

Enhancing Climate Resilience in Malaysian Cities: Barriers and Strategies for Sustainable Urban Development in Malaysia

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Abstract

As climate change intensifies, Malaysian cities face increasing risks from floods, extreme rainfall, heatwaves, and droughts, threatening communities, infrastructure, and economic development. This study examines the barriers and strategies for enhancing urban climate resilience using a mixed-methods approach, including a survey of 101 city stakeholders and ten expert interviews. Findings reveal major institutional, financial, and technical challenges, including fragmented governance, policy gaps, limited public awareness, insufficient investment, and inadequate technical capacity. Experts advocate integrated strategies: operationalizing the National Adaptation Plan (NAP), enforcing climate policies, scaling up investments, strengthening infrastructure, promoting public-private partnerships, and building technical and community capacity. These measures aim to shift adaptation from reactive and fragmented to proactive and systemic, supporting 13th Malaysia Plan (2026–2030), and SDGs 9, 11, and 13. The study provides actionable insights for policymakers and urban planners, enhancing understanding of key drivers of climate resilience and guiding sustainable urban development in Malaysia.

Keywords: Barriers, Climate Change, Strategies, Resilience, Sustainable Urban Development

1. Introduction

Climate change is one of the most pressing global challenges, simultaneously affecting ecosystems, human societies, and economies worldwide. Rising global temperatures, increasing frequency and intensity of extreme weather events, and shifting climate patterns have heightened the urgency for adaptive measures that enhance climate resilience. Strengthening resilience to climate-related disasters is essential to safeguard both natural and human systems, as emphasized by the Intergovernmental Panel on Climate Change [1]. As mitigation efforts alone are no longer sufficient, reducing vulnerability and ensuring long-term sustainability require proactive and integrated adaptation strategies. Building awareness and capacity for climate resilience is therefore a critical first step in empowering communities, industries, and governments to effectively anticipate, withstand, and recover from climate impacts.

Malaysia is highly vulnerable to the impacts of climate change, facing accelerating sea level rise, extreme rainfall, and increasing flood frequency that threaten livelihoods, infrastructure, and economic stability. With over 8,840 km of coastline, mean sea level has risen approximately 3.2 mm per year in Peninsular Malaysia and 2.9 mm in Sabah, Sarawak and Labuan, and is projected to rise up to 0.74 m by 2100, exacerbating coastal flooding and erosion [2]. Floods have become the most frequent natural disaster in Malaysia, accounting for about 85 % of all disaster events since 2000 [3], and the December 2021 floods alone caused RM6.1 billion (≈ 0.4 % GDP) in damages, displacing over 70,000 people and killing more than 50 [3, 4]. In 2024, flood-related losses reached RM933.4 million (≈ 0.05 % GDP), with agriculture, housing and infrastructure heavily affected [5]. A recent national assessment suggests that a 1-in-20-year flood event could erode up to 4.1 % of GDP by 2030 without adaptation measures, underscoring the potentially severe macroeconomic impacts [3]. These climate-induced hazards also threaten food security and rural incomes, with key rice granary yields projected to decline by up to 31 % by 2030 [6]. Despite these alarming trends, public and policy awareness of climate resilience remains limited, constraining adaptation efforts.

Urban resilience refers to the capacity of cities to anticipate, adapt to, and recover from climate-related shocks while sustaining livability, inclusiveness, and long-term sustainability. Malaysian cities are at a critical juncture, as rapid urbanization currently exceeding 78 % of the national population has intensified pressures on infrastructure, natural resources, and urban ecosystems [5]. These structural stresses are compounded by climate change impacts, including more frequent extreme rainfall, inadequate drainage capacity, rising flood exposure, and increasing heatwaves effects in dense metropolitan areas such as Greater Kuala Lumpur and Penang [1, 3]. Urban flooding has become Malaysia's most recurrent climate hazard, with damages from recent events exceeding RM6 billion in a single season, highlighting systemic vulnerabilities in urban planning and stormwater management [4]. Given Malaysia's strong dependence on climate-sensitive sectors such as agriculture, tourism, and industry, integrating climate resilience into urban development is no longer optional but essential to safeguard economic stability, ecosystem integrity, and community well-being.

In response, Malaysia has increasingly prioritised climate resilience initiatives. The National Climate Change Policy 2.0 (NCCP 2.0) (2024) embeds adaptation into national planning, focusing on adaptive resource management, institutional capacity building, and cross-sector coordination to reduce vulnerability to floods, heat stress, and sea level rise [2]. Urban initiatives such as Community Resilience Implementation Plans (CRIPs) in Kuala Lumpur engage residents in flood preparedness, early warning systems, and heat mitigation [7]. NGO-led and city-scale programmes promote nature-based solutions and climate-aware urban planning to reduce heat island effects and improve stormwater management [8]. Despite progress, persistent funding gaps, institutional fragmentation, and limited public preparedness evidence, the need to scale up implementation of resilience and better link national frameworks with local action to ensure effective and equitable outcomes [9, 10, 11]

Although global research on climate resilience has expanded, much remains conceptual or focused on high-income contexts, with limited empirical studies addressing integrated adaptation in rapidly urbanising, climate-vulnerable regions [12]. Systematic reviews show fragmented approaches, highlighting the absence of cohesive resilience frameworks [13]. In Southeast Asia, adaptation studies often focus on sectoral responses, such as agriculture, without fully integrating urban, community, and governance dimensions [14]. In Malaysia, while awareness of climate change is moderate, preparedness and institutional support for systematic resilience remain inadequate [9]. Moreover, community-based adaptation studies are scarce, and older adults' vulnerability is underexplored, revealing gaps in inclusive, context-specific resilience planning [11, 15].

Collectively, existing studies reveal a persistent gap between national climate resilience frameworks and their translation into effective local action within urban and community contexts. Addressing this

gap, this study investigates urban climate resilience in Malaysian cities through the lens of sustainable urban development, focusing on governance and community-level adaptation mechanisms. The analysis identifies critical constraints to effective climate adaptation including insufficient financing, policy and enforcement limitations, and gaps in technical capacity while examining institutional and planning pathways to strengthen resilience. This research aims to provide an understanding of how Malaysian cities can foster climate resilience in the context of chronic environmental challenges while promoting sustainable, inclusive urban development by identifying opportunities alongside obstacles.

