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Mitigating Urban Stress Through Nature-Based Solutions: Green Spaces in Relocation Decision-Making

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Abstract: As urbanization progresses, urban stress has become an increasingly prominent concern, diminishing city residents' well-being and overall quality of life. Responding to these challenges, nature-based solutions involving urban greenery have emerged as potential stress mitigators, providing respite from the demands of urban life. This paper examines the role of urban green spaces as compensatory strategies for common urban stressors, such as traffic noise annoyance at home, home overcrowding, and the negative effects of the COVID-19 pandemic, in city dwellers' decision-making processes for residential relocations. The data for the analysis are drawn from a primary survey in two German cities, Cologne and Hamburg, encompassing 1,846 randomly selected respondents. The findings suggest that, particularly in the initial stages of considering relocation, individuals use urban green spaces to compensate for stressful urban living conditions. These green space compensation strategies may prevent individuals from progressing to subsequent stages of relocation decision-making. Recognizing the importance of urban green spaces in mitigating urban stress not only enhances the well-being of city dwellers but also improves understanding of effective strategies for planning resilient cities.

Key-words: urban green, green spaces, cities, residential relocations, well-being, urban stressors, traffic noise, COVID-19, overcrowding

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1 Introduction

Over half of the world's population lives in urban areas and projections suggest this number could rise to almost 70% by 2050 (United Nations, 2023). Urbanization poses challenges to residents' well-being, leading to increased stress from crowded spaces and noise pollution (Park & Evans, 2016). Cities are also vulnerable to unexpected crises, as shown by the recent coronavirus pandemic (Berdejo-Espinola et al., 2021; Mouratidis, 2021). These stressors substantially increase the risk of mental disorders (see Gruebner et al., 2017; Peen et al., 2010 for reviews) and decrease city dwellers' overall well-being (Mouratidis, 2021; Nigg et al., 2023). As cities grow, creating stress-coping urban environments becomes important, aligning with the United Nations' Development Goal (SDG) 11 for sustainable, inclusive and resilient cities (United Nations, 2023).

Nature-based solutions in cities are important for the physical and mental well-being of a growing number of city dwellers (Gascon et al., 2015; Hartig et al., 2014; Hong et al., 2019; Zhao et al., 2024) and are known for their restorative and stress-alleviating potential (Kaplan, 1995; Ulrich et al., 1991). Recently, there has also been growing interest in the role of green spaces for mitigating urban stressors. This interest aligns with the goal of universal green space access in SDG 11 (United Nations, 2023). Research shows their potential to reduce noise (see Dzhambov & Dimitrova, 2014 for review; Van Renterghem, 2019), address overcrowding (He et al., 2022; Zhang et al., 2023), and mitigate the negative effects of the pandemic (Berdejo-Espinola et al., 2021; Mouratidis, 2021; Nigg et al., 2023). Urban stressors not only negatively impact well-being and health of city residents (Gruebner et al., 2017; Peen et al., 2010), but can also influence relocation processes (Rüttenauer & Best, 2022; Stawarz et al., 2022; Wolpert, 1966). City dwellers often want to escape daily urban stressors by moving to the urban outskirts (Stawarz et al., 2022) to enjoy city benefits without having to cope with constant urban stress (Bilotta et al., 2013). As ongoing urban sprawl poses substantial challenges (United Nations, 2023), it is important to understand how green spaces can prevent urban dwellers from leaving cities in the presence of urban stressors.

This study aims to address this research gap by analyzing compensation strategies, focusing on how the usage of green spaces can help cope with urban stressors linked to

relocations. Using data from a primary survey with a random sample of 1,846 respondents in two large German cities, the study follows a staged process of relocation decision-making (Kalter, 1997; Kley, 2011) to analyze how green space usage acts as a coping strategy for urban stressors.

2 Conceptual framework and research landscape

2.1 Urban stressors in cities

Stress refers to settings in which individuals experience suboptimal external conditions that exceed their personal coping abilities (Bilotta et al., 2013; Park & Evans, 2016). Stress is inherently subjective, with what one person perceives as stressful potentially appears less so for another person in the same context.

Noise is unwanted sounds differing in intensity, frequency, and duration (Bilotta et al., 2013). Noise annoyance, the first urban stressor in this analysis, differs from mere presence of noise, as stress responses are highly subjective. Traffic noise annoyance has been identified as a key factor reducing city dwellers' quality of life (Dzhambov & Dimitrova, 2014). The negative effect on quality of life often becomes evident before recognizable psychological or physiological symptoms appear (Gruebner et al., 2017).

Overcrowding, intensified by rapid population growth (United Nations, 2023), is another relevant urban stressor. Though mitigation of negative effects of overcrowding by urban green spaces is normally studied in the context of urban density on the district level (He et al., 2022; Zhang et al., 2023), this analysis concentrates on overcrowding at home, as overcrowding is mainly perceived in the person's immediate area (Park & Evans, 2016). The majority of people living in Europe (European Union, 2003) and North America (Klepeis et al., 2001) spend most of their time indoors, emphasizing the impact of overcrowding at home over external density in the respective district.

The COVID-19 pandemic is considered an urban stressor in this study. While unexpected events like the pandemic are not traditional urban stressors, they have been shown to

be relevant temporary stressors (Berdejo-Espinola et al., 2021), negatively affecting urban residents' quality of life (for reviews see Mouratidis, 2021; Nigg et al., 2023) and influencing relocation processes (Stawarz et al., 2022).

Environmental psychology traditionally assesses stress through physiological indicators like increased blood pressure or stress hormone levels triggered by environmental conditions (e.g. Bilotta et al., 2013; Park & Evans, 2016). However, stress can also manifest as dissatisfaction with living situations, causing individuals to consider relocation (Kley, 2011; Wolpert, 1966). Therefore, the *first hypothesis* is:

Urban stressors, such as traffic noise annoyance at home (*H1a*), home overcrowding (*H1b*), and the negative impact of the COVID-19 pandemic (*H1c*) boost relocation processes in cities.

