Exploring Disparities in Canadian Households' Satisfaction with Indoor Environmental Quality

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Abstract

This study delves into the relationship between income, housing qualities, and indoor environmental quality (IEQ) perceptions in Canada. An online survey of about 1,100 Canadian residents from diverse socioeconomic groups capturing a representative sample of Canadian society was conducted. Using various statistical analyses, and reclassification methods, notable differences in IEQ perceptions among income groups are brought to light. High-income individuals consistently express higher levels of satisfaction across multiple domains compared to middle-income individuals, while middle-income individuals tend to report higher satisfaction levels than those with lower incomes. However, no significant differences are found among income groups for thermal comfort during the heating season. There are also inequalities in occupancy arrangements, with wealthier households tending to have larger living spaces or preferences for separate rooms. There are also variations in occupant density, with linear regression models indicating an inconsistency in expected bedrooms and challenging existing estimations made by ASHRAE and NREL.

Introduction

It is important to ensure that household diversity is fairly represented in the housing archetypes used in building performance simulations. These simulations are often used to inform changes in building codes. Hence, they should accurately reflect the demographics of households so that decision-makers create building codes that are more inclusive and effective (Estrella Guillen et al., 2021). This approach recognizes that households have diverse perceptions and preferences, depending on factors such as family size, income level, cultural background, and accessibility requirements.

On the other hand, even though Canada stands as one of the leading global energy producers, not all residents have access to or can afford sufficient building and energy services in their homes to meet their indoor environmental quality (IEQ) requirements (Riva et al., 2023). For instance, Riva et al. (2021) reported that 6% to 19% of Canadian households are living in energy poverty. According to the Canadian Income Survey 2021 (Statistics Canada, 2023a), 7.4% of Canadians (about 2.8 million) live below the poverty line. Built environments continue to have adverse effects on the physical, mental, and emotional health as well as the overall well-being of individuals with lower socioeconomic status even in developed countries (Seyedrezaei et al., 2023).

Low-income households often bear the burden of inadequate home insulation and older heating systems, leading to higher energy consumption and increased financial strain. These households face significant barriers to improving energy efficiency, such as financial constraints that limit their ability to renovate or retrofit their dwellings (Thomson & Snell, 2013). According to the 2021 Canadian Housing Survey (CHS), 74.7% to 70.6% of respondents reported being satisfied or very satisfied with their ability to maintain a comfortable temperature in their homes during the winter and summer, respectively. Additionally, about 60% of respondents reported being satisfied with the energy efficiency of their homes. CHS 2021 revealed that 9.1% and 4.8% of Canadians experienced poor indoor air quality due to odours and patches of mould or mildew larger than one square metre, respectively. In another survey conducted within a French Canadian municipality, it was found that 21% of the 161 dwellings examined exhibited signs of mould on either their walls, ceilings, or floors. Additionally, nearly half of the households surveyed reported cohabiting with a pet, while 12% of them reported exposure to tobacco smoke. It was found that pets, tobacco smoke, and mould were significantly associated with certain respiratory symptoms and diseases (Lévesque et al., 2018). Living in poor housing conditions and experiencing low temperatures can lead to increased health risks for individuals with chronic and severe illnesses, such as cardiac conditions and respiratory diseases (Dear & McMichael, 2011). Studies have shown that there is also a connection between anxiety, stress, and depression resulting from the struggle to balance bills, heating needs, and debt while living in inadequate housing conditions (Thomson et al., 2017).

The statistics and findings outlined above clearly showed the importance of housing conditions and energy efficiency, especially for vulnerable communities. The underlying

reasons why a large population experiences discomfort in different domains may be associated with the socioeconomic factors of households. However, there are limited studies that have investigated and characterized the impact of socioeconomic factors on building performance and housing conditions from an engineering perspective. Therefore, it is crucial to conduct more in-depth analyses to identify areas where disparities have bigger impacts. To achieve this, a survey was conducted with about 1,100 Canadian respondents from a variety of socioeconomic groups. This paper aims to address the following research questions:

1. Are there noticeable differences in the perceived IEQ factors within residential buildings among residents from various income groups?
2. Are there significant inequalities in residential occupant density across income groups?

