

## Study on Window's Operation and Thermal Comfort in North China with Central Heating

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**Abstract:** China's rapid infrastructure development has led to an increase in centrally heated buildings, with rising expectations for indoor thermal comfort. However, indiscriminate heating in North China, regardless of building characteristics like age or insulation, can result in overheating, prompting residents to open windows. This article presents a survey investigating whether North China residents open windows due to high indoor temperatures. The study focused on window operation and thermal comfort, collecting 208 valid responses out of 236 distributed questionnaires across multiple Chinese cities. Results challenge the initial hypothesis, revealing diverse reasons for window openings. Over 95% open windows "to let in fresh air," while only 21% do so to cool rooms. This research suggests limited overheating during the heating period and a continued demand for fresh air even in cold conditions, diverging from the initial hypothesis.

**Keywords:** Central Heating, Window Operate, Thermal Comfort, North China.

### 1. Introduction

#### 1.1 Background

In recent years, the field of urban energy systems and indoor environmental quality has gained significant attention as societies grapple with the challenges of energy consumption, sustainability and resident comfort in residential buildings (Hou et al, 2017). Thus, understanding the intricacies of human comfort and corresponding behaviours within indoor spaces has become more important in optimizing energy usage and enhancing the quality of life for citizens.

North China, as a huge area as well, experiences distinctive energy demand patterns driven by the need for heating, cooling and fresh air (Zhou et al, 2018). The central heating systems that are widely used in North China, coupled with the cultural practices of window opening, contribute to the intricate balance between indoor thermal comfort and energy consumption. Thus, investigating residents' behaviours in relation to window operation becomes an essential step in devising effective strategies for energy-saving renovations and indoor environmental quality improvements.

The billing method is one of the most important factors influencing residents' attitude towards the heating. Currently, the heating service for most apartments is charged by area rather than based on actual heat consumption (Chang, 2022). Thus, people tend to use heating extensively without caring about how much they use, leading to a higher indoor temperature. In addition, there is no benefit to saving energy and no cost when wasting energy in the process of heat consumption, which provides little incentive for the residents to save energy (Chang, 2022).

## 1.2 Motivation

Under the background as mentioned above, there was already several research focusing on indoor thermal conditions and occupant comfort. However, there was a notable research gap exists in understanding the link between thermal conditions with window operation behaviours during the central heating period in North China's urban contexts.

Furthermore, this research was the one which the author has been interested in for years, due to the personal experience of the author. The author lived in an apartment located in North China heated by a central heating system every year from November to early April. However, the rooms were sometimes overheated for dozens of days every winter. In this case, the most common action of the family of the author was opening the windows to cool down the rooms. In this apartment of the author, it was hard to turn down the heating by the family themselves. Over time, it was thought to be an energy waste by the author to open windows in winter just to cool down the room. The author was curious about if this consequence was a common case as other residents and was longing for a better solution for the energy waste. As a result, this research was able to be achieved.

## 1.3 Hypothesis

Based on the information as well as the personal experience mentioned above, the hypothesis of the research was set as: **people living in apartments with a central heating system in North China open the windows of their homes during the heating period mostly aiming to reduce the indoor air temperature.**

## 2. Methodology

To concept the idea of the survey, a set of case studies about previous surveys were searched and studied, such as Zhou et al (2018) and Qin (2020). From the article, it can be realised that how did the questionnaire like, what was the structure of the survey, and from the analysis chapter, which questions were important. It provides the possibility for this research to refer to the existing surveys to some extent.

Constrained by practicalities, this study would focus on the survey by questionnaire and the corresponding data, which had the advantages such as timeliness and reach as well as disadvantages like subjectivity. To deal with the limitation, more questions about different relative topics were planned, trying to get more information that could have been collected by other methods.

Based on the initial experience with central heating as well as the work of the case study, a draft version of the questionnaire was produced. To fit the operation of the survey in North China, the questionnaire was translated into Simplified Chinese by the author at the same time. After the initial translation, the questionnaire in both two languages was shared with several native Chinese speakers to check the translation and grammatic, or if there were any uncommon vocabulary, making sure that it could be understood by people with different education levels.