2.2 The role of green spaces in mitigating urban stress

Urban green spaces offer a valuable counterbalance to the challenges of city life. Extensive research highlights their positive effects on general well-being (see Gascon et al., 2015; Hartig et al., 2014 for reviews; Hong et al., 2019; Kley & Dovbishchuk, 2021; Zhao et al., 2024), with mechanisms such as promoting physical activity (Bonaccorsi et al., 2020; Kim & Miller, 2019) or strengthening community bonds (Groenewegen et al., 2012).

The positive effects of green spaces on well-being are supported by psychological theories, such as the attention restoration theory (Kaplan, 1995), which suggests that green spaces promote relaxation of general attention (Lindal & Hartig, 2015). Moreover, the stress recovery theory (Ulrich et al., 1991) underscores the role of green spaces in lowering stress levels, thus reducing overall anxiety and depression (Groenewegen et al., 2012). In the context of exposure to stressors, the restorative and recovery effects of green spaces are conceptualized as providing an energy recharge to cope with such stressors more effectively. Furthermore, when compared to stressful urban environments, urban settings featuring green spaces promote better stress recovery and overall recuperation among city dwellers (Ulrich et al., 1991).

Urban nature serves not only as a restorative and stress-alleviating beneficial counterbalance to urban stressors but in specific cases it might also act as a protective shield against their negative effects. For *noise annoyance*, a view of greenery from a window can minimize noise by simply blocking or reducing visibility of noise sources (Van Renterghem, 2019). Additionally, natural sounds from vegetation, like wind or birdsong, can soften or mask traffic noise (Van Renterghem, 2019). This paper emphasizes the role of neighborhood green spaces in stress and noise reduction regardless of whether the residential building has a quiet side. Having a quiet side of a building significantly reduces urban residents' noise annoyance (Diekmann et al., 2022) and of course has a direct influence on the presence of less noisy private gardens or shared yards. However, when it comes to green spaces in the neighborhood, both local residents with and without a quiet building side benefit similarly from these green spaces within walking distance from their homes (Gidlöf-Gunnarsson & Öhrström, 2007). The mere presence of green spaces in the neighborhood (Koprowska et al., 2018; Li et al., 2010; Van Renterghem, 2019) and their accessibility within walking distance (Dzhambov & Dimitrova, 2015) have been shown to reduce noise annoyance at home.

In cases of *overcrowding at home*, urban green spaces offer residents an alternative for spending their leisure time, essentially expanding their living space. Additionally, having green window views at home can serve as a psychological escape, increasing the recuperation likelihood in densely-populated urban areas (Lindal & Hartig, 2015).

During the *COVID-19 pandemic* in Germany, although many facilities were closed during lockdowns, most public spaces, including urban green spaces, stayed open. Urban nature, as an alternative to indoor environments, reduced feelings of isolation and provided an opportunity for leisure with a relatively low infection risk (Mouratidis, 2021). The exact pattern of the changed frequency of green space usage due to the COVID-19 pandemic remains divergent, with some residents increasing their usage and others decreasing it (Berdejo-Espinola et al., 2021). However, the motivation behind it shifted to a more intentional green space usage for physical and mental well-being benefits (Berdejo-Espinola et al., 2021).

Mitigating urban stressors by using urban green spaces aligns with the psychological theories of attention restoration (Kaplan, 1995) and stress recovery (Ulrich et al., 1991), suggesting that individuals use green spaces beneficially for rebuilding depleted mental resources and reducing stress levels. If dissatisfied with their current living situation, including the level of urban stressors, individuals may consider moving to a more favorable residential environment and use urban green spaces to compensate for the stressful impacts of their current living conditions. Additionally, reducing stress levels through the compensatory usage of green spaces can help to minimize the need to relocate. Hence, the *second hypothesis* suggests:

H2: Urban green space usage acts as an adaptive mechanism for mitigating urban stressors, thus weakening the process of relocation decision-*making*.

2.3 Urban green spaces and relocation decision-making

In this study, the three-stage model for migration decision-making (Kalter, 1997; Kley, 2011) is applied, which is also suitable for residential relocations. Based on the psychological Rubicon model of decision processes (Gollwitzer, 1996; Heckhausen, 1991), decision-making prior to the actual relocation involves two stages: *considering* and *planning* relocation. While considering relocation, city dwellers evaluate aspects of their living situation, weigh up pros and cons, and establish preferences. Once this assessment is completed, individuals might 'cross the Rubicon' and decide in favor of moving, proceeding to the subsequent stage of planning a relocation.

While housing and neighborhood characteristics are expected to influence considering relocation, their impact may diminish for 'crossing the Rubicon' and transitioning to the planning stage, which is often more due to the influence of life course events and social bonds in both the current and the new place of residence (Kley, 2011). Adaptive strategies are expected to emerge early in the relocation decision-making process when city residents consider relocating. At this point, the mitigative usage of green spaces can offer numerous benefits, potentially outweighing dissatisfactory factors in the current living situation. Essentially, the positive effects of urban green spaces may be so impactful that

individuals decide against 'crossing the Rubicon' and drop their relocation considerations. Examining the effectiveness of green space usage in relocation processes becomes crucial to determining whether negative impacts can actually be mitigated, thus minimizing the probability of further relocation steps. Therefore, the *third hypothesis* is:

Urban green space usage is most relevant in the initial relocation decision-making stage when individuals consider relocation (*H3a*), potentially deterring them from deciding for relocation and progressing to the planning stage by effectively mitigating urban stressors (*H3b*).

3 Data, variables and method

3.1 Data collection

This study is based on data from a primary survey conducted in two large German cities, Cologne and Hamburg, from September 2020 to February 2021.[i] The similar frequency of urban green space usage in both cities allows pooling for the analysis, and the statistical control of the city of residence does not directly impact the study's associations.

Sampling was restricted to telephone landlines within the area codes of the two cities, because mobile phone numbers could not be limited spatially to Cologne and Hamburg. Using random digit dialing (Häder et al., 2019) and additional random selection at household level via the *last birthday* method, a sample of 1,846 respondents was drawn after data cleansing.[ii]

Respondents, aged 18 or older, included city residents who had lived at their place of residence for at least 12 months, ensuring familiarity with their residential area. To analyze relocation behavior adequately, individuals considering relocation were intentionally oversampled. Design weights correct for this oversampling[iii] and individual selection probability within the household in both descriptive analyses and regression models.

