 4 h on weekdays are less likely to be dissatisfied than those who were absent for less than 4 h. The effect of *satisfaction with sound quality* is 1.24 (CI(95%) 1.04–1.38) time on occupants leaving the apartment for less than 4 h than the effect on other occupants (model 1c).

6.4.3.2. Problems with IEQ. Occupants' perception of IEQ problems seems to be impacted by the number of hours that they spend in the apartment on weekdays (Table 12). For occupants who leave the apartment for less than 4 h, the problems that have the highest

Table 11
Relationship between overall satisfaction and problem with IEQ applied to sub-groups, model 2b.

Model 2 applied to separate	General model 2	Gender		Age				Health		Life style		
Sub-groups	Reference values	Woman	Man	Under 35 years	36–50 Years	51–65 Years	More than 66 years	Smoker	Non-smoker	Away 0–4 h	Away 5–9 h	Away >10 h
Draught	1.602*	1.733*	1.412*	1.823*	1.587*	1.566*	1.322**	1.900*	1.471*	1.123(n)	1.834*	1.823*
	[1.44–1.78]	[1.50–1.99]	[1.19–1.67]	[1.44–2.29]	[1.27–1.98]	[1.20–2.04]	[1.09–1.60]	[1.44–2.49]	[1.30–1.65]	[.95–1.32]	[1.55–2.16]	[1.43–2.32]
Dust	1.560*	1.725*	1.391*	1.528*	1.499*	1.342**	1.424*	1.404***	1.591*	1.509*	1.673*	1.319**
	[1.42–1.70]	[1.53–1.94]	[1.20–1.60]	[1.23–1.88]	[1.23–1.82]	[1.10–1.63]	[1.21–1.66]	[1.07–1.83]	[1.44–1.75]	[1.30–1.74]	[1.44–1.93]	[1.08–1.60]
Too low temperature	1.490*	1.557*	1.502*	1.511*	1.399**	1.017(n)	1.532*	1.521***	1.501*	1.402*	1.483*	1.480*
	[1.33–1.66]	[1.34–1.80]	[1.26–1.77]	[1.18–1.93]	[1.11–1.76]	[0.80–1.28]	[1.24–1.88]	[1.06–2.18]	[1.33–1.68]	[1.8–1.66]	[1.24–1.76]	[1.16–1.87]
Unpleasant smell	1.486*	1.532*	1.487*	1.864*	1.259(n)	1.460**	1.207(n)	3.370***	1.329*	1.706*	1.580*	1.297***
	[1.33–1.65]	[1.32–1.77]	[1.24–1.77]	[1.47–2.35]	[.98- 1.60]	[1.12–1.90]	[.96–1.50]	[2.28–4.97]	[1.18–1.49]	[1.41–2.05]	[1.32–1.88]	[1.02–1.63]
Dry air	1.433*	1.397*	1.559*	1.756*	1.043(n)	1.865*	1.679*	1.145(n)	1.518*	1.428*	1.606*	1.286***