Data and methods

Data and survey design

The survey consists of multiple sections requesting information about various topics, including socio-economic factors, housing conditions and satisfaction, comfort in different domains (such as thermal comfort, indoor air quality, visual comfort, and acoustic comfort), utilities, and energy efficiency. This research was approved by the research ethics board of the authors' university. The survey was administered anonymously through an online voluntary questionnaire. Data collection spanned from August 2023 to January 2024, employing a structured questionnaire divided into two distribution waves.

Due to limitations in sample size and representativeness, regions such as the Atlantic provinces and three territories comprising less than 7% of Canada's population were excluded from the geographic-related analysis to mitigate selection biases. Nonetheless, the findings of this study may still offer insights applicable to these regions to some extent. The distribution of responses across Canada, along with their respective percentages, is as follows: 556 in Ontario (46.3%), 233 in Quebec (19.4%), 133 in British Columbia (11.1%), 125 in Alberta (10.4%), 39 in Manitoba (3.2%), and 32 in Saskatchewan (2.7%). The distribution of responses in terms of age and gender was also controlled during the recruitment stage to ensure the sample represents the entire population, however, since every respondent represents the entire household and the information of other members of the household was not collected, there might be some level of variation compared to the population. Table 1 shows the distribution of the sample by gender and age group.

The satisfaction ratings for indoor air quality and acoustic comfort (home and neighbourhood noise were assessed using an 11-point Likert scale, ranging from zero (indicating very dissatisfied) to ten (indicating very satisfied), with five indicating a neutral state (neither satisfied nor dissatisfied). Regarding thermal sensation/comfort, the same Likert scale was employed, albeit with different interpretations: zero represented feeling too cold, ten denoted feeling too hot, and five indicated a state of comfort. However, the authors acknowledge that the relationship between temperature and subjective thermal sensation could be non-linear and depends on the type of scale used (Schweiker et al., 2017). A similar scale was employed for visual comfort with a focus on merely natural light through windows where zero, five, and ten represent very little, average, and a lot of natural light, respectively. After the ratings, respondents were prompted with questions to contextualize their (dis)satisfaction, offering predefined multiple options. Additionally, respondents had the opportunity to provide insights into the likely causes of poor quality in their homes through an open-ended question. We also asked respondents for socioeconomic information such as ethnicity, age, after-tax income, number of occupants, dwelling tenure, and utility costs.

Table 1: Distribution of the sample by gender and age group

Age Group	Female	Male	Non binary	Other	Prefer not to say
18 - 24	103	77	4	1	3
25 - 44	180	180	6	2	3
45 - 64	181	207	0	0	1
> 65	122	97	0	0	0

Income classification and adjustment

To streamline the economic analyses, it is necessary to categorize respondents' income into a smaller number of groups. According to the Organization for Economic Co-operation and Development (OECD, 2019), individuals falling within 75 percent to 200 percent of the median household income after tax are considered members of the middle class. In Canada, with a median household after-tax income of $68,400 in 2021 (Statistics Canada, 2023b), the middle-class income range is defined as $51,300 to $136,800. This study classified respondents earning below or above this bracket as the "lower-income" and "upper-income" groups. However, it is important to note that the lower-income group determined herein is not equivalent to other concepts in the economic context, namely "low-income" individuals, or households, which are defined based on other economic measures such as the low-income line, low-income cutoffs, or market basket measure (Zhang, 2010).

Although the approach used to classify households' income is widely used, it fails to take into account the impact of household size. To facilitate comparisons across households of different sizes, adjusted incomes are also calculated. It is based on a widely accepted equivalence scale called "square root of household size" (Buhmann et al., 1988). The adjusted income is calculated by dividing the total income by this adjustment factor:

$$Adjusted\ Income = \frac{Household\ Income}{\sqrt{N}} \quad (1)$$

N denotes the size of households. This concept suggests that as the number of household members increases, their needs increase at a decreasing rate. These adjusted incomes are typically used to calculate inequality indicators such as the Gini coefficients (Statistics Canada, 2022). They can also serve the engineering field when capturing inequalities in housing among different income groups. To define the adjusted income range of the middle class, we again use the OECD's brackets. However, the lower and higher bonds should be also adjusted. To do so, we divide the previous cutoff values by the square root of the average household size in Canada which is equal to 2.46 (Statistics Canada, 2023c). Consequently, the adjusted middle-class income range is from $32,700 to $87,200. Similarly, the adjusted income of each respondent is calculated according to their respective household size and classified based on the three adjusted income groups.

