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Influence of indoor environmental quality and dwelling satisfaction aspects on overall satisfaction: Findings from a Swedish national survey.

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Abstract. The objective of this study is to contribute to the discussion on the impact of dwelling satisfaction aspects (size, standard, layout, appearance/aesthetics, well-being, cost and area/neighbourhood) and perceived indoor environmental quality (thermal comfort, air quality, satisfaction with daylight and acoustic comfort) on occupants' overall satisfaction. This article uses data from the Swedish National Survey, BETSI (2007/08). The results are representative of adults living in multi-family and single-family buildings (1597 responses/955 buildings). Linear regression models are developed with overall satisfaction as the dependent variable and independent variables: seven satisfaction aspects, four indoor environmental quality factors and all combined (eleven). An all-model explained 54.7% of the results (best performed). All the retained variables (except satisfaction with daylight) are statistically significant predictors. Satisfaction with well-being (b = 0.286) and satisfaction with dwellings' standard (b = 0.188) have the greatest effect on overall satisfaction. The model with the IEQ aspects explained only 35.5% of the results. Reliability statistics (Cronbach's alpha) and confirmatory factor analysis have been implemented in the dataset. The responses can be categorized into two clusters. The two clusters were significantly different across living duration, dwelling type, age category and tenure status.

1 Introduction

More than ever, building occupants are considered to be consumers with continuously increasing expectations needs and living standards. Understanding the aspects and factors contributing to occupant satisfaction with their build environment is a significant topic of interest [1]. All key actors involved in the building and operation process, from designers, architects, engineers and developers to facility managers and installers, have to become aware of and appreciate the needs of the occupants and what makes them satisfied, mainly for economic but also for other reasons.

Given the amount of time that people spend indoors, the quality of the indoor environment (IEQ), which includes thermal, acoustic, indoor air quality, and visual factors, can have a significant effect on the quality of life of those who experience it [2]. High quality indoor environment for residential buildings is essential for good physical and mental health, high productivity and learning performance, stress level, sleep quality and comfort of occupants [3]. Extensive research indicates that the perception of a dwelling's indoor environmental quality has linear and non-linear relationship (negative, positive or in both directions) with building characteristics and satisfaction of its users [4]. The research is focused mainly on commercial office buildings [5-8]. Extensive studies also exist for residential buildings, single-family houses and apartments [9-11]. It would be reasonable to assert that occupant satisfaction reduces when IEQ issues arise. The quantification of this relationship has been proved to be very complicated.

The aim of this study is to contribute to the discussion on the impact of indoor environment quality factors (thermal comfort, air quality, acoustic comfort and satisfaction with daylight) on overall satisfaction as well as investigate how specific dwelling satisfaction aspects (size, standard, layout, appearance/aesthetics, well-being, cost, area/neighbourhood) affect it. The analysis is based on survey responses collected during a commissioned project by The Swedish National Board of Housing, Building and Planning (Boverket). The results are representative of adults living in multifamily buildings and single-family houses in Sweden and contribute to the existing knowledge about perceived IEQ and occupants' satisfaction with their dwellings. Applying a quantitative model enables us to measure the extent to which the perception of IEQ and satisfaction of specific aspects influence the overall satisfaction. The differentiation with previous work on the topic that used the specific database is that the analysis extends to the entire examined building stock (apartments and single-family houses; [1]). In addition, the specific satisfaction

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aspects have never been analysed before in association with the overall satisfaction of the occupants.

2 Methods and materials

The BETSI (Bebyggelsens Energianvändning, Tekniska Status och Innemiljö) study was commissioned by the Swedish National Board of Housing, Building and Planning (Boverket) in 2006 as a reference project [12]. The project's objective was to collect information on the indoor environmental conditions, energy consumption, and technical condition of the Swedish residential building stock, as well as the comfort, satisfaction and health of the occupants. A total of approximately 1400 residential buildings (single-family houses and apartments) were inspected in the BETSI study (heating season). The current analysis includes 955 residential buildings, 563 single-family houses (1078 occupants) and 392 multi-family buildings (apartments; 519 occupants). The subgroup was selected because the occupants of these dwellings have answered all questions of the satisfaction and IEQ variables in the questionnaire. The percentage of apartments is inadequately represented in the dataset. This characteristic has no impact on this study, which does not characterize the building stock but instead emphasizes on relationships.