The paper is organized as follows: Section 1 and Section 2 outline the climate resilience background. Methodology, data collection, and analysis are outlined in Section 3 and Section 4. Meanwhile, the conclusion in Section 5 follows key arguments and proposed strategies for enhancing climate resilience in Malaysian cities.

2. Literature Review

2.1 Previous Studies on Climate Resilience in Sustainable Urban Development

Cities are at the frontline of climate change due to high population densities, rapid urban growth, and concentrated infrastructure systems. These pressures are particularly acute in developing countries, where weak institutional capacity, limited financial resources, and accelerated urbanisation constrain the ability to build effective urban resilience [16]. As a result, the literature increasingly emphasises integrating climate mitigation and adaptation into urban planning to reduce vulnerability and support sustainable urban development. Strengthening infrastructure to withstand climate shocks is a core component of urban resilience, with nature-based solutions such as parks, green roofs, and urban forests shown to mitigate urban heat island effects, improve stormwater management, and enhance biodiversity [17]. In the Malaysian context, where rapidly expanding cities face recurrent flooding, rising urban temperatures, and governance and financing constraints, these strategies are particularly critical yet remain unevenly implemented, underscoring the need for context-specific urban resilience research [9].

Climate adaptation and climate resilience, though often discussed together, refer to related but distinct concepts. According to the [21], climate adaptation is “the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities,” whereas climate resilience is “the capacity of social, ecological, and socio-ecological systems to anticipate, absorb, accommodate, or recover from the effects of climate change in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions” [21]. Empirical research highlights that urban and rural areas are disproportionately exposed to climate hazards, especially in developing countries, due to high population density, rapid urbanization, and inadequate infrastructure [2, 19]. Effective adaptation and resilience-building require coordinated actions across local governments, communities, and the private sector, integrating local knowledge, technologies, and supportive policies [7]. Social equity and inclusion are critical, as marginalized groups often bear the highest climate vulnerability [16]. Studies also underscore the importance of green infrastructure, nature-based solutions, and community-based adaptation as key strategies to strengthen urban resilience [17, 19].

In Malaysia, these principles are particularly relevant given the country’s dense urban populations, growing infrastructure demands, and exposure to climate shocks such as flooding, heatwaves, and coastal hazards, highlighting the urgent need for context-specific resilience and adaptation strategies [20, 22]. Sustainable urban development in Malaysian cities faces both challenges and opportunities, especially Kuala Lumpur and Penang, are highly vulnerable to climate impacts [23, 24]. Key barriers to effective climate adaptation in Malaysian cities include weak public engagement, insufficient

128 funding, and fragmented institutional frameworks [9, 25, 26]. Green infrastructure such as urban parks,
129 green roofs, and permeable pavements can mitigate urban heat islands and manage stormwater,
130 enhancing climate resilience [27]. Rapidly urbanizing cities also require climate-resilient urban design,
131 including energy-efficient buildings and low-carbon transport systems, to reduce vulnerability [28].
132 Community-based adaptation strategies further complement these efforts, as residents in flood-prone
133 areas implement local flood barriers and water management systems [29]. However, monitoring and
134 evaluation remain limited, underscoring the need to better integrate national climate policies with local
135 urban planning and governance mechanisms to strengthen resilience outcomes [11, 19].

136 While global and local research has identified strategies for enhancing climate resilience, a clear
137 gap remains in empirical studies that connect national frameworks with their practical implementation
138 at the city level in Malaysia. The following section examines urban climate resilience mechanisms in
139 global and Malaysia cities focusing on governance and community-level adaptation to inform
140 sustainable urban development and climate risk reduction.

141 **2.2 Global and Regional Initiatives on Climate Resilience**

142 Global efforts on climate resilience have advanced through coordinated international frameworks
143 and initiatives aimed at reducing vulnerability and enhancing adaptive capacity. Key milestones
144 include the ACCCRN (2008) for urban resilience in Asia, the Paris Agreement (2015) and SDGs 11
145 & 13 promoting climate action and sustainable cities, and the Sendai Framework (2015–2030) guiding
146 disaster risk reduction. Targeted initiatives like CREWS (2015) and the UN-Habitat Resilient Cities
147 Initiative (2021) have strengthened early warning systems and urban resilience models, while recent
148 efforts such as the IFRC Global Climate Resilience Platform (2023–2028) and the UAE Framework
149 for Global Climate Resilience (COP28, 2023) emphasize locally-led adaptation, funding, and
150 accountability at the global scale. The UNDRR Strategic Framework 2026–2030 guides countries in
151 accelerating disaster risk reduction and building climate resilience through targeted, measurable
152 actions aligned with the final phase of the Sendai Framework. Table 1 shows the major global
153 initiatives and frameworks for climate resilience.

154
155 **Table 1** Major global initiatives and frameworks for climate resilience [1, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39,
156 40]

Year	Initiatives	Descriptions
2008	Asian Cities Climate Change Resilience Network (ACCCRN)	- This was established in 2008, focusing on urban areas in Asia countries such as India, Indonesia, Thailand, and the Philippines. - Integrating knowledge-efficient urban planning with an assessment and collaboration with multiple stakeholders were few activities that being highlight under this initiative.
2015	Paris Agreement	- 196 countries have adopted it - Came out with climate policy, limiting global warming below 2°C, preferably to 1.5°C above pre-industrial levels. - This has driven every country's climate action every five years
2015	Sustainable Development Goals (SDGs)	- Goals 13 and 11, specifically aiming at climate action and sustainable cities and communities, respectively.

		- Two goals have goals that are showing on global effort to build a resilience cities which include societies benefit.
2015 - 2030	Sendai Framework for Disaster Risk Reduction	- A blueprint with a few areas that are being explored: (a) risk identification, (b) governance and regulation, (c) investment of risk reduction, (d) enhancement for responses toward risk - This framework complements Disaster Risk Reduction (2015 - 2030) to ensure the policy can understand the intervention of multiple hazards and risks.
2015	Climate Risk and Early Warning Systems (CREWS) Initiative	-This initiative was established to deal with vulnerable groups in Papua New Guinea that have faced hazards such as drought, food shortage, and water crisis. - Early warning system that incorporates with monitoring system and can prepare decision-makers to try to mitigate.
2021	Resilient Cities Initiative (UN-Habitat)	- Bridging knowledge and bringing awareness as a strategy to enhance the idea of climate resilience to people who are vulnerable to such hazards. - Programs, conferences, and workshops were held and thus resulted in a climate resilience model.
(2023–2028)	Global Climate Resilience Platform (IFRC)	-Multi-year global effort raising funds and supporting locally-led adaptation and resilience actions to support vulnerable populations.
2023 (COP28)	UAE Framework for Global Climate Resilience	-First international declaration placing climate adaptation and resilience at the center of global climate action and establishing a work program to improve measurement and accountability
2025–2030	UNDRR Strategic Framework 2026–2030	-Strategic plan to accelerate disaster risk reduction and resilience implementation in the final phase of the Sendai Framework.

