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Assessing the Built Environment's Reflectivity, Flexibility, Resourcefulness, and Rapidity Resilience Qualities against Climate Change Impacts from the Perspective of Different Stakeholders

Mohammed M. Al-Humaiqani [1] and Sami G. Al-Ghamdi [1,2,3,*]

[1] Division of Sustainable Development, College of Science and Engineering, Hamad Bin Khalifa University, Qatar Foundation, Doha P.O. Box 34110, Qatar
[2] Environmental Science and Engineering Program, Biological and Environmental Science and Engineering Division, King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia
[3] KAUST Climate and Livability Initiative, King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia
* Correspondence: sami.alghamdi@kaust.edu.sa; Tel.: +966-12-802-8040

Abstract: The frequency and severity of climate change are projected to increase, leading to more disasters, increased built environment system (BES) vulnerability, and decreased coping capacity. Achieving resilience objectives in the built environment is challenging and requires the collaboration of all relevant sectors and professionals. In this study, various stakeholders were engaged, including governmental authorities, regulatory bodies, engineering firms, professionals, contractors, and non-governmental and non-profit organizations (NGOs and NPOs, respectively). The engagement was carried out through the answering of a questionnaire survey that reflects their perceptions about climate change adaptation, the built environment resilience qualities (RQs), and the degree of resilience of the existing built environment and their perceived capacities. The results were analyzed using several statistical tests. The results revealed that advancing public understanding and management tools, reducing economic losses, and developing necessary plans still require improvement. Additionally, the BESs were ranked concerning accepting the change and uncertainty inherited from the past or generated over time. This study emphasized the perception that the decision-making domain is crucial for delivering a reflective built environment. Additionally, features such as advancing public understanding and management tools, reducing economic losses, and developing necessary plans still require improvement. Furthermore, there is a belief in the importance of the task forces within the community as part of an emergency response plan, and a less reflective system would have less recovery speed. Therefore, the rapidity characteristic of a built environmental system to accept the change and uncertainty inherited from the past or generated over time is correlated to the system's reflectivity quality. This study emphasizes the significant correlation between the different RQ traits. It also encourages researchers to formulate more objective methods to reach a set form for measuring RQs as an engineering standard.

Keywords: climate change; resilience qualities; built environment; reflectivity; flexibility; resourcefulness; rapidity; capacity

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1. Introduction

Concerns about natural, climate change, and man-made effects on the built environment systems are increasing as climate risks and impacts are growing. The effects and hazards increase the vulnerability of urban areas and put the environment, infrastructure, and populations at risk [1,2]. The concerns are growing more and more in developing countries than developed ones due to the rapid population increase and expansion of urban areas [3–5]. Climate change puts communities and built environment systems at risk and makes them more vulnerable [1,6,7]. The implications may considerably affect many aspects of life and go beyond expectations. The risk gradually increases, specifically in areas where no mitigation measures are being implemented to reduce the expected climate change impacts. Additionally, the vulnerability increases when the systems are exposed to combined risks (climate impacts, natural hazards, intentional attacks, etc.).

Natural hazards are among the problems that built environment systems face in different parts of the world. In recent years, potential earthquakes, volcanoes, droughts, wildfires, hurricanes, and other natural challenges have become more evident, with various destructive powers depending on the location [8,9]. Their destruction magnitude is higher in dense areas where different businesses, economic activities, and populations are congested. The impact on the built environment is not limited to climate change; the natural events continue to cause damage to the existing structures and losses of economies and lives every year [10,11]. The events gradually increase the losses through individual elements, ending in partial or complete system collapse [12]. The challenge of natural hazards increases, especially in developing countries where dealing with highly destructive events is unbearable [13,14]. However, resilience to such events as a key point to protecting people, developments, economics, and business will remain a burden on governments.

Similarly, non-natural hazards, also known as man-made disasters, are another challenge that societies, economics, and built environment systems face. Man-made disasters include the dispersion of radioactive gases in the atmosphere, terrorist attacks, transportation disasters, wars, etc. [15,16]. Communities may occupy areas prone to natural hazards such as landslides, mudslides, floods, and debris flow, resulting in more vulnerability to extreme events [17]. On the other hand, industrial accidents are another example of man-made disasters, of which process industries form about 17%, as demonstrated by past research [18–21]. On the other hand, occupation in prone areas to flooding, exposure to flash floods, landslides, and debris flow requires early warning and action plans [17]. Hence, there is a need to reduce the risk of man-made disasters as considered by the Sendai Framework for Disaster Risk Reduction and recognized by the international community [22].

In response to these potential risks and impacts, communities need to consider actions that eventually avoid or reduce such risks [23,24]. In addition, establishing strategies that allow systems to respond to the disaster effectively and bounce back if they have already undergone stress are required [25]. In other words, communities and built environment systems need to be resilient. A resilient system is less prone to disturbance, copes with disturbances, and can allow flexible responses to any climate event [26]. It can generally respond to a disaster and spring back to normal conditions. Overall, the term resilience is used in governance, politics, and planning [27], quantified by the system's ability to withstand and absorb shocks and continue functioning [28–30]. In practice, resilience can characterize the capacity of systems and communities to recover from natural or climatic stress [31–33].

In the built environment, resilience against climate change and natural and man-made hazards becomes very important. Resilience, in general, is needed to protect the systems from damage and breakdown and communities from collapse and losses of life [34]. Hence, incorporating resilience requirements at the planning, design, and construction stages will enhance the adaptive capacity of the systems and allow them to adapt to change during a disruptive event and recover quickly [35]. Resilience is assessed using different quantitative and qualitative frameworks [36]. The assessment could be conducted locally, nationally, or internationally [37].

1.1. Disaster Preparedness

Climate can increase disaster risk with the continuity of human beings' unsustainable activities. So, reducing climate disaster risk is an increasingly important policy issue, mainly in the areas that suffer from economic and human losses associated with disasters [38]. Taking measures to prepare the built environment systems and reduce the climate change impacts and natural and man-made hazards become a necessity more than a privilege. The measures may include predicting and preventing disasters (most preferred). Additionally, they should include effective coping with the consequences and mitigating the impact on vulnerable systems and communities [39]. In line with the Federal Emergency Management Agency (FEMA) definition, preparedness is simply explained as uninterrupted planning covering several vital actions such as proper organization, regular training, on-time evaluation, adequate exercise, and accurate equipping. It must also include corrective actions demonstrating effective coordination during a disaster event. Governments and relevant organizations take a critical role in developing preparedness tools, including knowledge and capacities among communities. Correspondingly, response and recovery organizations, communities, and individuals' behaviors are considered critical to ensure proper response and recovery from a current or imminent disaster [40].

Preparedness to adapt to climate change impacts and natural and man-made hazards can happen in various ways. A legal support mechanism against such hazards or dedicated national policy guidance on adaptation is considered adequate. Additionally, financial commitment needs to be ensured to support the implementation of adaptation actions [41]. Preparedness is important in different sectors, including built environment systems [42], life support activities [41], humanitarian efforts [43], etc. Preparedness against climate change disasters and natural and man-made hazards requires the development of risk reduction policies and programs [43]. Additionally, public attitudes and awareness play significant roles in reducing losses.

1.2. Quantifying Resilience

Resilience quantification approaches are different from one discipline to another. They are categorized into two distinct categories: quantitative and qualitative approaches (indicators) with subcategories [44]. The two approaches are required because some aspects of life cannot be quantified and need to be explained without a scale [36]. The quantitative methods category contains two subcategories: (1) general resilience approaches, which include domain-agnostic measures applied to quantify resilience across applications, and (2) structural-based modeling approaches, which model domain-specific representations of the resilience components. The qualitative methods category comprises two subcategories: (1) conceptual frameworks, including best practices, and (2) semi-quantitative indices, including the expert's assessments of various resilience qualitative aspects. However, qualitative approaches might be limited by the non-extent of some indicators that prevent further comparisons. The most qualitative approaches define communities considering societal and social factors such as community values and interests. The qualitative indicators contain aspects that are considered essential factors. The aspects include diversity, participation, communication, efficacy, coordination, equity, etc. The indicators are deemed suitable for informing decision-making because they are values added to a composite indicator. Quantitative indicators may depend on other indicators covering specific aspects of community resilience. The indicators can be aligned into different resilience domains: economic, social, institutional, community capital, housing, environmental, and infrastructure. The environmental resilience domain covers risk and exposure, sustainability, and protective resources, and the infrastructure domain of resilience covers healthcare, housing, transportation networks, communication services, etc. [45].

1.3. Resilience Qualities (RQs)

To build a resilient system, the essential resilience qualities need to be ensured to enable a system to respond promptly and prevent failure or breakdown due to external disruption. Resilient cities are those in which their individuals, communities, institutions, and businesses can survive and have the capacity to withstand and adapt during any short- or long-term disruption. The qualities demonstrated by a resilient urban system include reflectivity (Rf), robustness (Rb), redundancy (Rd), flexibility (Fx), resourcefulness (Rs), rapidity (Rp), inclusiveness (Ic), and integration (It). However, several frameworks have introduced resilience indicators, focusing on the preparedness attributes to climate change and natural and man-made hazards. Resilience indicators, such as Rb, Rd, and Rs, are essential for the built environment system and effectively correlate with preparedness attributes [39]. At the same time, security, safety, and predominantly alarm systems reveal a robust connection to Rp.

RQs can be included in different functions of the built environment system. Several ways to help build a more resilient built environment system include improving Rs, Rd, and system robustness (Rb). One or more RQs can be applied to build a resilience system or model. Whereas Rs and Rp reflect the systems' post-disaster adaptation capacities, Rb and Rd attributes estimate the infrastructure systems' pre-disaster capabilities [46]. An urban system's resourcefulness (Rs) can directly affect its Rb, Rd, and Rp [47]. Such effects may emphasize the need to improve the policy system and strengthen the urban resilience assessment [47]. The effects could also appear in the ability of urban governance to respond to disasters, mostly due to the poor interaction between institutions [48].

Some resilience frameworks are only built based on the four RQs: Rb, Rd, Rs, and Rp [49]. For instance, the framework introduced by Tyler and Moench [4] incorporates ecological, infrastructure, institutional, and social resilience factors. In contrast, Bruneau et al.'s [50] framework involves the community's organizational, technical, economic, and social dimensions.

1.4. Objectives

A resilient built environment system involves several RQs, and each quality contributes to one or more system capacities. The qualities improve the system's ability to withstand climate change impacts while residents can survive and thrive even during climatic stresses or shocks. It is argued that the preparedness and response of the affected built environment are insufficient, with a longer recovery process [33]. The literature review done for this study highlights the importance of preparedness and incorporating relevant strategies. For instance, disaster preparedness and response can be enhanced through the collective efforts of different stakeholders, including government-owned entities, residents, and private sectors [38,39,51–53]. It also highlights the significance of incorporating RQs such as robustness, redundancy, resourcefulness, and rapidity into the systems [39].

Resilient systems have revealed that an integrated approach between different RQs is needed to meet performance expectations. There are some intricacies in understanding how RQs can be incorporated into built environment systems' planning and design strategies. However, research has investigated the incorporation of RQs from a combating climate change risk perspective and the implications of not including such a practice in achieving an acceptable resilience level. A questionnaire-based approach was applied to tackle the gap in this research. A survey questionnaire was used to collect the perspectives of different stakeholders to achieve the following objectives: (1) determine the different perceptions of involved stakeholders regarding the resilience of the built environment against climate change; (2) investigate the interlinkages and interrelations between different resilience indicators, measures, and characteristics based on their responses; and (3) determine the significance of the RQs for the different built environment systems and categories.

