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# 'Stakeholder Perceptions' of the Impacts of Climatic Features on Residents and Residences: A UK Study

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**Abstract:** Liveable housing environments face the menace of global climate change. Built infrastructure (including buildings and houses) continuously experiences significant impacts that are exacerbated by natural variability in the climate. Our study examined how climate change impacts the resilience of residential buildings, increases maintenance frequency, and the wellbeing and comfort of residents in UK residential buildings. This study used deductive reasoning and an empirical epistemological methodology as the basis of primary data collection via a questionnaire survey. The instrument was designed to gather data on the frequency of maintenance and the wellbeing of residents and their perceptions regarding the impacts of climate change. Through regression analysis of the data, the findings showed a significant relationship between climate change and the wellbeing of the occupants of UK residential buildings. Also, physical wellbeing and social wellbeing are more important to the occupants than their mental wellbeing. The cost of maintenance of residential buildings in the UK has an upward trajectory due to the continuously reducing resilience of building fabrics caused by the impacts of climate change; for instance, a recent increase in rainfall/storms resulted in unprecedented flooding, which damaged the fabrics of some UK residential buildings.

**Keywords:** UK climate; impacts of climate change; resilience of building fabrics; residential buildings; deterioration of building fabrics; occupants of buildings



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## 1. Introduction

Droughts, heavy precipitation, flooding, and rises in temperature are a few examples of climate-induced risks that can endanger human health and the built environment and result in significant financial losses [1]. The urgency of addressing the impacts of climate change is evident globally, reshaping economies, communities, behaviours, and landscapes [2]. Hurlimann et al. emphasise the crucial role of building resilience through adaptation strategies to oppose both current and future impacts of climate change, alongside efforts to reduce greenhouse gas emissions to net zero by 2050 [3]. This underscores the power of the construction industry professionals in shaping a more resilient future. However, the last Conference of the Parties (COP) 28 UAE-United Nations Climate Change Conference resolved to accelerate energy transition and emissions reduction before 2030 [4].

Developing a 'liveable' housing environment is not just a priority, but a necessity of various sectors, especially the construction industry [5]. Housing environments face different challenges that impact liveability, such as climate change and its effects [6]. Moreover, the UK Department for Environment, Food & Rural Affairs asserted that infrastructure continuously experiences significant impacts exacerbated by natural variability in climate [7]. This impact extends to buildings and houses, making the need for immediate action against climate change even more apparent. Moreover, a recent report by Lacasse et al. shows that the impacts of climate change significantly influence the frequency of maintenance and deterioration of buildings [8].

This research explored the stakeholders' perceptions of the impacts of climatic features on residents and residences in the UK. The preceding overview gave rise to the following research questions (RQ).

1. What are the stakeholder perceptions on how climate change significantly impacts residential building occupants?
2. What are the stakeholders' views about the potential impacts of climate measures on building occupants?
3. What are stakeholders' views on how climate change is impacting the resilience of residential buildings?
4. What is the opinion of the stakeholders on the relationship between the effects of climate change and the degradation of building materials?

Liveable housing environments face the menace of global climate change. The main aim of the Building Act 1984 and Building Regulations 2000 in the UK is to ensure health, security, safety and wellbeing, waste reduction, energy and water conservation, and comfort for the occupants or users [9]. Even though much has been discovered about how energy systems, emissions, ambient greenhouse gas concentration, and climate change are related, comparatively little research has concentrated on the effect of climate change on residential buildings [10]. The quality of the built environments influences the severity of climate change impacts on them [11,12], as informed in RQ4. However, most buildings needed to be constructed considering the impacts of climate change [13]. Future cities strive to be sustainable, liveable, and resilient to ensure that their citizens live happily and healthily in affordable homes that are cost efficient and resilient to any future shocks and stresses [14]. The impacts of climate change are primarily felt in densely populated areas, affecting people's domestic lives, such as increased risk for flooding in certain regions, drought, heat stress, rainstorms, snowstorms, ice storms, thunderstorms and lightning, windstorms, including hurricanes, cyclones, typhoons, tornadoes and whirlwinds, sandstorms, landslides, avalanches, sea level rise, fires and bush fires, overturning of trees, and health problems [15,16]. This view informed RQ1 and RQ2. Zhou et al. claimed that in the north of Europe (Bodø), freeze-thaw damage and wood decay are expected to grow (81% and 68% of the cases, respectively) due to climate change altering the heat and moisture behaviour of building components [17]. Vardoulakis et al. opine that the degree to which buildings are affected by the impacts of climate change depends on the location, microclimate, and housing type [12]. Climate risk also affects its residents' socioeconomic composition and attitudes, resources, and governance conditions [18].

The global climate has been relatively stable at about 14 °C since the ice age, which ended 11,000 years ago [19]. However, science has shown that, since 1880, the average temperature has increased by 0.08 °C per decade, or one °C between 1900 and 2021 [20]. The Anthropogenic global warming theory predicts that by the year 2100, the Earth's temperature could rise by an additional 3 °C, which could threaten water availability, agricultural productivity, sustainable development, forest fire risk, drought, and flooding because of the rise in the sea level [19]. Additionally, Fawzy et al. warn that global warming will increase from 1 °C to 1.5 °C if emissions persist between 2030 and 2052 [21].