Malaysia's climate resilience efforts have evolved through national policies, planning frameworks, community programs, and civil society initiatives. Foundational policies such as the National Policy on Climate Change (NPCC, 2009) and National Urbanisation Policy 2 (2019) laid the groundwork for integrating climate adaptation and sustainable urban development. Subsequent initiatives, including the Twelfth Malaysia Plan (2021–2025), Malaysian Climate Change Action Council (MyCAC, 2021), and National Climate Change Policy 2.0 (2024), strengthened cross-sectoral climate governance and low-carbon development strategies. The formulation of Malaysia's National Adaptation Plan (MyNAP, 2025–2027), city-level programs like the Urban Climate Resilience Program (UCRP), Pelan Tindakan Iklim Pulau Pinang 2030, and Iskandar Puteri Climate Action 2030, as well as community-focused initiatives such as CRIPs and U-INSPIRE, demonstrate multi-level engagement in adaptation and resilience-building. National events and planning tools, including the Kuala Lumpur Sustainability Summit (KLSS 2025) and PTKL2040, alongside civil society movements like Klima Action Malaysia, further reinforce Malaysia's commitment to building climate-resilient cities and communities through

171 integrated policy, planning, and grassroots action. Table 2 outlines the Malaysia's climate resilience–
 172 related policies and initiative.

173
 174 **Table 2** Malaysia's climate resilience–related policies and initiative [7, 37, 41, 42, 43, 44, 45, 46, 47, 48, 49,
 175 50, 51]

Year	Initiative / Effort	Description
2009	National Policy on Climate Change (NPCC)	-Malaysia's original national climate policy mainstreaming climate change into development planning; integrates adaptation and resilience with sustainable development goals across sectors.
2019	National Urbanisation Policy 2 (NUP2)	-Guides sustainable urban growth by promoting ecological networks and green spaces to enhance environmental health and urban resilience.
2021–2025	Twelfth Malaysia Plan (12MP)	-National Development Plan that integrates climate resilience through enhanced disaster risk management, nature-based solutions, and infrastructure adaptation, aligning with SDG goals including climate action.
2021	Malaysian Climate Change Action Council (My CAC)	-National council to guide climate mitigation, adaptation, and low-carbon development strategies across Malaysia.
2024	National Climate Change Policy 2.0 (NCCP 2.0)	-Updated national policy guiding Malaysia's climate action pathway, embedding climate resilience, adaptation, risk-based approaches, and whole-of-government climate governance.
2025–2027	Malaysia's National Adaptation Plan (MyNAP)	-Malaysia began a process to strengthen climate resilience capacity and draft a whole-of-government National Adaptation Plan with stakeholder engagement across key sectors.
2025 (ongoing)	Urban Climate Resilience Program (UCRP) – Melaka & KL	-A program in partnership with Zurich Malaysia and local authorities that builds urban community resilience to climate-related hazards through localized projects.
2025	Kuala Lumpur Sustainability Summit (KLSS) 2025	-National summit under ASEAN chairmanship promoting regional climate resilience through dialogue, knowledge exchange, and green initiative
2025	Kuala Lumpur Structure Plan 2040 (PTKL2040)	-Long-term urban planning blueprint embedding climate resilience, liveability, inclusion, green infrastructure, and sustainable development (policy phase)
2025	IFRC Climate Resilience Support (Malaysia)	-Malaysian Red Crescent Society participates in IFRC's Global Climate Resilience Programme to scale up climate-smart disaster risk reduction and community resilience
2026–2030	Thirteenth Malaysia Plan (13MP)	-National Development Plan emphasising sustainability, green economy and resilience as core growth pillars through 2030.

Ongoing	Community Resilience Implementation Plans (CRIPs) – Kuala Lumpur	-Local climate resilience plans co-created with communities under the Urban Climate Resilience Programme, including flood early warning systems and capacity building.
Ongoing	Pelan Tindakan Iklim Pulau Pinang 2030	-City-level climate action plan focusing on mitigation, adaptation, green infrastructure, and resilience strategies.
Ongoing	Iskandar Puteri Climate Action / Pelan Tindakan Iklim Iskandar Puteri 2030	-City-level climate action framework integrating mitigation and adaptation into local development planning.
Ongoing (Civil Society)	Klima Action Malaysia (KAMY)	-Youth-led climate activist network advocating for equitable climate policies, awareness, and community capacity building on climate risks.
Ongoing (Education & Local Engagement)	U-INSPIRE Malaysia / DRR Education Initiatives	-Youth and professional programs integrating disaster risk reduction awareness and skills in schools and communities to build resilience.

The literature indicates strong alignment between global climate resilience agendas and Malaysia's national and local initiatives, particularly in integrating adaptation into urban planning and disaster risk management. However, existing studies consistently point to persistent implementation challenges, including fragmented governance, uneven institutional capacity, limited adaptation financing, and weak technical and monitoring systems [9,11,19,25, 26]. Consequently, climate resilience in Malaysia's urban development context remains largely reactive and insufficiently embedded in planning and decision-making processes. To address these gaps, this study aims to enhance climate resilience in Malaysia by identifying key challenges and proposing strategic pathways to support the effective implementation of climate resilience measures within urban development.

3. Research Methodology

3.1 Research Process

Bridging the findings of this study required data integration from disparate sources. The methods include a questionnaire-based survey and a supporting semi-structured interview, as well as qualitative and quantitative methods. First, quantitative data were collected regarding industry stakeholder perceptions of climate resilience, barriers to its implementation, and approaches for sustainable urban development through cross-sectional surveys. Following this, ten (10) experts were interviewed in a semi-structured format to elicit their views on the primary climate resilience challenges as well as the key drivers and techniques for sustainable urban development. The rationale for employing this explanatory approach is that quantitative data provides a broad overview of the research problem, allowing for a comprehensive analysis. Meanwhile, collecting qualitative data is essential to clarify, expand, or interpret the quantitative results [52, 53].