61.6% of the dwelling's occupants are the property's owners (19.1% under tenancy). 51.6% of the occupants are women and almost all occupants are non-smokers (91.1%). 22.9% of the occupants are younger than 40, 34.5% are between 40 and 60, and the remaining occupants are older than 60. One third of the occupants were away from home between zero and four hours (21.6% more than 10 hours). One third of the occupants were living in the house less than 5 years (46.6% more than 10 year).

The questionnaire was developed from Uppsala University, Medical Science Department, based on previous research [13, 14]. The questions reflect to the "MM-questionnaire", which was developed at the Örebro University Hospital (1980s; [13, 14]). The questionnaire was posted by mail to residents in April and May of 2008 (two reminders). Almost half (46%) of the people participated in the study. The questionnaire is divided into six categories and includes 35 questions. In the first section of the survey, respondents were asked about their general view of the interior environment (satisfaction) and whether or not particular problems existed in their dwellings. The following three sections linked to more extensive questions about occupants' assessment of thermal comfort, air quality and sound quality. The fifth section contained health-related questions, whereas the sixth section provides information on the individuals. This analysis focuses on the questions about IEQ factors and satisfaction aspects which were given on a five-point ordinal scale: "very dissatisfied" (1), "dissatisfied" (2), "acceptable" (3), "satisfied" (4) and "very satisfied" (5) or "very poor" (1), "poor" (2), "acceptable" (3), "good" (4) and "very good" (5). Detailed information about the occupants' survey and variables can be found in Refs. [3, 10-17]. For this analysis the satisfaction of daylight is used as IEQ factor.

2.1 Statistical analysis

The descriptive statistics of all the examined factors and aspects (IEQ and satisfaction); median, average and standard deviation are presented in Table 1. The range (min-max) is from 1 to 5 for all variables. Two different linear regression models were implemented with overall satisfaction as the dependent variable and a) the four IEQ variables or b) the seven variables regarding satisfaction as predictors. In addition, a backward stepwise linear regression model (based on the lowest AIC values) was implemented with overall satisfaction as the dependent variable and all the other variables (N = 11) as predictors. The goodness-of-fit for the stepwise model was evaluated with the Nagelkerke R-squared (R^2), the confusion matrix, as well as the accuracy, sensitivity and specificity metrics. The assumptions of homoskedasticity and normality of residuals were assessed for each linear model.

In order to reduce the dimension of the data, confirmatory factor analysis was additionally implemented with questions regarding thermal comfort, indoor air quality, acoustic comfort and satisfaction with dwelling daylight to load in one factor entitled "IEQ" and all the other questions about satisfaction (N = 7) grouped in the factor entitled "satisfaction". The regression scores of the two-factor solution for each participant was stored in the dataset (Table 3). Additionally, the reliability coefficient (Cronbach's alpha) was determined independently for IEQ and satisfaction variables (same underline dimension and construct; [18]). All the variables regarding IEQ and satisfaction (N = 12) were included in K-means clustering. The within-cluster sum of squares and average Silhouette width were also calculated for 10 different cluster solutions in order to obtain the optimal number of clusters (Figures 1 and 2).

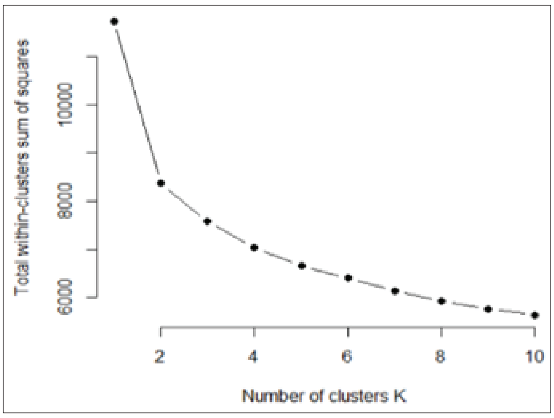

Fig. 1. Total within-cluster sum of squares (max 10 clusters).

Table 1. Descriptive statistics for IEQ and satisfaction variables (range from 1 to 5).