3.2 Variables

The dependent variables of the study cover two decision-making stages in the relocation process: considering and planning relocation (Kley, 2011). To measure considering relocation, participants were asked, "*Have you recently thought about moving out of your apartment or house to live somewhere else?*" If respondents answered affirmatively, a follow-up question was asked: "*Are you planning to move within the next 12 months?*"

To measure urban green space usage, respondents were asked about their frequency of visits to four natural amenities within a 15-minute walk from their homes: parks, river- and lakeshores, woods, and fields. Respondents could choose the options *daily, weekly, monthly, yearly, less frequently* or *never* if these green spaces were nearby. Despite the variable being ordinally scaled, it is treated as quasi-metric in the analysis, with higher values indicating more frequent usage, following similar approaches in previous studies (Hong et al., 2019; Kim & Miller, 2019; Zhao et al., 2024). This procedure is acceptable given the variable's sufficient categories and large sample size (DeMaris, 2004, pp. 303-307), as in this study. While dichotomizing the variable would lead to similar results, treating green space usage as quasi-metric preserves the graduated nature of the data.

Urban stressors were measured as follows: Traffic noise annoyance at home was measured by asking respondents to rate on a 7-point scale how much road traffic noise bothered them at home, regardless of the time of day. Overcrowding was calculated by the number of persons per room, excluding kitchens, bathrooms, and rooms smaller than six square meters. The negative impact of the COVID-19 pandemic was assessed by examining the extent to which respondents experienced financial or occupational setbacks, disruptions to their usual hobbies, feelings of spatial confinement at home, a decrease in outdoor time, or a reduction in physical activity due to the pandemic.

Relocation processes and stress mitigation strategies might be influenced by sociodemographic characteristics such as age (e.g. Berdejo-Espinola et al., 2021; Bonaccorsi et al., 2020; Clark & Huang, 2003; Coulter, 2013; de Groot et al., 2011; Geist & McManus, 2008; He et al., 2022), gender (e.g. de Groot et al., 2011), migration background (e.g. Coulter, 2013; de Groot et al., 2011), or material resources (e.g. Clark & Huang, 2003; Coulter, 2013;

de Groot et al., 2011; Diekmann et al., 2022) and therefore the household's socioeconomic status. Socioeconomic status was analyzed based on detailed information about respondents' occupational and employment status, including details about partners living in the same household. [iv]

Household composition, such as living alone, with a partner, or with children, is examined for its potential impact on expected outcomes (Coulter, 2013; Geist & McManus, 2008; Kley, 2011; Kley & Dovbishchuk, 2021; Kley & Stenpaß, 2020; Kulu, 2008). The study also considers housing characteristics, including owner-occupied housing, known to reduce relocation likelihood (Clark & Huang, 2003; Coulter, 2013; Kley, 2011; Kley & Dovbishchuk, 2021), and the presence of (semi-)private green spaces. Given that the availability of (semi-)private green spaces enhances well-being (Kley & Dovbishchuk, 2021; Zhao et al., 2024) and their absence triggers considering relocation (Kley & Dovbishchuk, 2021), the models consider the availability of a private garden, balcony, terrace or a semi-private shared green yard. The rationale behind this is that if these spaces are available, individuals might employ different compensation strategies rather than relying solely on urban green spaces.

To assess respondents' connectedness to nature, a shorter version of the nature relatedness scale by Nisbet et al. (2009) was used. This connection could influence residents' decisions about where to live and their preference for using urban green spaces as compensation strategies. The scale covered emotional, cognitive, and behavioral aspects, with the top three items from the original scale selected for each. To capture its potential impact on adult housing preferences (Bayrakdar et al., 2019; Kley & Stenpaß, 2020), two additional items about childhood nature experiences and valuing nature in raising children were included. A factor analysis of these eleven items justified combining them into one single measure of nature relatedness.

The models consider life course events that commonly trigger relocation processes such as births (Clark & Huang, 2003; de Groot et al., 2011; Geist & McManus, 2008; Kley, 2011; Kulu, 2008; Wagner & Mulder, 2015), changes in partnership status (Clark & Huang, 2003; de Groot et al., 2011; Geist & McManus, 2008; Kley, 2011; Wagner & Mulder, 2015), and starting a new job or studies (de Groot et al., 2011; Kley, 2011). The study combines

these events into a variable covering job changes, partner's job changes, cohabitation, marriage, childbirth, moving out of the parental home, completing high school, or starting further education. This combined life course event variable indicates whether any of these events occurred in the previous six months or were expected in the subsequent six months.

3.3 Methodology

The study uses a generalized ordered logit regression (Williams, 2016) to analyze the stages of the relocation decision-making process as an ordinal dependent variable, where individuals may first not consider relocation, then consider it, and finally plan to relocate. The advantage of this method is that it can show how different factors influence the transition to each stage, relaxing the assumption that predictor effects remain constant across stages.

To examine stress compensation strategies during relocation processes, the focus shifts to the analysis of interaction coefficients between urban green space usage and urban stressors. In this analytical step, the significance of these interactions is determined, and it is assessed whether considering them changes the strength or direction of the relationships between the predictors and the relocation stages. Essentially, the analysis aims to capture whether the impact of urban green space usage is moderated by experiencing urban stressors, and the product term approach is applied to test for these moderating effects (Baron & Kenny, 1986; Busemeyer & Jones, 1983; Pearl, 2014). A product term is calculated that accounts for both urban green space usage and urban stressors and it is then integrated into the models. All analyses were performed using Stata version 17.

Finally, open-ended responses were quantitively analyzed to identify which aspects respondents dislike about their neighborhoods, including reasons for considering relocation if applicable. Categorization was done using MAXQDA. This mixed-methods approach, which combines quantitative and qualitative methods, strengthens claims about causality, especially when analyzing the impact of the built environment on human actions (Næss, 2016).