3.2 Questionnaire Survey

A structured questionnaire was developed to gather insights from city stakeholders on the implementation of climate resilience in sustainable urban development. The survey aimed to: (i) assess respondents' knowledge, perceptions, and awareness of climate resilience within urban planning; and (ii) identify the key barriers hindering effective integration of climate resilience measures. The questionnaire items were derived from an extensive literature review on challenges to achieving climate resilience alongside sustainable urban development [19, 54, 55, 56] to ensure the survey captured well-recognized factors and provided meaningful insights. A pilot survey was conducted with five professionals involved in urban planning and development to refine the instrument before full deployment.

The questionnaire was divided into three sections:

- i. Section A: Respondent demographics, including age, professional background, role, and level of involvement in urban development projects.
- ii. Section B: Respondents' perceptions and knowledge regarding climate resilience in urban development.
- iii. Section C: Barriers to successful implementation of climate resilience measures. The questionnaire comprised 12 items on barriers to implementing climate resilience measures (refer to the Table 4), with respondents rating each statement on a five-point Likert scale from 'strongly disagree' to 'strongly agree,' capturing their familiarity, understanding, and attitudes toward these challenges.

Respondents were selected using a non-probability sampling method, specifically criterion purposive sampling, to ensure that participants possessed the knowledge and experience necessary for providing informed insights [57]. Selection criteria included: (i) extensive professional experience in urban development or related fields, and (ii) active involvement in city planning, infrastructure, or climate resilience projects. Both online and in-person survey modes were employed to maximize participation. This approach resulted in a total of 101 responses from an initial sample of 384 urban development professionals, achieving a response rate of 26%. The survey participants represented a diverse range of stakeholders, including local and federal government officers, developers, town planners, architects, engineers, environmental consultants, academics and researchers, and NGO representatives. Despite the moderate sample size, the purposive sampling approach ensured that the data captured perspectives from highly relevant and knowledgeable individuals, consistent with prior studies demonstrating that meaningful results can be obtained from well-defined, targeted samples [58]. The demographics of participants have been presented in Table 3.

Table 3 Demographic Profile of Respondents

	Respondent Characteristics	Number of Respondents (total= 101)
Years of experience	Less than five (5) years	18
	Between 6 and 10 years	36
	Between 11 and 15 years	23
	More than 16 years	24
Designation	Government officer	16
	Engineer	25
	Developer	10
	Town Planner	12
	Environmental Consultant	8

Architect	10
NGOs	6
Academician and Researcher	14

3.3 Interview

The qualitative phase was conducted and reported in alignment with the COREQ (Consolidated Criteria for Reporting Qualitative Research) guidelines to ensure transparency, credibility, and methodological rigor [59]. Ten (10) experts were purposively selected based on predefined criteria, including a minimum of five years of professional experience and direct involvement in urban, infrastructure, or urban development projects related to climate resilience. The sample comprised two developers, two consultants, four government officers, and two town planners, ensuring representation across key stakeholder groups central to urban climate decision-making. Although limited in number, the sample size is methodologically justified, as qualitative inquiry prioritizes depth, richness, and analytical insight rather than volume; prior studies suggest that 10–15 expert interviews are sufficient to generate robust thematic understanding [60, 61]. The semi-structured interview questions were designed to stimulate critical reflection and stakeholder dialogue on climate resilience and sustainable urban development, focusing on:

- (i) the extent to which climate change mitigation and adaptation measures are currently integrated into urban development in Malaysia.
- (ii) key barriers constraining the implementation of sustainable urban and climate-resilient initiatives.
- (iii) additional perspectives that motivate stakeholder engagement in addressing climate-related challenges.

3.4 Data Analysis

Data analysis employed a mixed-methods approach. Quantitative data were examined using descriptive statistics including frequency distributions, mean, standard deviation, and reliability analysis to ensure consistency and interpretability. Qualitative data was analyzed through systematic content and thematic analysis, with iterative coding capturing patterns, relationships, and insights. This integrated approach allowed the study to quantify trends while providing rich explanatory insights, effectively linking quantitative findings with expert perspectives in the explanatory sequential design.

3.4.1 Reliability Test

The 12 items in Section C of the questionnaire, focusing on climate resilience implementation barriers, were assessed for reliability, yielding Cronbach's alpha of 0.821. Following established guidelines, values above 0.70 were considered satisfactory, indicating a high level of internal consistency [62].

3.4.2 Descriptive Statistics

Quantitative data were analyzed using descriptive statistics to summarize respondent characteristics and responses. Frequency distributions illustrated the prevalence of specific perceptions, means captured central tendencies, and standard deviations reflected variability of the 12-item climate resilience barriers scale. This detailed descriptive analysis provided a solid foundation for interpreting trends and patterns, supporting the integration of quantitative results with qualitative insights.

3.4.3 Content Analysis

All interviews were conducted using a standardized semi-structured protocol, audio-recorded with informed consent, and transcribed verbatim. Raw narrative data from notes and recordings were manually transcribed and analyzed using a combined content and systematic thematic approach [63]. Iterative coding enabled the identification and refinement of themes that accurately captured patterns, relationships, and insights within the data. Both convergent and divergent viewpoints were explicitly examined: dominant themes such as governance fragmentation, financing constraints, and capacity gaps were highlighted, while variations across professional groups were preserved to avoid oversimplification. The synthesis prioritized analytical relevance and explanatory value over mere frequency, consolidating themes only when supported by multiple narratives or offering critical insight into the quantitative findings.

In line with COREQ reporting norms and ethical standards, full audio recordings and transcripts are not publicly disclosed; however, anonymized excerpts and detailed thematic descriptions ensure traceability between raw data and reported results. This approach guarantees that expert perspectives are methodologically justified, rigorously analyzed, and effectively integrated within the explanatory sequential research design.

4. Results and Discussion

4.1 Questionnaire Survey

This section encompasses the data gathered from participant comments via the application of questionnaire forms. The data gathered is essential for assessing the degree of understanding of the importance of climate resilience ideas and the actions being taken. The results are further analyzed utilizing percentage frequency distributions.