Variables	Median	Average (st.dev.)
Overall satisfaction	5	4.50 (0.62)
Satisfaction with size	5	4.44 (0.79)
Satisfaction with standard	4	4.29 (0.74)
Satisfaction with layout	4	4.33 (0.75)
Satisfaction with daylight	5	4.56 (0.68)
Satisfaction with appearance/aesthetics	4	4.20 (0.82)
Satisfaction with well-being	5	4.58 (0.62)
Satisfaction with cost	4	3.92 (1.04)
Satisfaction with area/neighbourhood	5	4.41 (0.79)
Thermal comfort	4	4.07 (0.81)
Air quality	4	4.14 (0.76)
Acoustic comfort	4	4.02 (0.90)

All statistical analyses were conducted with SPSS software version 26.0 (SPSS Inc., Chicago, IL, USA) and R software (ver. 4.2.0; R Core Team 2022). The Chi-Square test of independence was used to compare the percentages of the categorical variables between the clusters [18]. All the statistical comparisons are considered statistically significant at the 5% significance level (two-tailed tests).

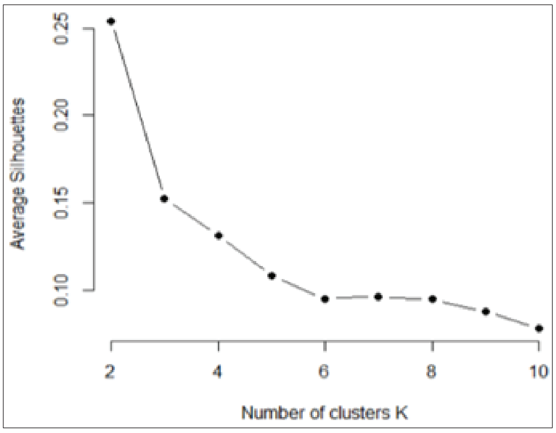

Fig. 2. Average silhouettes (cluster analysis; max 10 clusters).

3 Results and discussion

The variables that attained the highest score were the satisfaction with well-being (M = 4.58, SD = 0.62), daylight (M = 4.56, SD = 0.68) and overall satisfaction (M = 4.50, SD =0.62; Table 1). The parameters that attained the lowest scores were the satisfaction with cost (M = 3.92, SD = 1.04) and acoustic comfort (M = 4.02, SD =0.90). In most variables the average value is over 4 (“satisfied” and “good”) and medians equal with 5 (“very satisfied” and “very good”). In general, the occupants feel very satisfied with the condition of their dwellings. The cost is a significant parameter for consideration for dwellings in Scandinavia. Finally, the relative “dissatisfaction” with the acoustic comfort of the indoor environment is consistent with findings of prior research [5, 17].

3.1 Regression models

A linear regression model was implemented with overall satisfaction as the dependent variable and the seven variables regarding satisfaction as independent variables. The model was overall significant and explained 52.8% of overall satisfaction. All the variables included in the model were significant ($p < 0.05$; *). Satisfaction with well-being (b = 0.302) and satisfaction with dwelling standard (b = 0.227) had the greatest effect on overall satisfaction (not presented). The regression model with the IEQ variables as predictors accounted only for 35.5% of overall satisfaction. All the variables included in the model were significant. Satisfaction with dwelling daylight (b = 0.248), followed by acoustic comfort (b = 0.215) had the greatest effect on overall satisfaction (not presented). Previous findings regarding high air quality impact on overall satisfaction (significance) cannot be confirmed [1]. Finally, a backward stepwise linear regression model was implemented with overall satisfaction as the dependent variable and all the other variables as predictors. The model was overall significant and explained 54.7% of overall satisfaction (best performed). The excluded variable was “satisfaction with daylight” ($p = 0.696$). In the final model, all the retained variables were significant predictors.

Satisfaction with well-being (b = 0.286) and satisfaction with dwelling standard (b = 0.188) had the greatest effect on overall satisfaction (Table 2). Adding the factors related to IEQ does not result in a substantial improvement in goodness-of-fit.

Table 2. Standardized coefficients of the stepwise backward linear regression model.

Variable	Beta	t
Constant	-	8.111*
Satisfaction with size	0.077	3.896*
Satisfaction with standard	0.188	7.939*
Satisfaction with layout	0.059	2.679*
Satisfaction with appearance/aesthetics	0.100	4.277*
Satisfaction with well-being	0.286	11.795*
Satisfaction with cost	0.075	3.839*
Satisfaction with area/neighborhood	2.204	0.028*
Thermal comfort	0.060	2.859*
Air quality	0.074	3.331*
Acoustic comfort	0.085	4.161*