4 Findings

4.1 Key characteristics of the sample

Table 1 provides descriptive statistics for all variables. About 23% of respondents are considering relocating, with 26% of this group already in the relocation planning stage, representing 6% of the total sample.

Table 1: Descriptive characteristics of the sample

	Mean	Min	Max
Considering relocation	0.229	0	1
Planning relocation	0.059	0	1
Female	0.563	0	1
Migration background	0.255	0	1
Hamburg	0.503	0	1
Age	53.4	18	96
Socioeconomic status:[1]			
blue-collar workers	0.214	0	1
routine sales and service workers	0.325	0	1
lower-grade professionals	0.314	0	1
higher-grade professionals	0.147	0	1
Homeownership	0.455	0	1
Single-person household	0.212	0	1
Living with child(ren)	0.346	0	1
Living with partner	0.669	0	1
Private balcony, terrace or garden	0.817	0	1
Shared green yard	0.229	0	1
Urban green space usage:			
daily	0.145	0	1
weekly	0.319	0	1
monthly	0.293	0	1
yearly	0.127	0	1
less frequently	0.064	0	1
never	0.028	0	1
not available	0.024	0	1
Traffic noise annoyance at home	2.406	1	7
Density (persons per room)[2]	0.708	0.111	4
Negative influence COVID-19 pandemic[3]	1.953	0	6
Life course events (any)[4]	0.205	0	1
Nature relatedness[5]	5.176	1	7
No. of persons		1846	

Notes: means design weighted;
[1] Determined at the household level based on detailed information about the occupational and employment status of respondents and their partners. Prioritization follows higher status, using data on prior occupations in cases of unemployment or retirement.
[2] Excluding kitchens, bathrooms, and rooms smaller than six square meters.

[3] Index (0/6) including financial and occupational setbacks, feelings of spatial confinement within the dwelling, as well as reduced engagement in hobbies, outdoor time, or physical activity.
[4] Indicates whether any of these events occurred in the past six months or were expected in the next six months: job change or partner's job change, cohabitation, marriage, childbirth, moving out of the parental home, completing high school, starting further education.
[5] Adapted scale (1/7) based on Nisbet et al. (2009), which includes emotional, cognitive, and behavioural dimensions, and childhood experiences with nature.

Urban green space usage is shown by frequency: 15% of the respondents visit them daily, while the majority visits neighborhood green spaces weekly (32%), or monthly (29%). Less common are annual visits (13%) or less frequent usage (6%), and 3% report to never visit neighboring urban green spaces. Only 2% lack any green spaces nearby. On average, respondents visit urban green spaces on a weekly to monthly basis.

Urban stressors include on average moderate annoyance from traffic noise, scoring 2.4 on a scale of 1 to 7. Individuals considering relocation show higher levels of annoyance at 2.7 (not shown in the table). Regarding overcrowding, on average, there is less than one person per room in the surveyed population.[v] Shifting to the negative influence of the pandemic, respondents, on average, experienced two out of the six mentioned COVID-19 pandemic challenges.

4.2 Urban stressors and green space usage as predictors in relocation decision-making

Table 2 shows the results of using a generalized ordered logit model to evaluate predictor relevance for considering and planning relocation. This method analyzes whether predictors are equally important for both considering relocation and subsequently transitioning to the planning stage ("="), or if their relevance changes across the stages, testing the proportional odds assumption.

Frequent urban green space usage is associated with a higher probability of considering relocation, but it does not seem to influence the transition to the planning stage. When interpreting this finding, a justified question arises: are individuals with frequent usage of urban green spaces more likely to consider relocation, or is it equally plausible that those considering relocation are more likely to visit urban green spaces? Due to the study's cross-sectional nature, causality cannot be tested. To disentangle this somewhat,

Section 4.3 analyzes the potential role of urban green spaces as a coping strategy for dealing with urban stressors when considering relocation in cities.

Traffic noise annoyance at home increases the likelihood of considering relocation in cities. However, this annoyance does not significantly impact the transition to planning relocation. Overcrowding at home, measured by persons per room, appears irrelevant for relocation decision-making when accounting for homeownership (0.27, $p = 0.208$ without homeownership, not shown in the table). Lastly, challenges from the COVID-19 pandemic make it more likely for city dwellers to both consider and plan relocation.

The only predictor with a stronger positive impact on transitioning to the relocation planning stage than considering relocation is the combined life course events variable. This finding supports earlier research emphasizing such events as relocation triggers (Clark & Huang, 2003; de Groot et al., 2011; Geist & McManus, 2008; Kley, 2011; Kulu, 2008; Wagner & Mulder, 2015). Age and cohabitation with a partner also change their influence during the transition to relocation planning. Increasing age prevents respondents from shifting to relocation planning, aligning with prior research suggesting older individuals are less likely to move (Coulter, 2013; Geist & McManus, 2008). Living with a partner discourages respondents from considering relocation, and this influence becomes more pronounced during the transition to planning relocation, consistent with previous research (Geist & McManus, 2008; Kulu, 2008).

The remaining predictors show similar impacts on both considering and planning relocation. More affluent socioeconomic status groups are more likely to consider and plan relocations, aligning with previous research (Clark & Huang, 2003; Coulter, 2013; de Groot et al., 2011). Homeownership reduces the probability of relocation decision-making, consistent with prior findings (Clark & Huang, 2003; Coulter, 2013; Kley, 2011; Kley & Dovbishchuk, 2021). Similarly, living in a single-person household decreases the probability of relocation decision-making (Coulter, 2013). In line with earlier research findings (Kley & Dovbishchuk, 2021), the presence of private and shared green spaces reduces the likelihood of relocation intentions in an urban context. All analyses consider respondents' nature relatedness (Nisbet et al., 2009) and show that a strong nature relatedness increases the probability of relocation intentions among city dwellers.

