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Exploring Homeowners' Attitudes and Climate-Smart Renovation Decisions: A Case Study in Kronoberg, Sweden

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Abstract: This study aims to assess the factors influencing homeowner behaviour regarding climate-adaptive renovations. This study extends the Theory of Planned Behaviour (TPB) by integrating additional factors such as inherent homeowner qualities (IHQs) and building attributes (BAs) to better capture climate-adaptive renovation decisions. Different configurations for the impacts of these additional factors were tested, and their correlation to homeowner attitudes (ATs) and homeowner intentions (INTs) was studied. The results indicate that attitudes related to beliefs about climate change impacts are the strongest predictors of climate-adaptive behaviour. It was also found that IHQ was a strong determinant of homeowner attitudes and had a strong indirect impact on homeowner intentions to perform climate-adaptive renovations. Given the significant role of cognitive attitudes in shaping climate-adaptive behaviours, policy interventions should focus on fostering more climate-conscious attitudes. Targeted public campaigns can highlight localised climate risks and the benefits of adaptive renovations. Sharing narratives from regions affected by severe climate events, potentially in the form of targeted workshop sessions, could make climate risks more tangible, especially for those without direct exposure, fostering greater public engagement and adaptive actions.

Keywords: planned behaviour; multifactor regression; climate resilience; retrofitting

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1. Introduction

1.1. Background

The global climate change crisis poses significant challenges to communities worldwide; even countries such as Sweden, previously thought to be relatively safe from its impacts [1], have begun to experience climate disasters at an increased rate. In recent years, the country has witnessed a pronounced escalation in climate-related risks, including floods, landslides, storms, and heatwaves. In the period between 2005 and 2021, approximately 13,800 natural disaster-related damage incidents occurred per year [2]. The cost of these damages has amounted to approximately 844 million SEK or €74.9 million annually [2]. A significant portion of the existing European housing stock remains vulnerable to these evolving climate hazards, despite continued efforts by the European Union to include climate resiliency within building codes [2].

In Sweden, there have also been several initiatives in this direction. Climate Ordinance (2018:1428) [1] mandates municipalities and regional governments to conduct climate vulnerability and risk assessments and develop goals for improving resiliency to these risks. Several amendments have been made to the Planning and Building Act and the

Environmental Code to account for the impacts of changes in local climates, like rising water levels, greater precipitation, and increasing average temperatures. A National Expert Council for Climate Adaptation has also been appointed with the intention of reviewing and evaluating climate studies and producing regular update reports.

With rising global temperatures and an increase in extreme weather events, conventional building practices face heightened vulnerability to the impacts of climate change. In response, there is a pressing need for scientific inquiry into climate-smart renovation approaches. The Energy Performance of Buildings Directive (EPBD) of the European Union highlights the need for climate-smart retrofits that are critical to improve a building's energy efficiency and resilience to climate change [2]. Measures may be mitigative, avoiding greenhouse gas emissions through improved energy and material efficiency, or adaptive, improving buildings' resistance to the increasing frequency and intensity of extreme weather events [3]. By strategically combining these approaches within climate-smart retrofits, a more sustainable and resilient built environment can be established to meet the challenges of a changing climate.

1.2. Context of Study

This study is conducted in the Kronoberg region in the south of Sweden (shown in Figure 1). This region covers 8466 square kilometres divided into 8 municipalities and is home to approximately 204,000 people [4].

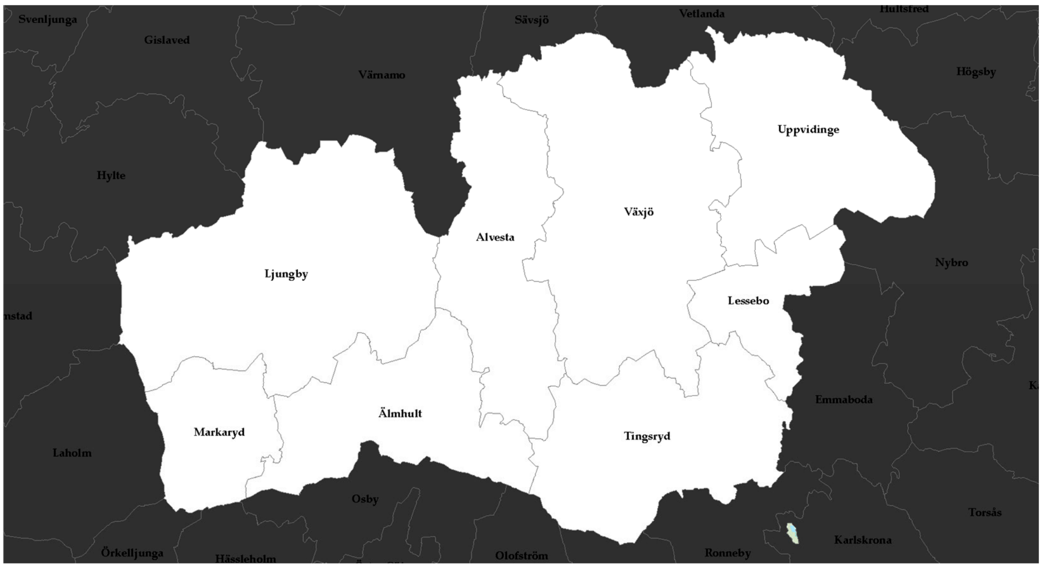

Figure 1. Map of the Kronoberg region in Sweden adapted from [5].

The region experiences a temperate oceanic climate characterised by mild winters and cooler summers due to the influence of the Gulf Stream and the region's proximity to the North Atlantic [6]. Though the climate tends to be moderate, the region experienced a major storm in 2005, in which 75 million cubic metres of forest land were destroyed and tens of thousands were left without access to power and phone network service [7]. In 2020, the entire Kronoberg region experienced unusually high precipitation, leading to floods in some residential areas in Växjö, Älmhult, and Ljungby, forcing the municipality and its residents to act in implementing adaptive measures more serious mitigative measures against climate disasters. Given the region's history with climate disasters, albeit fewer than other regions in comparison, this region presents an ideal setting for conducting this study. Though multiple government sources have specified climate adaptation as a priority [6,7], it is not clear whether this desire is reflected in the homeowners residing in the region.