Data analysis and statistical methods

Ratings obtained through the Likert scales described above are typically categorized as ordinal, primarily due to the non-linear relationship between temperature and subjective thermal sensation, as suggested by some studies (Schweiker et al., 2017). This relationship may vary depending on the specific scale employed. However, it is worth noting that in this context, the intervals between values hold some degree of significance, as the scale employs equivalent numerical values as well. To determine whether ordinal ratings for the scale of each comfort domain are normally or non-normally distributed, we used the Shapiro-Wilk (S-W) normality test (Shapiro & Wilk, 1965). This test showed that ratings for indoor air quality, natural light, and home and neighbourhood noise are all normally distributed as their p-values are greater than .05 ($p > .05$). On the other hand, ratings of summer and winter temperatures indoors are non-normally distributed as their p-values are significantly less than .05 ($p \leq .05$). For normally distributed data, parametric tests, specifically independent samples t-tests, are used to test whether the mean difference between two unrelated groups is statistically significant. Moreover, for non-normally distributed data, non-parametric tests equivalent to t-tests for comparing two groups are used. Mann-Whitney test is the non-parametric alternative to independent samples t-tests with an ordinal scale (Licina & Yildirim, 2021). In both scenarios, the income groups already defined (e.g., lower vs. middle) are compared to determine whether there is a statistically significant difference between the means in two independent groups (Mishra et al., 2019).

Poisson regression was employed to investigate the association between the number of occupants and bedrooms in households across different income categories. Poisson regression is particularly suited for count data, such as the number of bedrooms, and allows us to model the relationship between predictors, like the number of occupants.

Collapsing ratings

To enhance the clarity and effectiveness of the interpretation process, we established specific intervals for categorizing the ratings. By aligning these intervals with distinct satisfaction levels, our method ensures consistency and facilitates a comprehensive understanding of the data, akin to the insights gleaned from statistical tests. These intervals are delineated into categories such as "Very Little" (ranging from 0 to 3), "Neutral" (ranging from 4 to 6), and "A Lot" (ranging from 7 to 10) for natural light ratings, as well as "High Satisfaction," "Moderate Satisfaction," and "Dissatisfaction" with the same rating ranges for satisfaction levels of other IEQ ratings. For temperature ratings, we classified them into three categories: "Cold," "Neutral," and "Warm." The intervals for each category are as follows: "Cold": Ratings ranging from 0 to 3. "Neutral": Ratings ranging from 4 to 6. "Warm": Ratings ranging from 7 to 10.

Table 2: Mean and variance values for the ratings of different IEQ factors.

Metrics	$\bar{x}$	s^2	$\bar{x}$	s^2	$\bar{x}$	s^2
Unadjusted Income	**Lower**		**Middle**		**Upper**	
Air Quality	6.20	4.74	6.73	3.85	7.37	3.79
Natural Light	6.68	5.02	7.08	3.78	7.58	3.52
Summer Temp.	6.20	3.08	5.86	2.22	5.82	1.94
Winter Temp.	4.63	2.53	4.72	2.06	4.79	1.86
Home Noise	6.23	6.16	6.79	5.00	7.49	3.88
Neighbourhood Noise	6.47	5.82	6.60	6.18	7.43	4.60
Adjusted Income	**Lower**		**Middle**		**Upper**	
Air Quality	6.17	4.61	6.80	3.81	7.46	4.25
Natural Light	6.66	4.71	7.13	4.02	7.66	3.56
Summer Temp.	6.14	3.24	5.97	2.16	5.67	1.51
Winter Temp.	4.60	2.54	4.73	2.05	4.88	1.74
Home Noise	6.14	6.02	6.93	4.75	7.55	4.43
Neighbourhood Noise	6.50	5.91	6.63	5.76	7.54	5.24