Table 2: Relevance of green space usage and urban stressors for considering and planning relocation

	Not considering versus considering	Model 1 (b)	Considering versus planning
Female	-0.01		=
Migration background	-0.10		=
Hamburg	0.12		=
Age	-0.00		-0.03 ***
Socioeconomic status[1] (ref.: blue-collar workers)			
routine sales and service workers	0.51 **		=
lower-grade professionals	0.61 ***		=
higher-grade professionals	0.58 **		=
Homeownership	-0.49 ***		=
Single-person household	-0.66 **		=
Living with child(ren)	-0.04		=
Living with partner	-0.57 **		-0.90 ***
Private balcony, terrace or garden	-0.45 **		=
Shared green yard	-0.49 ***		=
Urban green space usage	0.13 **		-0.07
Traffic noise annoyance at home	0.14 ***		0.04
Density (persons per room)[1]	0.07		=
Negative influence COVID-19 pandemic[1]	0.18 ***		=
Life course event (any)[1]	0.74 ***		1.08 ***
Nature relatedness[1]	0.35 ***		=
No. of persons		1846	
Pseudo R^2 (degrees of freedom)		0.111 (24)	

Notes: Generalized ordinal logit regression, design weighted, robust standard errors applied;
+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001;
= estimated coefficient is equal across the stages of considering and planning relocation (the proportional odds assumption is met, p<0.05).
[1] See Table 1 for details.

4.3 Coping with urban stressors: Green space usage in relocation processes

Table 3 includes product terms calculated for assumed moderating effects of urban stressors, reflecting interactions between green space usage and the corresponding urban stressor. Table 3 presents key predictors, with detailed models provided in Table A in the Appendix.

Table 3: Interaction effects of urban green space usage and urban stressors for considering and planning relocation (selected predictors)

	Not considering versus considering	Considering versus planning	Not considering versus considering	Considering versus planning
	Model 2 (b)		Model 3 (b)	
Urban green space usage	0.02	-0.18 +	0.03	=
Traffic noise annoyance at home	-0.07	-0.18	0.14 ***	0.03
Density (persons per room)[1]	0.09	=	0.06	=
Negative influence COVID-19 pandemic[1]	0.18 ***	=	-0.00	0.33 *
Urban green space usage ##				
## Traffic noise annoyance at home	0.04 +	=		
## Negative influence COVID-19 pandemic			0.03	-0.02
No. of persons	1846			
Pseudo R^2 (degrees of freedom)	0.117 (29)		0.118 (30)	

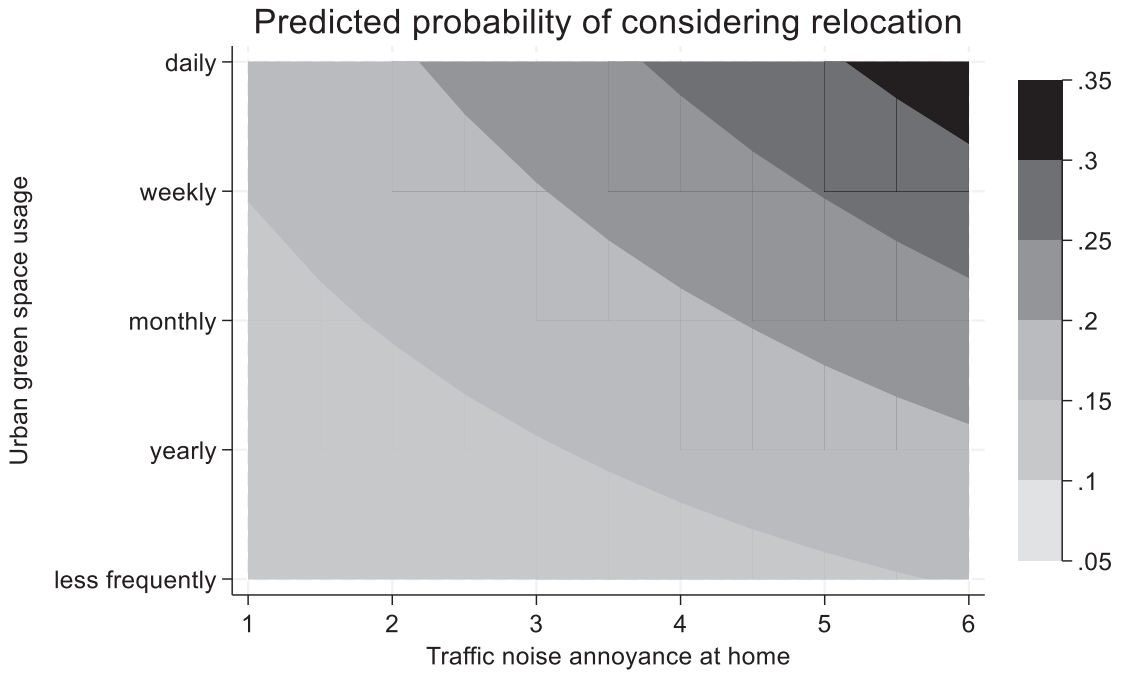
Notes: Generalized ordinal logit regressions, design weighted, robust standard errors applied;
+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001;
Due to consistent patterns similar to Model 1, not all predictors are detailed in this table for sake of conciseness. For a detailed overview, refer to Table A in the appendix.
= estimated coefficient is equal across the stages of considering and planning relocation (the proportional odds assumption is met, p<0.05).
[1] See Table 1 for details.

Model 2 shows no direct influence of green space usage or traffic noise annoyance on considering relocation when their interaction coefficient is introduced, but the significant interaction coefficient suggests a potential moderating effect. To further analyze this moderating effect, Figure 1 illustrates the predicted probability of considering relocation based on the frequency of urban green space usage and the level of traffic noise annoyance at home. The prediction of the probability of considering relocation is not straightforward when the frequency of urban green space usage is considered without taking into account the influence of urban stressors, like traffic noise annoyance at home. For example, an individual visiting urban green spaces daily without being annoyed by traffic noise has a relatively low 15% probability of considering relocation. Conversely, someone visiting urban green spaces daily but experiencing high traffic noise annoyance at home has a higher probability of considering relocation that reaches 35%. This suggests that the relationship between green space usage and the probability of

considering relocation is influenced by the level of traffic noise annoyance at home, which acts as a moderating factor in this context.