The National Infrastructure Commission reported that the UK's temperature rose by 0.90 degrees Celsius between 2005 and 2014 compared to 1961 and 1990 [22]. Since 1990 was the warmest year on record, this temperature is predicted to climb even more in the UK, especially in the summer, reaching 4 °C in the south and 2.5 °C in the north by the 2080s [23]. The rate of climate change and its impact on the environment and housing liveability are largely determined by the level of greenhouse gas emissions. Residential buildings emit 15% of $CO_2$ using fossil fuels for space heating and hot water production, which play a significant role in this [24]. Gupta and Gregg argue that a warming climate compromises comfort and liveability, prompting UK policymakers to focus on mitigating climate change by aiming to reduce $CO_2$ emissions by 80% by 2050 [25].

Climate change has led to more frequent heat waves, which not only impact residential buildings but also the health of their occupants, particularly those with limited ability to manage temperature, such as the elderly, infants, the sick, and those living alone [26,27]. Hence, it necessitates the use (energy) of a mechanical cooling system, which also contributes to climate change through greenhouse gas emissions [28]. Dino and Meral Akgül projected that the increased severity of climate change impacts primarily the built environment, threatening both indoor and outdoor activities, leading to occupant discomfort, health issues, decreased productivity, and even displacement due to factors such as population growth, changes in building energy usage, and increased demand for comfort [29]. Sanders and Phillipson further supported that climate change affects residential buildings through the impact of the combination of wind and precipitation, i.e., wind-driven rain [30]. It is anticipated that buildings would sustain significant damage from wind-driven rain (WDR) due to climate change, such as damage to building materials resulting from moisture ingress through cracks, failure of building elements, and frequent gutter over-spill [31]. A study on the preservation of cultural assets made of ancient brick masonry in London indicated medium risk by 2040 and high risk by 2080 due to moisture buildup, mould growth, and freeze-thaw (FT) cycles [32]. The potential risks to buildings and residents are a significant concern that our research aims to address. The deposition of moisture resulting from wind-driven rain (WDR) can have a negative effect on building wall components and ultimately affect their performance over time [31].

Murray and Ebi opined that climate actions, such as mitigation and adaptation, are crucial for reducing the long-term consequences of global warming on buildings [33]. Climate change damage is a global issue, with disastrous events predicted if urgent action is not taken to limit global temperatures to 2 °C [34]. Extreme climate events have resulted in significant human casualties and property losses [35]. The urgency for action is evident, as global warming threatens water availability, agricultural productivity, and the resilience of nations towards climate emergencies [25]. The impacts of climate change are already observable, necessitating adaptive measures for both new and existing residential buildings to maintain a healthy indoor environment and occupant comfort [36,37].

A study conducted by Kreft et al. shows that more than 530,000 people died worldwide between 1994 and 2013, and about USD 2.17 trillion of public and private property (PPP) was lost due to over 15,000 extreme climate events [35]. In addition, over 10,600 people lost their lives in 2014/15 alone because of a lack of sufficient asset integrity in many infrastructures around the globe, exacerbated by adverse weather conditions. The threat continues as it was estimated that 80 million people across 20 states were warned over climate change disasters [10].

While studies have focused on the impacts of climate change mitigation and energy retrofitting programs on indoor air quality [38,39], the House of Common Library has highlighted research areas such as assessing the risks of climate change to building fabric from moisture, wind, and driving rain and the health impact of changes in air quality in residential buildings [12]. Therefore, our research explored the stakeholders' perceptions of the impacts of climatic features on residents and residential buildings in the UK, including floods, wind damage, driving rain, increases in wildfires, subsidence, and the internal/external environment of buildings. Moreover, the stakeholders' perceptions would point to immediate and long-term concerns, which would be addressed by individual homeowners, communities, local authorities and the UK Government bodies. Different perspectives enhance collaboration between policymakers and stakeholders in decision-making. This includes co-designing and consulting procedures, ensuring openness, prioritising public health or future requirements, and developing a strategy to minimise the impacts of climate change [40,41].

## 2. Methodology

This study used a quantitative survey approach to address the research questions indicated in the introduction. The quantitative method is widely accepted in social science research and is most suited for quantifying more data [42]. The choice and use of questionnaires in quantitative research design processes often consider the aim of this study, the kind of data to be collected, and the resources available [43]. A questionnaire was deemed fit for this study for these reasons:

- To easily pool data from different locations in the UK.
- To ensure confidentiality and promote honest responses due to the sensitivity of the subject matter.
- To indirectly moderate the researchers' participation in the survey and thus reduce biases [43].

This study employed a five-point Likert scale in the questions, designed to address issues related to the impact of wind, rain, temperature rises, humidity, flooding, drought, and wildfire on residents and residential buildings and to determine how climate change affects occupants of buildings. However, the questionnaire included 30 multiple-choice closed-ended questions.

The impacts of wind, rain, a rise in temperature, humidity, flooding, drought, and wildfire on residential buildings and the impacts of climate change on the occupants of buildings were examined to seek the stakeholders' opinions. Some questions were used to check for consistency among the replies and to evaluate how well participants understood climate change and its effects on residential structures in the UK. This covers questions 24–25, 33–34, and 36–37. Question 24 was put across to the respondents as climate change negatively impacts the occupants of residential buildings in the UK. In contrast, question 25 was presented to the respondents, as climate change has positive impacts on the occupants of residential buildings in the UK.

The questionnaire survey was conducted online using the Pollfish platform. Prior to data collection, the Ethics Committee of the Faculty of Science and Engineering of the University of Wolverhampton granted ethical permission.

A pilot study was first conducted where ten responses were received and informed the following changes:

- Several lengthy questions were re-edited.
- A few questions were removed since they did not affect the study's objective.
- Certain questions were asked more than once; these were eliminated.
- Additionally, typographic problems were found and fixed.