	[1.29–1.59]	[1.21–1.61]	[1.32–1.83]	[1.36–2.25]	[0.82–1.32]	[1.47–2.36]	[1.39–2.02]	[0.83–1.56]	[1.35–1.70]	[1.21–1.67]	[1.34–1.91]	[1.01–1.63]
Stuffy air	1.389*	1.666*	1.134(n)	1.083(n)	1.988*	1.489*	0.945(n)	1.240(n)	1.447*	0.939(n)	1.439*	1.723*
	[1.24–1.55]	[1.43–1.93]	[0.96–1.33]	[0.86–1.35]	[1.51–2.60]	[1.18–1.87]	[0.72–1.23]	[0.89–1.71]	[1.28–1.63]	[0.77–1.13]	[1.21–1.70]	[1.35–2.18]
Outdoor noise	1.171*	0.944(n)	1.409*	1.162(n)	1.191(n)	0.976(n)	1.556*	858(n)	1.250*	1.481*	1.088(n)	1.208(n)
	[1.07–1.27]	[0.83–1.06]	[1.23 –1.60]	[0.96–1.39]	[0.97–1.45]	[0.81–1.17]	[1.31–1.83]	[0.67–1.09]	[1.13–1.37]	[1.28–1.71]	[0.94–1.24]	[0.00–1.45]
Unstable temperature	1.076(n)	1.003(n)	1.069(n)	0.935(n)	1.197(n)	2.079*	0.774***	1.932*	0.917(n)	1.176(n)	1.292**	0.833(n)
	[0.96–1.20]	[0.85–1.17]	[0.90–1.27]	[0.72–1.20]	[0.93–1.52]	[1.61–2.67]	[0.61–0.97]	[1.35–2.74]	[0.80–1.03]	[0.97–1.42]	[1.07–1.55]	[0.65–1.05]
Too high temperature	1.035(n)	1.004(n)	1.049(n)	1.171(n)	0.869(n)	0.571*	1.053(n)	0.801(n)	1.149***	1.084(n)	1.047(n)	0.808(n)
	[0.93–1.14]	[0.87–1.15]	[0.90–1.21]	[0.93–1.47]	[0.71–1.06]	[0.45–0.71]	[0.84–1.31]	[0.58–1.08]	[1.03–1.28]	[0.92–1.27]	[0.89–1.22]	[0.65–1.00]
Electric stat	0.940(n)	0.854(n)	1.102(n)	0.879(n)	0.950(n)	1.399***	0.901(n)	0.630(n)	1.047(n)	0.874(n)	1.021(n)	0.882(n)
	[0.81–1.08]	[0.71–1.02]	[0.86–1.40]	[0.61–1.26]	[0.69–1.29]	[1.03–1.88]	[0.70–1.16]	[0.38–1.02]	[0.89–1.22]	[0.70–1.09]	[0.80–1.29]	[0.64–1.20]
Cigarette smell	0.952(n)	1.001(n)	0.934(n)	0.779***	0.862(n)	1.10(n)	1.225***	0.972(n)	0.970(n)	0.986(n)	0.777*	1.246***
	[0.86–1.04]	[0.88–1.13]	[0.81–1.07]	[0.64–0.94]	[0.70–1.05]	[0.89–1.35]	[1.00–1.49]	[0.54–1.74]	[0.88–1.06]	[0.84–1.15]	[0.66–0.90]	[1.02–1.51]
R2	0.110	0.135	0.08	0.122	0.104	0.124	0.075	0.173	0.107	0.086	0.145	0.109
N	5054	2763	2247	987	986	1360	1721	602	4387	1988	2056	1142