In Model 2 (Table 3), it is noteworthy that the association between urban green space usage and the likelihood of transitioning to relocation planning changes direction (-0.18, p = 0.057), again indicating a moderating effect (Baron & Kenny, 1986). This suggests that using urban green spaces as a compensatory strategy for traffic noise annoyance at home when considering relocation can reduce the probability of 'crossing the Rubicon' and transitioning to the planning stage of relocation.

Figure 1: Predicted probability of considering relocation by neighborhood green space usage and traffic noise annoyance at home

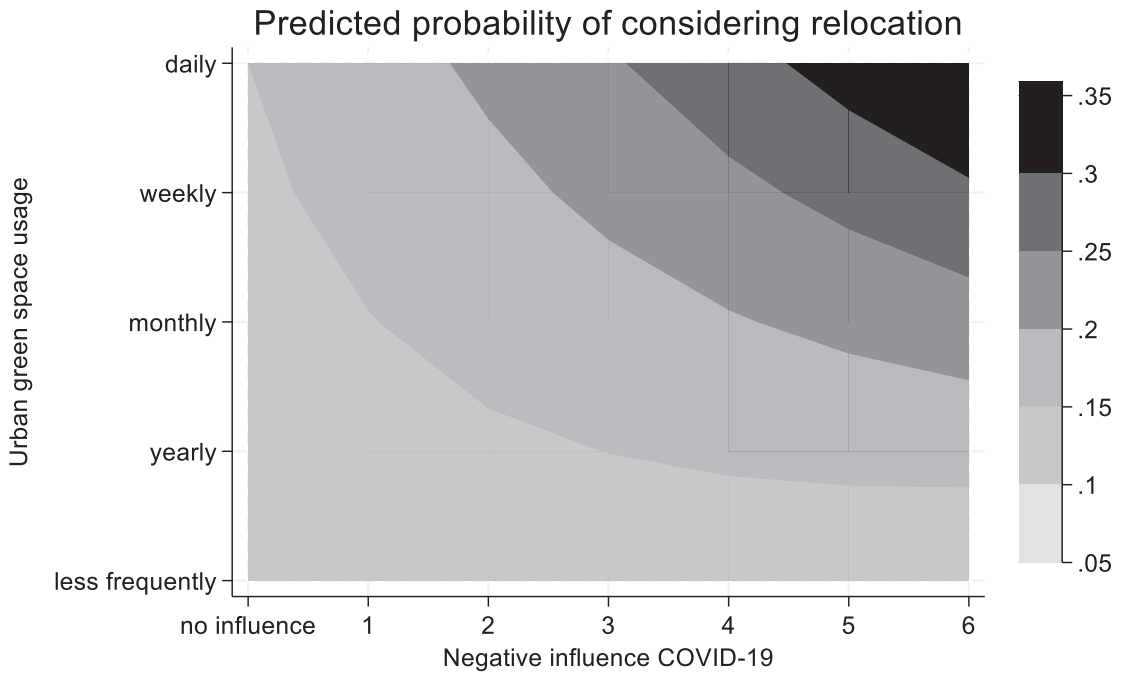


Notes: Based on Model 2; design weighted.

Figure 2 illustrates the predicted probability of considering relocation when taking into account the frequency of urban green space visits and the impact of the coronavirus pandemic, based on Model 3 (Table 3). To predict relocation probability depending on the frequency of visiting urban green spaces, it is essential to capture the influence of urban stressors like the pandemic's negative impact. For someone who visits urban green spaces daily and was unaffected by the pandemic, there is a relatively low 5% probability of considering relocation. Conversely, a person with the same daily green space usage

but experiencing a high negative impact from the pandemic has a higher 35% probability of considering relocation. This highlights that the connection between green space usage and the likelihood of considering relocation is shaped by the negative impact of the COVID-19 pandemic, acting as a moderating factor. The effectivenenss of the green space usage compensation strategy becomes more evident during the transition to the relocation planning stage. When a less effective compensation strategy of green space usage is applied, there is an increased probability of transitioning to the planning stage due to the negative impact of the coronavirus pandemic (0.33 in Model 3, p = 0.037).

Figure 2: Predicted probability of considering relocation by neighborhood green space usage and negative influence of COVID-19 pandemic



Notes: Based on Model 3; design weighted.

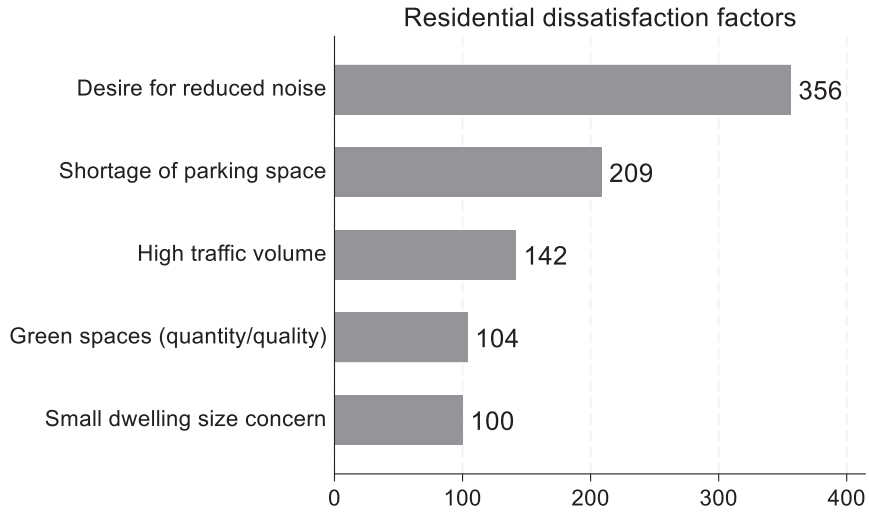
4.4 Residential dissatisfaction factors: qualitative insights

The analysis in Figure 3 sheds light on potential causal links between green space usage, urban stressors, and relocation processes. From the coding of open-ended responses about what respondents dislike in their neighborhoods and reasons for considering relocation, noise stands out as the most frequently cited factor contributing to residential

dissatisfaction. Almost one in five respondents (356 mentions, equaivalent to 19% of respondents) express dissatisfaction with the current noise situation at home.While the responses do not explicitly specify the type of noise, the third dissatisfaction factor indicates that 8% of respondents mentioned concerns about high traffic volumes. This might imply that at least some portion of the reported noise complaints related to a desire for reduced noise might be linked to high traffic volumes.