This study aims to quantify the built environment's resilience to cope and adapt to climate change risks and stresses. It collects the perception and points of view of different stakeholders, including governmental authorities, engineering firms, non-governmental organizations (NGOs), private sectors, climate change experts, sustainability managers, practitioners, professionals, etc. The rationale behind the study objectives is the escalation of climate change and its direct and indirect threats to the built environment, which were discussed in many studies [6,43,51,54–67]. Understanding and underscoring the importance of built environment resilience can enhance relevant policies and strategies [6,68].

For objective 1, the research determined the quality of opinions of the participants and their understanding of resilience against climate change. It also determined the prioritization of the relevant measures from one area to another and the ability to improve the communities' understandings of resilience. Objective 2 investigated how the built environment RQs are interconnected and interrelated, while objective 3 focused on each quality's level of importance and how it works for each built environment system. For the first objective, the research determined the level of knowledge of each group of participants regarding the built environment resilience and their prioritization of the indicators that form each resilience quality. The second objective considered the interrelations of indicators of the RQs.

On the other hand, the third one looked at the resilience of the built environment systems by quantifying their magnitude of resilience from different aspects. The logic behind these objectives is the challenges the built environment systems face nowadays in exploring the level of resilience against the climate [6,54–67,69–83] to the method of designing, constructing, and operating the different built environment systems and ultimately improving their interrelations and interdependencies. It may also extend to other resilience goals and positively impact the relevant regulations and laws. Hence, the study captures the perspectives of policymakers, urban planners, developers, experts, and professionals from different stakeholders to reveal the preparedness of communities and built environment systems. It will be a good start to developing progressive policies and strategies to formulate the pillars of a resilient built environment system considering the existing physical, social, technological, and economic infrastructure status. This study represented all stakeholders (regulatory bodies, the construction industry sector, non-profit and non-governmental organizations, and academia).

2. Methods and Procedures

A questionnaire survey was designed and distributed to collect the views and opinions of regulators, experts, professionals, researchers, and academics regarding the built environment RQs. The standardization and objectivity of the people's engagement were ensured by having the survey as a numerical, structured, and closed-ended questionnaire [84]. This survey comprised four RQs, namely, reflectivity, flexibility, resourcefulness, and rapidity, as shown in Figure 1. in colored segments. The remaining four RQs hatched in grey were studied separately. Typically, the eight RQs serve the planned holistic RQs framework. This figure is used across all the publications generated from this research, maintaining the defined color coding for each RQ and highlighting the excluded ones in light grey color. The purpose is to keep all published works linked to each other and clarify the RQs' diversity to the readers. The distribution process of the questionnaire survey among the targeted audience is explained in Figure 2.

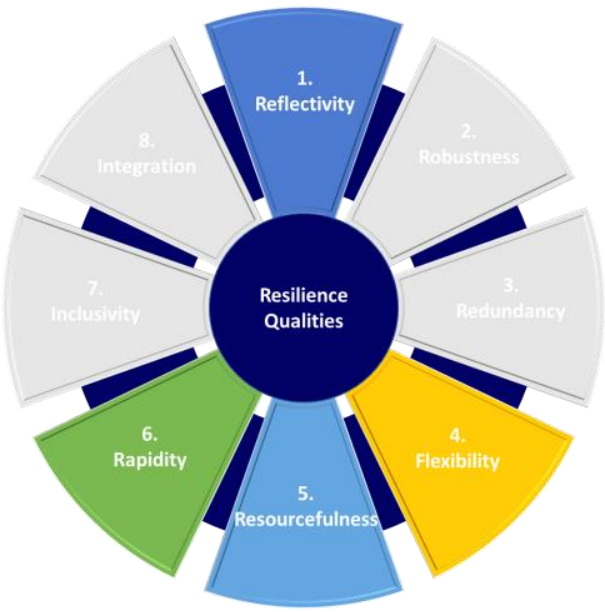


Figure 1. Built environment resilience qualities (RQs) covered in this study.

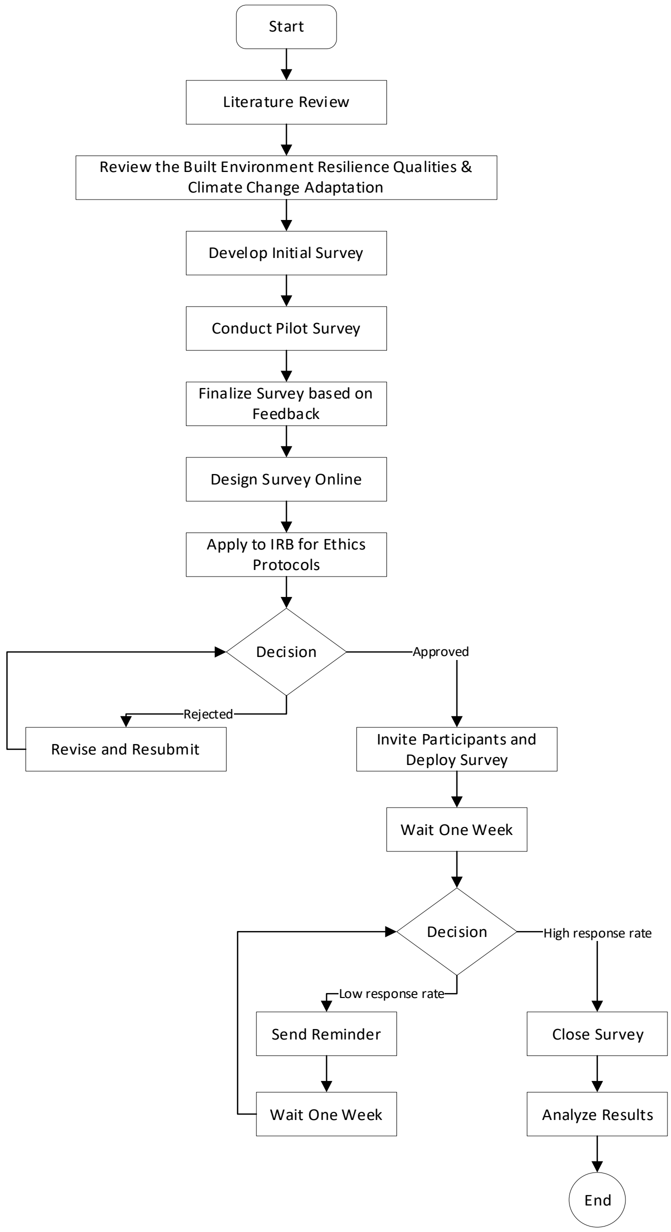


Figure 2. Research methodology: activity diagram and survey distribution process.

2.1. Questionnaire Design

First, the stakeholders were classified into three main groups considering each group's scope of work and business, as shown in Figure 3. The three groups were (1) regulatory bodies and government-owned entities, (2) the construction industry, and (3) non-governmental organizations and academia. The participants were questioned to determine their working fields, occupations, roles, experiences, which part of the world they built their capacities and knowledge in, and what sector they are currently working in. The survey questionnaire structure is arranged into three parts. The first part includes a brief about the survey scope followed by the study's objectives, and thereby the importance of the audience targeted to complete it. It also declares that there is no risk involved due to the engagement in the study and ensures the confidentiality of information. The second part of the questionnaire includes the demographic questions, which appear once the participant accepts to join the study. This part contains questions about characterizing the respondents' demographics regarding education level, occupation, years of experience, the sector and the area they work in, etc. After a respondent selects the type of sector they work for, the relevant questions appear. This part (third part) includes four main topics: (1) leveraging reflectivity (Rf), (2) enhancing flexibility (Fx), (3) encouraging resourcefulness (Rs), and (4) improving rapidity (Rp). Table 1 summarizes the questionnaire's design and content; Table 2 outlines the question structure, participants' occupations, roles, subjects, and indicators covered in the questionnaire; and Table 3 presents the respondents and statistical test applied against questions. In total, the respondents from each group had around fifty questions to answer. The survey questions were prepared to address the three objectives discussed in Section 1.4.

The survey's sample size was determined according to scientific references by making assumptions about the targeted audience. It was determined following guidelines recommended by Cohen et al. [84], who mainly listed the applicable online calculators for sampling, such as the one suggested by Creative Research Systems [85], MaCorr [86], Raosoft [87], the SurveyMonkey website [88], and Qualtrics [89]. The margin of error was 5%, and the confidence level was 95%. Determining the survey population size was challenging due to the sensitivity of group selection and the limited number of targeted audiences in the three different groups of stakeholders. It was assumed to be several hundred for the three groups considering each group had limitations to determine.

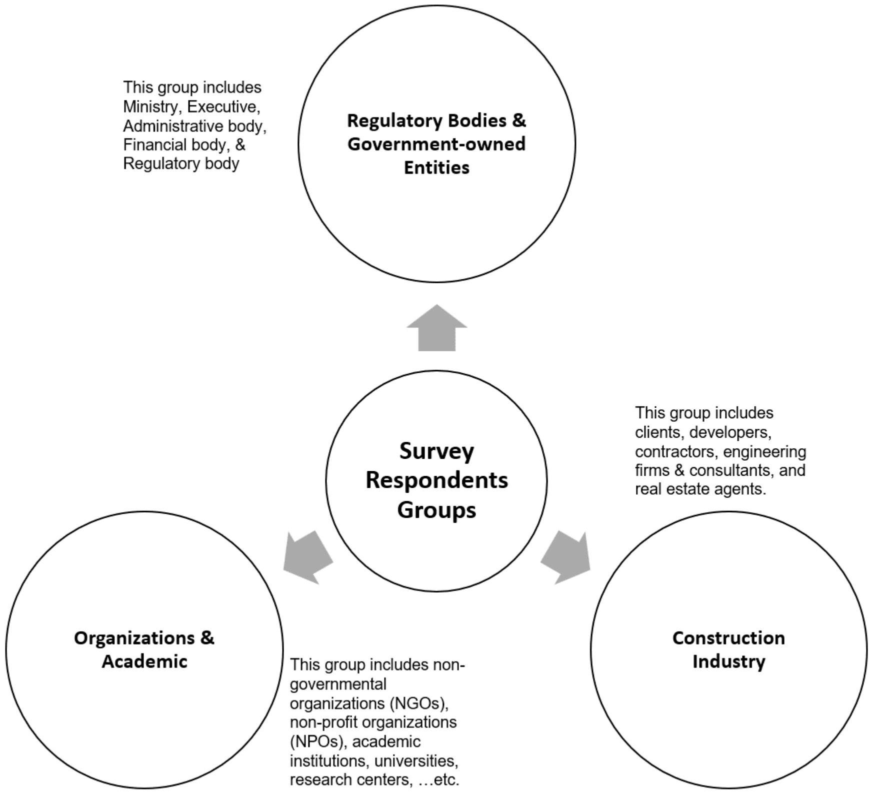


Figure 3. Survey respondents' groups.

Table 1. Design and content of the questionnaire.

Question #	Question Type	Issues Tackled/Investigated
Q 1	Consent question	General questions to enable the participant to quit participation in the study.
Q 5–10	Demographic questions	These questions enable providing demographic information about the audience.
Q 11–12	Notes	General notes for the participants to understand how questions are designed and linked.
Q 13–65	Group 1 questions	Questions about the four RQs designed for group 1.
Q 66–117	Group 2 questions	Questions about the four RQs designed for group 2.
Q 118–167	Group 3 questions	Questions about the four RQs designed for group 3.