2. Previous Studies and Theoretical Framework

There has been significant study in the past on the area of climate disaster response in Europe, particularly within the field of studying damage and homeowners' responses in affected areas. The most common natural hazard affecting numerous areas across Europe has been flooding, which has been studied extensively from the perspective of its impacts, predisposing factors, and effective mitigation strategies. Poussin et al. conducted a survey-based study of 885 houses in flood-prone areas across France to identify the effectiveness of flood mitigation strategies [8]. Similar studies exist for disaster-prone areas in Germany [9], the Netherlands [10], and Italy [11]. Ootegem et al. used socioeconomic indicators within a multivariate pluvial flood damage model in Flanders, Belgium. They found a strong correlation between risk awareness, income, and propensity for insurance claims for damages from flooding [12]. In Sweden, Mobini et al. have extensively studied the distribution of flood events [13] and damage claims [12]. The study on impacts of heatwaves, for Sweden in particular, is not quite as diverse as follows: Rocklöv et al.'s study has shown that increases in mean daily temperature have been causally linked to higher summer mortality [14], and sensitive groups experience higher odds of premature death during heatwave periods [15]. While these studies adopted a multifactor regression-based approach to find inherent and external qualities of homeowners that would make them more predisposed to dangers of natural hazards, they do not integrate homeowner attitudes into their analysis.

A survey-based approach was also adopted within the studies of Pardalis et al., in which they implemented path modelling analysis to model the causal relationship between the factors leading to energy renovation based on the renovation decision process [16] and the reasons that homeowners might have for pursuing a certain type of renovations [17]. A similar study was conducted in Germany with the purpose of elucidating the decision-making process of homeowners when performing renovations. It was found that the values, beliefs, norms, and routines of homeowners played a significant role in the decision-making process in addition to economic status [18]. Baumhof et al., through a national online survey, identified factors influencing house owners' behaviour in relation to energy refurbishment [19].

The theory of planned behaviour (TPB) is used in this paper, as it provides a solid framework to examine the relationship between underlying factors, behaviour, and intentions. Figure 2 provides a visual representation of TPB. According to this theory, human behaviour is influenced by the following three core elements: attitudes towards the behaviour, subjective norms, and perceived behavioural control. These factors together shape an individual's intentions, which are the most direct predictors of actual behaviour [20]. Attitudes reflect an individual's positive or negative evaluation of the behaviour. A distinction must be made here as follows: in this study, cognitive attitude refers to the homeowner's beliefs and knowledge about the impacts of climate change and the effectiveness of climate-adaptive renovations in addressing those impacts. In contrast, behavioural attitude pertains to an individual's actions or responses towards climate-adaptive renovations. When referring to 'attitude' within this study, cognitive attitudes are being considered. Subjective norms capture perceived social pressure to engage in or refrain from the behaviour, and perceived behavioural control represents the individual's belief in their ability to perform the behaviour under given circumstances [21]. The model assumes that individuals make rational decisions based on available information and deliberative thought processes, which can sometimes limit its applicability to behaviours influenced by habits, emotions, or external constraints [22]. Moreover, while TPB has been widely applied to study behaviour in areas such as environmental sustainability [23] and disaster risk reduction [24], it has been criticised for not adequately addressing the gap between intention and actual behaviour, known as the intention–behaviour gap. To address this limitation, this study extends the TPB framework by incorporating the following two additional contextual factors: inherent homeowner qualities (IHQs) and building attributes (BAs). These factors were included based on prior empirical research indicating that demographic and structural factors can significantly shape decision-making in climate adaptation contexts as follows:

- Inherent Homeowner Qualities (IHQs): Homeowner characteristics, such as income level, education, and age, have been shown to influence decision-making in home renovation and climate adaptation. These variables provide a deeper understanding of the social and economic constraints that impact intention formation.
- Building Attributes (BAs): Structural features of a home, including its current energy efficiency, age, and renovation history, directly affect the feasibility and necessity of climate-adaptive renovations. Without accounting for these attributes, the model would lack critical explanatory power regarding the practical limitations homeowners face.

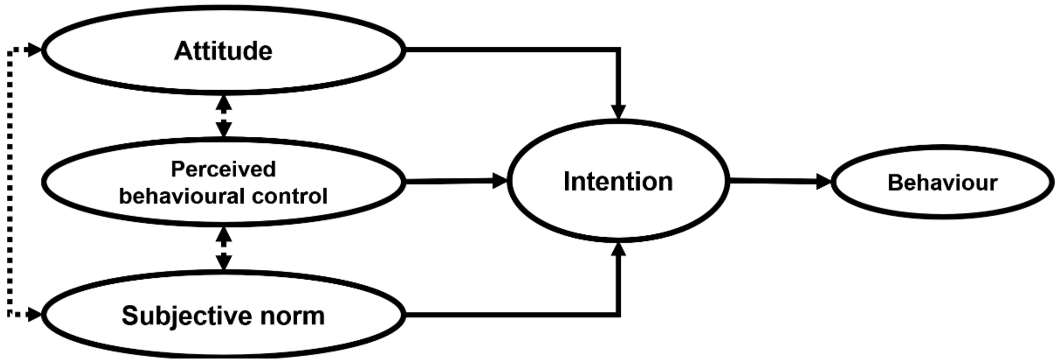

Figure 2. Theory of planned behaviour (TPB) adapted from [20].

These extensions align with previous studies that suggest that contextual and situational variables play a crucial role in shaping pro-environmental behaviours. By integrating IHQ and BA, this study aims to provide a more comprehensive model that better captures the complexity of climate-adaptive renovation decisions.