Small dwelling size appears as one of the top five reasons for residential dissatisfaction. Notably, most mentions come from individuals considering relocation, with 14% citing small dwelling sizes, compared to 3% of those not considering relocation (not shown in the figure). This aligns with other research (Clark & Huang, 2003; Coulter, 2013), emphasizing the relevance of overcrowding at home in residential relocation processes.

Figure 3: Top five residential dissatisfaction factors



Notes: The top five residential dissatisfaction factors are derived from responses to open-ended questions regarding disliked aspects of the neighborhood, encompassing reasons for considering relocation, if applicable, coded with MAXQDA. The graph displays occurrences for each residential dissatisfaction factor with a count greater or equal to 100, totaling 2,037 entries from 1,846 individuals.

Approximately 6% of individuals (104 mentions) spontaneously cited inappropriate provision of green spaces in their residential environment, ranking it among the top five reasons for residential dissatisfaction. It should be noted that the question used for the analysis in Figure 3 was asked at the beginning of the questionnaire, ensuring respondents were not pre-informed about the survey's subsequent focus on the relevance of green spaces.

5 Concluding discussion

This study analyzed how urban green spaces mitigate urban stressors and influence decision-making processes in residential relocations. By examining the three-stage relocation decision-making model (Kley, 2011) with primary data collected in two major German cities, the research focused on key urban stressors, including traffic noise annoyance at home, home overcrowding, and the negative impact of the COVID-19 pandemic.

The study findings suggest that the analyzed urban stressors influence relocation decision-making. Traffic noise annoyance at home increases the likelihood of considering relocation, corroborating *hypothesis H1a*. The negative impact of the coronavirus pandemic increases the probability of both considering relocation and transitioning to the subsequent stage of planning relocation, in line with *hypothesis 1c*. While not apparent in the regression analysis, the relevance of home overcrowding as an urban stressor in the context of relocation processes is highlighted through qualitative analysis. A notable distinction is evident when comparing those considering relocation (14%) and those who are not (3%), with a substantial difference in the acknowledgement of home overcrowding as a contributor to residential dissatisfaction. The qualitative analysis, based on respondents' open-ended responses, focuses on subjective perceptions of confinement, which is possibly more influential in relocation processes than the quantitative measure of living space density used in the regression analysis. This finding aligns with *hypothesis 1b*, suggesting that overcrowding at home, as an urban stressor, plays a role in driving relocation processes in cities.

Usage of green spaces in the neighborhood is most relevant at the beginning of relocation decision-making processes, when city dwellers consider relocation, thus supporting *hypothesis 3a*. Contrary to the possible assumption that such usage might be driven by the absence of private gardens, terraces, balconies, or shared yards, the data show no evidence for this assumption, as the stepwise inclusion of coefficients for private and semi-private green spaces into Model 1 hardly changes the relationships in question (results available on request).

The positive association between frequent urban green space usage and the probability of considering relocation suggests that such usage serves as a coping strategy for urban stressors like traffic noise annoyance at home and the pandemic's negative effects. This supports *hypothesis 2* and aligns with prior research highlighting green spaces' compensatory role in reducing noise perceptions (Dzhambov & Dimitrova, 2014; Dzhambov & Dimitrova, 2015; Gidlöf-Gunnarsson & Öhrström, 2007; Koprowska et al., 2018; Li et al., 2010; Van Renterghem, 2019) and mitigating pandemic impacts (Berdejo-Espinola et al., 2021; Mouratidis, 2021; Nigg et al., 2023).

Regarding traffic noise at home, acting as a moderator between urban green space usage and relocation decision-making, the study indicates that using urban green spaces in the early stage of the relocation decision-making process can prevent city dwellers from progressing to subsequent relocation stages. In the context of the pandemic's negative impact, if there is a lack of compensatory green space usage during the stage of considering relocation, there is a higher probability of transitioning to the planning stage due to the pandemic's effects. These findings provide support for *hypothesis 3b*, suggesting that urban green space usage might discourage individuals from advancing to further relocation decision-making stages by mitigating urban stressors. Supplemented by insights from the qualitative analysis, which underscores the importance of ensuring a sufficient supply of green spaces in urban residential areas, providing access to such spaces suggests a potential contribution to balancing out relocation processes in cities.

In the three-stage model of migration decision-making (Kley, 2011), the transition from considering to planning relocation is a symbol for 'crossing a psychological Rubicon' (Gollwitzer, 1996; Heckhausen, 1991). It implies commitment to the planned relocation and makes it more difficult to give up these plans in the subsequent planning stage. The link between this psychological phenomenon and compensatory green space usage, which prevents the transition to the planning stage in the presence of urban stressors, underscores the positive impact of green spaces in cities. The green space usage strategy acts as a buffer when considering relocation, not only mitigating urban stressors but also keeping individuals from progressing to the planning stage. While city dwellers might

consider a relocation triggered by urban stressors, usage of green spaces in their neighborhood discourages them from committing to a relocation. This not only prevents city dwellers from 'crossing the Rubicon' and deciding in favor of a relocation, but also contributes positively to city resilience, highlighting green spaces' influence on the adaptive capacity of cities to transforming circumstances.

Using green spaces as a coping strategy aligns with psychological theories on attention restoration and stress recovery that emphasize the positive effects of natural environments in managing stress, suggesting that individuals recover better from stressors in naturals environments compared to urban settings (Kaplan, 1995; Ulrich et al., 1991). When facing urban stressors, city dwellers turn to green spaces as a coping mechanism for stress reduction. These coping strategies remain significant when considering important relocation predictors, like homeownership (Clark & Huang, 2003; Coulter, 2013) and key life course events (Bayrakdar et al., 2019; Clark & Huang, 2003; Coulter, 2013; de Groot et al., 2011; Kley, 2011; Kulu, 2008; Wagner & Mulder, 2015).