Results

Statistical tests

Table 2 presents mean ($\bar{x}$) and variance (s^2) values of respondents' assessments of various indoor environmental quality factors across different income brackets. After adjusting income brackets for household size, the sample distribution within income groups changed significantly. While the sample size of the lower-income group remained relatively unchanged, there was a decrease of approximately 50 respondents in the middle-income bracket, with a corresponding increase in the upper-income bracket.In some cases, adjusting for income leads to a decrease in variance, indicating a more homogenous perception within income groups. However, in other cases, adjusting for

income results in an increase in variance, suggesting greater variability in perception within income groups. The detailed analyses among income groups will be discussed after presenting the results of statistical tests.

Table 3 presents the results of *t*-tests assessing the differences in satisfaction ratings across various income groups for four IEQ factors whose ratings are normally distributed: indoor air quality, natural light, home noise, and neighbourhood noise. In the unadjusted income groups, significant differences are observed across income categories for most factors. Generally, lower-income individuals consistently report lower satisfaction levels compared to middle and upper-income counterparts. For instance, in indoor air quality, there was a significant difference between lower and upper-income groups ($t = -6.345$, $p < .001$), with a medium effect size ($d = -0.553$), indicating a substantial difference in perceived air quality between these groups. For instance, in the lower-middle comparison, t-statistics range from -2.767 to -3.770, with corresponding p-values less than .01, indicating significant differences in satisfaction ratings for natural light and indoor air quality between lower and middle-income groups. Similarly, in the lower-upper comparison, t-statistics range from -4.672 to -6.345, with all p-values being less than .001, highlighting significant disparities in satisfaction ratings for all environmental factors analyzed between lower and upper-income groups. The trend persists in the middle-upper comparison, with significant differences observed across most IEQ factors. However, for the neighbourhood noise ratings, there is no significant difference observed between lower and middle-income groups.

In the adjusted groups, after accounting for household size, similar patterns of significant differences persist across income groups. Lower-income individuals almost consistently express lower satisfaction levels compared to middle and upper-income counterparts, as evidenced by the significant t-statistics and low p-values. For instance, in the lower-middle comparison for indoor air quality, the t-statistic is -4.603 with a *p*-value of <.001, indicating a significant difference even after adjusting for household size. Both adjusted and unadjusted analyses reveal significant differences in home noise satisfaction across income groups. Adjusting for household size strengthens the significance of these differences, particularly in the lower-middle and lower-upper comparisons, where the t-statistics increase, and the *p*-values decrease in the adjusted analysis. This suggests that household size adjustments accentuate the observed disparities in home noise satisfaction between income groups. In the unadjusted analysis, significant differences in neighbourhood noise satisfaction are observed only in the lower-upper and middle-upper comparisons, indicating that lower-income individuals report lower satisfaction levels compared to upper-income individuals in neighbourhood noise. Overall, adjusting for household size appears to influence the perceived differences in indoor environmental factors across income groups, highlighting the importance of considering household characteristics in understanding perceptions of indoor environmental quality.

Table 3: T-statistics and p-values for the ratings of different IEQ factors.

Metrics	**t-stat.**	**p-value**	**t-stat.**	**p-value**	**t-stat.**	**p-value**
Unadjusted Groups	**Lower-Middle**		**Lower-Upper**		**Middle-Upper**	
Air Quality	-3.770	<.001	-6.345	<.001	-3.665	<.001
Natural Light	-2.767	.006	-4.809	<.001	-2.941	.003
Home Noise	-3.426	<.001	-6.156	<.001	-3.695	<.001
Neighbourhood Noise	-0.735	.462	-4.672	<.001	-3.933	<.001
Adjusted Groups	**Lower-Middle**		**Lower-Upper**		**Middle-Upper**	
Air Quality	-4.603	<.001	-6.115	<.001	-3.387	.001
Natural Light	-3.424	.001	-4.837	<.001	-2.738	.006
Home Noise	-5.140	<.001	-5.980	<.001	-2.883	.004
Neighbourhood Noise	-0.799	.424	-4.392	<.001	-3.901	<.001

Table 4: U-statistics and p-values for the ratings of summer and winter temperatures.