The pilot study was operated once the questionnaire draft was created. Several relatives and friends of the author with different age ranges and backgrounds were selected randomly to read the questionnaire draft and try to make an answer. After that, the volunteers were asked to give their comments, or anything unclear about the questions or the options. During the work of pilot study, several comments were collected from different volunteers and fixed. All the adjustments were operated on the questionnaire survey in both English and Chinese versions at the same time.

After the work of editions, a formal version questionnaire attached with an information sheet and other necessary documents for participants in Chinese was finished. There were 28 questions at most for participants to answer, which would be some questions skipped over depending on the answer to the corresponding questions.

To make better use of the original data, some analysis methods were considered including descriptive analysis to summarise the survey results and comparative analysis (Fink, 1995). Furthermore, there were some open-ended questions in the questionnaire to gather qualitative insights from participants. The responses to these open-ended questions were analysed using a thematic approach to identify recurring patterns, sentiments, and key concepts. By employing this approach, a qualitative layer was added to the analysis, providing deeper insights into participants' perspectives beyond the quantitative data collected through closed-ended questions. While the analysis approach was not elaborate, it enabled the extraction of valuable qualitative insights and contributed to a more comprehensive understanding of participants' views and experiences.

### 3. Results and discussion

After the collecting of the questionnaires, 236 samples were collected. Within it, 208 samples are active, which are both conforming to the requirement of the Information Sheet and living in an apartment with at least one openable window and heating system.

#### 3.1 Basic information

Over half samples are aged 45-64 years, while one-third of them are aged 26-44 years. Thus, most of the samples were expected to be middle-aged people and professionals, while the gender of the samples was roughly balanced with slightly more females at M:F=93:113.