Table 2. Question structure, participants' occupations and roles, and subject and indicators covered.

Questions, Respondent	Audience and Responses Boundaries	Questions Subject and Indicators Covered
Q 1–12, All Respondents: Multiple Choice	All respondents. Mandatory questions and notes.	Demographic information to better understand the background characteristics and identity of the participants. Education background, the industry where they work, represented entity, role, and experience; geographical exposure of experience.
RQ1	The respondents' collective understanding, views, and opinions about leveraging reflectivity (Rf) in the built environment systems and the effort to improve the resilience of urban climate change and natural hazards and foster the coping and adaptation capacities in urban systems and communities from the following audience:	Leveraging reflectivity (Rf) by entities, organizations, institutions, and the public through reacting to disturbances and sharing their views and feedback, they learned from pasts to leverage them to decision-making. The main reflectivity indicators are: (1) Learning from the past. (2) Active participation of professional stakeholders and experienced actors. (3) Planning for the future. (4) Preparation for disasters. (5) Decision-making facilitation. (6) Reflective environment systems.
Q 13–30, All Respondents: Multiple Choice	(1) Regulatory and government-owned entities	
Q 66–84, All Respondents: Multiple Choice	(2) Construction industry.	
Q 118–132, All Respondents: Multiple Choice	(3) NGOs, NPOs, academic institutes, and research centers.	
RQ4	The respondents' collective understanding, views, and opinions about enhancing the flexibility of built environment systems and the ability to adopt alternative strategies to a climate change crisis and natural hazards.	Enhancing any system's flexibility (Fx) means adaptability to environmental variations. It significantly connects to adaptability and refers to the capacity for change through emergency planning and preparation in the aftershock of disturbances. The main flexibility indicators are: (1) Identifying, quantifying, and controlling the flexibility. (2) Adopting alternative strategies to the crisis. (3) Adaptation and inherent capacity. (4) Climate adaptation policies and processes. (5) Incorporating traditional knowledge and practices. (6) Efforts to mitigate climate change impacts and natural hazards.
Q 31–40, All Respondents: Multiple Choice	(1) Regulatory and government-owned entities.	
Q 85–94, All Respondents: Multiple Choice	(2) Construction industry.	
Q 133–143, All Respondents: Multiple Choice	(3) NGOs, NPOs, academic institutes, and research centers.	
RQ5	The respondents' collective understanding, views, and opinions about encouraging resourcefulness (Rs) to identify problems, establish priorities, and allocate and mobilize resources.	Resourcefulness (Rs) is the capacity to identify problems; allocate and mobilize resources before, during, and after an event; and establish priorities considering human factors. The main resourcefulness indicators are: (1) Disaster Preparedness. (2) Emergency Management. (3) Resources Utilization. (4) Mitigating the Losses by the Community. (5) Visualize and Act. (6) Identify Problems and Establish Priorities.
Q 41–55, All Respondents: Multiple Choice	(1) Regulatory and government-owned entities	
Q 95–107, All Respondents: Multiple Choice	(2) Construction industry.	
Q 144–157, All Respondents: Multiple Choice	(3) NGOs, NPOs, academic institutes, and research centers.	
RQ6	The respondents' collective understanding, views, and opinions about improving the rapidity of the system to recover from the encountered crisis in a short time, even with some losses.	Rapidity (Rp) is the system's capacity to bounce back from a crisis, even with some losses. It refers to how quickly responsiveness, adaptation, and recovery activities enable the affected system or facility to recover to its full operational function. The main resourcefulness indicators are: (1) Responsiveness and Restorative Capacity. (2) Adaptation. (3) Rapid Recovery. (4) Recovery Activities (Resource allocation).
Q 56–65, All Respon-dents:Multiple Choice	(1) Regulatory and government-owned entities.	
Q 108–117, All Respondents: Multiple Choice	(2) Construction industry.	
Q 158–167, All Respondents: Multiple Choice	(3) NGOs, NPOs, academic institutes, and research centers.	

Table 3. Respondents and statistical test applied.

Questions, Respondent, and Type of Statistical Test	**Respondent Role**	**Subjects**
Q 13–65, Decision makers and Planners (mainly Governmental Authorities): Ranking and Multiple Choices. Statistical Test: Relative Importance Index (RII), Pearson's Chi-Squared, Q 66–117, Sustainability Professionals and Practitioners, Environmental Managers, Sustainability Engineers, Sustainability Experts, and Senior Sustainability Managers: Ranking and Multiple Choice Statistical Test: Pearson's Chi-Squared, Relative Importance Index (RII), Cronbach's Alpha (α), Mann–Whitney U-test.	Group 1: Decision makers and planners understand linking coping and adaptation strategies and actions to climate impacts, integrating climate into existing planning, and adopting forward-looking climate-informed goals. Group 2: Engineering and sustainability experts and senior managers utilize the sustainable existing management practices and tools and adopt new best practices in different ways to cope with climate changes (short-term) and adapt (long-term). Engineering managers, experts, and professionals are required to ensure resilience traits are prioritized in their work field, specifically in construction projects. The questions reveal the role played in adhering to the minimum requirements that directly contribute to reducing the potential climate change impacts. Additionally, they lead in coordinating processes for the multiple components of BESs, understanding the climate change resilience policy and procedures and statutory requirements, and facilitating the best resilience plan implementation.	Description and climate change adaptation arrangement, resilience performance attributes such as the awareness of resilience quality definition and ranking of climate change impacts consequences. Additionally, a description of the influence of decision-making towards improving built environment capacity. Learn from the past to inform future decisions and better recognize changing circumstances. Additionally, how to manage change and not be limited to persistence. The effort being made or to be made to advance the built environment to be more resilient and the level of preparedness in different sectors, including the construction industry. Description of utilizing existing learning from the past strategies and tools and adapting and deploying new methodologies beyond the day-to-day business and the level of awareness of the climate change impacts and risks. They use existing management tools differently and adopt new practices to cope with climate change. Type of management and sustainability plans that are pursued, determining if climate change adaptation plans are integrated into the overall management plan, a potential reflection of the past problems in the new plans. Furthermore, understanding the preparedness of the construction industry for climate change.
Q 118–167, Climate Change Experts, Scientists, Graduate Students, Professors, Scholars, Researchers, etc. Representatives of Society Development Organizations, Sustainability Programs, and Voluntary Firms: Ranking, Likert, and Multiple Choice Statistical Test: Pearson's Chi-Squared, Relative Importance Index (RII), Cronbach's Alpha (α), Mann–Whitney U-test.	Group 3: Incorporating climate change responsibility practice within the context of a developing city/system influences firms to increase ecological disclosure and improve systems performance, influence through engagement to further react to the damages caused by climate change and natural hazards and unsustainable practices as well as the collaboration with governmental organizations and other stakeholders [90]. Pursuing research on climate change and built environment resilience and determining the potential incorporation of required regulations and standards towards advancing resilience strategies.	Additionally, the complexity level in measuring the quality of corrective actions that could occur as a response to a climate change event. The preparedness of the construction industry for climate change and natural hazards. Type and quality of sustainable development actions, determining the role played and influence on the plans toward reduction of climate change impacts and risks. Research description, the complexity level in quantifying climate change impacts, identifying characteristics of resilient urban communities, and increasing climate change preparedness.

2.2. Questionnaire Distribution Process

The participants in this study were determined using a probability sampling method. Representatives for each audience group were chosen considering their profiles, experiences, and background knowledge. Respondents from regulatory bodies and government-owned entities and institutions were considered group one. Group two included the respondents from the construction industry (construction projects' developers, project management companies, real estate, design firms, consultants, contractors, etc.). Group three involved respondents from NGOs, NPOs, universities, and academia and research institutes. Most entities were approached directly and briefed about the research objectives, asking for their assistance in distributing the survey among the potential respondents at their entity. The researchers visited some governmental institutions in Qatar considered regulatory bodies and approached others via phone and email. Furthermore, the researchers contacted several engineering entities and construction companies on a regional level, including the gulf cooperation countries (GCC). In addition, many NGOs, NPOs, universities, and academic institutes were contacted to participate in the study.

The questionnaire survey was electronically distributed among the audience using the SurveyMonkey platform, as shown in Figure 4. The approval letter was granted by the institutional review board (IRB) in Qatar, and an introductory email was communicated to the targeted audience. More than two thousand respondents, including decision-makers, managing directors, regulators, experts, professionals, researchers, academics, etc., from different engineering and non-engineering disciplines, were approached through various means, from which 250+ responses were accomplished with 180+ completed responses. Demographic information of the respondents, including their roles, occupation, educational background, industry and entity they represent, experience, and geographical exposure of expertise, are discussed in Section 3.

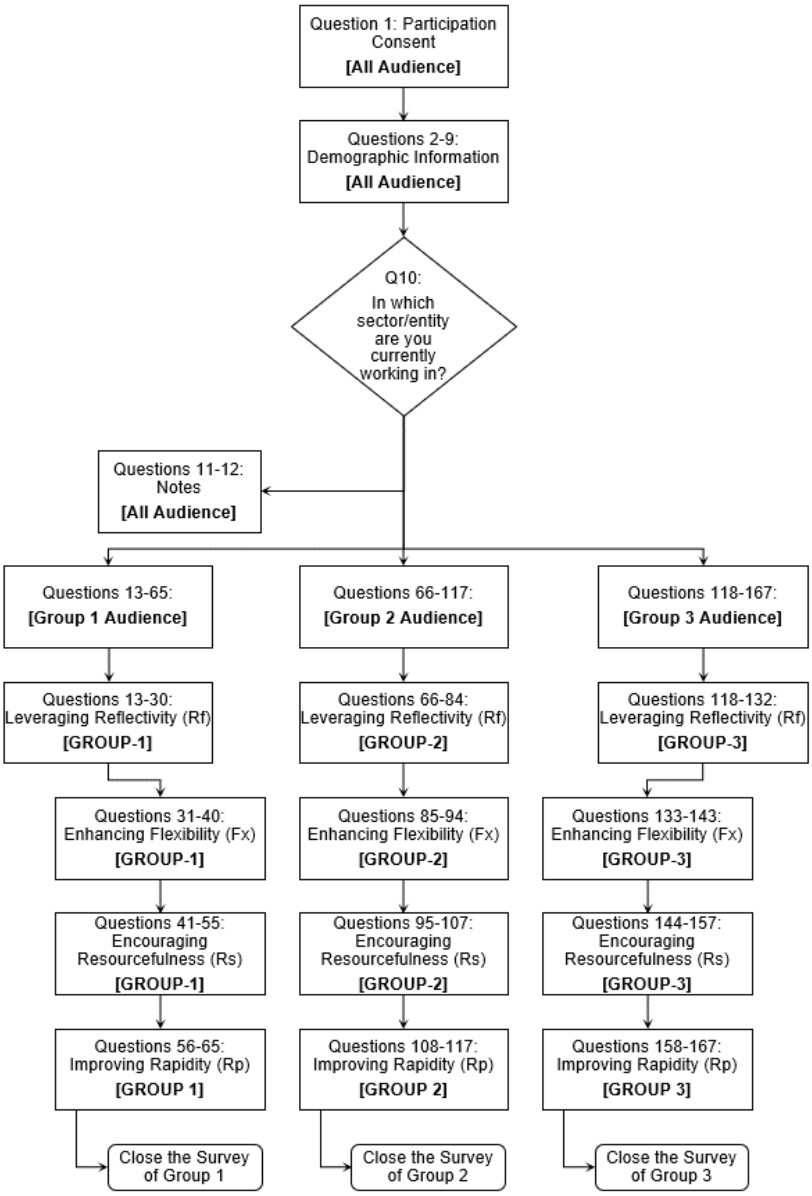


Figure 4. Survey electronic distribution process.