Several studies have applied extended or modified versions of the Theory of Planned Behaviour (TPB) to explore decision-making in house renovation. Guo et al. investigated the implementation of an improved elevator system in a building, studying homeowners' responses. However, their application of the theory was somewhat limited [24]. A separate study in China examined a green redevelopment project by integrating perceived risk and perceived cost into the TPB framework. It found that the subjective norm had a significant impact on green redevelopment behaviour [25]. In Malaysia, another study using TPB identified significant relationships between cost, attitude, information, knowledge, awareness, management, government support, and technology training in relation to the intention to adopt green building technology [26]. Additionally, a study on the role of immediate emotions in TPB showed that incorporating emotions—such as those experienced during decision-making—can enhance the TPB's ability to predict and influence pro-environmental behaviours [27]. In Flanders, Belgium, Conradie et al. surveyed participants to identify the determinants of energy-efficient renovations and found that both subjective norms and attitudes significantly predicted intention, with attitudes being the most influential factor [28]. Bal et al. examined social housing renovations and found that subjective norms often hindered sustainable behaviour in housing contexts [29]. Numerous other studies have been carried out internationally that apply TPB within various contexts related to climate adaptation. The most relevant of these studies is presented in Table 1.

Table 1. Studies focusing on the application of TPB and extended TPB.

Country	Context of Application	Findings
Maldives [25]	Factors affecting migration in response to environmental and socio-economic factors	Based on a modified framework of TPB, it was found that migration was driven by perceived economic gains rather than environmental concerns
Australia [26]	Factors influencing the decision to drive through flooded waterways	Based on a modified TPB framework to include a risk perception factor, it was found that while attitudinal beliefs were a significant factor, risk perception played a major role in determining intention.
Australia [27]	Effectiveness of different theories when being applied to disaster preparedness	Attitudes and perceived behavioural control influence preparedness intentions; factors from other theories, such as protection motivation and social-cognitive theory, also play a significant role. Trust in authorities, past disaster experience, and community engagement are identified as critical elements in enhancing preparedness efforts
Netherlands [28]	Applying the extended model of TPB to understand barriers to people joining a renewable energy community	Attitude and subjective norms were both found to be strong predictors of intent, while perceived behaviour has a significant but modest impact. Additional relationships between attitudes towards renewable energy, environmental concern, financial gain, and willingness to change behaviour and attitude towards renewable energy communities were also found.
United Kingdom [29]	Applying the extended model of TPB to understand willingness to pay for low carbon fuel jets (LCFJs)	Social trust, perceived risks, and attitude were the strongest indicators for willingness to pay for LCFJ. Although the overall perception of the benefits of LCJF outweighs the associated risks, the level of awareness of LCJF use was found to be low.
France [30]	Applying modified TPB to a survey of coastal populations to analyse property relocation policies in response to sea level rise	Social norms, a perceived sense of control, could help increase the acceptability, and greater trust in policymakers could lead to better acceptance of adaptation strategies.
Malaysia [31]	Integration of TPB and the Technology Acceptance Model (TAM) to study acceptance of renewable energy technology	Attitude and perceived behaviour control were important in determining intention to adopt renewable energy technology, while perceived ease of use and usefulness were significant in determining attitudes. Subjective norms were not found to play a role in influencing intentions. The extended model integration, both including additional factors, was found to have greater explanatory power than both TPB and TAM individually.

Table 1. *Cont.*

Country	Context of Application	Findings
Belgium [32]	Integration of the Unified Theory of Acceptance and Use of Technology (UTAUT) and TPB to examine the adoption of distributed energy resources by small and medium-sized enterprises (SMEs)	Intrinsic psychological and behavioural factors, such as social norms, hedonic motivation, social influence, and awareness of technology, play a crucial role in driving DER adoption. Meanwhile, extrinsic elements, including financial incentives, ownership structures, and comfort, consistently encourage uptake; however, the adoption of certain DERs is hindered by technological complexities and high costs.
India [33]	Application of extended TPB and multistage sampling to analyse farmers' intention in using climate forecasts for making informed decisions in farming	Positive attitudes toward the reliability and relevance of climate information significantly enhance adoption, while social influence from agricultural peers, local leaders, and government agencies further encourages uptake. Perceived behavioural control, particularly regarding access to technology and literacy levels, presents challenges to adoption.
China [34]	Integration of Construal Level Theory (CLT) and TPB to analyse factors that influence adaptive behaviours to drought and water saving	Improving public perceptions of climate change could enhance the perceived attractiveness and motivation for adaptation efforts, while fostering more favourable perceptions of water conservation could improve the perceived practicality and implementation potential of adaptive strategies. Firsthand experience also affected individual behaviours, but the impact was indirect.
Portugal [35]	Application of TPB to analyse intentions of participating in adaptation processes for climate change	Stakeholders' intention to engage was strongly influenced by subjective norms, which were shaped by their normative beliefs regarding policymakers and other stakeholders. Additionally, their perceived behavioural control, driven by their understanding of relevant policies and instruments, also played a significant role in predicting engagement intentions. The workshops carried out as part of the study were effective in affecting intentions to participate in certain processes.
India [36]	Application of the lifestyle of health and sustainability (LOHAS) tendency as an extension to understand sustainable consumption behaviour	The LOHAS tendency was confirmed to be an antecedent to attitudes of consumers, which in turn becomes an important predictor for consumer behaviour.
Lithuania [37]	Applying TPB to understand determinants of intentions to use renewable energy.	The level of development of renewable energy and financial capabilities of respondents had the most impact on intention to use renewable energy. A significant positive relation was also observed between subjective norms and intention to use renewable energy, but no such correlation was observed between attitudes and intention to use renewable energy.

While alternative behavioural theories, such as Protection Motivation Theory (PMT) and Norm Activation Theory (NAT), could have been considered, TPB was selected due to its well-established empirical support in predicting decision-making processes related to pro-environmental behaviour. PMT primarily focuses on threat appraisal and coping mechanisms, making it more applicable to contexts where individuals perceive immediate risk (e.g., disaster preparedness). NAT emphasises moral and normative influences but does not explicitly incorporate perceived behavioural control, which is critical for understanding whether individuals feel capable of undertaking home renovations. In contrast, TPB provides a structured yet flexible approach that accounts for both social and psychological determinants of behaviour while allowing for the integration of additional contextual factors.