#### 3.2 Factors influencing window operation

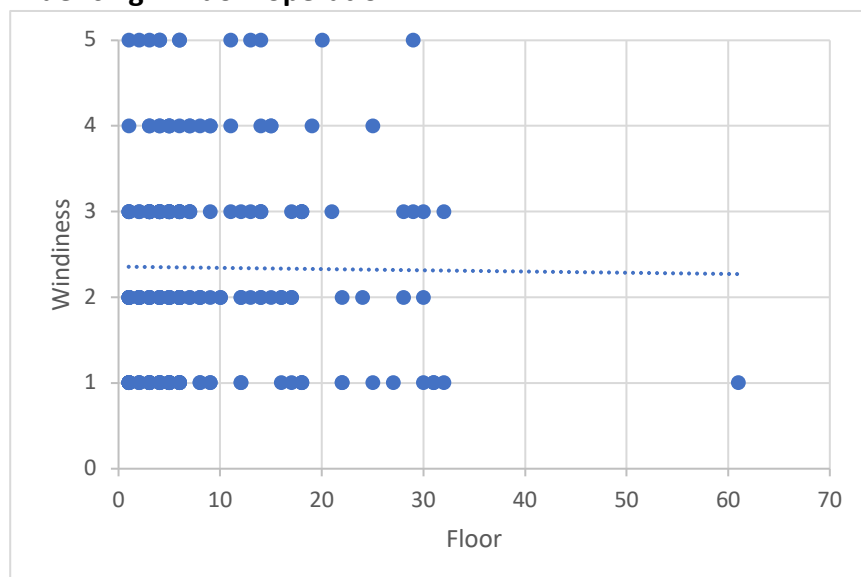


Figure 1. Windiness-floor scatterplot of all valid samples

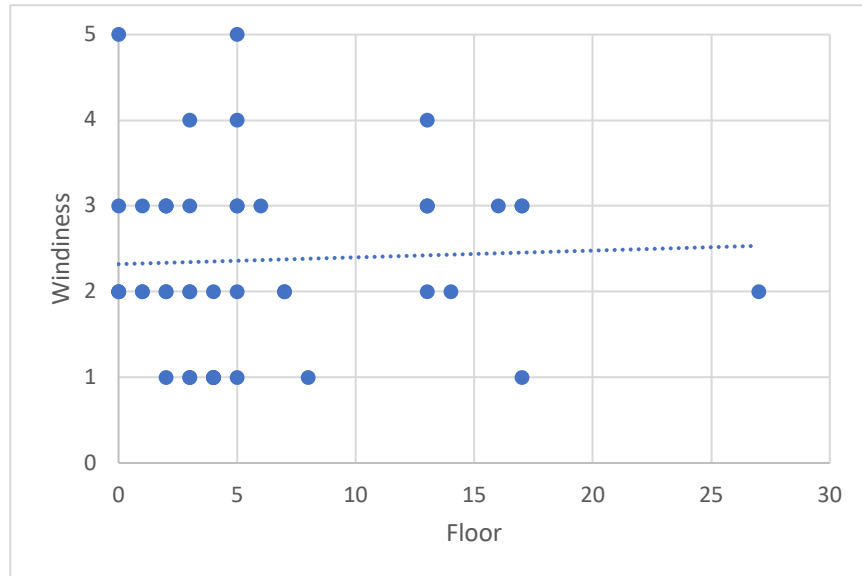


Figure 2. Windiness-floor scatterplot of samples who close windows to keep away from the wind

Table 1. Relationship between floor and windiness

	Average floor	Average windiness	Multiple R	Significance F	P-value
People close their windows worrying about the wind	6.17	2.37	0.05	0.76	0.76
All valid samples	7.57	2.35	0.01	0.88	0.88

To find out how wind affects window operation and the relationship between floor and windiness, questions were asked in the survey. The results are shown in Figure 1 and Figure 2. On the one hand, there was almost no difference in average windiness between all valid samples and people closing windows because of the wind, even the average floor of all valid samples was higher than those of wind-worrying samples. After analysis, as shown in Table 1, multiple Rs were both very low and significance Fs were both very high, which means there was no significant relationship between windiness and floor. Thus, the saying “the higher floor, the windier” was wrong.

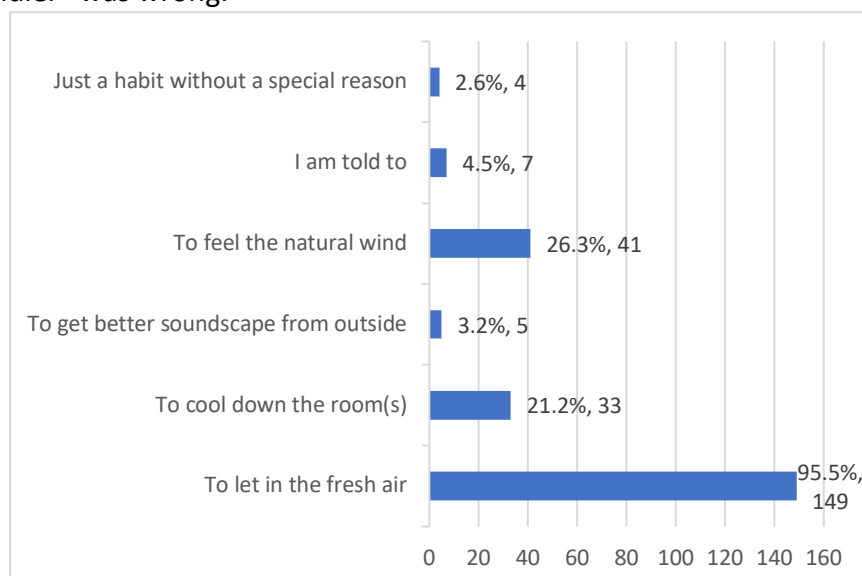


Figure 3. The reason why open window(s) during heating period

Figure 3 shows the result of why the participants opened their windows, which was a multiple-choice question. As we can see, over 95% of the participants thought they opened

windows to let in the fresh air, while only about one-fifth of them opened windows to cool down their rooms. At the same time, over one-fourth of the samples chose “to feel the natural wind”, which was also a contribution to the indoor air quality. Thus, the overall hypothesis was proved to be wrong basically, opening windows to improve indoor air quality was a much more popular reason than opening windows to get a better thermal condition.