2.3. *Questionnaire Reliability and Validity*

The survey was designed and drafted according to a set of criteria. The initial draft survey was communicated with three professionals from each group who had at least a profound experience in climate change, urban resilience, sustainability, green buildings, civil engineering, or the environment. As explained in Table 2, the questions were designed for three groups and prepared based on the four targeted RQs, in which each quality contained up to six indicators. The questions were tailored and simplified to reflect precisely the understanding and knowledge of respondents from each group. Nevertheless, some general questions remained common for all; hence, they were answered by all. The studied indicators were kept the same for all groups to assess each indicator based on views from different groups. The chosen professionals agreed on the proposed questions, highlighting some minor comments addressed before issuing the survey's final draft. In addition, an application to the Institutional Review Board (IRB) hosted by Qatar Biomedical Research Institute at Hamada Bin Khalifa University was submitted to comply with the codes of conduct and ethics and ensure the confidentiality of respondents' profiles and participation.

The responses were automatically collected over five months through the SurveyMonkey platform. The validity and reliability of the questionnaire results were ensured using different statistical techniques. A Cronbach's Alpha (α) test was applied to test the reliability and consistency of the measures, including Likert measures. Additionally, Pearson's chi-squared (X^2) and Student's T-tests were applied to determine the complexity and correlations between the measured indicators. Furthermore, an extra verification of the attained results was applied using the Mann–Whitney U-test, which is discussed in Section 3.4.

3. Results and Discussion

Survey responses were collected from May through September 2022. Participants were asked about their perceptions on issues related to the impact of climate change on the built environment and their experiences in the reaction of the built environment to disturbances caused by climatic and natural disasters, as done by Ngin et al. [91]. Additionally, they were asked about the impacts of climate change on the city's systems and the coping and adaptation strategies that need to be considered to avoid damage in different phases of resilience, including preparedness, response, recovery, and adaptation. The questions also captured their perspectives on requirements to reduce the potential risks of climate change on the built environment systems and thus communities. The different participant definitions and types are graphically presented in Figures 3 and 5, respectively. Most of the responses were provided by engineers or equivalent employees from the construction industry (group 2), such as contractors, consulting companies, design firms, etc., forming about 52% of the total responses. The responses from the executive entities (i.e., regulatory and government-owned entities) formed 27% of the total responses, followed by group 3 (i.e., NGOs, NPOs, universities, and academia) with a total of 21%, as shown in Figure 6. The percentage ratio of the responses from the three groups was approximately 1:2:0.8, in which the majority of responses were collected from participants with experience of between 6 and 25 years.

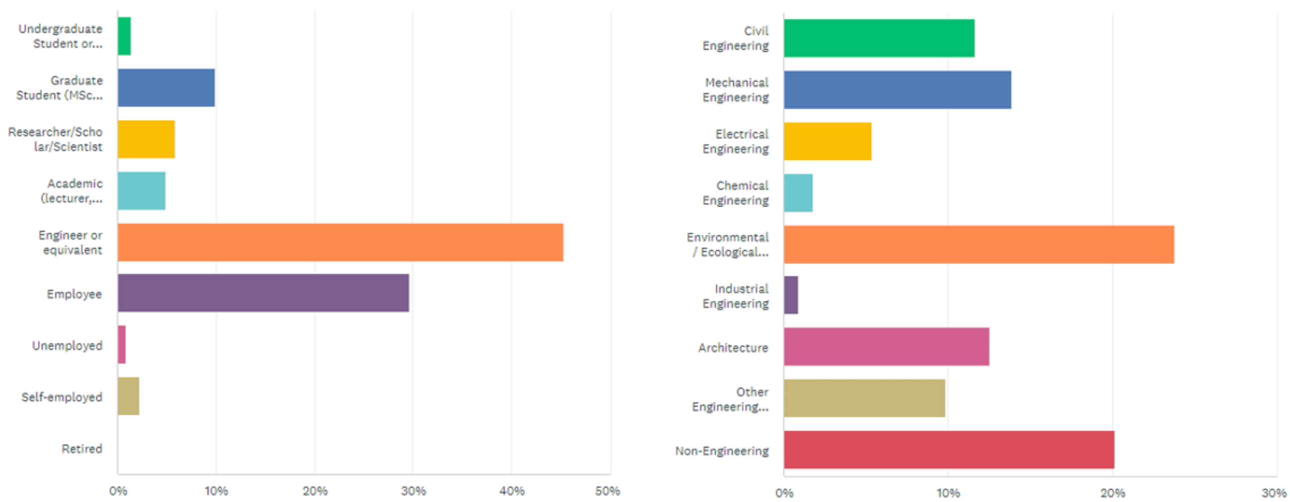


Figure 5. Types of participants engaged in the study.

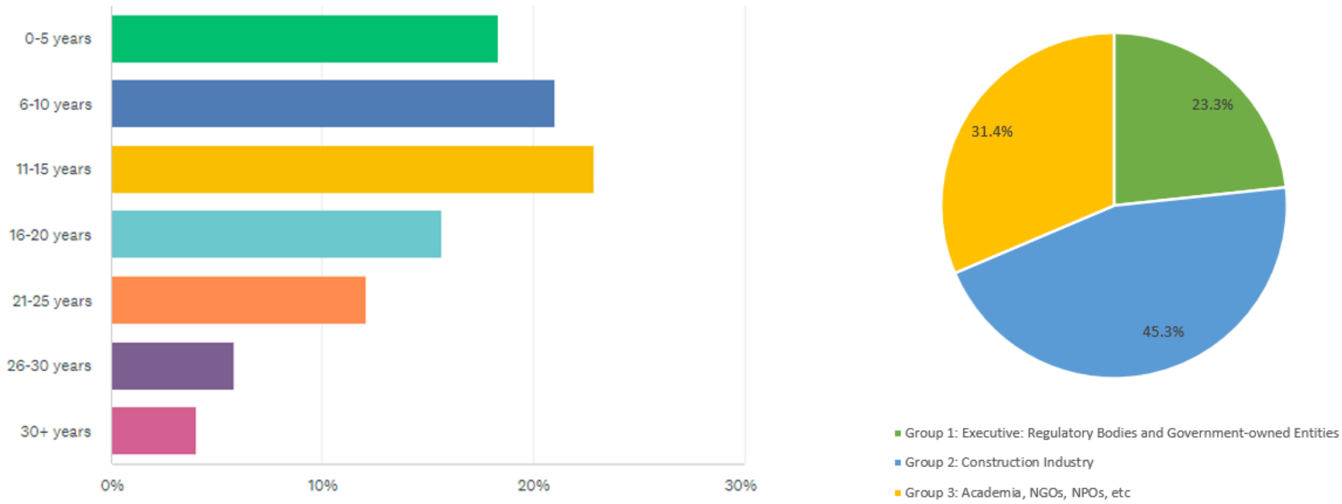


Figure 6. Years of experience of participants and types of entities engaged in the study (%).

3.1. Awareness of the Respondents about Resilience of the Built Environment

Awareness of climate change issues and natural hazards is vital, specifically where the climate changes dramatically. In this study, the respondents' understandings of the significance of the resilience of the built environment against impacts driven by climate change needed to be determined by asking the respondents about the different resilience aspects through defined indicators. Figures 7 and 8 depict the total number of respondents and the rate of responses across the various groups with 100% correct answers. A Pearson's chi-squared (X^2) test was applied to determine the influence of the group type on the proper response rate of public awareness, management efforts, mortality and economic efforts, and necessary plans for reducing potential climate change and natural disasters. Statistically, there was insufficient evidence against the null hypothesis of differences in grouping and professionalism types (p-value of 0.995 at 5% significance). Thus, no prevalent group had superior knowledge of the importance of public awareness and attitudes related to climate change disaster reduction, improving management efforts, reducing mortality and economic losses, and developing necessary plans for implementation. Most respondents from group 1 (executive and regulatory) and group 3 (NGOs and academia) believed that the efforts made in these areas are good and excellent. At the same time, the construction industry (group 3) expressed that the level of effort is mainly between average and good. This could be interpreted that improvement is still needed to advance public awareness and management, reduce economic losses, and develop necessary plans.

3.2. Ranking Resilience Qualities

The survey questionnaire was designed based on the information extracted from the literature, maintaining a high level of clarity for all targeted groups. The three groups of respondents were targeted to answer these questions, as explained in Sections 2.1 and 2.2. The respondents were asked to rank several items belonging to different indicators that formed the selected four RQs of the built environment for this study based on their purviews and experiences. The total number of defined indicators for each studied RQ was between four and six. They were determined based on the abundance of relevant information gathered from the literature. The ranking range varied from one question to another, depending on the applied scale. Rank 1 represented the top important resilience quality based on selected indicators, as explained in Table 4. The importance was ranked using the relative importance index (*RII*) on a range from 1 to 5, applying Equation (1):

$$RII = \sum \frac{W_i}{A \times N'} \quad (1)$$

where W_i is the weighting assigned to each variable by the respondent, A is the highest weight, and N' is the total number of respondents.

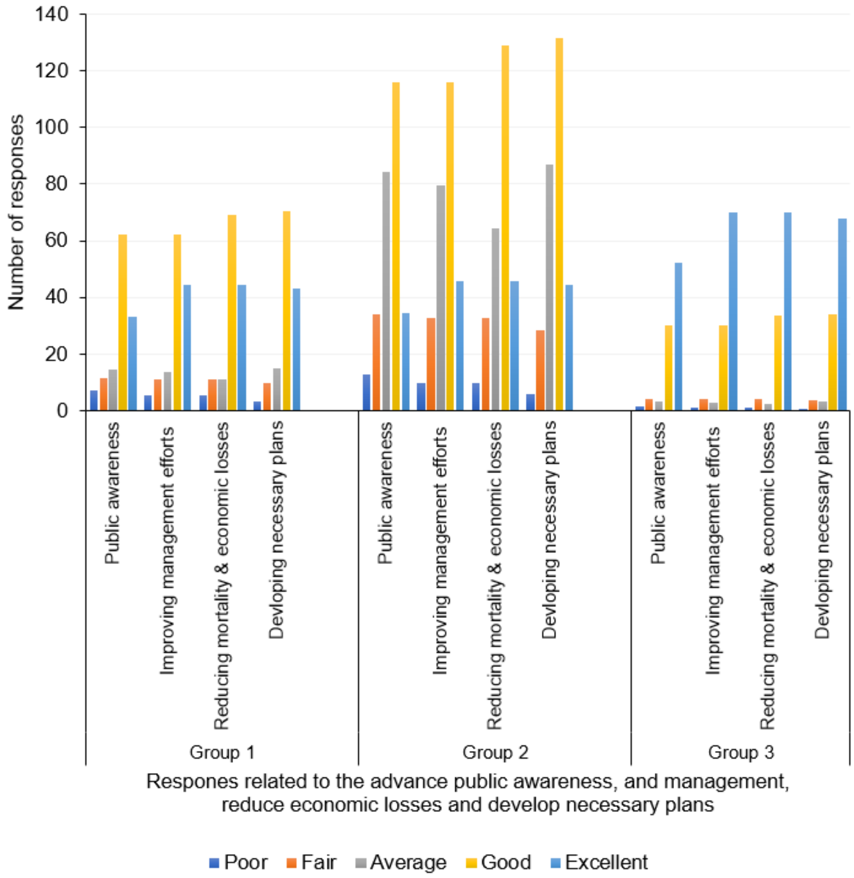


Figure 7. Answers evaluating the stakeholders' awareness and attitudes, improving management efforts, reducing mortality and economic losses, and developing necessary plans for disaster reduction from the perspectives of different groups.