4.1.1 The familiarity with the concept of climate resilience

Figure 1 illustrates respondents' familiarity with climate resilience in Malaysia. All environmental consultants and NGO participants (100%) reported being 'very familiar' or 'somewhat familiar,' while over 70% of government officers, architects, town planners, academics, and researchers also demonstrated strong understanding. In contrast, more than one-third of engineers and developers reported being 'not familiar at all,' revealing critical knowledge gaps among key urban development stakeholders. Understanding climate resilience is especially vital in Malaysia, given the country's high vulnerability to climate-related hazards such as floods, heatwaves, and extreme rainfall. Adequate knowledge enables stakeholders to anticipate risks, embed adaptive strategies into urban planning, and implement sustainable interventions that protect communities and infrastructure, thereby ensuring long-term urban resilience [64].

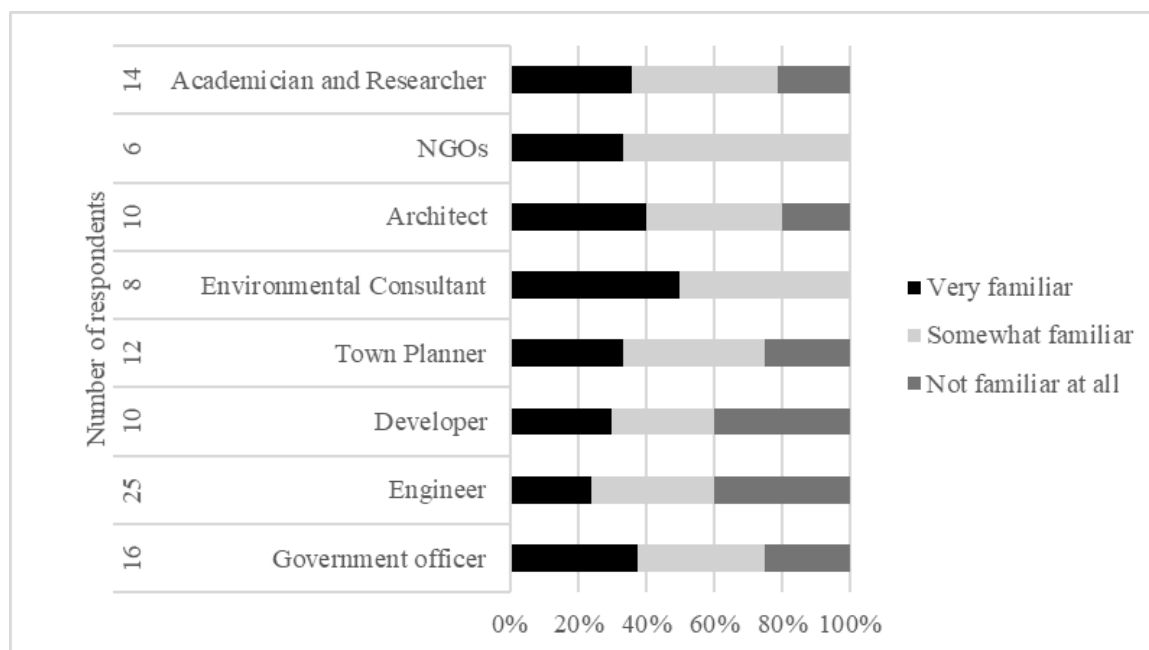


Figure 1 *Distribution of Familiarity of Respondents with the Concept of Climate Resilience*

4.1.2 The extent of understanding the term “climate resilience”

Figure 2 illustrates participants’ understanding of climate resilience across professional sectors. As explained by [65], climate resilience is the ability of a system (natural, social, or economic) or a community to anticipate, prepare for, respond to, and recover from the adverse impacts of climate change. While sustaining protection from extreme weather events and ensuring long-term sustainability also constitute important elements of resilience, adapting to and recovering from climate impacts is the essence of resilience. The survey results in Figure 2 depict that over half of environmental consultants and NGO participants correctly identified resilience as the ability of systems or communities to adapt to climate impacts, while roughly a quarter of town planners, architects, and academics recognized this definition. In contrast, fewer than 25% of government officers, engineers, and developers selected the adaptation-focused definition, with many associating resilience instead with protection from extreme weather or long-term sustainability. These results reveal significant knowledge gaps among key urban development stakeholders, underscoring the need for targeted awareness and capacity-building initiatives to ensure effective implementation of climate resilience strategies in Malaysia’s urban planning context.