### 3.3 About heating system

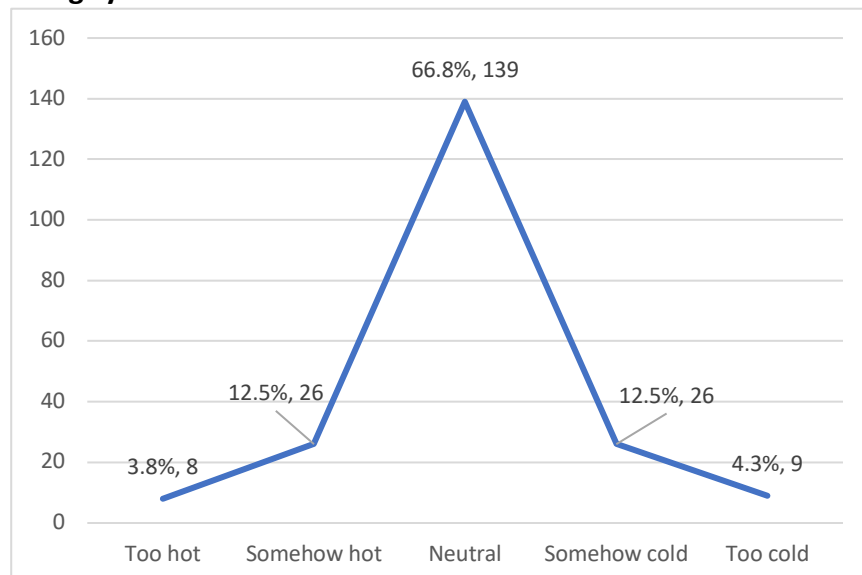


Figure 4. Description of the temperature inside the apartments and/or room most time spent during the heating period

As listed in Figure 4, over two-thirds of the participants felt neutral about their home during the heating period, while the number of people feeling hot and feeling cold was almost the same. Thus, the thermal conditions in the apartments with central heating in North China were fulfilling overall, without any preference for cold or hot.

### 3.4 Comments about the heating system as well as thermal comfort

The survey also collected attitudes about the advantages and disadvantages of their central heating system as well as the best improvement to enhance the thermal comfort in the apartment. Overall, the most mentioned topics were located in the adjustability and temperature of the heating system. Most people wanted their heating to be adjustable or automatic, while many residents would like it to be warmer.

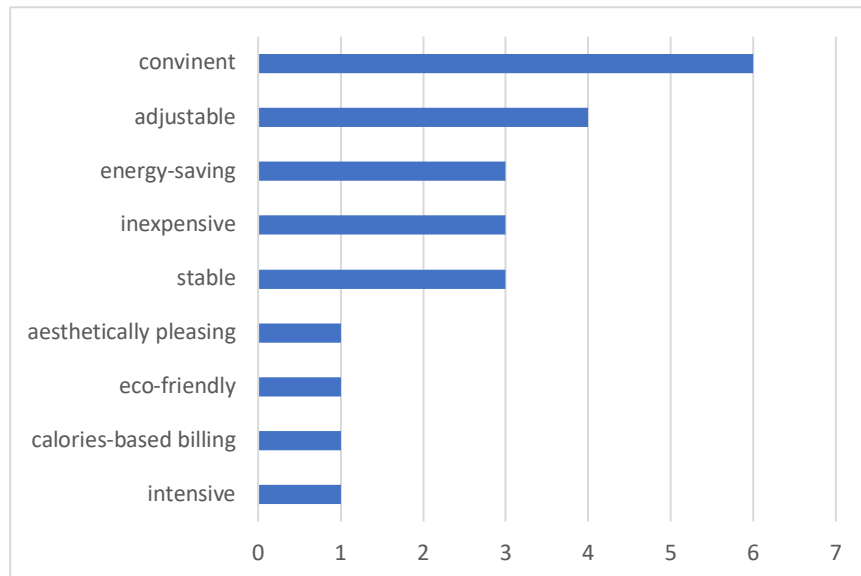


Figure 3. The reason why open window(s) during heating period

#### 4. Results and discussion

This study fills a gap in research about possible overheating in residential buildings located in North China during the central heating method by providing large-scale survey results about residents' experience with central heating systems as well as their window operation habits during the heating period which is mostly in winter.

Based on the work done during this research, the hypothesis made at the beginning of the article was responded to be wrong, not many people open their windows to cool down the room during the central heating period in North China. On the contrary, over two-thirds of participants feel neutral about the thermal condition of their apartments during the heating period, which disagrees with the author's experience that the heating caused it overheating in apartments. Additionally, this research had more findings that were interesting such as the wind didn't rise with the floor and the most popular reason to open the window is to let in the fresh air.

As initial research by a postgraduate student, there were several limitations undoubtful, such as conducting a survey about the central heating period which is usually located in the date from November to March in July and lacking any real-time monitoring data or specific climate data.

In light of the insights gained from this study, there are some possible avenues for future research by doing a longitudinal study or investigating the impact of various central heating systems.

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