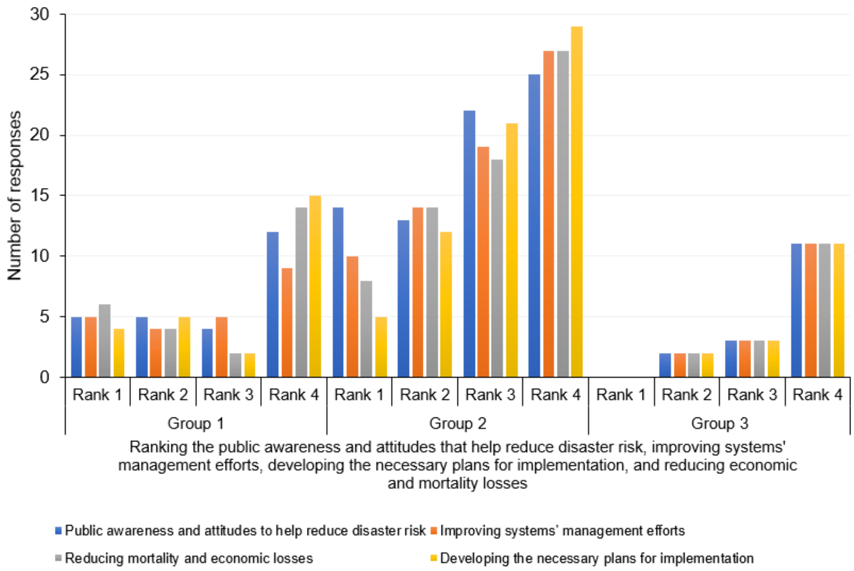


Figure 8. Groups' responses to ranking the awareness and attitudes of stakeholders.

Table 4. Summary of the typical resilience quality indicators in this study.

#	Resilience Quality (RQ)/Indicator	Scope/Definition	Reference
1.0	**Leveraging Reflectivity (Rf)**	The needed reaction of the institutions, organizations, and entities to disturbances and sharing views and feedback from previous experiences to inform future decision-making.	[92,93]
1.1	Learning from the past		
1.2	Active participation of professional stakeholders and experienced actors		
1.3	Planning for future		
1.4	Preparation for disasters		
1.5	Decision-making facilitating		
1.6	Reflective environment systems		
4.0	**Enhancing Flexibility (Fx)**	The ability of the system to adopt alternative strategies to a climate change crisis and natural hazards and adaptability to environmental variations. Additionally, it is about the capacity to accept changes in the aftershock of disturbances through emergency planning.	[94–96]
4.1	Identifying, quantifying, and controlling the flexibility		
4.2	Adopting alternative strategies to the crisis		
4.3	Adaptation and inherent capacity		
4.4	Climate adaptation policies and processes		
4.5	Incorporating traditional knowledge and practices		
4.6	Efforts to mitigate climate change impacts		
5.0	**Encouraging Resourcefulness (Rs)**	The capacity to identify problems and priorities and allocate and mobilize resources before, during, and after a disastrous event considering human factors.	[46,97]
5.1	Disaster preparedness.		
5.2	Emergency management		
5.3	Resources utilization		
5.4	Mitigating the losses by the community		
5.5	Visualize and act		
5.6	Identify problems and establish priorities		
6.0	**Improving Rapidity (Rp)**	The ability of the system to quickly recover from the encountered crisis. The concept is about how the features of responsiveness, adaptation, and recovery activities enable the affected system to recover to its full operational function quickly.	[39,98,99]
6.1	Responsiveness and restorative capacity		
6.2	Adaptation		
6.3	Rapid recovery		
6.4	Recovery activities (resource allocation)		

3.3. Leveraging Reflectivity (Rf)

Leveraging reflectivity (Rf) can take place through reacting to disturbances and sharing views and what was learned from the past to leverage them to future decision-making. In this study, several indicators were defined based on the previous research work and resilience frameworks. The indicators included learning from the past, active participation of professional stakeholders and experienced actors, planning for the future, disaster preparation, decision-making facilitation, and reflective environment systems.

The respondents from the three groups ranked the four built environment systems in terms of accepting the change and uncertainty inherited from the past or generated over time. Groups 1 and 2 ranked open space and movement systems as the top two systems that accepted the change and uncertainty from the past or developed over time, as outlined in Table 5 and Figure 9. Both groups had the same perception regarding life support and shelter systems, resulting in the same ranking. The ranking given by Group 3 respondents agreed with group 1 concerning the open spaces; however, they believe in the opposite regarding life support and movement systems. The life support systems were ranked third by groups 1 and 2 and assigned a ranking of two by the third group. The shelter systems (i.e., buildings) ought to have the lowest ranking among the three groups. They were ranked the lowest by all three groups; however, the results showed that the overall ranking of shelter systems matched the perception of group 1. The assigned ranking could be attributed to the history of the building sector in withstanding climate impacts experienced over the past years [100,101]. This might allow for arguments about the capacity of shelter systems to accept climate change consequences. Table 5 outlines the results concerning the relative importance index of the reflective built environmental systems.

Table 5. Relative importance index of the reflective built environmental systems that accept the change and uncertainty inherited from the past or generated over time ranked by multiple respondent groups.

Statement Subject	Group 1		Group 2		Group 3		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Shelter systems (i.e., buildings)	0.6065	4	0.6846	4	0.6121	4	0.6507	4
Life support systems (i.e., energy and water supply systems, etc.)	0.7226	3	0.7256	3	0.6667	2	0.7113	3
Movement systems (i.e., transportation infrastructure (roads, bridges, etc.))	0.7290	2	0.7410	1	0.6485	3	0.7169	2
Open space systems (i.e., the utility for park and recreation purposes)	0.7355	1	0.7385	2	0.6788	1	0.7239	1

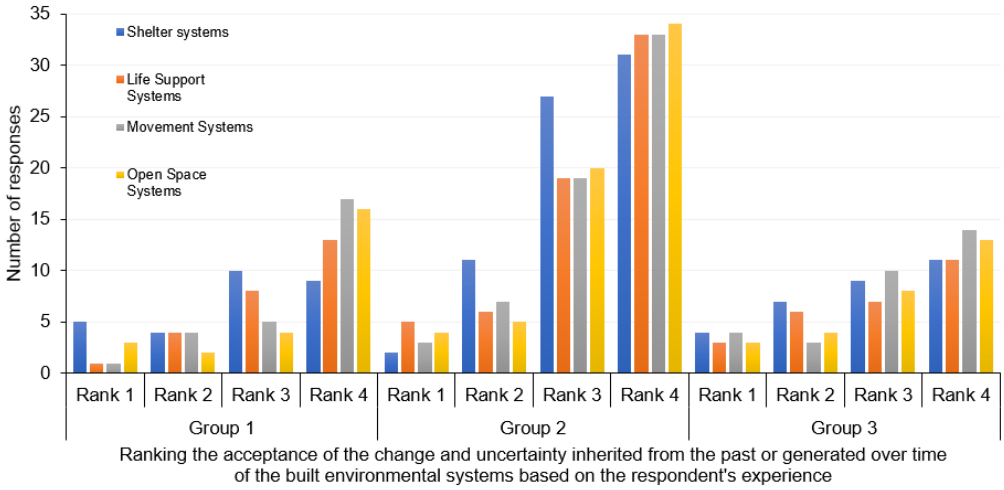


Figure 9. Ranking the acceptance of the change and uncertainty inherited from the past or generated over time by the built environment systems based on the respondents' experiences.

The responses showed that the quality and capacity of the built environment systems play a significant role in managing the needed services and resources during emergencies promptly and correctly. The improper installation and management of life support systems, mainly in developing regions, lack such capacities, which makes them more vulnerable to climate change consequences. The three groups believe in leveraging previous climatic experiences to inform future decision-making. The use of previous climatic experiences by governmental authorities was ranked on a scale of 5 (the range was 1 (lowest) to 4 (highest)). Similarly, the ranking of integration of uncertainty and flexibility explicitly into the decision-making process and the engagement of NGOs, academia, and the construction sector was determined, as shown in Figure 10. Most respondents believe that the previous climatic experiences are not fully leveraged by the governmental authorities while planning leverage to inform future decision-making. At the same time, the respondents distrust the level of engagement the NGOs, NPOs, academia, and construction companies in the policy-making decision techniques to increase the preparedness of the built environment against climate change disasters. On the other hand, the results determined that the current integration of uncertainty and flexibility explicitly into the decision-making process is still insufficient. Improving the level of integration would enhance the preparedness of the built environment systems against climate change disasters, reduce capital expenditure, and improve investment value.

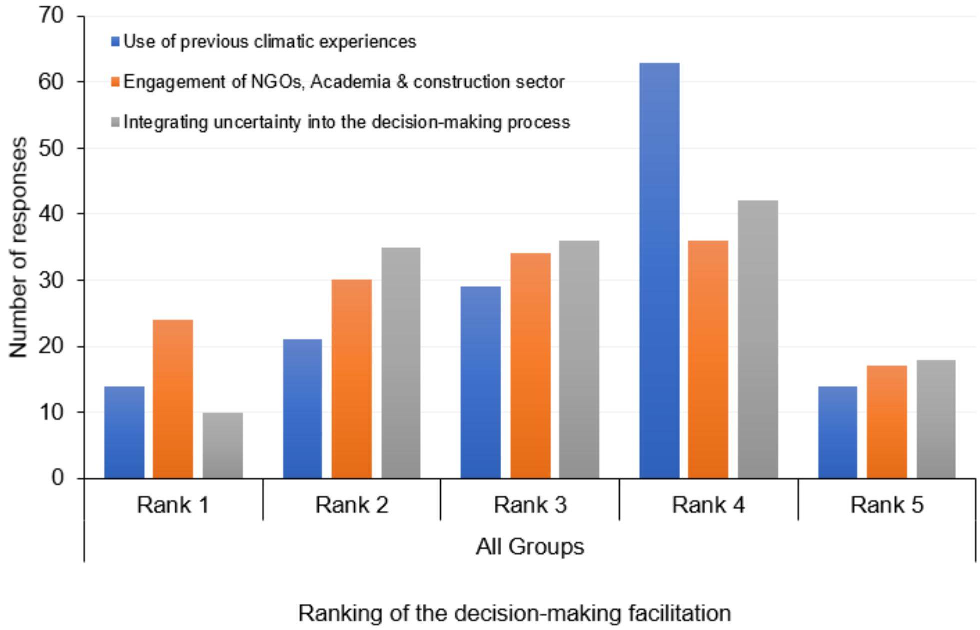


Figure 10. Ranking of the decision-making facilitating: previous climatic experience, engaging other parties, and integrating uncertainty into the process.