The participants for this study were randomly selected from UK households that were deemed vulnerable to climate change. This geotargeting was accomplished using Pollfish, an online platform known for its user-friendly multimedia interface that aids in quick data collection from people anywhere in the world [44]. A total of 550 questionnaires were distributed to UK residential addresses, randomly selected from the lists of homes vulnerable to climate change impacts. In response, 330 questionnaires were returned, but 14 were excluded due to incomplete information. This resulted in a net sample size of 316, representing a response rate of approximately 57.1%. The net data used were obtained from the following nations: 222 from England (70%), 8 (3%) from Northern Ireland, 42 (13%) from Scotland, and 44 (14%) from Wales as shown in Table 1.

**Table 1.** Demographic Information.

| Variable | Categories | Frequency | Percentage (%) |
|---|---|---|---|
| Gender | Female | 166 | 52.5 |
| | Male | 150 | 47.5 |
| | Total | 316 | 100 |
| Age | >54 | 59 | 18.7 |
| | 16–17 | 3 | 0.9 |
| | 18–24 | 22 | 7 |
| | 25–34 | 89 | 28.2 |
| | 35–44 | 96 | 30.4 |
| | 45–56 | 47 | 14.9 |
| | Total | 316 | 100 |

**Table 1.** *Cont.*

| Variable | Categories | Frequency | Percentage (%) |
|---|---|---|---|
| Education | Elementary | 2 | 0.6 |
| | Diploma/Certificate | 83 | 26.3 |
| | Postgraduate | 55 | 17.4 |
| | Bachelor | 131 | 41.5 |
| | Vocational | 45 | 14.2 |
| | Total | 316 | 100 |
| Level of knowledge | Knowledgeable | 139 | 44 |
| | Low Knowledgeable | 118 | 37.3 |
| | Not Knowledgeable | 17 | 5.4 |
| | Very knowledgeable | 42 | 13.3 |
| | Total | 316 | 100 |
| Income | Under £15,000 | 48 | 15.19 |
| | Between £15,000 And £29,999 | 69 | 21.84 |
| | Between £30,000 And £44,999 | 59 | 18.67 |
| | Between £45,000 And £74,999 | 76 | 24.05 |
| | Between £75,000 And £124,999 | 33 | 10.44 |
| | Between £125,000 And £199,999 | 9 | 2.85 |
| | £200,000 or More | 14 | 4.43 |
| | Prefer not to say | 8 | 2.53 |
| | Total | 316 | 100 |
| Area of residence | England | 222 | 70 |
| | Northern Ireland | 8 | 3 |
| | Scotland | 42 | 13 |
| | Wales | 44 | 14 |
| | Total | 316 | 100 |

### *2.1. Analysis and Results*

#### 2.1.1. Demographic Information of the Respondents

Table 1 shows the sociodemographic characteristics of the respondents. The table displays the respondents' positions where 42 respondents (13.3%) indicated that they were very knowledgeable of the impacts of climate change on residents and residences, 139 (44%) had knowledge, 118 (37.3%) had low knowledge, and 17 (5.4%) indicated not knowledgeable. Eighty-three respondents (26.3%) had diploma certificates, and fifty-five (17.4%) had postgraduate degrees. A total of 131 (41.5%) attended university, and 45 (14.2%) attended vocational-technical college. The collation revealed that most respondents had university degrees. A total of 150 (47.5%) were male, and 166 (52.5%) were female. Most respondents were between 35 and 44 years old, comprising 96 (30.4%) people. The age group of 25–34 represented 89 (28.2%) people from the sample, 59 (18.7%) were above 54 years, 22 (7%) were aged 18–24 years, and 3 respondents (10.9%) were aged 16–17 years.

#### 2.1.2. Respondent Resident and Residencial Types

Table 2 shows that 71 respondents (22.5%) had two occupants, 66 respondents (20.9%) had 3, 9 respondents (2.9%) had 7, 78 respondents (24.7%) had 4, 40 respondents (12.7%) had 5, 11 respondents (3.5%) had 6, and 41 respondents (13%) had 1. Results indicate that the majority of households had four occupants. Moreover, 257 (81.3%) had insurance, 32 (10.1%) had no house insurance, and 27 (8.5%) were not sure of their residential building insurance. A total of 199 (63%) were homeowners, 115 (36.4%) rented the property, and 2 (0.6%) were others. Regarding their type of residence, seventy-one (22.5%) indicated detached buildings, 144 (46%) indicate semi-detached houses, 67 (21%) indicate Terrace buildings, 11 (4%) indicate a house-end-terraced, and 23 (7%) indicate others. On the type of floor of the residence, two hundred and one (63.6%) indicate concrete floors, 31 (9.8%) indicate timber floors, and 84 (26.6%) are still determining their building floor type.

**Table 2.** Respondent resident and residential types.

| Variable | Categories | Frequency | Percentage (%) |
|---|---|---|---|
| Building types | Detached | 71 | 22.5 |
| | End terrace | 11 | 4 |
| | Other | 23 | 7 |
| | Semidetached | 144 | 46 |
| | Terrace | 67 | 21 |
| | Total | 316 | 100 |
| Property ownership type | Others | 2 | 0.6 |
| | Owned | 199 | 63 |
| | Rented | 115 | 36.4 |
| | Total | 316 | 100 |
| Property insurance | No | 32 | 10.1 |
| | Not sure | 27 | 8.5 |
| | Yes | 257 | 81.3 |
| | Total | 316 | 100 |
| Floor types | Concrete | 201 | 63.6 |
| | Timber | 31 | 9.8 |
| | Not sure | 84 | 26.6 |
| | Total | 316 | 100 |
| Number of occupants | 1 | 41 | 13 |
| | 2 | 71 | 22.5 |
| | 3 | 66 | 20.9 |
| | 4 | 78 | 24.7 |
| | 5 | 40 | 12.7 |
| | 6 | 11 | 3.5 |
| | 7 | 9 | 2.9 |
| | Total | 316 | 100 |

## 3. Reliability Analysis and Key Results

An alpha Cronbach's value of 0.903 for 30 itemized attributes in the questionnaire revealed good internal reliability [45]. It revealed an excellent internal reliability level, as shown in Cronbach's alpha reliability test values table. A weighted index was applied to each degree of agreement: "Strongly agree" was assigned a score of 5, "agree" of 4, "unsure" of 3, "disagree" of 2, and "Strongly disagree" of 1, as shown in Table 3 below.

