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Article

Designing a knowledge transfer model for accelerating urban climate adaptation in Malaysia

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Abstract: The urgency of adapting urban areas to the increasing impacts of climate change has prompted the scientific community to seek new approaches in partnership with public entities and civil society organizations. In Malaysia, Penang Island has developed a nature-based urban climate adaptation program (PNBCAP) seeking to increase urban resilience, reduce urban heat and flooding, strengthening social resilience, and build institutional capacity. The project includes a strong knowledge transfer component focused on encouraging other cities in the country to develop and implement adaptation policies, projects, and initiatives. This research develops a model adopting the most efficient processes to accelerate the transfer of knowledge to promote urban adaptation based on the PNBCAP. The methodology is developed based on a review of literature focused on innovation systems and change theories. The integration of success strategies in adaptation contributes to informing the creation of solutions around the alliance of local, state, and national government agencies, scientific institutions, and civil society organizations, in a new framework designated the Malaysian Adaptation Sharing Hub (MASH). MASH is structured in 3-steps and will function as an accelerator for the implementation of urban climate adaptation policies, with the target of creating 2 new adaptation-related policies to be adopted annually by each city member, based on knowledge gathered in the PNBCAP. It is concluded that, to speed up urban adaptation, it is necessary to reinforce and promote the sharing of knowledge resulting from or associated with pilot projects.

Keywords: climate adaptation; urban adaptation; nature-based solutions; knowledge transfer; systems of innovation; change theory

1. Introduction

While Malaysia is already experiencing the impacts of climate change, the execution of urban adaptation projects is still in its early stages. Considering the importance of accelerating urban adaptation in the country, the two main objectives of this paper are to identify strategies from the systems of innovation and change theories, and categorize priority actions in a pilot project, in order to transfer knowledge to support scaling up Nature-based Solutions (NbS) for urban adaptation in Malaysia.

The pilot project selected is the Nature-based Climate Adaptation Program for the Urban Areas of Penang Island (PNBCAP), which was initiated in 2019 by Think City (TC), a social impact organization based in Malaysia. The City Council of Penang Island (MBPP) and the Department of Drainage Drainage and Irrigation (JPS) were receptive to jointly execute the program, as the worst floods on record in Penang had taken place just two years before, in 2017, confirming that adaptation efforts tend to be reactive, as adaptation projects tend to be initiated after a community is impacted by extreme weather (Amundsen et al., 2010). The organization also reached out to

UN-Habitat (UNH), to invite it to join as the Multilateral Implementing Entity (MIE) in the application for funding to the Adaptation Fund (AF). The goal of the project is to build urban resilience. Its main scope involves the introduction of nature-based solutions (NbS) in order to reduce the urban heat island (UHI) effect and overall temperatures and to improve stormwater management to reduce flooding. To the main scope, two components were added, the strengthening of social resilience and building institutional capacity. The Adaptation Fund (AF) will fully fund the execution of the PNBCAP with a total amount of US $10 million. The 5-year program's execution was officially launched in September 2022 with the inception workshop.

The Penang program is the first urban adaptation project to have been developed for Malaysia, being a pilot also in terms of the use of NbS. Research suggests that pilot projects should be developed not only to accelerate adaptation efforts, but also to fill existing knowledge gaps (Castelo et al., 2023; Frantzeskaki et al., 2019; Kabisch et al., 2016; Van Oijstaeijen et al., 2020). Additionally, Malaysian researchers have called for the development of adaptation projects at the local level (Pereira and Zain, 2022). This paper addresses the challenge identified previously (Cortinovis et al., 2022; Fastenrath et al., 2020; UN Climate Action Summit, 2019) of transitioning from pilot projects to implementing NbS on a large scale, a process commonly described as "scaling up", which depends on knowledge transfer taking place. The research question is how to design the knowledge transfer component of the PNBCAP pilot project to facilitate the scaling up of NbS for urban adaptation in Malaysia. There are two research aims: to explore a governance framework that can promote the sharing of knowledge and scaling up of NbS in urban adaptation projects in Malaysia; and to further the understanding on how pilot projects can contribute to the scale-up NbS urban adaptation. The knowledge gap identified is a framework for knowledge transfer to promote the scaling up of NbS for urban adaptation in the country.