The three groups were asked about using previous climatic experiences, engagement of NGOs and the academia and construction sectors, and integrating uncertainty into the decision-making process. The purpose was to determine the correlation with decision-making facilitating. The results shown in Figure 11 indicated a slight skew towards a correlation in using previous climatic experiences; engagement of NGOs and academic and construction sectors, and integration of uncertainty into the decision-making process. This confirmed that these three indicators were strongly connected to decision-making facilitating concerning BESs resilience against climate change. This emphasized the perception that the decision-making domain is crucial for delivering a reflective built environment.

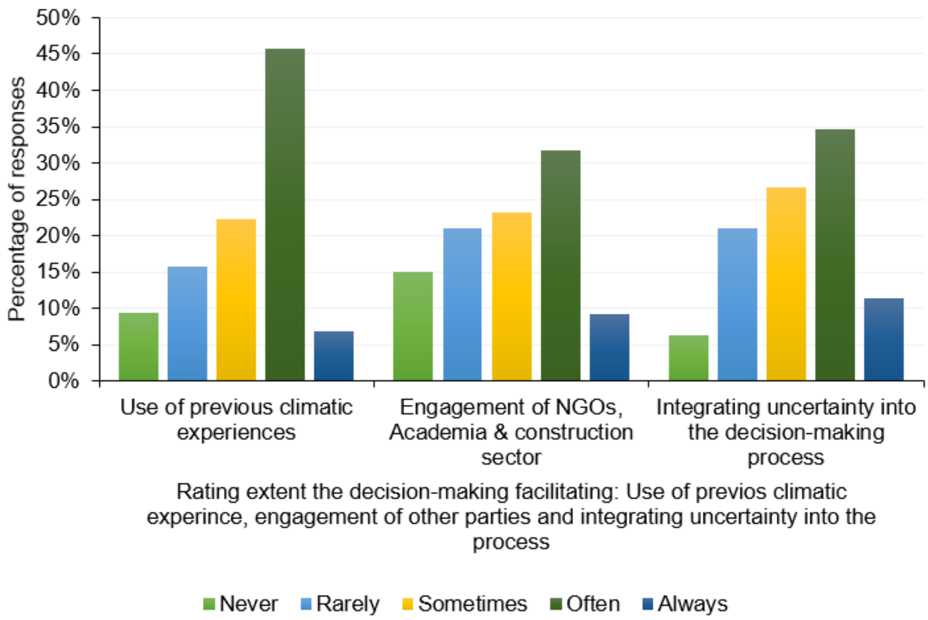


Figure 11. Correlation extent of decision-making facilitating various indicators.

Similarly, the participants from three groups were asked if relevant authorities and organizations have the capacity to plan for anticipated or unknown climate change disasters. The results presented in Figure 12 showed that 57% accept the notion; however, about 43% of responses revealed that the relevant authorities' capacities do not exist or are not known yet. This might be attributed to limited engagement and participation in such organizational activities that relevant authorities and regulatory bodies must ensure.

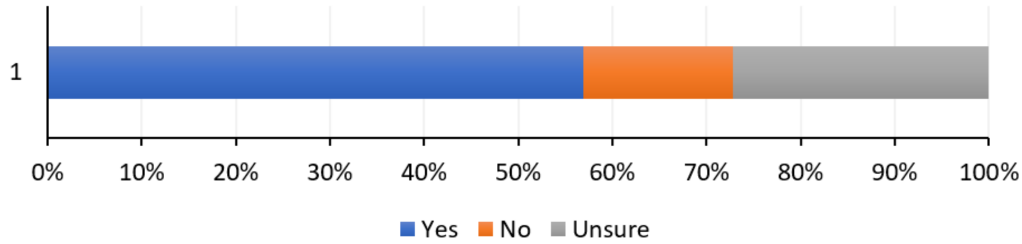


Figure 12. Capacities of local government authorities and other relevant organizations to plan for anticipated or unknown climate change disasters.

The relative importance index (RII) analysis was applied to the reflective environment systems to determine the adoption of three main practices. The practices include seeking permanent solutions based on the current status of the built environment systems; and modifying standards, norms, and regulations based on the collected information and emerging evidence from climate change stress and shocks experienced. The results showed that pursuing permanent solutions is the most important to be adopted, as outlined in Table 6. The reason could be attributed to the fact that understanding the possible solutions is crucial to achieving a more resilient built environment [102]. The emerging evidence from the experienced climate change stress was evaluated to be the lowest since the respondents believed more in the significance of updating the relevant standards, norms, and regulations based on the collected information. The emerging evidence might be more useful once it results from environmental systems built according to updated and modified standards that contribute to permanent solutions.

Table 6. Relative importance index of the reflective built environmental systems through adapting resilience practices.

Statement Subject	**Group 1**		**Group 2**		**Group 3**	
	RII	**Rank**	**RII**	**Rank**	**RII**	**Rank**
Seeking permanent solutions based on the current status of the built environment systems	0.6581	1	0.6658	1	0.6121	2
Modifying standards, norms, and regulations based on collected information	0.6258	3	0.6430	2	0.6364	1
Emerging evidence from climate change stress and shocks experienced	0.6387	2	0.5949	3	0.5758	3

3.4. Flexibility and Resourcefulness: Relationship and Performance

Flexibility refers to the ability of a system to change, evolve, and adapt in response to sudden events and changing circumstances. It may include other ways of introducing and incorporating practices and local knowledge [103]. The encounterable challenges of identifying, quantifying, and controlling the flexibility of an urban system were also determined, as in Figure 13. The correlation extent of main encounterable challenges showed a high skew toward a correlation between the flexibility of a BES in innovative techniques, advanced management strategies, and emergency planning. The skewness revealed the relationship between the flexibility indicators and the principles of leveraging previous climatic experiences to inform decision-making as part of the reflectivity resilience quality.

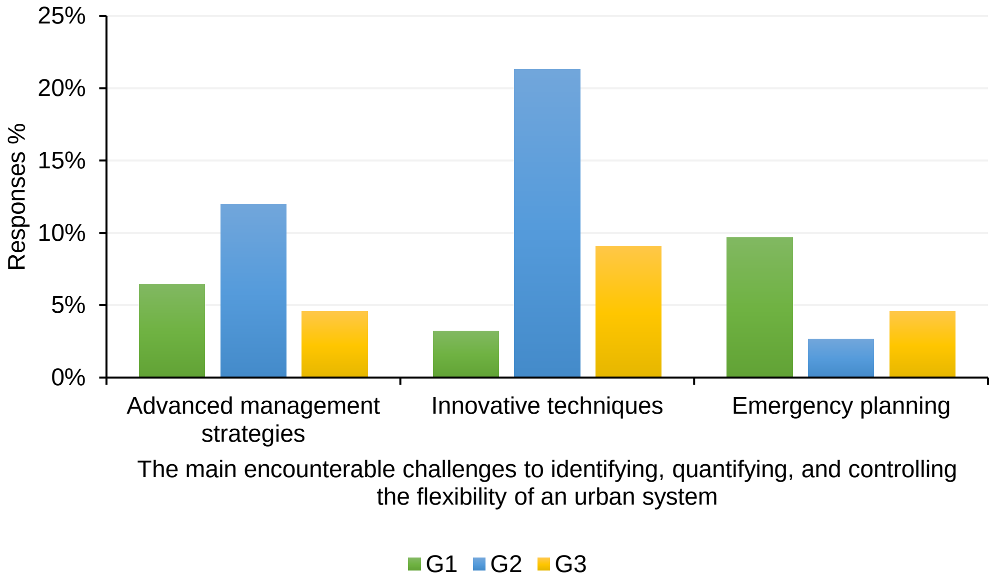
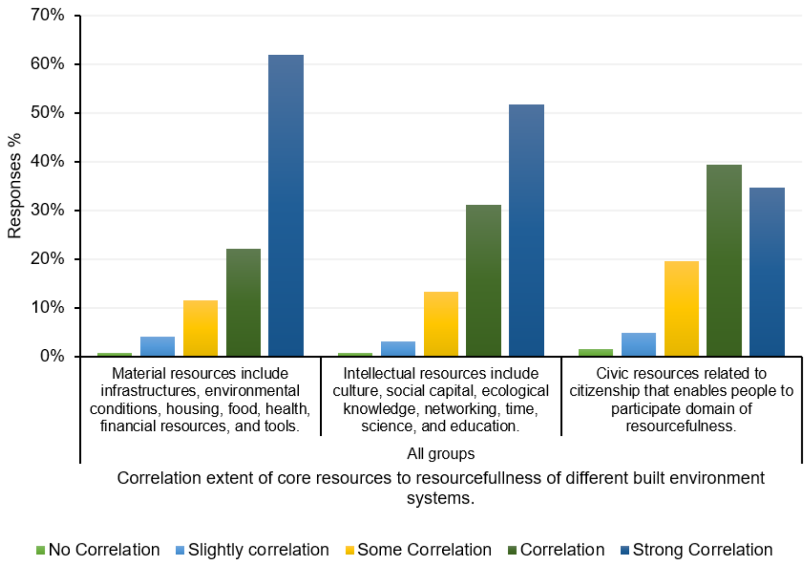


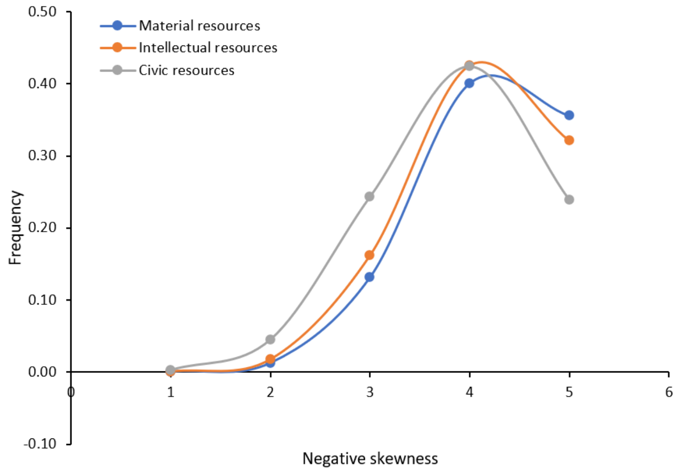
Figure 13. Identifying the main encounterable challenges to identifying, quantifying, and controlling the flexibility of an urban system.

In this study, the correlation extent of core resources that constitute resourcefulness was determined by asking the respondents about the level of the resourcefulness of a built environment system affected by the core resources. The core resources include material resources such as infrastructures, environmental conditions, housing, food, health, financial resources, and tools. Additionally, they include intellectual resources such as culture, social capital, ecological knowledge, networking, time, science, and education. Furthermore, the resources include civic resources related to citizenship that enables people to participate in the domain of resourcefulness. Figure 14 indicates a strong skew towards a correlation of the core resources in materials selection, intellectual resources, and civic resources related to citizenship, which confirmed that the core resources were directly associated with the resourcefulness of the built environment systems. This affirmed the notion that the resourcefulness of the built environment systems domain is crucial for resilient systems. The participants were asked about the difficulty of evaluating the capacity of the existing built environment systems to withstand different climate variations and limit the potential degradation of performance indicators. The results shown in Figure 15 revealed that the existing systems can partially withstand climate change variations such as temperature, flooding, sea level rise, etc. This may be attributed to the non-undertaking of climate-proofing in the design and construction processes of the built environment system [104]. In total, 27% of respondents indicated that the existing built environment would struggle with climate change variations. However, 30% of the respondents believe in the capacity of the existing systems to withstand such challenges.