3. Materials and Methods

3.1. Aim and Objectives

The aim of this paper is to investigate how homeowners' perceptions shape their decision-making processes related to renovations for climate change adaptation. Through a comprehensive analysis of the influence of these perceptions on behaviours, particularly in the context of home renovation, this study aims to provide nuanced insights into the complex dynamics of homeowners' perspectives. The main goal of this analysis is to highlight the challenges and opportunities for enhancing the climate resiliency of existing homes. The overall research question being addressed is as follows: "To what extent do internal and external factors influence homeowners' attitudes towards climate change risk and adaptive renovation?"

3.2. Survey Design

The data analysed in this paper was collected via an online survey targeting owners of one- and two-family houses residing in the Kronoberg region of Sweden. The survey was conducted over a period of 45 days in winter 2023. The survey design was guided by the Theory of Planned Behaviour (TPB) and the relevant literature. Each question was structured to align with one of the five main TPB constructs—attitudes, subjective norms, perceived behavioural control, intentions, and behaviour. Additionally, two extra thematic areas were incorporated based on prior studies [34]. These included homeowner characteristics (socioeconomic and demographic attributes) and building attributes (size, condition, and state of housing). Based on these, it was hypothesised that the two main factors influencing the model would be based on inherent homeowner qualities, the socioeconomic and demographic attributes, and building attributes, referring to the size, condition, and state of their housing. This draft contained questions inspired by the study of Bravo et al., with more questions being added addressing each thematic section of TPB [38], along with five questions for each subsection of TPB. To validate the survey, an initial draft was reviewed by a panel of experts in housing studies and behavioural sciences. Following this, the survey was pre-tested with 10 randomly selected homeowners from the Kronoberg region, who provided qualitative feedback on clarity, relevance, and ease of understanding. Based on their input, modifications were made to improve wording and response options. Table 2 presents a summary of the questions that were asked in the survey and how these were grouped based on the thematic areas of TPB.

Table 2. Summary of all questions present in the survey.

Question No.	Explanation of Question	Possible Responses and Associated Value	Identified Thematic Area
Q00	Type of house you live in	Townhouse, semidetached house, detached house, etc.	BA
Q01	Year of birth	>1985 (1), >1975 (2), >1965 (3), >1955 (4), ≥1925 (5)	IHQ
Q02	Highest level of education		IHQ

Table 2. *Cont.*

Question No.	Explanation of Question	Possible Responses and Associated Value	Identified Thematic Area
Q07	Year the house was constructed	10-year intervals between 1930 and 2020 (1–11)	BA
Q08	Length of time lived in current house	5-year intervals between <5 and >20 years (1–5)	BA
Q09	Heated living area of the house	30 sqm intervals between <31 and >120 sqm (1–5)	BA
Q10	Connection to municipal water system	Yes (1)/no (0)	BA
Q11	Type of heating system used in the house	Different types of heat pumps, boilers, or fireplaces (1–11)	BA
Q12	Primary façade material used	Brick (1), concrete (2), wood (3), or other (0)	BA
Q13	Describing the quality of aspects of the house: Water quality; Air quality; Thermal comfort	Likert scale rating, 1 (very poor)–5 (very good)	ATT
Q14	Past experiences of problems relating to: Indoor humidity or mould; Icicles on the roof; Flooding; Sewage overflow; Drainage; Roof overload; Detachment of exterior siding; Water/air leakage; Poor ventilation; Overheating; Lowered water quality; Structural damage from flooding	Likert scale rating, 1 (no problems)–5 (serious problems)	PBC
Q15	Past renovations in the last 10 years relating to: Façade; Drainage; Sewer; Roof; Windows; Roof insulation; Basement insulation; Outer layer insulation	Likert scale rating, 1 (major renovation)–3 (none)	BHV
Q16	Reasons for carrying out said renovation: Due to ageing/deterioration; Due to damages; To increase safety; To improve energy performance; To save money	Yes (1)/no (0)	PBC
Q17	Party responsible for carrying out said renovations	Owner with help of acquaintances (1), partially with help of companies (2), employed companies independently (3), and employed a general contractor (4).	SN
Q18	Financing of the renovation: Own savings; Mortgage loan; Private loan; Other	Yes (1)/no (0)	IHQ
Q19	Gross annual household income	150,000 SEK intervals between below 300,000 SEK to more than 750,000 SEK (1–5)	IHQ
Q20	Insurance provider	Alternatives between Sweden's top 10 insurance providers (1–10)	IHQ
Q21	Have you experienced any damage to any of the following: Façade; Drainage; Sewer; Roof; Windows; Roof insulation; Basement insulation; Outer layer insulation	No (0), yes (due to other reasons) (1) and yes (caused by climate disaster phenomena) (3)	BA
Q22	Knowledge regarding home insurance coverage	Likert scale rating, 1 (know nothing)–5 (know a lot)	IHQ
Q23	Coverage of climate-related damages under home insurance	Yes (1)/no (0)	IHQ
Q24	Impact of climate change on daily lifestyle	Likert scale rating, 1 (none)–5 (severe)	SN
Q25	Plans for future renovations in the next 10 years: Façade; Drainage; Sewer; Roof; Windows; Roof insulation; Basement insulation; Outer layer insulation	Yes (serious renovation) (3), yes (maintenance) (1), and no (0)	INT