**Table 3.** Descriptive information about the impacts of climate change on UK residential buildings.

| Codes | Variables | Mean Score | % Mean Score | SD | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|---|---|---|
| **CCB1** | Residential buildings are now being impacted by climate change in the UK. | 3.86 | 77.152 | 0.8 | 21.20% (67) | 48.42% (153) | 25.95% (82) | 3.80% (12) | 0.63% (2) |
| **CCB2** | Erosion has an impact on residential buildings in the UK. | 3.89 | 77.722 | 0.8 | 19.94% (63) | 56.96% (180) | 15.82% (50) | 6.33% (20) | 0.95% (3) |
| **CCB3** | Heatwaves result from climate change. | 4.18 | 83.544 | 0.8 | 36.39% (115) | 50% (158) | 8.86% (28) | 4.43% (14) | 0.32% (1) |
| **CCB4** | A rise in temperature has a negative effect on residential buildings. | 3.81 | 76.14 | 0.9 | 26.27% (83) | 36.71% (116) | 29.43% (93) | 6.65% (21) | 0.5% (3) |
| **CCB5** | Residential buildings in the UK are experiencing the impacts of drought due to climate change | 3.52 | 70.444 | 1.0 | 16.14% (51) | 36.08% (114) | 34.49% (109) | 10.44% (33) | 2.85% (9) |
| **CCB6** | Flood causes major damage to residential buildings in the UK. | 4.30 | 86.076 | 0.8 | 48.42% (153) | 39.87% (126) | 6.33% (20) | 4.43% (14) | 0.95% (3) |

**Table 3.** *Cont.*

| Codes | Variables | Mean Score | % Mean Score | SD | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|---|---|---|
| **CCB7** | Climate change reduces the resilience of residential buildings in the UK. | 3.83 | 76.518 | 0.8 | 20.57% (65) | 46.84% (148) | 27.85% (88) | 4.11% (13) | 0.63% (2) |
| **CCB8** | Climate change increases the impacts of wildfire. | 4.27 | 85.38 | 0.8 | 45.25% (143) | 42.41% (134) | 6.96% (22) | 4.75%(15) | 0.63% (2) |
| **CCB9** | Wildfire impacts residential buildings in the UK. | 3.39 | 67.784 | 1.1 | 14.24% (45) | 37.66% (119) | 32.42% (74) | 22.15% (70) | 2.53% (8) |
| **CCB10** | Climate change influences coastal inundation and impacts residential buildings in the UK. | 3.74 | 74.874 | 0.8 | 18.04% (57) | 43.99% (139) | 32.91% (104) | 4.43% (14) | 0.63% (2) |
| **CCB11** | Climate change causes an increase in windstorms that affect residential buildings in the UK. | 3.86 | 77.216 | 0.9 | 24.05% (76) | 47.15% (149) | 20.57% (65) | 7.28% (23) | 0.95% (3) |
| **CCB12** | Climate change causes an increase in extreme cold and affects residential buildings in the UK. | 3.84 | 76.836 | 1.0 | 24.05% (76) | 49.05% (155) | 16.46% (52) | 7.91% (25) | 2.53% (8) |
| **CCB13** | Climate change causes an increase in humidity, which impacts UK residential buildings. | 3.90 | 77.974 | 0.8 | 22.78% (72) | 49.68% (157) | 23.42% (74) | 2.85% (9) | 1.27% (4) |

### *3.1. The Impacts of Climate Change on UK Residential Buildings*

Table 3 illustrates the measured impacts of climate change on residential buildings in the UK. For instance, 48.42% and 39.87%, respectively, strongly agree and agree that floods cause major damage to residential buildings in the UK compared to other impacts; this may arguably be due to increased precipitation. Also, 19.94% and 56.96% of the respondents strongly agree and agree that erosion also impacts UK residential buildings. According to the respondents, 26.27% and 36.71% strongly agree and agree, respectively, that a temperature rise has a negative impact on UK residential buildings. This leads to the building occupants suffering from the impacts of heat waves; as supported by the respondents, 36.39% and 50%, respectively, strongly agree with and agree with that effect. This may be due to a decrease in precipitation. Hence, 20.57% and 46.84% strongly agree and agree, respectively, that there is a reduction in the resilience of UK residential buildings. A total of 24.05% and 47.15% strongly agree and agree that windstorms resulting from climate change affect UK residential buildings. A total of 22.78% and 49.68% responses strongly agree and agree, respectively, that humidity due to climate change impacts UK residential buildings, hampering the sustainability of the buildings. A total of 24.05% and 49.05% strongly agree and agree, respectively, that climate change causes an increase in extreme cold, which impacts the quality of residential buildings; hence, the building's performance might be reduced.