Metrics	**u-stat.**	**p-value**	**u-stat.**	**p-value**	**u-stat.**	**p-value**
Unadjusted Groups	**Lower-Middle**		**Lower-Upper**		**Middle-Upper**	
Summer Temp.	99840	.020	46347	.019	39277	.525
Winter Temp.	89583	.504	39892	.364	37457	.705
Adjusted Groups	**Lower-Middle**		**Lower-Upper**		**Middle-Upper**	
Summer Temp.	108189	.236	34076	.010	33917	.043
Winter Temp.	100699	.414	27649	.152	29117	.332

As shown in Table 4, the Mann-Whitney tests were conducted to compare ratings of indoor air temperatures during the summer and winter seasons across income groups as they were not normally distributed. In terms of summer temperatures, significant differences are observed between lower- and upper-income groups, as well as between lower- and middle-income groups, with lower-income groups experiencing higher temperatures. However, in winter temperatures, no significant differences are found among income groups. Adjusting for income slightly changes the trends observed in summer temperatures. While the probability of significant differences increased for lower-upper and middle-upper comparisons, it decreased for lower-middle comparisons. In winter temperatures, adjusting for income has minimal impact, with no significant differences observed among income groups.

These findings underscore the influence of income disparities on indoor temperature satisfaction, particularly during the summer season.

Detailed IEQ perception

After performing statistical tests, the ratings are reclassified based on the methods used to gain a better understanding of the income groups' differences.

The data indicates a substantial difference in perception regarding indoor air quality among income groups. As shown in Figure 1, higher-income respondents tend to report higher levels of satisfaction with indoor air quality compared to their lower-income counterparts. When examining satisfaction levels based on income, respondents from the upper-income group stand out with the highest proportion expressing high satisfaction (72.2%), compared to 47% in the lower-income group and 59.3% in the middle-income group. Moreover, a lower proportion of individuals within the upper-income group report dissatisfaction with indoor air quality (5.3%) compared to 10.9% and 3.9% in lower- and middle-income groups, respectively.

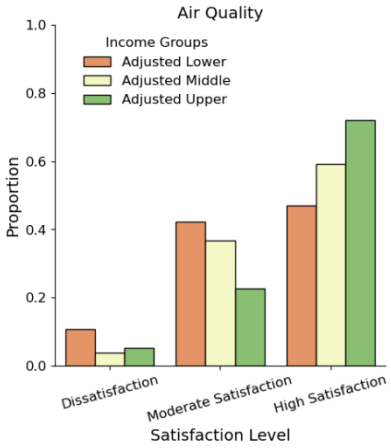


Figure 1: IAQ satisfaction levels across income groups.

visual comfort.

The analysis of natural light satisfaction through windows across adjusted income groups unveils discernible disparities in perceptions among different economic strata. As shown in Figure 2, respondents from the upper-income group exhibit the highest proportion expressing satisfaction with natural light, with 97.2% reporting a neutral perception, indicating an average amount of natural light. Conversely, individuals in the lower- and middle-income groups show similar patterns, with the majority reporting neutral satisfaction levels (84.4% and 88.7%, respectively) and a smaller proportion expressing dissatisfaction, representing very little natural light (15.6% and 11.3%, respectively). Notably, no respondents across all income groups reported a lot of natural light through windows in their houses.