Table 2. *Cont.*

Question No.	Explanation of Question	Possible Responses and Associated Value	Identified Thematic Area
Q26	Reasons for planned renovation: Due to ageing/deterioration; Due to damages; To increase safety; To improve energy performance; To save money	Likert scale rating, 1 (disagree)–5 (agree)	BHV
Q27	Who should be held responsible for future damage resulting from a climate-related event/phenomenon,	Myself, the municipality, the County Administrative Board, and the insurance provider	SN
Q28	Previous experience with climate change-related events/phenomena: Heatwaves; Cold waves; Drought; Extreme snowfall; etc.	Yes (1)/no (0)	ATT
Q29	Experience of this phenomenon	Directly, indirectly, or unaffected by it	ATT
Q30	Expected likelihood of climate-related event/phenomenon soon	Likert scale rating, 1 (very low)–5 (very high)	
Q31	Extent of influence of previous experience of climate-related events/phenomena on decisions for major renovation or maintenance of your house	Likert scale rating, 1 (very low)–5 (very high)	PBC
Q32	Need to relocate due to climate disasters in the last 20 years.	Yes (in Sweden), yes (outside Sweden), no	
Q33	Knowledge about climate change and its impacts	Likert scale rating, 1 (very low)–5 (very high)	ATT
Q34	Extent of impact of climate change on surrounding society	Likert scale rating, 1 (very low)–5 (very high)	SN
Q35	Participation in training programmes for climate disaster response/preparedness	Yes (for a long time) (2), yes (recently) (2), no (but I intend to) (1), and never (0)	BHV
Q36	Which of the following climate change-related events/phenomena concerns you the most regarding your house: Heatwaves; Cold waves; Drought; Extreme snowfall; etc.		ATT
Q37	Other climate change-related measures taken: Using energy-efficient bulbs; Purchasing energy-efficient electronic appliances; Using smart heating/cooling solutions; Using renewable energy solutions; Reducing air travel; Reduce, reuse, recycle.; Minimise organic material waste.; Calculate my household's carbon footprint	Yes (1)/no (0)	BHV
Q38	Do you take any additional measures to adapt to climate change (multiple options may be selected): Collect rainwater to reduce consumption; Plant trees to create shaded areas; Invest in protective measures for my house; Educate myself to raise awareness about climate change; Planting tree species and forestry practices less vulnerable to storms and fires.		BHV
Q39	You identify as	Male, female, and other/do not wish to respond	IHQ
Q40	Are you married/cohabiting?	Yes (1)/no (0)	IHQ
Q41	Number of adults (>18 years old); children (13–17 years old); children (<13 years old) living in the house	None	IHQ

The questions were grouped based on the thematic areas that they addressed based on the theory of planned behaviour. For example, questions under 'Inherent Homeowner

Qualities' (IHQs) address socioeconomic and demographic attributes of the homeowners, and questions under "Behaviour" (BHV) address the underlying behaviours of performing renovations. For questions where either a rating had to be provided for multiple aspects of the house (e.g., Q15) or multiple options could be chosen, the sum over all responses was calculated for each question. However, given that the number of responses was small, not all questions could be considered. To address this limitation, multifactor analysis was conducted to find which questions were most statistically significant. This ensures that only the most relevant and independent variables are included in the regression analysis, minimising noise in the model. Equation (1) was used to perform factor analysis:

$$X = LF + E \quad (1)$$

Here X is the matrix of observed questions, L is the factor loading matrix, F is the matrix of common factors, and E is the matrix of unique factors. Based on this, the eigenvalues for the matrix were calculated, and questions with eigenvalues greater than 0.5 were selected for further analysis. These significant variables were then isolated, and their sum was calculated. The sum values for each variable were then used for performing the OLS regression and 2-SLS regression. Table 3 shows the questions selected for each variable based on the multifactor analysis.

Table 3. Grouping of significant questions based on TPB.

Variable	Ques.	Explanation
IHQ	Q19	Annual household income
	Q41	Number of adults in household
BA	Q00	Type of house
	Q09	Heated living area of the house
ATT	Q24	Impact of climate change on daily life
	Q28	Experience of climate disasters
PBC	Q14	Previous experience with damages to aspects of the house
	Q16	Reasons for carrying out renovations in the past 10 years.
	Q30	Expected damage to the house in the next 10 years
SN	Q34	Impact of climate change on society
INT	Q25	Plans to carry out future renovations
BHV	Q15	Parts of the house renovated over the past 10 years.
	Q35	Participation in training programmes for climate disaster response/preparedness
	Q37	General climate change-related measures they take.
	Q38	Measures taken to adapt to climate change

Figure 3 shows two modified versions of the TPB model that were used to structure the analysis in this paper. AT, PBC, and SN are treated as independent variables in this study, while IHQ and BA are included as contextual variables that may influence homeowners' intention and behaviour. The inclusion of these variables is based on previous studies [21], which suggest that contextual factors significantly affect decision-making in home renovations. In addition to the 2-SLS analysis, the correlation between input variables and behaviour is also studied for comparison.

Python 3.11 was used to perform the analysis of the results, while Microsoft Excel® was used for data pre-processing and cleaning. A two-stage least squares (2-SLS) regression analysis was then conducted, followed by ordinary least squares (OLS) regression to investigate the relationship between the input variables and INT and BHV. The choice of OLS and 2-SLS regression models is driven by the following two main considerations: (1) the need to understand the direct relationships between variables and (2) the need to control for potential endogeneity. Ordinary least squares (OLSs) regression was used first to establish baseline relationships between input variables and INT/BHV. However, since there is a possibility of endogeneity—where certain input variables may be correlated with the error term—2-SLS regression was introduced as a robustness check. The use of 2-SLS allows for the correction of potential biases by incorporating instrumental variables that help isolate the true causal effect. This methodological approach aligns with prior research that has applied the theory of planned behaviour within similar empirical frameworks [17,22,25]. The function for the first stage of the 2-SLS regression is given by Equation (2):

$$\hat{\beta} = X\left(X^T X\right)^{-1} X^T y \tag{2}$$

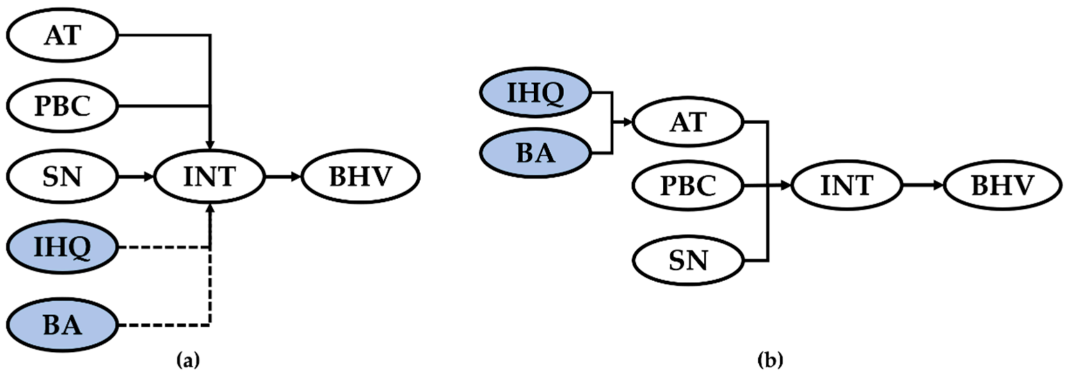

Figure 3. Two possible configurations for extended TPB wherein IHQ and BA are either direct determinants of intention (**b**) or determinants of atittude indirectly determining intention (**a**).