In addition to what was discussed in Section 3.3, the collected responses from three groups showed that resourcefulness indicators were more likely to support emergency management rather than rely on the community to mitigate losses. This may be attributed to the considerable 40% of respondents reinforcing the importance of emergency management as a top principle to be considered to enhance the response of the systems and the entire community, according to [105]. Additionally, according to Figure 16 and Table 7, 34% of respondents endured were assigned to disaster preparedness, bringing this indicator to the second significance level. This might be attributed to the cruciality of measures taken to prepare for disaster events and reduce the effects, as done by Samsuddin et al. [39].



(**a**) Responses percentages



(**b**) Skewness representation

Figure 14. Correlation extent of main encounterable challenges to identifying, quantifying, and controlling the flexibility of an urban system.

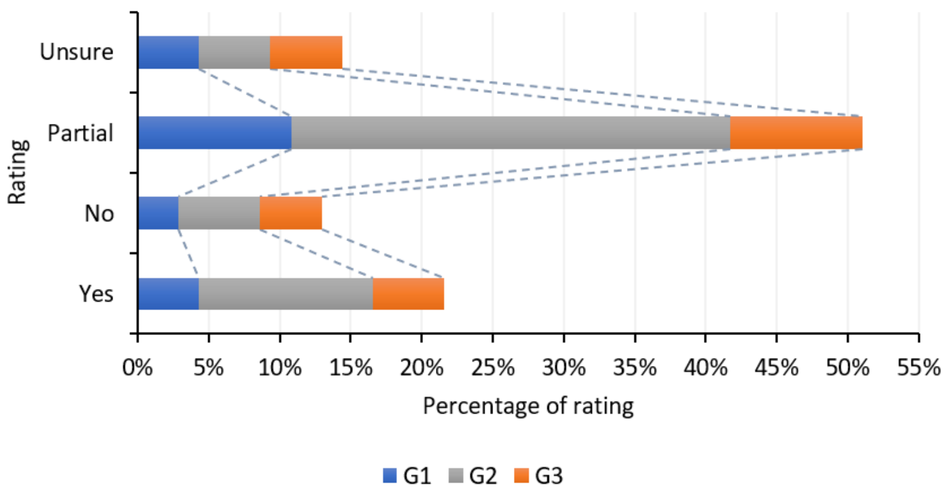


Figure 15. Responses of the existing built environment systems withstanding different climate variations and limiting the potential degradation of performance indicators.

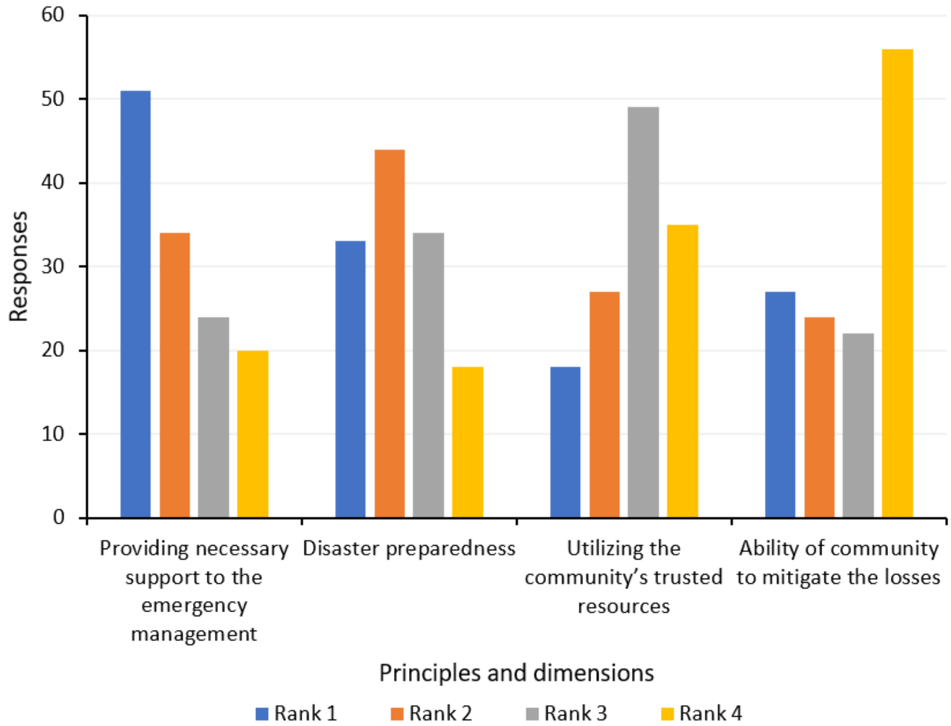


Figure 16. Participants' responses to ranking the acceptance of the change and uncertainty inherited from the past or generated over time of the built environmental systems based on the respondents' experiences.

Table 7. Relative importance resourcefulness index of various general resilience principles ranked by multiple respondent groups.

Statement Subject	Group 1		Group 2		Group 3	
	RII	Rank	RII	Rank	RII	Rank
Providing necessary support to the emergency management system through the political and economic structure	0.5446	4	0.5036	4	0.5703	3
Disaster preparedness through preparing the residents and the whole community	0.5982	3	0.5616	3	0.5547	4
Utilizing the community's trusted resources to allow the community to cope with the climate change hazards	0.6339	2	0.7319	1	0.6719	2
The ability of the community to mitigate the losses through making smart decisions	0.7232	1	0.7029	2	0.7031	1

Resourcefulness means that the system can rapidly find different ways to meet its needs or achieve its goals during an event or shock or when it undergoes stress [103]. It is also known as the ability of the system to identify problems, determine priorities, and manage resources when a disaster happens [39]. Resourcefulness could be calculated using existing proposed indexes, such as the composite index applied by Zona et al. to quantify the resourcefulness of communities on a country level [105]. Although Mackinnon and Derickson argued resourcefulness as an alternative to resilience because it problematizes and rectifies the recognition and redistribution issues [106], it is considered one of the main qualities by several resilience indexes. The respondents were asked certain questions about identifying the problem and establishing priorities. The results of Figure 17 implies that 64% believed in the importance of the task forces within the community as part of an emergency response plan to protect the built environment systems. This explains why 55% of respondents highlighted their unsureness of any current community engagement, directly or indirectly, in mitigating the losses caused by climate change disasters. This again emphasizes the need for reducing climate change events' impacts on the built environment by engaging communities.

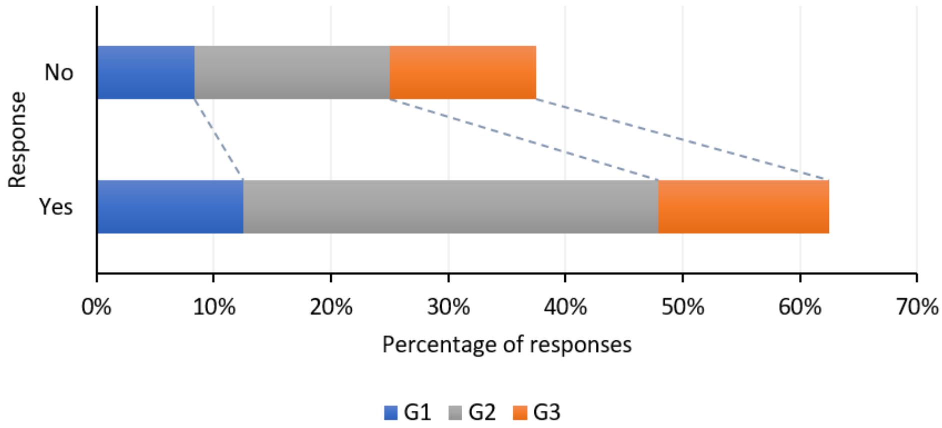


Figure 17. Community engagement in mitigating the losses caused by climate change disasters.

In this study, a non-normal distribution was assumed, and the nonparametric statistical test known as the Mann–Whitney U-test was used to determine whether the different participants from the three groups had different ranking opinions about the importance of the different principles and dimensions of flexibility. The three groups resulted in a total of four tests per group based on the following two hypotheses:

H0: Null hypothesis: The three groups have the same mean (H0: G1 = G2 = G3). In other words, there is no difference between them.

H1: Alternate hypothesis: The three groups do not have the same mean (H0: G1 ≠ G2 ≠ G3). In other words, there are three different means.

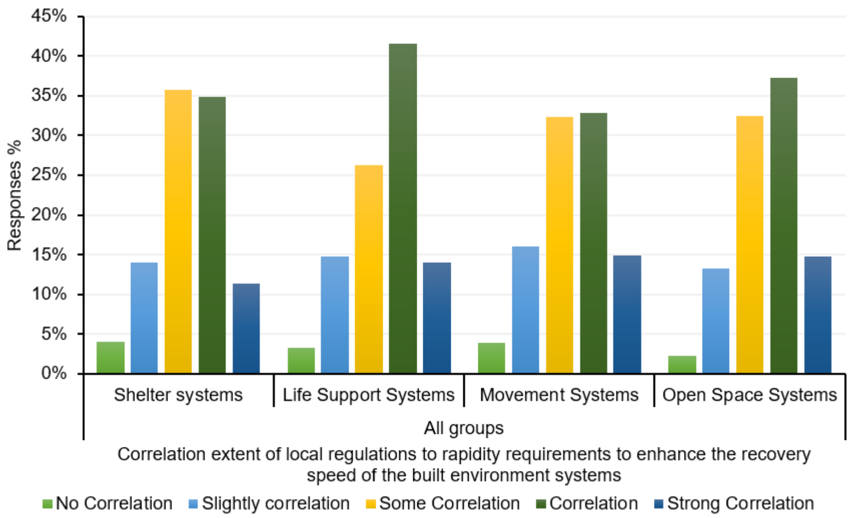
Table 8 presents the statistical Mann–Whitney U-test results, which showed the rejection of the null hypothesis with those *p*-value results below 0.05. All importance rankings of Test 2 (G1 and G3) and Test 3 (G2 and G3) showed significant statistical differences in the rankings. In contrast, Test 1 (G1 and G2) showed significance for providing necessary support to the emergency management system, disaster preparedness through preparing the residents, and mitigating the losses through making smart decisions by the community. On the other hand, Test 1 showed no significance for utilizing the community's trusted resources. The results reflected the differences between groups and validated the differences obtained from the ranking on their perceptions of the importance of flexibility principles and dimensions.

Table 8. Mann–Whitney U-test results for comparing groups and the importance of some flexibility principles and dimensions over or below 0.05.