3.2 Confirmatory factor analysis

Table 3 presents the loadings of each question on its corresponding factor. The model's fit was adequate (CFI = 0.903, TLI = 0.876, RMSEA (95% CI) = 0.091 (0.085, 0.097)), and only the question regarding satisfaction with dwelling's cost did not attain a factor loading greater than 0.5. The model with the IEQ factors attained a pseudo-R^2 equal to 48.0% and the model with the satisfaction factors accounted for 53.8% of overall satisfaction's variability. For the model, which included all the predictors the R^2 was equal to 53.9% and the IEQ factors were non-statistically significant ($p = 0.092$). Again, the use of both factors improved slightly the model's fit, and the satisfaction factors performed better compared to the IEQ factor. The internal reliability coefficients (Cronbach's alpha) were estimated as 0.70 (0.67, 0.72; good) and 0.81 (0.79, 0.82; very good), for IEQ and satisfaction, respectively. Again, the satisfaction responses described overall satisfaction better than the IEQ responses. Including all 12 questions the Cronbach's alpha was equal to 0.874 (very good).

Table 3. Factor loadings for the two-factor confirmatory factor analysis.

Variable	Factor 1	Factor 2
Satisfaction with size	-	0.519
Satisfaction with standard	-	0.734
Satisfaction with layout	-	0.678
Satisfaction with daylight	0.518	-
Satisfaction with appearance/aesthetics	-	0.727
Satisfaction with well-being	-	0.755
Satisfaction with cost	-	0.474
Satisfaction with area/neighborhood	-	0.544
Thermal comfort	0.642	-
Air quality	0.716	-
Acoustic comfort	0.605	-

3.3 Cluster analysis

All the variables regarding IEQ and satisfaction (N = 12) were included in K-means clustering. Figures 1 and 2 present the WSS and average silhouette width for 10 different cluster solutions, indicating that a number of 2 clusters is adequate for the sample (Figure 3). Cluster 2 presents lower values compared to cluster 1 for all factors and aspects. Occupants' characteristics were compared across the two clusters using the chi-squared test. The two clusters were significantly different across living duration, dwelling type, age category and tenure status ($p < 0.05$; *). The first cluster consisted mainly of single-family houses with the majority of persons being owners (72%) and living in their houses for 10 years or above (49%), also over 60-year-old (46.8%) The second cluster was more balanced in terms of dwelling type, age category and living duration in the dwelling (Table 4). For time spent outside the dwelling, the occupant percentages were similar for both clusters.

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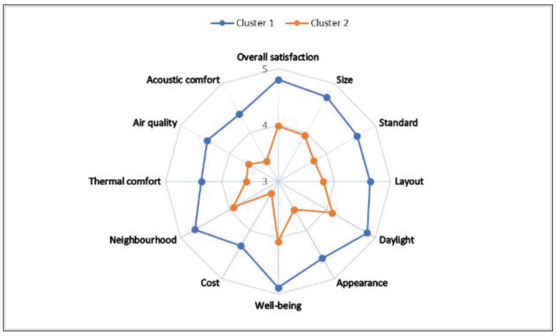

Fig. 3. IEQ and satisfaction factors for the proposed 2 clusters.

Table 4. Distribution of demographic and occupancy characteristics for the two different clusters.

Variable	Cluster 1 (%)	Cluster 2 (%)
Female	50.6	53.3
Male	49.4	46.2
< 40 years	18.7	29.8
40 - 59 years	34.5	34.6
> 60 years	46.8	35.6
No smoking	92.1	89.3
Smoking	7.9	10.7
< 5 years	27.6	43.3
6 - 10 years	23.4	14.3
> 10 years	49.0	42.4
0 - 4 hours	35.3	31.5
5 - 9 hours	44.4	44.6
> 10 hours	20.3	23.9
Apartment	23.2	48.1
Single-family house	76.8	51.9
Tenancy	9.6	35.0
Ownership	72.0	44.1
Condominiu m	18.4	20.9

4 Conclusions

Occupants living in dwellings in Sweden are overall very satisfied. The analysis showed that satisfaction aspects perform generally better compared to IEQ factors in predicting overall satisfaction. The fit-all model does not improve the accuracy significantly. Confirmatory factor analysis and internal reliability coefficients calculation confirm the previous finding. Such result is most likely related to the generally good IEQ standards in Swedish dwellings, leading to occupants placing less emphasis on IEQ when it comes to overall satisfaction.

Two clusters of variables were derived with different demographic and occupancy characteristics. The two clusters reflect the level of satisfaction across all variables (cluster 1 = high satisfaction, cluster 2 = low satisfaction). The clusters were significantly different across living duration, dwelling type, age category and tenure status, highlighting the influence and importance of sociodemographic parameters.

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