*$p \leq 0.001$; **$p \leq 0.01$; ***$p \leq 0.05$; (n) $p > 0.05$.

Table 12
Relationship between overall satisfaction and problem with IEQ applied to sub-groups, model 2b.

Model 2 applied to separate	General model 2	Location			Construction year				
Sub-groups	Reference values	North	Central	South	<1960	1961–1975	1976–1985	1986–1995	1996–2005
Draught	1.602*	1.706**	1.607*	1.386*	1.766*	1.758*	1.060(n)	0.980(n)	0.621**
	[1.44–1.78]	[1.20–2.40]	[1.38–1.85]	[1.16–1.65]	[1.30–2.38]	[1.46–2.11]	[0.82–1.35]	[0.70–1.35]	[0.471–0.81]
Dust	1.560*	2.245*	1.630*	1.391*	1.602*	1.587*	0.894(n)	1.589*	1.692*
	[1.42–1.70]	[1.63–3.08]	[1.44–1.83]	[1.17–1.65]	[1.24–2.06]	[1.34–1.87]	[0.71–1.11]	[1.26–1.99]	[1.38–2.06]
Too low temperature	1.490*	0.431*	1.497*	2.011*	1.049(n)	2.111*	1.489**	1.174(n)	2.115*
	[1.33–1.66]	[0.30–0.61]	[1.28–1.73]	[1.66–2.43]	[0.76–1.44]	[1.73–2.56]	[1.17–1.89]	[0.86–1.56]	[1.69–2.63]
Unpleasant smell	1.486*	1.796**	1.370*	1.578*	1.393***	1.415**	2.740*	1.826**	2.035*
	[1.33–1.65]	[1.18–2.73]	[1.18–1.58]	[1.30–1.91]	[1.03–1.87]	[1.14–1.74]	[2.09–3.58]	[1.29–2.57]	[1.56–2.64]
Dry air	1.433*	1.612**	1.500*	1.363*	1.464***	1.712*	1.117(n)	1.258(n)	1.109(n)
	[1.29–1.59]	[1.13–2.28]	[1.29–1.74]	[1.14–1.61]	[1.08–1.97]	[1.39–2.09]	[0.88–1.41]	[0.92–1.70]	[0.90–1.36]
Stuffy air	1.389*	1.214(n)	1.441*	1.316**	1.177(n)	1.578*	1.706*	1.828*	1.914*
	[1.24–1.55]	[0.82–1.77]	[1.23–1.68]	[1.09–1.57]	[0.86–1.59]	[1.28–1.94]	[1.30–2.22]	[1.31–2.54]	[1.54–2.37]
Outdoor noise	1.171*	1.699*	1.171***	1.084(n)	0.975(n)	1.415*	1.263***	1.245(n)	1.426*
	[1.07–1.27]	[1.26–2.28]	[1.03–1.32]	[0.93–1.26]	[0.76–1.24]	[1.20–1.66]	[1.01–1.56]	[0.99–1.56]	[1.18–1.71]
Unstable temperature	1.076(n)	1.119(n)	0.952(n)	1.512*	1.308(n)	0.931(n)	0.901(n)	1.28(n)	1.487**
	[0.96–1.20]	[0.74–1.68]	[0.81–1.11]	[1.23–1.84]	[0.93–1.82]	[0.76–1.14]	[0.68–1.18]	[0.92–1.77]	[1.15–1.91]
Too high temperature	1.035(n)	1.014(n)	1.085(n)	0.829***	0.975(n)	1.093(n)	0.956(n)	1.353***	1.089(n)
	[0.93–1.14]	[0.70–1.45]	[0.94–1.24]	[0.69–0.99]	[0.72–1.30]	[0.912–1.31]	[0.74–1.22]	[1.05–1.74]	[0.87–1.34]
Electric stat	0.940(n)	1.005(n)	0.998(n)	0.915(n)	1.16(n)	0.683***	0.712***	0.984(n)	0.822(n)
	[0.81–1.08]	[0.67–1.49]	[0.80–1.22]	[0.70–1.18]	[0.76–1.77]	[0.52–0.88]	[0.51–0.99]	[0.67–1.42]	[0.55–1.22]
Cigarette smell	0.952(n)	0.602**	1.199**	0.768**	0.883(n)	0.981(n)	0.958(n)	1.383***	0.827(n)
	[0.86–1.04]	[0.44–0.82]	[1.05–1.83]	[0.65–0.90]	[0.68–1.14]	[0.83–1.15]	[0.77–1.18]	[1.05–1.81]	[0.65–1.05]
R2	0.110	0.113	0.118	0.123	0.083	0.169	0.114	0.140	0.139
N	5054	678	2655	1721	637	1636	876	809	1096

$^{*}p \le 0.001$; $^{**}p \le 0.01$; $^{***}p \le 0.05$; (n) $p > 0.05$.

impact on overall satisfaction are problems with *unpleasant smell* (odds ratio 1.70), *dust* (odds ratio 1.50) and *outdoor noise* (odds ratio 1.48). Analysis with interactive variables (model 2c) indicates that the effect of *problems with outdoor noise* on occupants who leave the apartment for less than 4 h is 1.44 (CI(95%) 1.18–1.75) times the effect of *outdoor noise* on other occupants. Occupants who leave the apartment for 5–9 h on weekdays were found to be more sensitive to *draught* (odds ratio 1.31, CI (95%) 1.06–1.62) and *unstable temperature* (odds ratio 1.27, CI(95%) 1.06–1.60).