This equation estimates the predicted values of endogenous variables using the instrumental variables, ensuring that endogeneity does not bias the regression coefficients. The equation for the second stage of regression, used to find the relationship between input variables and INT, is given in Equation (3):

$$INT = \beta_1 IHQ + \beta_2 BA + \beta_3 ATT + \beta_4 PBC + \beta_5 SN \tag{3}$$

Similarly, the relationship between input variables and BHV is given in Equation (4):

$$BHV = \beta_1 IHQ + \beta_2 BA + \beta_3 ATT + \beta_4 PBC + \beta_5 SN \tag{4}$$

Here, $\hat{\beta}$ is the ordinary least squares estimator, X is the matrix regressor variable, X^T is the transpose of the variable matrix, and y is the vector value of the response variable. The assumption underlying OLS is that explanatory variables are independent of the error term. However, if this assumption is violated due to endogeneity concerns, the 2-SLS model provides a more reliable estimation by instrumenting endogenous variables. This step is particularly important when studying behavioural decision-making, as omitted variable bias and simultaneity issues are common. To ensure robustness, only variables that had a p-value ($p > |z|$) less than 0.05 were considered for further analysis. This threshold ensures that the selected factors have a statistically significant impact on the dependent variables. Figure 4 contains a workflow of the analysis of results.

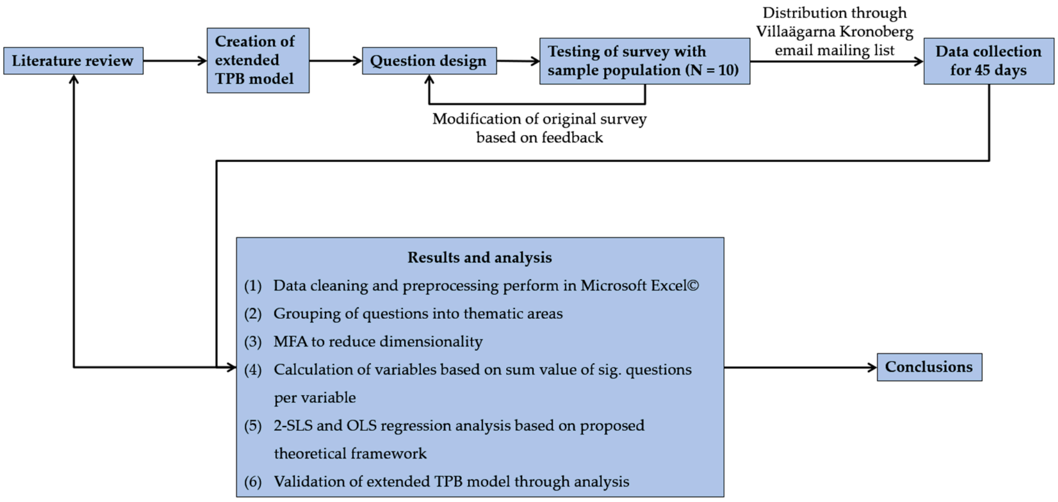

Figure 4. Methodological framework.

4. Results and Discussion

The survey was shared with 1395 members of Villaägarna Kronoberg; 143 responses were received, of which 139 responses were used for analysis, giving a response rate of ~10%. Table 4 contains a summary of the basic socioeconomic indicators of responses obtained from the survey. To evaluate whether the responses had internal consistency, the McDonald's omega value was calculated using Equation (5):

$$\omega = \frac{(\Sigma\lambda_i)^2}{(\Sigma\lambda_i)^2 + \Sigma\psi_i} \tag{5}$$

Table 4. Comparison of survey response data with data from SCB (adapted from [13]).

Age Group (Years)	<39	40–49	50–59	60–69	70–79	>79
Survey	2.38	7.94	11.9	25.4	40.5	11.9
SCB data	14.1	19.1	20.8	21.1	16.9	8.03
Year house was built	Before 1950	1951–1960	1961–1970	1971–1980	1981–1990	After 1991
Survey	26.3	12.8	16.5	24.8	6.02	13.5
SCB data	38.6	8.29	15.8	22.3	6.73	8.31

Here, λ_i is the factor loading for each item and ψ_i is the error variance for each item. McDonald's omega value was used instead of Cronbach's alpha due to its more robust nature, as it does not assume tau-equivalence [38]. Based on this equation, the omega value must be over 0.7 to be reliable. For this study, the calculated omega value was 0.83, suggesting good reliability of responses.

4.1. Non-Response Bias

It is necessary to identify whether the breadth of responses collected through the survey are representative of the population of the Kronoberg region. The data for this table was adapted from [13], as presented in Table 4.

The survey responses, in terms of homeowner age, skewed heavily towards the older age groups, with those within the '70–79' age group being heavily over-represented, along with the 'older than 79' age group. Conversely, all homeowner groups below the age of 59 were represented, with no respondents from the 'below 39' age group present in the survey results. While it is hard to ascertain exactly how this would impact the results, it is important to note that the results are not representative of the actual population of homeowners in the Kronoberg region, skewing the inherent homeowner qualities. Conversely, such a large discrepancy was not observed in the responses for the year the respondents' house was built, meaning the responses regarding house age may be considered a fair representation of the total single-family dwelling stock in the Kronoberg region. Addressing the age group discrepancy between the surveyed sample and the general population of the Kronoberg region presents an opportunity for future research adopting various alternative distribution channels. To assess whether our sample size was sufficient for the regression models employed, we conducted a Monte Carlo-based power analysis. Using the observed effect sizes from our OLS and 2-SLS models, we simulated repeated samples to estimate the statistical power. These results are presented in Table 5.