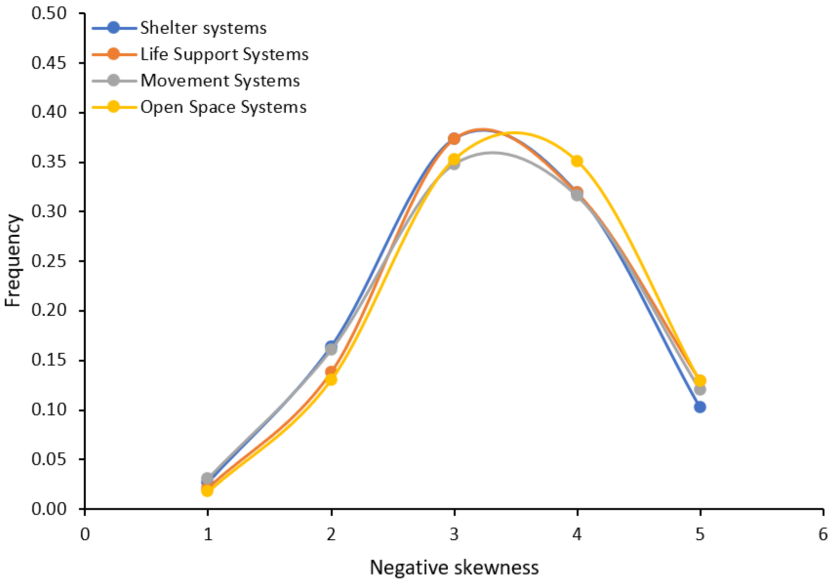
Flexibility Principles and Dimensions Ranked in Terms of Groups' Influence	Mann–Whitney U-Test Results		
	Test 1	Test 2	Test 3
	G1 and G2	G1 and G3	G2 and G3
Providing necessary support to the emergency management system by the political and economic structure	0.5521	0.8591	0.3866
Disaster preparedness through preparing the residents and the whole community	0.5398	0.6722	0.9181
Utilizing the community's trusted resources to allow the community to cope with the climate change hazards	0.0402	0.4388	0.3372
The ability of the community to mitigate the losses through making smart decisions	0.6572	0.6262	0.9390

3.5. Improving Rapidity (Rp)

The rapidity (Rp) of a built environment system refers to its capacity to recover quickly from an encountered crisis, even with some losses. It concerns the speed affected systems or facilities need to recover to their full operational function through responsiveness, adaptation, and recovery activities. This section determined whether the enhancement of the recovery speed of the built environment systems and the requirements of the local regulations and standards were correlated. The respondents were asked about the level of correlation for the four different built environment systems (shelter, life support, movement, and open space systems). Figure 18 shows a skew toward a medium "correlation" between the recovery concerning the local regulations and standards. However, 15% of the responses indicated a "strong correlation," which might be considered weak, especially if a high rapidity is sought from the system. This may emphasize the need to revise the local standards and regulations to advance the recovery requirements. Furthermore, this output affirmed that the rapid recovery of the built environment system was quite significant.



(**a**) Responses percentages



(**b**) Skewness representation

Figure 18. Correlation extent of local regulations to rapidity requirements to enhance the recovery speed of the built environment systems.

Table 9 outlines the relative importance index analysis conducted to determine the ranking of the recovery speed against climate change impacts demonstrated by the built environment systems. The results show that groups 2 and 3 ranked the open space systems at the top compared to others, while group 1 believed in the movement systems. The life support systems were also ranked at the top by group 3, but groups 1 and 2 assigned them to 2 and 3, respectively. Group 1 affirmed that the shelter systems had the lowest ability and speed capacity to recover from a climate event, while groups 2 and 3 believed in their average capacity. This can be interpreted that with a less reflective system, as obtained in Section 3.3, there would be less recovery speed. Therefore, the rapidity characteristic of a built environmental system to accept the change and uncertainty inherited from the past or generated over time was correlated with the system's reflectivity quality.

Table 9. Relative importance index analysis for recovery speed against the climate change impacts demonstrated by the built environment systems ranked by multiple respondent groups.

Statement Subject	Group 1		Group 2		Group 3	
	RII	Rank	RII	Rank	RII	Rank
Shelter systems (i.e., buildings)	0.7000	4	0.6700	2	0.6414	4
Life Support Systems (i.e., energy and water supply systems, etc.)	0.7667	2	0.6667	3	0.6966	1
Movement Systems (i.e., transportation infrastructure (roads, bridges, etc.))	0.7750	1	0.6400	4	0.6690	2
Open Space Systems (i.e., the utility for park and recreation purposes)	0.7417	3	0.6800	1	0.6966	1

An unexpected result from group 2 was the low ranking for movement systems compared to the other two groups, which mainly believe shelter systems are worthy of the low ranking. However, groups 1 and 2 contrarily allocated ranking 3 for the life support and open space systems. This is evidence that the perspectives of the groups related to the rapidity of the built environment systems against climate change could differ significantly. This could be due to the professional experiences and advancement that shape their beliefs [107].

3.6. Complexity in Evaluating Some Resilience Characteristics

To evaluate the level of complexity of different main resources for the reflectivity and resourcefulness resilience qualities and their adoption by the different authorities and organizations, a sequence of resources was presented with a five-argument Likert scale. The scale ranged from very easy (1) to very hard (5). The questions were developed based on a comprehensive review done of the literature and relevant resilience reports, frameworks, and climate action plans [6,35,102,103,105,108]. The included resources or items were those seeking permanent solutions based on the current status of the built environment systems (resource 1); modifying standards, norms, and regulations based on collected information (resource 2); emerging evidence from climate change stress and shocks experienced (resource 3); material resources include infrastructures, environmental conditions, housing, food, health, financial resources, and tools (resource 4); intellectual resources include culture, social capital, ecological knowledge, networking, time, science, and education (resource 5); and civic resources related to citizenship that enables people to participate domain of resourcefulness (resource 6). The reliability and internal consistency of the question and selected scale helped ensure the reflection of the overall complexity when evaluating the adoption of reflectivity and main resourcefulness resources using the Cronbach's Alpha (α) test. The α ranged from 0 to 1, in which higher values indicated more significant internal reliability and consistency. The results from this study showed a value of 0.7628, showing a high consistency, representing the complexity level in evaluating the main resources of reflectivity and resourcefulness. The complexities of the defined resources are presented in Figure 19.

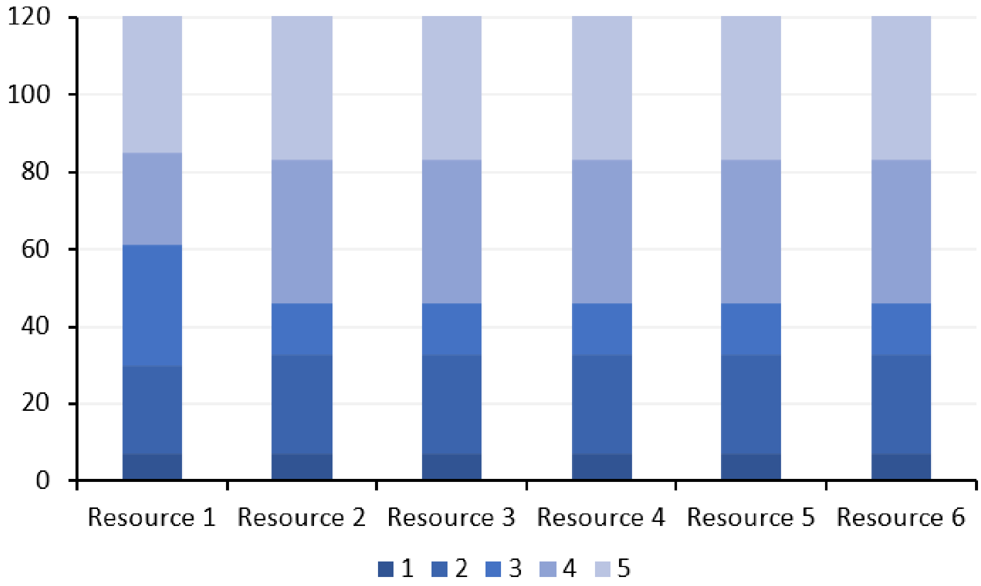


Figure 19. Main reflectivity and resourcefulness resources and complexity results.

4. Conclusions

Assessing the resilience qualities of the built environment enables policymakers, researchers, and professionals to understand the extent to which the built environment achieves climate change adaptation and resilience compliance. This study was based on a questionnaire survey designed to investigate relevant different groups' understandings of the built environment resilience and how they perceived the level of significance of resilience indicators that form the resilient built environment systems. It was also designed to study and explore the correlation between the defined four resilience qualities from the perspective of the four groups. The participants in the study were grouped into three groups according to their educational background, type of organizations and authorities, and industrial sectors. The results support the importance of resilience indicators and characteristics for the built environment systems, which were classified into four categories according to the literature, international standards, and the latest related report.

This study was undertaken by reviewing the academic literature to summarize the resilience qualities and their indicators, which provided the basis for drafting the questionnaire survey. The questionnaire focused on four main resilience qualities of the built environment, including reflectivity, flexibility, resourcefulness, and rapidity, and was tailored to three main groups of respondents. Consequently, the obtained responses were statistically analyzed to evaluate the four resilience quality indicators, including correlations between different indicators. In this study, different stakeholders, including governmental authorities, regulatory bodies, engineering firms, professionals, contractors, and non-governmental and non-profit organizations (NGOs and NPOs), were interviewed and investigated in terms of their understanding and knowledge levels about (1) climate change adaptation, (2) the built environment resilience qualities and their measures and indicators, and (3) the degree of resilience of the existing built environment and their perceived capacities to reduce the climate change consequences.

The results of this research study show the need to take into account the resilience indicator related to reflectivity, flexibility, resourcefulness, and rapidity, especially in the more vulnerable areas or those more sensitive to climate change impacts. They also show that no predominant group had a better knowledge of the importance of public awareness and attitudes related to climate change disaster reduction. Additionally, advancing the public understanding and management tools, reducing economic losses, and developing necessary plans still require improvement. They also emphasize the perception that the decision-making domain is crucial for delivering a reflective built environment. For reflectivity, the responses showed that the quality and capacity of the built environment systems play a significant role in managing the needed services and resources during emergencies promptly and correctly. They also outline the results concerning the relative importance index of the reflective built environmental systems. Most resilience indicators were ranked on a scale of 1 to 5 and 1 to 4. The ranking showed the different perceptions of the different groups of respondents.

Furthermore, the results validated the differences between groups obtained from the ranking on their perceptions of the importance of flexibility principles and dimensions. The majority believe in the importance of the taskforces within the community as part of an emergency response plan to protect the built environment systems. This explains why more than half of respondents highlighted their uncertainty of any current community engagement, directly or indirectly, in mitigating the losses caused by climate change disasters. The results showed that a less reflective system would have less recovery speed. Therefore, the rapidity characteristic of a built environmental system to accept the change and uncertainty inherited from the past or generated over time is correlated to the system's reflectivity quality.

This study encountered limitations due to several reasons. The authors planned to test the eight defined resilience qualities simultaneously, but the number of questions derived from a thorough review of the relevant and most up-to-date literature was huge, and it was impossible to have it in a single questionnaire. The defined indicators for each quality were between four and six, resulting in many questions that led to very long and complex analyses to determine the correlations, interrelations, combined rankings, and weightings. Additionally, the responses received from each group included an insufficient response variety, limiting the determination of correlations between some indicators. Furthermore, unknown circumstances and constraints made it difficult for many governmental and regulatory authorities to participate in the study. Hence, the authors rarely received positive responses from regional authorities. A final limitation to highlight is the geopolitical competition between governments to meet climatic commitments and obligations, especially the relevant articles of the Paris Agreement, which limits the number of expected audiences and may influence the responses of participants ones.

Overall, the results from this study show high consistency, representing the complexity level in evaluating the resilience qualities. They also emphasize the significant correlation between the built environment systems' different resilience quality (RQ) traits. The study contributes to policy, industry, and academia and encourages researchers to formulate more objective methods to reach a set form for measuring RQs as an engineering standard. Overall, achieving climate change resilience objectives in the built environment is challenging and requires the collaboration of all relevant sectors and professionals. Additionally, the study may help decision-makers gain more confidence in advancing the relevant policies supporting the resilience movement's action of a resilient built environment.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15065055/s1. Supplementary Document containing the full statistical inferencing and Institutional Review Board (IRB) approval.

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