6.4.4. Heath

6.4.4.1. Satisfaction with IEQ. A smoking habit was found to be not statistically significant (model 1a, Table 7). However, analysis with model 1b indicates that people who smoke are more sensitive to the effect of *satisfaction from air quality*, which is 1.82 (CI(95%) 1.43–2.31) times the effect of *air quality* for non-smokers.

6.4.4.2. Problems with IEQ. The results (model 2c) show that the effect of *problems with unstable temperature* for smokers is 2.02 (CI(95%) 1.45–2.81) and *unpleasant smell* 2.15 (CI(95%) 1.52–3.03) times the effect those variables have on non-smokers. This is reflected in the importance ranking of IEQ problems in the group of smokers. The results showed that for occupants who smoke, *problems with unpleasant smell* (odds ratio 3.37) had the highest impact on overall satisfaction, followed by *problems with unstable temperature* (odds ratio 1.93) (Table 11).

7. Conclusions

This paper examined the effect that perception of indoor environment quality has on overall satisfaction and what influence the characteristics of individuals and building may have on overall satisfaction. The database used to investigate the issue was created from a fraction of data collected during a unique project commissioned by the Swedish National Board of Housing, Building and Planning. The nationally representative sample allows general conclusions to be drawn on how residents living in apartments in Sweden perceive indoor environment quality and how it influences their overall satisfaction. Even though the data used is based on information received from residents and therefore may present some level of subjectivity [2], it is the interaction between occupant and the building [34] that gives residents the very distinctive knowledge about building performance.

Although the data used carries a certain subjectivity, the subjective ratings proved to predict overall comfort better than objective indicators [17]. The pseudo-R2 for tested models was under 25%, suggesting that occupant satisfaction can only partly be explained by satisfaction with indoor air quality. However, even with those limitations, the presented analysis contributes to understanding the interaction between overall satisfaction and perception of IEQ.

Occupants living in apartment buildings in Sweden are in general very satisfied. Satisfaction with thermal comfort, sound and air quality was shown to have an impact on overall satisfaction, and satisfaction with indoor air was found to have the highest impact. These findings support results from earlier studies where satisfaction with air quality had the highest correlation with the acceptability of the overall environment [13,18] and impact on subjective well-being [35].

The most often observed problem with IEQ in Swedish apartments was dust, outdoor noise and problems with too low indoor temperature. Even though the problem of noise was the second most observed problem, the analysis indicated that outdoor noise did not have a high impact on overall satisfaction. The factors having the highest importance impact on overall satisfaction were draught, dust and too low temperature. However, the relative importance of problems with IEQ influencing overall satisfaction may differ depending on location, building construction year, occupant gender and life style.

Occupants in the southern part of Sweden showed higher sensitivity to issues related to thermal comfort, particularly problems related to indoor temperature. Interestingly, occupants living in the north part of Sweden, where local climate is considered to be more severe, reported that problems with indoor temperature may appear but are much less persistent than in southern Sweden. This may indicate a difference in building construction in Sweden. It is possible that buildings in the south are miscalculated with regard to indoor performance or that assumptions used in indoor comfort simulations are underestimated.

Different indoor environment problems seem to have an effect on occupants' overall satisfaction depending on building construction year. Generally, buildings constructed before 1975 indicated sensitivity to thermal comfort problems. This might be related to the fact that those buildings were built with insufficient insulation and the energy efficiency of windows is not as high as in the newest construction. Additionally, a considerable number of dwellings constructed between 1961 and 1975 belong to "The million home building scheme"[2] and many of them require substantial renovations [24]. Problems related to air quality were found to have the highest impact on overall satisfaction of occupants who live in buildings constructed between the mid-seventies to mid-nineties, which may also be explained by the building techniques and technology used. After the energy crisis in the seventies, issues regarding energy consumption and energy efficiency in buildings became more important, reflected in improvements in the airtightness of buildings. However, as buildings became more airtight, solutions regarding ventilation systems also emerged as a compelling issue.