### *3.2. Impacts of Climate Change on the Occupants of Buildings*

This study reports in Table 4 that 22.15% and 56.01% strongly agree and agree, respectively, that climate change has negative effects on the occupants of residential buildings in the UK, of which 24.68% and 55.70% strongly agree and agree, respectively, that climate change impacts increase the cost of building maintenance, which arguably may be from a combination of other factors, such as building age, location, types and so on. The culture and behaviour of residents are affected as 22.78% and 50% of the respondents strongly agree and agree, respectively, to that point. A total of 21.84% and 37.03% respondents, respectively, strongly agree and agree that the air quality is getting worse due to climate change, which affects the health and safety of the occupants of UK residential buildings as opined by 23.73% and 51.27% respondents, respectively, strongly agree and agree. A total of 15.82% and 47.78%, respectively, strongly agree and agree that the impacts of climate change have psychological consequences on the affected residential occupants. Hence, climate change is an important factor affecting the sustainability of UK residential buildings, as strongly agree 18.04% and 56.65% of respondents.

**Table 4.** Descriptive information about the impacts of climate change on the occupants of UK buildings.

| Codes | Variables | Mean Score | % Mean Score | SD | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|---|---|---|
| **CCO1** | Climate change has negative impacts on the occupants of residential buildings in the UK. | 3.91 | 78.292 | 0.85 | 22.15% (70) | 56.01% (177) | 13.96% (44) | 6.96% (22) | 0.95% (3) |
| **CCO2** | Climate change has positive impacts on the occupants of residential buildings in the UK. | 2.47 | 49.368 | 1.04 | 4.11% (13) | 13.92%(33) | 21.84% (69) | 44.94% (142) | 15.19% (48) |
| **CCO3** | Climate change impacts on residential buildings by increasing the cost of maintenance. | 4 | 79.936 | 0.79 | 24.68% (78) | 55.70% (176) | 15.19% (48) | 3.48% (11) | 0.95% (3) |
| **CCO4** | Climate change affects the way people live in their houses in the UK. | 3.85 | 77.088 | 0.9 | 22.78% (72) | 50.00% (158) | 18.35% (58) | 7.59% (24) | 1.27% (4) |
| **CCO5** | The indoor air quality is getting worse due to climate change. | 3.66 | 73.228 | 1 | 21.84% (69) | 37.03% (117) | 28.48% (90) | 10.76% (34) | 1.90% (6) |
| **CCO6** | Climate change affects the health and safety of the occupants of UK residential buildings. | 3.91 | 78.228 | 0.85 | 23.73% (75) | 51.27% (162) | 18.04% (57) | 6.33% (20) | 0.63% (2) |
| **CCO7** | The level to which climate change impacts a building has psychological consequences for the occupants. | 3.66 | 73.292 | 0.92 | 15.82% (50) | 47.78% (151) | 25.32% (80) | 9.18% (29) | 1.90% (6) |
| **CCO8** | The impacts of climate change on buildings have disrupted the occupants' family occupant's activities. | 3.37 | 67.468 | 0.99 | 9.81% (31) | 42.09% (133) | 26.90% (85) | 18.04% (57) | 3.16% (10) |
| **CCO9** | The impacts of climate change make the occupants feel anxious about living in the same building. | 3.3 | 65.95 | 1.05 | 13.29% (42) | 30.70% (97) | 32.59% (103) | 19.30% (61) | 4.11% (13) |
| **CCO10** | Climate change does not affect the liveability of UK residential houses. | 2.52 | 50.316 | 1 | 2.85% (9) | 16.46% (54) | 22.15% (70) | 46.52% (147) | 12.03% (38) |
| **CCO11** | Occupants need to vacate their building for a long time after an impactful incident of climate change. | 3.38 | 67.594 | 0.94 | 8.86% (28) | 40.82% (129) | 32.59% (103) | 14.87% (47) | 2.85% (9) |
| **CCO12** | Occupant's neighbours and friends are aware of the dangers that increased wind, rain, a rise in temperature, humidity, flooding, drought, and wildfire can pose to residential buildings. | 3.49 | 69.746 | 0.93 | 12.66% (12) | 39.56% (125) | 33.86% (107) | 11.71% (37) | 2.22% (7) |

Table 5 shows that 37.97 and 54.11% strongly agree and agree, respectively, that residential buildings should be more environmentally adapted to support measures to the impacts of climate change. Moreover, new buildings should be designed to improve their resilience to the impacts of climate change, with the respondents strongly agree and agree at 53.16% and 42.09%, respectively.

**Test of Hypothesis 1**

A multiple linear regression analysis was conducted to model the relationship between the variables [46,47], such as buildings, measures, and the building occupant variables. The following hypotheses were tested:

**H1.** *Climate change has a significant impact on residential building occupants.*

**H2.** *There is a significant impact of climate change measures/policy on residential building occupants.*

The dependent variable building occupants (CCO) regressed on predicting variable climate change impacts (CCM) and climate measures (CCM) to test hypotheses H1 and $H_2$. CCB and CCM significantly predicted building occupants CCO, $F$ (2) = 164.55, $p < 0.001$, which indicates that the CCB (Beta = 0.55, t = 11.6, $p < 0.001$) and climate measures (Beta = 0.25, t = 5.21, $p < 0.001$) play a significant role in shaping building occupants (B = 0.5, t = 2.78, $p < 0.006$). It means that when *CCM* and *CCB* are zero, the dependent variable *CCO* is expected to be approximately 0.5. The *p*-value is 0.006, indicating that the intercept is statistically significantly different from zero. More precisely, the null hypothesis that the coefficient of *(Constant)* is zero in the population is rejected. The results clearly depict that the CCB positively affects the occupants. H2 evaluates if climate measures have a significant effect on the building occupants. The results clearly depict that climate measures have a positive effect on occupants. Hence, H2 was supported, as shown in Table 6.