2. Literature review

2.1. Urban climate adaptation in Malaysia

Climate adaptation is one of the three areas covered by climate change policy in Malaysia, together with mitigation and vulnerability reduction (Zen et al., 2019). However, the country's climate change adaptation efforts are falling behind due to the lack of a dedicated and comprehensive national strategy for climate change adaptation and a National Adaptation Plan (NAP) that can guide systematic and comprehensive action (Pereira and Zain, 2022).

Only a National Policy on Climate Change (MNREN, 2019) has been developed. The document aims to create a framework to guide government agencies, industry, community, and other stakeholders to address the challenges of climate change holistically. The plan highlights general principles and objectives, key actions, and sectors. It also states that a collaborative approach to the problem is needed and lists as a key action the creation of an inter-ministerial and cross-sectoral committee to enable the implementation of climate change measures (MNREN, 2019). The Malaysian Climate Change Action Council (MyCAC) was created in 2021 to address this need, holding two meetings annually and being chaired by the prime minister

(Aziz, 2023).

The documentation submitted to the UNFCCC (MESTECC, 2018) is a detailed document that identifies six sectors that must be addressed in terms of adaptation: water and coastal assets, food security and agriculture, forestry and ecological diversity, infrastructure, energy, and public health. Urban areas are not addressed specifically and are mentioned mainly in the context of flood management and transportation. The approach to challenges related to heat is mostly focused on heatwaves, which are identified as a threat in terms of public health, and a related health risk plan is mentioned. Urban heat is not mentioned, and neither are specific adaptation measures addressing it. Heat stress is otherwise mentioned in association with impacts on livestock and wildlife and in the context of agriculture, where the need to develop heat-resistant crops and animal breeds is identified. Neither the UHI effect nor NbS are mentioned in the document, and urban greening is mentioned only in the context of environmental education in schools.

Urban adaptation is particularly important in the country, as Malaysia is one of the most urbanized countries in ASEAN, with 78% of its population being urban (Chee et al., 2021). Urban adaptation initiatives are lacking, as the country has yet to adopt the necessary adaptation policies and measures (Zen et al., 2019). Nevertheless, several projects addressing floods have been developed, which are the most common and devastating disaster in Malaysia (Ekhwan and Barzani, 2014), to which urban areas are highly vulnerable, and are estimated to increase with climate change (Khailani and Perera, 2013). There is substantial research focused on this challenge (MESTECC, 2018; Khailani and Perera, 2013).

Despite adaptation policy not mentioning urban greening, NbS, urban heat, or the UHI effect, research has been developed in the country addressing all these issues. The benefits of urban greening in terms of thermal comfort have been demonstrated, both physiological and psychological (Nasir et al., 2012). Research focused on the UHI effects in Putrajaya showed that it is influenced not only by urbanization but also by climate change impacts (Salleh et al., 2013). Research has been developed in Malaysia focused on heat, heatwaves, and public health, mentioning the difficulty in accessing data on impacts in the country, including mortality (Castelo, 2021; Arsad et al., 2022; Suparta and Yatim, 2019). A study published in 2023 (Yong et al., 2023) focused on the state of Selangor found an increase of 12.9% in the risk of hospital admissions for those aged 60 or older associated with an increase of 1 °C in mean apparent temperature. The study also found women to be more vulnerable than men to heatwaves in that state.

Adapting to climate change is a complex challenge, as it is significantly shaped by a range of diverse and conflicting interests, along with epistemological and/or scientific uncertainties (Palermo and Hernandez, 2020). Gaps in knowledge and information and the lack of integrated systems are identified as the main challenges for the government in terms of its effectiveness (Ali et al., 2021). Beyond the collaboration between different government agencies, research has shown the importance of participatory processes in climate adaptation, highlighting the importance of the local community's knowledge (Palermo and Hernandez, 2020). The degree of community engagement and support was also found to be linked to the

likelihood of success in NbS initiatives in general in Malaysia (Chee et al., 2021). Mainstreaming NbS within a coherent framework was also identified as particularly important in the country (Chee et al., 2021). In general, for the development of NbS, new institutional spaces for social innovation initiatives may need to be established to lead the design and/or facilitation of co-creation, requiring a collaborative and cross-departmental governance approach (Frantzeskaki, 2019). Novel approaches initiated at the local level were highlighted as being necessary for dealing with climate impacts in Malaysia (Pereira and Zain, 2022).