The paper has shown that weighting aspects of indoor environment is not stable and differs depending on the characteristics of buildings and individuals. The occurrence of IEQ problems influences overall satisfaction, but how occupants perceive the importance of problems with the indoor environment varies between different populations.

Further studies should focus on understanding relationships between factors impacting occupants' satisfaction and explore the structure created by causal effects between the related variables. An interesting approach for analysis could be factor analysis and structural modelling. Exploring whether a variable is causally linked to one particular variable or to a group of variables could give better understanding of the relationship between indoor environment, behaviour and occupant satisfaction. This knowledge could lead to further improvements in indoor climate simulation programmes and building construction.

Acknowledgements

The authors wish to thank The Swedish National Board of Housing, Building and Planning (*Boverket*) for providing access to data collected during a unique project BETSI.

References

[1] Abbaszadeh S, Zagreus L, Lehrer D, Huizenga C. Occupant satisfaction with indoor environmental quality in green buildings. Proceedings of healthy buildings 2006, Lisbon, vol. III; 2006. p. 365–70.
[2] Amerigo M, Aragones JI. A theoretical and methodological approach to the study of residential satisfaction. J Environ Psychol 1997;17(1):47–57.
[3] Becker R, Paciuk M. Thermal comfort in residential buildings – failure to predict by Standard model. Build Environ 2009;44(5):948–60.
[4] Bluyssen PM, Aries M, et al. Comfort of workers in office buildings: the European HOPE project. Build Environ 2011;46(1):280–8.
[5] Bonnefoy X, Braubach M, Krapavickaite D, Ormandy D, Zurlytel. Housing conditions and self-reported heath status: a study in panel block buildings in three cities of Eastern Europe. J Housing Built Environ 2003;18:329–52.
[6] Borooah VK. Logit and probit: ordered and multinominal models. Sage University Paper Series on Quantitative Applications in the Social Science, 07-138; 2001.
[7] Thousand Oaks, CAFörändringar av bostadsbeståndets fördelning på hustyper, ägarkategorier och upplåtelseformer 1990–2007. Sage Boverket. Available from:, http://www.boverket.se/Global/Boende/Dokument/Bostadsbest%C3%A5ndet.pdf; 2003 [accessed 01.11.12].
[8] Statistiska urval och metoder i Boverkets projekt BETSI; Boverket oktober 2009. Sweden: Boverket. Available from: http://www.boverket.se/Bygga-forvalta/sa-mar-vara-hus/om-undersokningen/; 2009.
[9] Brink M. Parameters of well-being and subjective health and their relationship with residential traffic noise exposure – a representative evaluation in Switzerland. Environ Int 2011;37(4):723–33.
[10] Brown Z, Cole RJ. Influence of occupants' knowledge on comfort expectations and behaviour. Build Res Inf 2009;37(3):227–45.
[11] Buis ML. Stata tip 87: interpretation of interactions in non-linear models. Stata J 2010;10:305–8.
[12] Cao B, Ouyang Q, et al. Development of a multivariate regression model for overall satisfaction in public buildings based on field studies in Beijing and Shanghai. Build Environ 2012;47:394–9.
[13] Chan EHW, Lam KS, Wong WS. Evaluation on indoor environment quality of dense urban residential buildings. J Facilities Manag 2008;6(4):245–65.
[14] Choi J, Aziz A, et al. Investigation on the impacts of different genders and ages on satisfaction with thermal environments in office buildings. Build Environ 2010;45(6):1529–35.
[15] Choi JH, Loftness V, et al. Post-occupancy evaluation of 20 office buildings as basis for future IEQ standards and guidelines. Energ Buildings 2012;46:167–75.
[16] Dekker K, de Vos S, et al. Residential satisfaction in housing estates in European cities: a multi-level research approach. Housing Stud 2011;26(4):479–99.