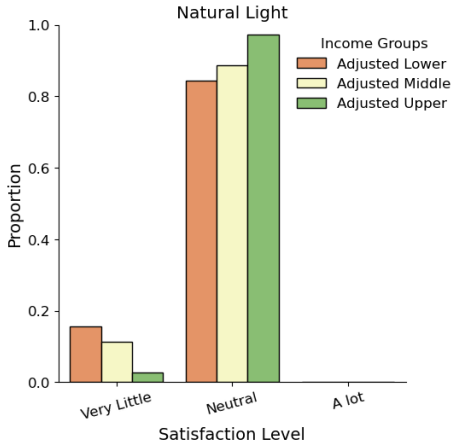
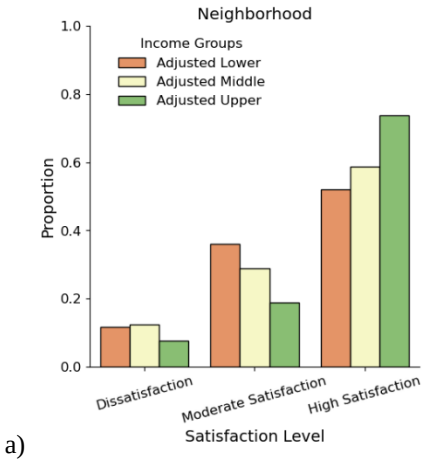


Figure 2: Natural light satisfaction levels across income groups.

The examination of neighbourhood noise and home noise perceptions across adjusted income groups highlights noteworthy differences in satisfaction levels among these economic classes. As shown in Figure 3-a, respondents within the upper-income group demonstrate a markedly higher satisfaction with neighbourhood noise, with 73.7% expressing high satisfaction compared to 52.1% in the lower-income group and 58.8% in the middle-income group. Similarly, a lower proportion of individuals in the upper-income group report dissatisfaction with neighbourhood noise (7.5%) compared to 11.80% and 12.4% in the lower- and middle-income groups, respectively. This disparity suggests a potential correlation between higher income levels and greater satisfaction with neighbourhood noise.

Figure 3-b illustrates a notable discrepancy in satisfaction levels regarding home noise perception across income groups. In the upper-income group, 70.7% of respondents reported high satisfaction with home noise, contrasting with 47.4% in the lower-income group and 62.2% in the middle-income group. Conversely, the proportion of individuals expressing dissatisfaction with home noise is notably lower in the upper-income group (4.5%) compared to 16% and 7.8% in the lower- and middle-income groups, respectively. These findings underscore a potential association between higher income status and enhanced satisfaction with home noise conditions.



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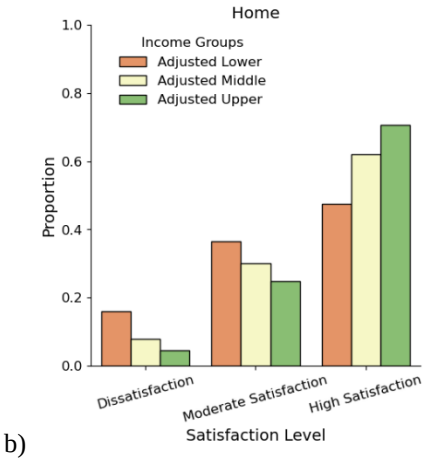
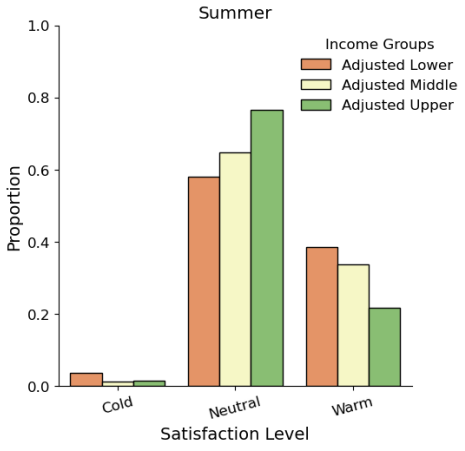


b)

Figure 3: a) Neighbourhood, and b) home noise satisfaction levels across income groups.

As shown in Figure 4-a, individuals in the upper-income group predominantly reported perceiving no hot or cold conditions during the cooling season in their homes, with 76.7% indicating neutrality, followed by 21.8% reporting warm temperature perception indicating undercooling. Conversely, respondents in the lower-income group exhibited a more balanced distribution, with only 58% perceiving neutrality and 38.4% reporting warm perception. The middle-income group falls in between, with 64.9% perceiving neutrality and 33.8% reporting undercooling. Interestingly, respondents across all income groups reported minimal dissatisfaction with overcooling during the summer, with the highest dissatisfaction proportion observed in the lower-income group (3.6%) which may infer their lack of control over central HVAC systems.