**Table 5.** Descriptive information on climate change measures.

| Code | Variables | Mean Score | % Mean Score | SD | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|---|---|---|
| **CCM1** | Climate change is an important factor affecting the sustainability of UK residential housing. | 3.85 | 77.03 | 0.82 | 18.04% (57) | 56.65% (179) | 19.30% (61) | 4.43% (14) | 1.58% (5) |
| **CCM2** | After the impacts of climate change on a building, the recovery process of returning the building to normalcy is fast. | 2.72 | 54.94 | 0.86 | 2.53% (8) | 13.92% (44) | 42.09% (133) | 36.39% (115) | 5.06% (16) |
| **CCM3** | Residential buildings should be more environmentally adapted to support measures that reduce the impacts of climate change. | 4.28 | 85.7 | 0.66 | 37.97% (171) | 54.11% (171) | 6.65% (21) | 0.95% (3) | 0.32% (1) |
| **CCM4** | Local climate change policies should adapt to different measures to reduce the impacts of climate change on residential buildings. | 3.98 | 79.62 | 0.78 | 23.42% (74) | 56.01% (177) | 17.41% (55) | 1.58% (5) | 1.58% (5) |
| **CCM5** | In order to reduce the impacts of climate change on residential buildings, the local climate change policies should adapt to different measures. | 4.47 | 89.37 | 0.64 | 53.16% (168) | 42.09% (133) | 3.48% (11) | 0.95% (3) | 0.32% (1) |

The following regression model was obtained: CCO = 0.5 + 0.28 · CCM + 0.49 · CCB· When all independent variables are zero, the variable occupants are 0.39. Through further evaluation, the null hypothesis that the coefficient of "CCB" was zero in the population was rejected. Also, the null hypothesis that the coefficient of "CCM" was zero in the population was rejected. $R^2$: The model explains 51% of the variation in building occupants. The adjusted $R^2$ is 0.551, showing that the model fits. A Multiple R-value of 0.72 [a] indicates that the predictors account for a significant portion of the variation in the dependent variable, indicating that the model fits the data well.

The ANOVA test result in Table 6 validates the earlier result, indicating whether there is a significant difference between the variables that were found to be significant. The table shows that the characteristics of the regression model are 38.24 sum of squares, 19.122 mean square, and 164.22 F-statistic (0.001). The results of the ANOVA test show that the observed variables were significant at the 1% level.

Model Coefficients

CCM: The coefficient for the independent variable CCM is 0.28. A one-unit increase in CCM is associated with a 0.28-unit increase in the dependent variable. This variable has a standardised coefficient (Beta) of 0.25, which, according to Pallant, means that it is 0.25 standard deviations away from the mean for everyone standard deviation increase in the independent variable [48].

CCB: The coefficient for the independent variable CCB is 0.49. A one-unit increase in CCB is associated with a 0.49-unit increase in the dependent variable. This variable has a standardised coefficient (Beta) of 0.55.

Both independent variables, CCM and CCB, are robust and statistically significant predictors of the dependent variable ($p < 0.001$ for both), providing a high level of confidence in the reliability of the results.

**Table 6.** Regression.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | **Regression Statistics** | | | |
| Multiple R | 0.72 [a] | | | | | |
| $R^2$ | 0.51 | | | | | |
| Adjusted $R^2$ | 0.51 | | | | | |
| Standard Error | 0.34 | | | | | |
| Observation | | | | | | |
| | | | ANOVA | | | |
| | Sum of Squares | Df | Mean Square | F-value | Significance F | |
| Regression | 38.243 | 2 | 19.122 | 164.225 | <0.001 | |
| Residual | 36.328 | 312 | 0.116 | | | |
| | | | Coefficients | | | |
| | Unstandardized Coefficients | Standardized Coefficients | | | | |
| Model | B | Beta | Standard error | T | P | Hypothesis supported |
| (Constant) | 0.5 | | 0.18 | 2.78 | 0.006 | |
| (CCB)–(CCO) ($H_1$) | 0.49 | 0.55 | 0.04 | 11.62 | <0.001 | Supported |
| (CCM) Measures ($H_2$) | 0.28 | 0.25 | 0.05 | 5.21 | 0.001 | Supported |

**Test of Hypothesis 2**

The $H_0$ hypothesis states that there is no significant relationship between climate change and the well-being of the occupants of UK residential buildings.

A multiple linear regression analysis similar to Table 6 was performed to examine the influence of the variables: Indoor air quality CCO5 (Beta = 0.04, t = 0.83, $p = 0.407$), health and safety CCO6 (Beta = 0.34, t = 5.71, $p < 0.001$), psychological consequences CCO7 (b = 0.1, t = 1.68, $p < 0.94$), and disruption of the occupants' family activities CCO8 (Beta = 0.13, t = 2.22, $p < 0.027$) and. The occupants feel anxious about living in the same building CCO9 (Beta = 0.1, t = 1.59, $p < 0.114$). On the variable side, climate change impacts residential buildings' CCB1.

The results show that the independent variables positively affect the dependent variable CCB1. Further, it was found that the effect was significantly different from zero, F = 30.43, $p = < 0.001$, $R^2 = 0.33$. Moreover, the $R^2 = 0.33$ depicts that they explained 33% of the variance from the variable CCB1. An ANOVA was used to test whether this value differed significantly from zero. The adjusted $R^2$ is 0.32, indicating that the model may somewhat overfit the data. The standard error of the estimate is 0.67, which is the average distance between the observed and anticipated values.