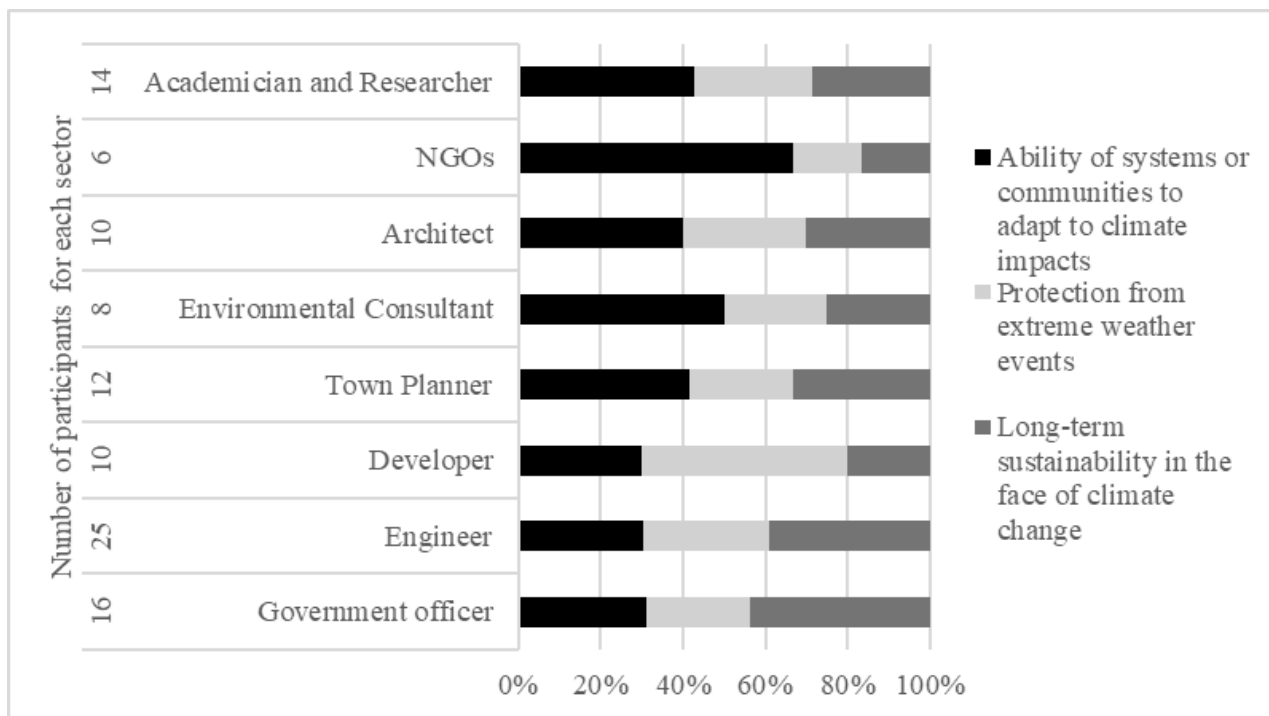


Figure 2 Respondent's Understanding of the Term Climate Resilience

4.1.3 The concerns about climate change implications in the region

Figure 3 illustrates the responses to respondent's concerns regarding the impact of climate change in Malaysian states. 45% of the respondents expressed concern about the impacts of climate change associated with flooding in their areas. Approximately 18% and 16% are concerned about the impacts of climate change on rising sea levels and drought, respectively. Meanwhile, some of the respondents selected extreme heatwaves (8%), degradation of the ecosystem (8%), and storms and typhoons (5%) as the lesser impacts of climate change. It supports findings by other researchers [66, 67, 68] that climate change in Malaysia is becoming increasingly worrisome as it faces more frequent and severe climate-related events, including higher temperatures, intense rainfall, flooding, and extended drought periods.

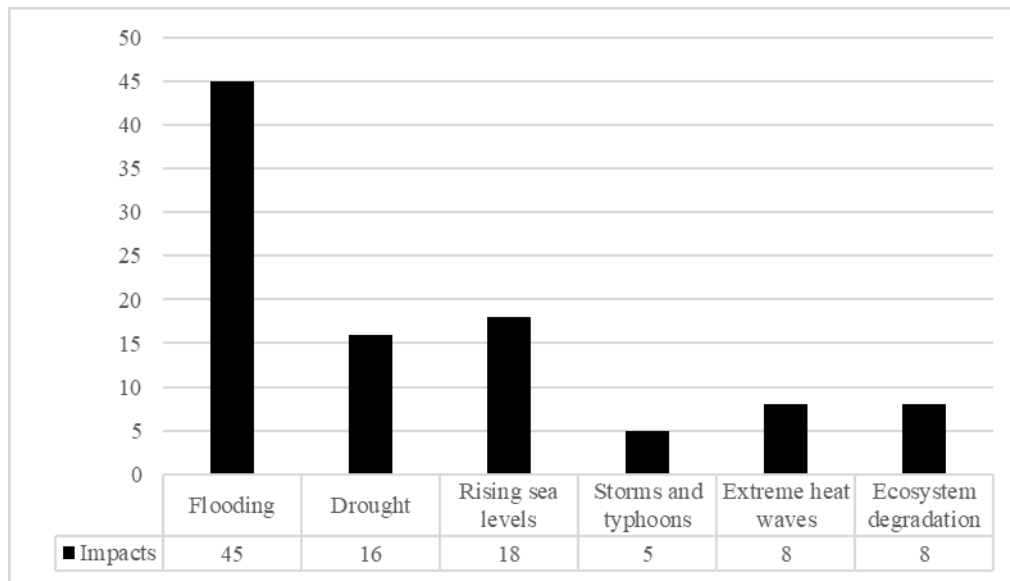


Figure 3 Respondent's Concern About the Climate Change Impacts

4.1.4 Barriers to Implementing Climate Resilience Measures in Urban Development

The analysis shows that financial constraints constitute the most significant barrier to implementing climate resilience measures in Malaysia, with the requirement for substantial investment in infrastructure and nature-based solutions recording the highest mean score (Mean = 3.9826), aligning with national analyses that emphasize the high capital requirements of climate adaptation projects and Malaysia's limited access to concessional climate finance as a middle-income country [69, 70]. This is followed by uneven public understanding of climate risks, particularly among rural and marginalized communities, which limits local participation in resilience planning (Mean = 3.9721). Governance-related barriers, including ineffective regulatory strategies and the prioritization of immediate socio-economic issues over long-term resilience, also scored relatively high (Mean = 3.8192). The lack of coordination among government agencies and the absence of a unified national adaptation plan were rated similarly (Mean = 3.7315), indicating moderate to high concern among respondents. This finding echo expert critiques of Malaysia's disjointed institutional landscape, where overlapping federal, state, and local responsibilities slow [71]. Inadequate and poorly maintained infrastructure further emerged as a notable barrier (Mean = 3.7264). Other challenges, such as uncertainty in climate data (Mean = 3.6286), limited technical capacity at the local government level (Mean = 3.5746), resistance to adopting climate-resilient practices (Mean = 3.4925), limited community involvement in decision-making (Mean = 3.3875), and weak monitoring and evaluation frameworks (Mean = 3.2584), recorded comparatively lower mean values but remain relevant constraints in the overall implementation of climate resilience measures. Collectively, these barriers underscore that advancing climate resilience in Malaysia requires not only financial investment but also strengthened institutional coordination, robust policy enforcement, enhanced data systems, and meaningful community engagement.

Table 4 Descriptive Statistics of The Mean (M) And Standard Deviation (SD) For the Barriers to Climate Resilience Implementation

Key Barriers to Implementing Climate Resilience Measures	Mean	Std. Deviation	Rank
Public understanding of climate risks and proactive adaptation is uneven, especially in rural and marginalised communities which hinders local support	3.9721	1.0731	2

and participation in resilience planning and implementation.			
Climate resilience measures require significant investment such as upgrading infrastructure or nature-based solutions.	3.9826	1.2915	1
Shortage of technical expertise and capacity at local government levels to implement advanced climate resilience solutions.	3.5746	0.9648	7
Lack of coordination between government agencies, sectors, and stakeholders can delay the implementation of climate resilience measures.	3.7315	1.0417	4
Many industries, businesses, and even individuals may be resistant to adopting new and climate-resilient practices.	3.4925	0.9751	8
Climate change projections can be uncertain, and reliable data on local climate impacts may be lacking.	3.6286	0.9325	6
Ineffective governance and inadequate regulatory strategies and plans for climate resilience and urban development.	3.8192	1.2862	3
Immediate issues such as poverty, public health, or economic growth are prioritized over long-term climate resilience efforts.	3.8192	1.8231	3
Limited involvement of communities in decision-making can reduce the effectiveness and acceptance of resilience measure	3.3875	1.5378	9
Malaysia lacks a unified national adaptation plan, leading to fragmented climate resilience efforts across ministries and agencies.	3.7315	0.9741	4
Many existing infrastructure systems (e.g., drainage, flood defences) are inadequate or poorly maintained, reducing their effectiveness under increasing climate stress.	3.7264	1.7436	5
Weak monitoring and evaluation frameworks mean that progress on resilience measures is difficult to track and improve	3.2584	0.9727	10

4.2 Interviews

To enhance clarification throughout the discourse of in-depth interviews outcomes, the key barriers, summary findings and strategies have been gathered in Table 5, Table 6, and Table 7, respectively.