As shown in Figure 4-b, the upper-income group showed the highest proportion perceiving no hot or cold conditions (81.20%), followed by 8.3% reporting overheating. In contrast, 68% of the lower-income respondents perceived neither hot nor cold conditions, with 10.7% reporting overheating and 21.33% indicating dissatisfaction with cold temperatures (underheating). Similarly, the middle-income group demonstrated a predominance of perceiving neutral conditions (74.6%), with 9.3% reporting overheating and 16.1% experiencing cold temperatures.



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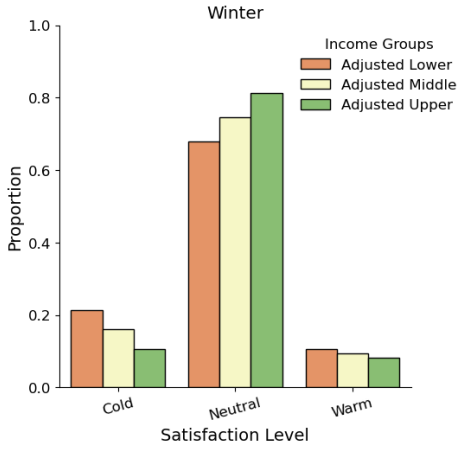

b)

Figure 4: Satisfaction with indoor temperature during a) summer, and b) winter across income groups.

Occupant density

The examination of bedroom distribution per occupant across adjusted income groups reveals intriguing disparities in housing arrangements among different economic strata. As shown in Figure 5, among upper-income respondents, there is a predominant trend of households having more than one bedroom per occupant, with 54.1% falling into this category. In contrast, a smaller proportion of households in this income group are categorized as having fewer than one bedroom per occupant (15.8%), while 30.1% are classified as having an equal ratio of bedrooms to occupants. For the middle-income group, a more balanced distribution is observed, with 36.2% of households having more than one bedroom per occupant, followed by 39.7% having an equal ratio, and 24.2% categorized as having fewer than one bedroom per occupant. Lastly, the lower-income group exhibits a higher proportion of households with an equal ratio of bedrooms to occupants (41.3%), followed by 35.5% categorized as having fewer than one bedroom per occupant, and 23.2% classified as having more than one bedroom per occupant.

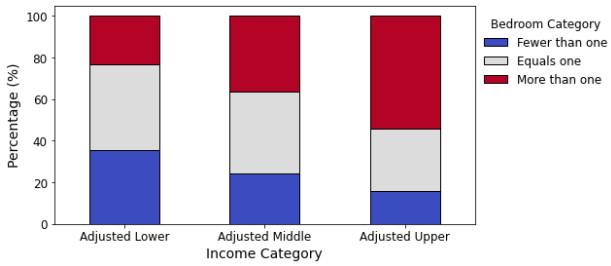

Figure 5: Distribution of bedroom(s) per occupant by income group.

The linear regression findings unveil nuanced trends in housing space allocation relative to household sizes across distinct income groups as shown in Figure 6. Within the lower-income bracket, for instance, a family of three which is close to the average size of Canadian families, as indicated by the regression equation suggests an average provision of approximately 2.72 bedrooms. Contrasting this, in the middle-income group, a household of similar size yields an estimated 2.92 bedrooms according to their respective equation. However, in the higher-income regression, a family of three is estimated to possess around 3.49 bedrooms, showcasing substantial disparities in housing space allocation based on income. These results also challenge existing standards' assumptions such as ASHRAE and NREL, estimating 2.0 and 3.6 bedrooms for a family of three.