**Test of Hypothesis 3**

**H0.** *There is no significant relationship between climate change and the deterioration of the fabric of a building.*

The regression analysis, as presented in Table 6, yielded insightful findings. The dependent variable (CCB1) regressed on predicting variables; reduced building resilience (CCB7) (Beta = 0.44, t = 0.82. $p < 0.001$), and cost of maintenance (CCO3) (Beta = 0.26, t = 5.21. $p < 0.003$), to test hypothesis $H_1$. The results, which strongly support H1, have significant implications for the model. The ANOVA findings (F = 93.7, $p < 0.001$, R2 = 0.33) further underscore the practical relevance of our model. These results clearly indicate the positive effect of reduced building resilience CCB7 and cost of maintenance CCO3 on CCB1.

## 4. Discussion of Results

### *4.1. The Impact of Climate Change on the Wellbeing and Comfort of Residents in Residential Buildings*

(a) Impacts of climate change on the occupants of residential buildings

The impacts of climate change on residential buildings significantly predicted building occupants, F (2) = 164.22, $p < 0.001$, which indicates that the impacts of climate change on residential buildings play a significant role in shaping building occupants, as shown in Table 6. This means that, when climate change impacts residential areas, it consequently affects the dynamics of building occupancy demonstrably.

Wollschlaeger argues that rising global temperature modifies the geophysical system and increases sea levels, excessive precipitation, and heat waves [49]. These changes impact infectious agents and heighten the severity of floods.

This study's findings show that 21.84% and 37.03% of respondents strongly agreed and agreed that climate change is the cause of the decline in air quality. Furthermore, 22.15% and 56.01% of respondents strongly agreed and agreed that it negatively affects the health and safety of occupants in UK residential buildings. These climate change effects negatively impact human health, especially those of the most vulnerable groups [49]. The features of climate change impacts on residential buildings that affect the comfort and well-being of the occupants used in this study are wildfire, flooding, temperature rise, humidity, drought, wind-driven rain, storm and extreme cold, which have a negative impact on the occupant. While the statement emphasises the direct link between climate change impacts and building occupants, it is critical to recognise that other factors may also play a role in the relationship between climate change on UK residential buildings and its effects on the occupants, such as socio-economic conditions, policy interventions, and individual behaviours.

The consequences of severe heat episodes regarding illness and death point to climate change as a growing public health concern [50]. According to Hess et al. and Kafeety et al., prolonged exposure to high temperatures can result in heat exhaustion, heatstroke, dehydration, and kidney and urinary tract infections [51,52]. Heat is a hazardous environmental factor that can lead to accidents, acute heat sickness, exacerbations of chronic diseases, and unfavourable pregnancy outcomes [51]. Extreme heat events (EHEs) occur when risks are most significant [51]. Also, 15.82% and 47.78%, respectively, strongly agreed and agreed that the impacts of climate change have psychological consequences on the affected residential occupants. In addition, social isolation has adverse effects on various health outcomes [52]. In the UK, residential building occupants are most affected by floods. According to Bouchard et at., flooding within the building exposes residents to disease-carrying ticks and Lyme disease [53]. While the impacts of heat waves and heat exposure on health are well established, the consequences of wildfires on health are not as well recognised [54]. However, Payne et al. opined that wildfire smoke reduces air quality and may impair cognitive function [55]. The UK government predicted that the risk of wildfires closer to residential buildings will rise by 30% to 50% due to climate change by 2080 [56].

This study shows that the building occupants feel the impacts of climate change more on their health and safety, disruption of family activities, and anxiety of their buildings. This indicates that higher levels of perceived health and safety concerns, disruptions in family activities, and increased anxiety among occupants due to climate change are associated with higher levels of climate change impacts on residential buildings. Arguably, the impacts of climate change on the occupant's health and safety and the disruption of family activities may result in psychological consequences. The evidence gathered for CCRA3 shows that the gap between the level of risk in the UK and the level of adaptation underway has widened: in other words, adaptation action is failing to keep pace with the worsening of climate risks [57]

(b) Impacts of climate measures/policy on residential building occupants

This study's results depict a positive effect of the climate measures/policy on the residential building occupants (b = 0.25, t = 5.21, $p < 0.001$). Climate measures/policy significantly predicted building occupants. In order to fulfil future energy and climate change objectives, the UK residential sector must now perform better and be more efficient [58]. Upgrading settlements under the direction of the community and local government increases resilience to climate change hazards [59]. There is a contention that policy ought to shift, requiring more sophisticated upgrading methods tailored to individual buildings and users; high-end retrofits can be encouraged where suitable and feasible, but not only for financial benefit [60]. The results clearly depict that climate measures have a positive effect on occupants. However, in contrast to the existing literature, this study also shows that the building occupants are more concerned about the impacts of climate change on their residential buildings than the measures and policies in place. However, they are both significant and essential in addressing the impacts of climate change. For instance, the awareness of the impact of climate change on residential buildings helps integrate climate-resilient strategies into planning and policy development, which could positively influence the well-being and safety of building occupants.

### *4.2. The Impacts of Climate Change on the Resilience of Residential Building*

Resilience, defined as the ability to recover from the effects of a hazardous event in a timely and efficient manner, is a concept gaining traction in the resilience of cities and communities [59,61]. The impacts of climate change on residential buildings regressed in terms of predicting variables and building resilience. This study's results depict a positive correlation between the impacts of climate change and reduced residential building resilience. The significant level P is less than 0.05. Hence, there is a significant relationship between climate change and the deterioration of the fabric of buildings. This means an increase in the impacts of climate change on residential buildings, causing the building's fabrics to deteriorate and thereby reducing its resilience. A total of 20.57% and 46.84% of respondents, respectively, strongly agreed and agreed that climate change reduces the resilience of residential buildings in the UK.