Table 5. Power values for each regression analysis for an increasing number of observations.

Number of Observations	OLS (INT)	OLS (ATT)	2-SLS (BHV)
136	0.854	0.993	0.358
200	0.953	0.999	0.397
300	0.993	1.000	0.521
400	1.000	1.000	0.600
500	1.000	1.000	0.680
600	1.000	1.000	0.739
700	1.000	1.000	0.784
725	1.000	1.000	0.808

For the number of actual observations in the survey ($n = 139$), the results showed that a minimum of 725 respondents would be required to achieve a power value above the threshold of 0.8 at an alpha level of 0.05. Given that this survey only had 139 respondents, this study has an insufficient sample size to provide generalisable results for the 2-SLS model.

4.2. Results from OLS Regression Analysis

4.2.1. OLS Regression Analysis for All Input Variables and INT

Comparable results were found in the OLS regression performed. These results are presented in Table 6.

Table 6. OLS regression results for all input variables with intention to perform climate-adaptive renovations.

Variable	$R^2 = 0.514$		
	β	Std. Error	*p*-Value
IHQ	1.090	0.842	0.198
BA	−0.179	0.548	0.745
AT	0.692	0.343	0.046
PBC	0.240	0.344	0.487
SN	0.395	0.678	0.561

Here, the obtained R-squared value was 0.514, indicating a weaker explained variance by the terms found. The difference in R^2 values may be indicative of the notion that the factors considered are not adequately capturing the underlying relationship between the independent (IHQ, BA, ATT, PBC, and SN) and dependent variable (INT). Much like for behaviour, the relation between intentions to perform renovation and attitude showed a statistically significant correlation with behaviour, while other variables were statistically insignificant. A stronger relationship between attitude and behaviour rather than attitude and intention may imply individuals' attitudes toward climate-adaptive behaviours. Given the number of insignificant variables, it is also possible that there is a strong presence of experience bias among respondents; the Kronoberg region has been relatively insulated from climate-related disasters in the past [39], and due to the infrequency with which climate disasters occur in the region, the respondents do not perceive these issues to be of necessary importance. This issue may be addressed through a larger sample size covering different regions of Sweden. Additionally, it was found that subjective norms played a much smaller role than in other studies [40–42]. This may also be resulting from the following cultural differences: Swedish society places greater importance on individualism [43,44]. Given this emphasis, it is possible that individualism is impacting why subjective norms have a smaller influence in Swedish society compared to respondent attitudes. However, a larger sample size would be needed to confirm this conclusion, despite agreement with previous works.

4.2.2. OLS Regression Analysis for IHQ, BA, and AT

Here, the relation between BA and AT was studied. These results are presented in Table 7.

Table 7. OLS regression for IHQ, BA, and AT.

Variable	**Significance Statistics for INT (R^2 = 0.47)**		
	β	**Std. Error**	***p*-Value**
IHQ	1.93	0.77	0.014
BA	0.688	0.35	0.052

Here, the obtained R-squared value was 0.47, indicating a weaker explained variance by the terms found. While this fit is moderate, it leaves significant unexplained variability, suggesting that other important factors influencing the dependent variable may not be included in the model. Despite this, the power analysis yielded a high value of 0.993, indicating a strong ability to detect true effects if they exist and reducing the likelihood of Type II errors. IHQ was found to be statistically significant at the 5% level ($p < 0.05$), while both IHQ and BA were found to be significant at the 10% level ($p < 0.1$). The main difference here indicates that inherent homeowner qualities, primarily income and household size, significantly affect attitude. The F-statistic of ~60 with a sample size of 136 suggests that at least one of the predictor variables is strongly correlated with the outcome. While the high power ensures that statistical significance is robust, the moderate R^2 highlights the limited explanatory strength of the model, meaning that other significant factors are present but have not been considered.

4.3. Results from 2-SLS Regression Analysis for All Input Variables and BHV

Table 8 shows the results from the regression analysis using the 2-SLS method. The R^2 value here was found to be 0.81. BHV only showed statistical correlation with AT (attitude) at the 5% level and with IHQ at the 10% level.

Table 8. 2-SLS regression for BHV.

Variable	**β**	**Std. Error**	***p*-Value**
IHQ	0.644	0.336	0.055
BA	0.167	0.202	0.402
ATT	0.322	0.123	0.009
PBC	0.204	0.129	0.115
SN	0.036	0.245	0.883

Based on the estimated parameters, only attitude proved to be statistically significant within the model, whereas all other variables showed no statistically significant effect. Additionally, a large standard error was found for all variables, potentially indicating the need for a larger sample size to reduce uncertainties. A positive coefficient implies that individuals with more positive attitudes toward the behaviour are more likely to exhibit it. In this case, the questions used for defining the attitude variable were concerning the impacts of climate change on the daily life of the respondent and their previous experiences with climate disasters. Other studies, like the study in Belgium, for example, showed similar results, with attitude being the most significant determinant of behaviour [41]. While this study cannot establish a strong causal determination, it is possible to state that a definite correlation exists. Studies have shown that past behaviours can have a positive correlation with current/future behaviours [21,44,45], while some alternate studies suggest that the relationship may follow a more inverted U-shaped relation [46]. The 'attitude' variable addresses questions related to the impacts of climate change on daily life and experiences with climate disasters. Cognitive attitudes involve beliefs and perceptions about the subject matter [6]. Although in the application of the theory of planned behaviour, questions addressing behavioural attitudes regarding thoughts and perceptions of the specific behaviour are given more weight [5], the results still show some correlation between having previously experienced climate change issues and engaging in climate-adaptive behaviours.