Table 5 Key Barriers to Implement Climate Resilience Measures

Key Barriers	Respondent's Opinions
Financial constraints and high cost of adaptation projects	- Respondents highlighted that climate adaptation requires substantial investment, yet Malaysia faces limited public funding and weak private sector participation. - Respondents noted that the high cost of nature-based solutions and climate-proofed infrastructure often

	prevents timely implementation, leaving climate-prone communities exposed.
Uneven public understanding of climate risks especially in rural communities	-Respondents emphasized that low climate awareness in rural and marginalized areas reduces community preparedness and engagement. -Recurrent flooding in states such as Kelantan and Terengganu was cited as evidence of insufficient understanding of early warnings and local adaptation measures, underscoring the need for targeted education and participatory approaches. -They emphasized the importance of targeted education, outreach, and participatory planning
Ineffective governance and prioritization of immediate socio-economic issues over long-term resilience	- Respondents noted that short-term development priorities, fragmented ministerial coordination, and weak policy enforcement undermine proactive adaptation. -Disaster management efforts are often reactive, particularly during major disaster events, rather than driven by long-term resilience planning.
Lack of coordination between government agencies and absence of effective policies	-Respondents believed that overlapping mandates and unclear responsibilities across federal, state, and local levels, resulting in delayed, disjointed, or inconsistent resilience measures.
Inadequate and poorly maintained infrastructure	-Respondents observed that outdated flood defenses and drainage systems significantly increase vulnerability. -Reactive maintenance, particularly in urban areas such as Kuala Lumpur and Johor Bahru, limits the effectiveness of resilience measures and exacerbates flood impacts.

Table 5 presents key barriers to implement climate resilience measures in Malaysia. The triangulation of the data obtained from the questionnaire survey and interviews reached saturation. Key barriers have been conclusive into three themes: institutional, financial and technical barriers, as shown in Table 6.

Table 6 Summary Findings of Key Barriers to Implement Climate Resilience Measures in Malaysia

Institutional	Financial	Technical
-Low climate awareness in rural and marginalized areas	-Limited public funding and weak private sector participation on adaptation projects	-Outdated flood defenses, drainage systems, and urban infrastructure exacerbate vulnerability
- Lack of coordination between government agencies and absence of effective policies	- High cost of nature-based solutions and climate-proofed infrastructure often prevents timely implementation	
-Ineffective governance and prioritization of immediate socio-economic issues over long-term resilience		

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384 **4.3 A Way Forward Towards Climate Resilience Measures in Malaysia Urban Development**

385 This section proposes targeted strategies to enhance Malaysia’s climate resilience framework in
386 urban planning, derived from the integration of 101 survey responses and ten in-depth expert
387 interviews. Data from the interviews were analyzed iteratively to ensure comprehensive coverage, with
388 particular attention to barriers identified in climate adaptation efforts. Based on these insights, the
389 strategies have been clustered into three key themes: Institutional, Financial, and Technical.

390 Table 7 summarizes expert recommendations, highlighting five critical steps for implementing
391 effective climate resilience measures: (i) strengthening governance and coordination across agencies,
392 implementing and enforcing MyNAP, and integrating climate resilience into urban and regional
393 planning; (ii) enhancing community engagement and participatory planning, particularly in flood-
394 prone and rural areas; (iii) mobilizing dedicated climate adaptation funding, incentivizing private
395 sector participation, and leveraging public-private partnerships; (iv) upgrading and maintaining critical
396 infrastructure, including drainage, levees, and flood defenses, while implementing nature-based
397 solutions and early warning systems; and (v) strengthening technical capacity at local levels and
398 improving climate data collection, monitoring, and evaluation frameworks. These expert-informed
399 strategies provide actionable guidance for policymakers and urban managers, emphasizing governance
400 coordination, resource mobilization, community participation, capacity building, and proactive
401 infrastructure planning to enhance urban resilience to climate-related hazards, particularly floods.

402
403 **Table 7** Key Strategies Based on Respondent’s Opinions for Effective Climate Resilience Measures
404 in Malaysia's Urban Development

Key Theme	Key Strategies	Respondents’ Opinions (from Interviews)	Key Responsibility
Institutional	Strengthen governance and coordination across agencies; implement and enforce MyNAP; integrate climate resilience into urban and regional planning	-Respondents emphasized that coordinated governance is essential, suggesting a clear division of roles across federal, state, and local agencies, with the MyNAP as a binding framework to guide proactive climate resilience management and long-term adaptation planning.	Federal government (policy & oversight), State & Local authorities (implementation & coordination), Ministry of Natural Resources and Environmental Sustainability (NRES) (climate planning)
	Enhance community engagement and participatory planning for flood-prone and rural areas	-Respondents highlighted that involving local communities in planning and decision-making improves awareness, fosters ownership of resilience initiatives, and ensures locally appropriate adaptation measures are adopted.	Local government, NGOs, community leaders, Civil Society Organization
Financial	Mobilize dedicated climate adaptation	-Respondents noted that sustainable financing mechanisms, including	Ministry of Finance, Development

	funding; incentivize private sector participation; leverage public-private partnerships	grants, subsidies, and private sector incentives, are critical to ensure timely implementation of climate change mitigation projects and nature-based solutions. - Collaboration between governments and private investors can help share the financial burden of climate resilience projects. PPPs can attract significant private sector investment in infrastructure, such as flood protection systems, sustainable agriculture practices, and green infrastructure in cities	Banks, Private Sector Investors, International Climate Funds
Technical	Upgrade and maintain critical infrastructure (drainage, levees, flood defenses); implement nature-based solutions and early warning systems	-Respondents stressed that regular maintenance and modernization of critical infrastructure, combined with nature-based approaches are key to reducing climate risks and ensuring resilience is sustained over time.	Public Works Department, Local Municipalities, Disaster Management Agencies
	Strengthen technical capacity and knowledge at local levels; improve climate data collection, monitoring, and evaluation frameworks	-Respondents emphasized that building local expertise and robust data systems supports evidence-based planning, timely response, and the scaling of climate-resilient practices across municipalities.	Universities, Research Institutes, Meteorological Department, Local Government Agencies