While there is a wealth of literature on building resilience [26,62,63], some studies have specifically examined how and to what extent the resilience of residential buildings could be impacted by climate change, but more research is needed. This study further contributes to filling this gap. Findings show that the impacts of climate change, such as increased temperatures, extreme weather events, and rising sea levels, reduce the resilience of residential buildings in the UK. This reduction is influenced by three main factors: the type of building makeup and the risk (vulnerability, exposure, hazard building risk as shown by [59], and the behaviour and awareness of the occupants [64]. The reduction in residential building resilience aligns with conclusions drawn from the existing literature and the cost of building maintenance variable. As such, this study contributes by defining the extent to which the impacts of climate change are experienced more. It demonstrates that the reduction in residential building resilience has a higher impact than the cost of building maintenance by 18%, offering practical insights for building resilience and maintenance professionals.

### *4.3. The Impacts of Climate Change on the Cost of Maintenance of Residential Buildings*

The regression analysis, a robust statistical tool, provides compelling evidence to support the alternative hypothesis. It reveals a substantial correlation between climatic change and building fabric degradation. This underscores the pivotal role of building resilience and maintenance costs in shaping the impact of climate change on UK residential buildings.

The research findings indicate a clear and significant link between climate change and the deterioration of building fabric. This implies that as the effects of climate change intensify, the condition of residential buildings worsens, leading to higher maintenance costs. A substantial majority, 24.68% and 55.70%, respectively, strongly agreed and agreed that climate change significantly increases the maintenance cost of residential buildings [65].

Research conducted by Islam et al. opposes this position by indicating that other factors, such as architectural design deficiencies (unavailability of certain construction materials on the market and challenging access to the building part that needs maintenance), have the most impact on increasing maintenance costs [66]. It can be argued that the impacts of climate change, such as the impacts of wildfire, rise in temperature, drought, humidity, wind, storm, and flooding, will reduce the building material capacity, thereby increasing the frequency of maintenance and, thereby, more cost accrued [43].

The life of the building depends on the integrity of the material used during construction; hence, the durability of materials can influence maintenance costs. According to Akadiri, the choice of building materials may result in high maintenance costs [67]. Materials used can deteriorate quickly due to the impacts of climate change [68].

Moreover, Islam et al. opined that, due to the impacts of climate change, building elements deteriorate faster than they should [66]. Thereby, increasing the maintenance cost. For instance, continuous extreme weather events, such as storms, increases in temperature, and flooding, can weaken building foundations and cause damage to roofing and cladding.

The positive coefficients for reduced building resilience and maintenance cost indicate that decreased resilience and higher maintenance costs are related to more significant degradation of building fabric. These findings may have ramifications for urban planning and maintenance decision-makers, architects, and lawmakers. This emphasises the need to consider the trade-offs between resilience and maintenance costs in building fabric.

## 5. Summary of New Findings

This study demonstrates that the reduction in the resilience of residential buildings measuring (0.44) of standardised β coefficients has a higher impact than the cost of building maintenance by 18%. In contrast to the existing literature, this study shows that building occupants are more concerned about the impacts of climate change on their residential buildings than the measures and policies in place: However, they are both significant and essential in addressing the impacts of climate change. The findings also show that the building occupants feel the impacts of climate change more on their health and safety, disruption of their family activities and anxiety of the building occupants.

## 6. Conclusions

This study's findings from the stakeholders' perspectives suggest that climate change significantly impacts residential buildings, thereby affecting the building occupants. It is arguable that climate impacts, such as heatwaves, temperature rises, drought, flood, wildfires, windstorms, coastal inundation, humidity, and extreme cold, have a detrimental effect on the occupants, altering the way residents live in their houses. According to the Stakeholders' perceptions, these impacts not only impact the health and safety of the occupants but also reduce air quality and negatively affect their mental well-being, thereby emphasizing the urgent need for action. The findings further demonstrate a significant relationship between climate change and the well-being of the occupants of UK residential buildings. However, the results indicate that the occupants' physical and social well-being are more crucial. The results also highlight a significant relationship between climate change and the deterioration of building fabric, suggesting that residential buildings in the UK will bear the cost of maintenance due to continuous reductions in building fabric resilience to the impacts of climate change.

In conclusion, the urgency of this study is underscored by the escalating risks associated with climate-related events, necessitating a comprehensive understanding and effective adaptation strategies and resilience measures for the built environment. This study's practical implications are significant, as it highlights how the reduction in residential building resilience directly impacts the cost of building maintenance. By providing empirical evidence on the factors influencing climate impacts resilience reduction and strategies for mitigating them, this study contributes to the body of knowledge and practice of minimising the impacts of climate change. The data from this study are particularly valuable for policymakers, urban planners, and other stakeholders involved in creating resilient and sustainable environments in the face of climate challenges.

## 7. Limitations

Data collection was restricted to occupants of UK residential houses. Due to the quantitative approach of this study, some answers to the structured questions may warrant elaboration. Thus, the results may need to be investigated deeply through interviews to further understand the concerns of specific respondents. However, this study's findings may be embraced and used as a benchmark to guide future decisions on the impacts of climate change on residents and residential buildings in other parts of the world.

Another limitation is that the study concentrated on stakeholders' perceptions about the impacts of climate change on their residences and residential areas. While their valid views are appreciated, the study did not progress to use instruments to measure these impacts. Such a follow-on investigation is being recommended as subsequent research.

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