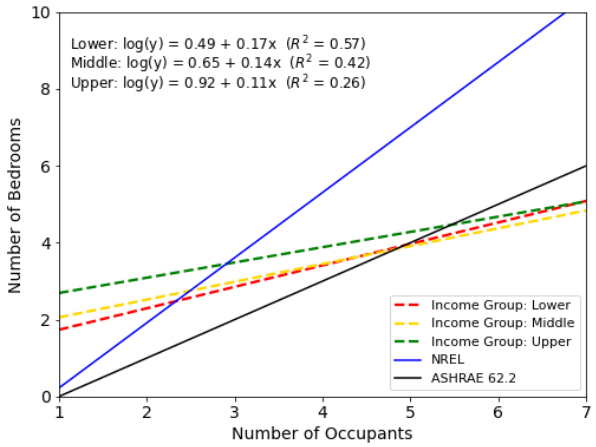

Figure 6: Relationship between the number of occupants and bedrooms by income group

The differences in R-squared values across income groups suggest variations in the underlying factors or mechanisms driving the relationship between the variables within each group. Certain socioeconomic factors or lifestyle differences associated with different income levels may influence the strength of the relationship between the variables. For instance, the higher-income group with the lowest R-squared may make less predictable choices in this regard due to the financial freedom they experience. These models highlight varying relationships between the number of bedrooms and occupants, emphasizing income-related differences in housing space provisions for households of equivalent sizes across income strata.

Figure 7 presents the distribution of satisfaction levels for home noise across different bedroom categories. Among households with a single bedroom, the majority express moderate satisfaction (41%), followed by high satisfaction (38.8%), while dissatisfaction is comparatively lower (20.2%). Conversely, households with more than one bedroom tend to exhibit higher levels of satisfaction, with the majority reporting high satisfaction (53.2%), followed by moderate satisfaction (38%), and a smaller proportion indicating dissatisfaction (8.8%). Interestingly, households with fewer than one bedroom also show a higher proportion of moderate satisfaction (43.3%) compared to those with a single bedroom, indicating a potential correlation between housing space and noise satisfaction levels.

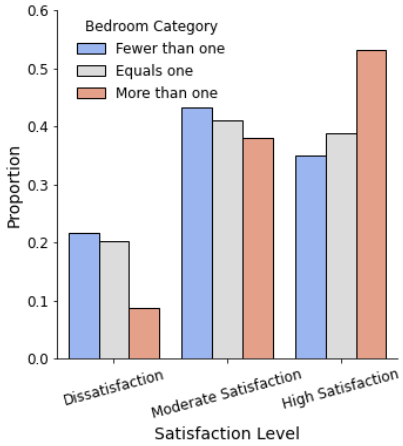

Figure 7: Home noise satisfaction levels across bedroom categories

Conclusion

This research delves into the connection between income and perceptions of IEQ factors in Canada, using a comprehensive survey. Through statistical methods like the Shapiro-Wilk, Mann-Whitney, and t-tests, as well as reclassification techniques, we discovered significant differences in IEQ perceptions among income groups. Upper-income participants tend to report higher satisfaction levels compared to those in the middle-income bracket, while middle-income earners often rated IEQ factors higher than their lower-income counterparts. However, there were a few exceptions. We found no major disparities among income groups regarding thermal comfort during the heating season as well as no significant between lower- and middle-income respondents in terms of their ratings of neighbourhood noise. Discrepancies in occupant density suggested a potential correlation between income level and housing arrangements, with higher income groups tending to have a greater proportion of households with more than one bedroom per occupant, possibly reflecting larger living spaces or preferences for separate rooms, leading to better acoustic comfort inside homes. Moreover, linear regression

models indicated discrepancies in expected bedroom counts and challenged existing estimates provided by ASHRAE and NREL. Additional investigation into the underlying drivers of households' perception of indoor environmental quality (IEQ) and housing patterns, including occupant density, would be highly beneficial for gaining a deeper understanding of the connection between income and housing attributes. It is recommended that future studies focus on exploring the mechanisms that contribute to these inequalities and devising specific interventions aimed at promoting equal access to comfortable indoor environments in various socioeconomic settings. We acknowledge that our sample is limited geographically, as respondents from Atlantic provinces and three territories in Canada were not included.

Acknowledgments

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