Malaysia is increasingly exposed to climate change impacts, with more frequent and severe floods, rising temperatures, and extreme rainfall threatening urban and rural communities, critical infrastructure, and economic development [65, 72]. Flooding is particularly pronounced: in 2024, 1,345 flood incidents were reported, up from 809 the previous year, illustrating heightened extreme rainfall and vulnerability across the country [73]. In response, the government has introduced climate resilience initiatives, including NCCP 2.0 and MyNAP, which aim to integrate adaptation into urban planning, sectoral policies, and disaster risk management frameworks.

Despite these initiatives, the survey of 101 city stakeholders identified persistent barriers, including fragmented governance across federal, state, and local agencies; inadequate funding and financial incentives for adaptation; low public awareness and limited community engagement, particularly in flood-prone rural areas; and insufficient technical capacity and poorly maintained infrastructure. These findings are consistent with previous studies highlighting similar constraints in Malaysia [10] and reinforce the tendency toward reactive, rather than proactive, integrated resilience measures. Expert interviews suggest that overcoming these barriers requires integrated institutional, financial, and technical strategies.

Institutionally, strengthening inter-agency coordination, operationalizing the MyNAP, enforcing NCCP 2.0 policies, and embedding climate resilience into urban and regional planning can reduce

fragmentation and improve proactive flood management. Enhancing community engagement and participatory planning ensures adaptation measures are locally relevant and socially accepted, aligning with the principles of community-based adaptation [74]. Mitigating the challenge of insufficient climate-related education and lack of technical know-how requires the public, as well as professionals, to undergo training and educational programs that build the necessary skills for effective climate adaptation [75]. Furthermore, a reduction in community hostility through increased awareness via participation can enable local people to become more involved in resilience initiatives. These programs help to augment climate change adaptation by creating awareness, enhancing technical skills, empowering communities, and fostering active policy involvement at all levels.

Financially, mobilizing dedicated adaptation funding, leveraging public–private partnerships, and incentivizing private sector participation can sustain long-term investments in resilient infrastructure and nature-based solutions [21, 76]. Additionally, scaling climate resilience investments, such as securing funding for adaptation infrastructure, will also alleviate resource constraints [77]. Increased investment enables greater capacity to manage climate risks, defend vulnerable populations, and bolster long-term sustainability. Publicly funded policies targeting climate resilience infrastructure in Malaysia promote long-term sustainability while signaling favorable conditions to the industry, allowing access to alternative funding sources. Ergo, enabling greater funding for environmentally friendly projects aids infrastructure financing in achieving targets [78].

Technically, upgrading critical infrastructure, including drainage systems, levees, water supply networks, and energy grids, implementing early warning systems, and strengthening local capacity for climate data, monitoring, and evaluation are essential. These measures are highlighted in Malaysia's NAP, which prioritizes resilient infrastructure and evidence-based risk management across multiple climate hazards, including floods, extreme rainfall, heatwaves, and droughts [44]. Research shows that robust infrastructure combined with data-driven monitoring and early warning systems reduces vulnerability, improves adaptive capacity, and supports climate-resilient urban and rural development [21, 75].

Collectively, these approaches address the gaps in financing, expertise, and policies overlooked in Malaysia while improving the governance framework for climate resilience to provide a better-informed strategy. Achieving these strategies leads to enhanced urban sustainability in Malaysia, thereby improving urban resilience and adaptation to climate change and ensuring sustainable development. The comprehensive approach helps to tackle the complex, interlinked challenges faced by Malaysia and work towards a sustainable, climate-resilient future.

6. Conclusion

This study provides a comprehensive assessment of the challenges and opportunities for enhancing climate resilience in Malaysian cities, integrating insights from a survey of 101 city stakeholders and ten in-depth expert interviews. The mixed-methods approach revealed significant variation in awareness and expertise: key urban development actors, including engineers and developers, exhibited limited understanding of climate resilience, whereas academics, NGOs, and environmental consultants demonstrated higher familiarity. The findings highlight persistent institutional barriers (fragmented governance, policy gaps, limited awareness), financial constraints (insufficient investment, high upfront costs), and technical challenges (limited expertise, inadequate monitoring, and infrastructure deficits).

Expert-informed strategies to overcome these barriers emphasize institutional, financial, and technical integration: enforcing climate policies and standards, operationalizing the MyNAP, embedding resilience into urban planning, scaling up investments, promoting public-private

partnerships, implementing educational and training programs, upgrading critical infrastructure, and strengthening data-driven monitoring and early warning systems. These strategies, aligned with Malaysia's NCCP 2.0 and urban planning frameworks, offer a pathway from reactive, fragmented adaptation toward proactive, systemic climate resilience that addresses multiple climate hazards, including floods, heatwaves, and extreme rainfall.

By advancing awareness, technical capacity, and coordinated planning, this study contributes to enhancing climate adaptation measures and urban resilience in Malaysia, supporting the achievement of SDG 13: Climate Action, SDG 11: Sustainable Cities, and SDG 9: Industry, Innovation, and Infrastructure, as well as the Malaysian Government's vision for a low-carbon, climate-resilient nation under the 13th Malaysia Plan (2026–2030). While limited by sample size and reliance on perception-based data, the findings provide a strong foundation for future research to expand scope, evaluate outcome-based resilience indicators, and inform evidence-based policy interventions to sustain Malaysia's climate-resilient urban development.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Nur Kamaliah, Damilola; **data collection:** Nur Kamaliah, Nur Shuhada, Nurul Atiqah; **analysis and interpretation of results:** Nur Kamaliah, Nur Shuhada, Zadariana; **draft manuscript preparation:** Nur Kamaliah, Damilola, Zadariana, Aminuddin. All authors reviewed the results and approved the final version of the manuscript.*

Data Availability Statement

The data that support the findings of this study are openly available upon request.

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