While this study provides valuable insights into urban residents using green spaces as a stress compensation strategy during relocation decision-making processes, it comes with certain limitations. (i) The cross-sectional design limits causal interpretations. While certain associations, like urban stressors triggering relocation, suggest causation, the link between green space usage and relocation is less clear. However, the analysis of compensation strategies in the relocation decision-making process points in the direction of causal connections: urban stressors moderate the relationship between green space usage and relocation. Qualitative analysis underscores that urban stressors affect residential satisfaction, with the lack of appealing green spaces ranking among the top reasons for residential dissatisfaction. (ii) Another concern might be the sample's representativeness, especially for young people, due to the landline-only surveying technique. While the exact percentage of households without landlines is unknown, estimates from Hamburg in 2016 suggest it was only 12.5% (Bock & Schnapp, 2016). The lack of a landline is unlikely to be systematically correlated with the studied associations, minimizing potential bias from this sampling method. (iii) Furthermore, nature affinity may influence

preferences for greener city districts and openness to compensatory green space strategies. Despite a strong link observed between nature relatedness (Nisbet et al., 2009) and both considering and planning relocation, the data consistently show an association between green space usage and relocation decision-making, even when controlling for nature relatedness.

In summary, the article highlights the importance of urban green spaces in the early relocation stages, analyzing their potential to mitigate the negative impacts of urban stressors during residential relocation processes. These findings provide valuable insights for urban planning, especially against the backdrop of growing urban populations (United Nations, 2023) and the comprehensive SDG 11 advocating widespread green space access (United Nations, 2023). Although green spaces strengthen city resilience by mitigating the negative effects of urban stressors, greening cities should not be a singular solution. Efforts should prioritize reducing key urban stressors like noise, especially from road traffic, and enhancing city resilience to unexpected events like the COVID-19 pandemic, as these have been shown to accelerate relocation processes in cities. Nevertheless, green spaces remain an important and indispensable resource for stress mitigation in urban areas.

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[i] While it may seem inappropriate to analyze green space usage in autumn and winter, the data show that such usage does not decrease solely due to diminished perceptions of prominent green features. The lowest green space usage occurred in the first month of the study, October, with minimal deviation throughout the study period. Monthly values are all in the range between weekly and monthly usage.

[ii] The minimal response rate according to AAPOR (2016) standards is 7.3 percent. It is not uncommon to have a somewhat low response rate in telephone surveys (e.g. less than

10% response rates in AAPOR, 2018; Marken, 2018). A lower response rate might influence the precision of findings, but it does not make the data less reliable (Meterko et al., 2015), particularly if the survey is conducted using a strict probability method.

[iii] Since the actual distribution of individuals considering relocation in the population is unknown, the completed randomized drawings on the specific day when the quota for individuals not considering relocation (50%) was reached was used to calculate the weighted distribution of respondents considering relocation within the parent population.

[iv] To calculate a household's socioeconomic status, priority was given to a higher status either of the respondent or spouse. In cases of unemployment or retirement, data on the prior occupations were used. Data were then coded according to the 2008 International Standard Classification of Occupations (ISCO08) scheme. Subsequently, socioeconomic classes were established at the household level following the Erikson–Goldthorpe–Portocarero (EGP) scheme (Erikson et al., 1979).

[v] At first sight, one might think that there is no overcrowding if the average number of rooms exceeds the number of persons. However, this is not the case: sufficient living space generally means that there is at least one more room available than the number of persons in the household (Clark & Deurloo, 2006; Gränitz, 2022). With a density of 0.708 persons per room, as shown in Table 1, it is observed that especially households with one or two persons are living in overcrowded housing (calculated from the density of 0.708 persons per room, this means 1.4 rooms for a one-person household and 2.8 rooms for a two-person household. The neutral housing size would be two rooms for one person and three rooms for two persons).

Appendix

Table A. Interaction effects of urban green space usage and urban stressors for considering and planning relocation (full models)

	Not considering versus considering	Considering versus planning	Not considering versus considering	Considering versus planning
	Model 2 (b)		Model 3 (b)	
Female	-0.01	=	-0.01	=
Migration background	-0.10	=	-0.10	=
Hamburg	0.13	=	0.12	=
Age	0.00	-0.03 ***	-0.00	-0.03 ***
Socioeconomic status[1] (ref.: blue-collar workers)				
routine sales and service workers	0.51 **	=	0.51 **	=
lower-grade professionals	0.61 ***	=	0.62 ***	=
higher-grade professionals	0.57 **	=	0.58 **	=
Homeownership	-0.48 ***	=	-0.49 ***	=
Single-person household	-0.66 **	=	-0.66 **	=
Living with child(ren)	-0.05	=	-0.05	=
Living with partner	-0.58 **	-0.92 ***	-0.57 **	-0.90 ***
Private balcony, terrace or garden	-0.46 **	=	-0.44 **	=
Shared green yard	-0.50 ***	=	-0.49 ***	=
Urban green space usage	0.02	-0.18 +	0.03	=
Traffic noise annoyance at home	-0.07	-0.18	0.14 ***	0.03
Density (persons per room)[1]	0.09	=	0.06	=
Negative influence COVID-19 pandemic[1]	0.18 ***	=	-0.00	0.33 *
Urban green space usage ##				
## Traffic noise annoyance at home	0.04 +	=		
## Negative influence COVID-19			0.03	-0.02
Life course event (any)[1]	0.74 ***	1.08 ***	0.75 ***	1.07 ***
Nature relatedness[1]	0.36 ***	=	0.35 ***	=
No. of persons	1846			
Pseudo R^2 (degrees of freedom)	0.112 (25)		0.112 (26)	

Notes: Generalized ordinal logit regression, design weighted, robust standard errors applied;
+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001;
= estimated coefficient is equal across the stages of considering and planning relocation (the proportional odds assumption is met, p<0.05).
[1] See Table 1 for details.