Several studies have examined policy-driven approaches to influencing homeowner adaptation to climate risks. Experiential learning initiatives, such as virtual simulations, participatory workshops, and real-life case studies, have been shown to reinforce the tangible consequences of inaction and improve preparedness. Given that homeowner attitudes are a key barrier to climate adaptation, experiential methods are particularly valuable as they allow individuals to internalise climate risks. While Sweden's building codes are already being modified to enhance climate resilience, increasing consumer awareness remains essential to ensure homeowners actively engage in adaptation measures. Paton [27] and Luis et al. [35] highlight how stakeholder engagement and risk communication strategies can enhance climate adaptation efforts. Financial incentives, including renovation subsidies, preferential loans, and insurance discounts for climate-adaptive upgrades, have been found to increase policy acceptability and encourage participation in sustainability measures. Studies by Conradie et al. [28] and Bazart et al. [30] emphasise the effectiveness of financial mechanisms in fostering climate-responsive behaviour. Mandating climate risk disclosure in real estate transactions has also been proposed as a way to ensure that prospective homeowners make informed adaptation decisions. Research suggests that access to climate information strengthens decision-making, with studies by Bazart et al. [30] and Ritu and Kaur [33] supporting this approach. Additionally, community-based adaptation networks can facilitate peer-to-peer learning and promote collective resilience investments.

The results indicate a potential discrepancy between the model's explanatory power and its statistical reliability. While the regression model exhibits a high R^2 value of 0.812, suggesting that it explains a substantial proportion of variance in the dependent variable, the power analysis yielded a low value of 0.36. This low power suggests that the model is failing to detect significant effects. The explanation for this is the sample size, which may be insufficient to provide the necessary statistical power despite the model appearing to fit the data well. Additionally, multicollinearity among predictors could inflate R^2 while simultaneously reducing the ability to detect individual predictor effects. Additionally, it was also found from the power analysis that due to the nature of the analysis, a minimum of 725 responses would be needed to form a concrete conclusion for the 2-SLS regression model, while the number of responses obtained was sufficient for the other two regression analyses.

5. Conclusions

This study investigated the factors influencing homeowner behaviour regarding climate-adaptive renovations, drawing upon an extended Theory of Planned Behaviour as its framework. The questions of the survey were designed based on the elements of the theory of planned behaviour, along with additional elements obtained from a literature review. Due to different possible configurations for the inclusion of inherent homeowner qualities (IHQs) and building attributes (BAs), the following three regression analyses were performed:

(i) OLS regression for IHQ, BA, AT, PBC, SN, and INT.
(ii) OLS regression for IHQ, BA, and AT.
(iii) 2-SLS regression for all input variables and BHV.

The results indicate that attitude (ATT) is the most significant predictor of both intention (INT) and behaviour (BHV). The OLS regression analysis for intention (Table 5) showed that attitude was the only statistically significant factor ($p = 0.046$), while all other variables—including IHQ, BA, PBC, and SN—were insignificant. Similarly, the 2-SLS regression for behaviour (Table 7) confirmed that attitude remained the strongest predictor ($p = 0.009$), whereas all other variables, including subjective norms, showed no statistically significant effect. This suggests that homeowners' beliefs about climate change impacts and their prior experiences with climate-related disasters strongly influence their willingness to adopt adaptive renovations. While inherent homeowner qualities (IHQs) and building attributes (BAs) were found to influence attitudes (Table 6), their direct effects on behaviour were limited. IHQ, which includes annual household income and household size, was statistically significant at the 5% level ($p = 0.014$) in predicting attitude, while BA, encompassing house type and heated living area, was significant at the 10% level ($p = 0.052$). This suggests that financial capacity and housing conditions shape climate-related attitudes but do not directly translate into renovation behaviour.

Policy implications of these findings suggest that simply raising awareness about climate risks is insufficient. Interventions should focus on shifting homeowner attitudes through targeted messaging and experiential learning. Case studies from areas that have experienced climate-related disasters, interactive workshops, and real-world examples of property damage could be effective in reinforcing the tangible consequences of inaction. Additionally, since income and household size influence attitudes, financial incentives such as renovation subsidies or preferential loans for climate-adaptive upgrades may encourage behaviour change.

6. Limitations and Further Work

Compared to previous studies, subjective norms (SNs) played a less significant role in influencing renovation decisions. This outcome may be attributed to Sweden's strong cultural emphasis on individualism. In contrast to findings from Belgium and other European contexts, where social norms heavily shape renovation behaviour, Swedish homeowners appear to rely more on personal attitudes than societal expectations. However, an alternative explanation is that the influence of subjective norms was not adequately captured due to the variable reduction process, which may have removed relevant predictors. This aligns with existing research on cultural differences in environmental decision-making, where collectivist societies exhibit stronger norm-driven behaviours than individualist ones. Additionally, the results suggest a potential experience bias in the surveyed population. The Kronoberg region has been relatively insulated from severe climate-related disasters, which may have led respondents to perceive climate-adaptive renovations as less urgent. This perception could reduce the explanatory power of the model (R^2 = 0.514 for INT, R^2 = 0.41 for AT) and contribute to potential overfitting (R^2 = 0.821 for BHV). A broader study including regions with more frequent climate-related events, such as Skåne or Gävle, may yield different findings by capturing a population with higher perceived climate risk.

Future research should address the limitations identified in this study. A longitudinal follow-up within 3–5 years could assess whether current attitudes translate into actual renovations over time, helping to establish stronger causal links. Expanding the sample size to include diverse geographic regions and a broader range of housing types would also improve generalisability. Furthermore, incorporating qualitative insights through interviews could provide deeper context on the psychological and financial barriers to climate-adaptive renovations.

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Abbreviations

The following abbreviations are used in this manuscript:

TPB	theory of planned behaviour
IHQ	inherent homeowner qualities
BA	building qualities
AT	attitude
PBC	perceived behavioural control
SN	subjective norm
INT	intention
BHV	behaviour
OLS	ordinary least squares
2-SLS	two-stage least squares

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