[17] Fransson N, Vastfjall D, et al. In search of the comfortable indoor environment: a comparison of the utility of objective and subjective indicators of indoor comfort. Build Environ 2007;42(5):1886–90.
[18] Frontczak M, Andersen RV, et al. Questionnaire survey on factors influencing comfort with indoor environmental quality in Danish housing. Build Environ 2012;50:56–64.
[19] Frontczak M, Schiavon S, et al. Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design. Indoor Air 2012;22(2):119–31.
[20] Frontczak M, Wargocki P. Literature survey on how different factors influence human comfort in indoor environments. Build Environ 2011;46(4):922–37.
[21] Gidlof-Gunnarsson A, Ohrstrom E. Noise and well-being in urban residential environments: the potential role of perceived availability to nearby green areas. Landscape Urban Plan 2007;83(2, 3):115–26.
[22] Humphreys MA. Quantifying occupant comfort: are combined indices of the indoor environment practicable? Build Res Inf 2005;33(4):317–25.
[23] Heeringa SG, West BT, Berglund PA. Applied survey data analysis. Boca Raton, FL: CRC Press Taylor and Francis Group; 2010.
[24] Högberg L, Lind H, Grange K. Incentives for improving energy efficiency when renovating large-scale housing estates: a case study of the Swedish Million Homes Programme. Sustainability 2009;1(4):1349–65.
[25] Indraganti M, Rao KD. Effect of age, gender, economic group and tenure on thermal comfort: a field study in residential buildings in hot and dry climate with seasonal variations. Energy Build 2010;42(3):273–81.
[26] Kamaruzzaman SN, Egbu CO, et al. The effect of indoor environmental quality on occupants' perception of performance: a case study of refurbished historic buildings in Malaysia. Energy Build 2011;43(2, 3):407–13.
[27] Kim J, de Dear R. Nonlinear relationships between individual IEQ factors and overall workspace satisfaction. Build Environ 2012;49:33–40.
[28] Lai ACK, Mui KW, Wong LT, Law LY. An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings. Energy Build 2009;41(9):930–6.
[29] Lai JHK, Yik FWH. Perceived importance of the quality of the indoor environment in commercial buildings. Indoor Built Environ 2007;16(4):311–21.
[30] Lai JHK, Yik FWH. Perception of importance and performance of the indoor environmental quality of high-rise residential buildings. Build Environ 2009;44(2):352–60.
[31] Lee TK, Cho SH, et al. Residents' adjusting behaviour to enhance indoor environmental comfort in apartments. Indoor Built Environ 2012;21(1):28–40.
[32] Lind H, Lundström S. Bostäder på marknadens villkor. Sweden, Stockholm: SNS Förlag; 2007.
[33] Mohit MA, Ibrahim M, et al. Assessment of residential satisfaction in newly designed public low-cost housing in Kuala Lumpur, Malaysia. Habitat Int 2010;34(1):18–27.
[34] Nicol F, Roaf S. Post-occupancy evaluation and field studies of thermal comfort. Build Res Inform 2005;33(4):338–46.
[35] Rehdanz K, Maddison D. Local environmental quality and life-satisfaction in Germany. Ecol Econ 2008;64(4):787–97.
[36] Hem för miljoner – Förutsättningar för upprustning av rekordårens bostäder. SABO. Available from: http://www.sabo.se/SiteCollectionDocuments/hemformiljoner_rapport_091102.pdf; 2009.
[37] Steemers K, Manchanda S. Energy efficient design and occupant well-being: case studies in the UK and India. Build Environ 2010;45(2):270–8.
[38] Varady D, Walker C, Wang X. Voucher recipient achievement of improved housing conditions in the US: do moving distance and relocation services matter? Urban Stud 2001;38:1273–304.
[39] Zalejska-Jonsson A. Evaluation of low-energy and conventional residential buildings from occupants' perspective. Build Environ 2012;58:135–44.
[40] Zhang YF, Altan H. A comparison of the occupant comfort in a conventional high-rise office block and a contemporary environmentally-concerned building. Build Environ 2011;46(2):535–45.

[2] Housing scheme introduced in Sweden in 1964 and aiming at construction one million dwellings within ten years period (1965–1974) [7,36].