2.2. Knowledge transfer and adaptation mainstreaming case studies

In this section, different case studies from adaptation knowledge transfer and mainstreaming are examined. Knowledge transfer in the context of adaptation has the main goal of assisting in mainstreaming adaptation policies. The IPCC AR5 WGII report defines adaptation mainstreaming as an increase in adaptation planning and implementation initiatives by and within governments (IPCC, 2014). Knowledge transfer and brokerage support mainstreaming adaptation policies by promoting diverse levels of interaction, helping to discuss opportunities, and identifying challenges and barriers perceived by stakeholders at an early stage (Jiricka-Pürrer et al., 2019).

A study in the Caribbean and Pacific (Robinson, 2019) sought insights into the drivers and barriers to mainstreaming adaptation at the national level. The study identifies several drivers, with the three most mentioned being institutional/organizational factors, the role of ‘champions’ or influential individuals within informal networks, and considerations related to risk and exposure. Likewise, multiple barriers are identified, with the three most commonly reported obstacles being conflicting development priorities, deficiencies in planning and governance, and insufficient manpower and human resources.

Another study on mainstreaming adaptation in Switzerland (Braunschweiger and Pütz, 2021) focused on investigating the adaptation implementation gap and the role of mainstreaming in overcoming it. Case studies of adaptation implementation measures were conducted at the local level. The study analyzed six strategies of mainstreaming as defined by Wamsler and Pauleit (2016) and found that the most successful strategy was a combination of programmatic mainstreaming (defined as the modification of the implementing body’s work by integrating aspects related to adaptation within on-the-ground operations, projects, and programs) with inter-organizational mainstreaming (defined as the collaboration and networking with other departments, and stakeholders to generate shared understanding and knowledge, develop competence and steer collective issues of adaptation). This strategy was called ‘‘cooperative mainstreaming’’. The study found that a lack of systematic regulatory and directed mainstreaming at the national and provincial levels largely limits adaptation at the local level. Other studies have reached similar conclusions. Bednar et al. (2019) focused on two provinces in Canada and also found that a more direct, hierarchical governance from higher levels is necessary to reduce the adaptation implementation gap.

Runhaar et al. (2018) meta-analysis examined the implementation gap worldwide

and found it to be substantially stronger in developing nations. The study concludes that the main reasons for the adaptation implementation gap are the lack of a political commitment to adaptation mainstreaming from higher levels of government and the absence of efficient collaboration and coordination among essential stakeholders. The study suggests measuring the success of adaptation mainstreaming in terms of policy outputs and outcomes.

A critical review focused on the effectiveness of mainstreaming adaptation into cities' master plans of low and middle-income developing countries in sub-Saharan Africa (Nyashilu, 2023) found overall poor results. The reasons identified were a lack of adaptive capacity from institutions, finance, and knowledge related to climate change. Additionally, urban development policies, plans, programs, and strategies did not integrate priority actions for climate change adaptation.

Research on mainstreaming adaptation measures into urban development in two coastal cities in Indonesia, Semarang and Bandar Lampung (Wijaya et al., 2020), found that the effort of mainstreaming adaptation substantially raises the level of knowledge of climate-related challenges and solutions for all stakeholders involved. The study identified the main drivers of successful mainstreaming of policies to be the motivation and initiative of municipal officers, capacity building, and support by the central government and international agencies.

Finally, a study focused on Melaka, Malaysia, found that a multi-level climate governance framework is crucial for mainstreaming climate initiatives in the country (Zen et al., 2019). Multi-level climate governance includes engaging in inter-sectoral, multi-stakeholder, and multi-faceted procedures connected to climate change adaptation and mitigation policies, encompassing a multitude of factors operating at different action levels (Zen et al., 2019). The study reports that Melaka City is translating national climate adaptation policy to local levels facilitated by a dual approach of both top-down and bottom-up climate efforts aimed at bridging the divide between local and national authorities, and by the progression towards multi-level climate governance. Cross-sectoral initiatives were combined with sub-national and local governance. This case study presents valuable lessons for adaptation in the country. Some of its limitations are the framework being mostly focused on mitigation, as specific threats of climate change are not addressed. This is understandable, as the country has yet to develop a NAP. Another limitation is the lack of identification of targets, which are mentioned only about low-carbon projects. Finally, the stakeholders involved include only government agencies at different levels, not engaging with scientific institutions or with the community.

2.3. Barriers and opportunities for the use of NbS in urban adaptation

Initiating climate adaptation projects at the municipal level presents numerous challenges, including a lack of institutional capacity. Developing nations often lack the necessary knowledge and resources. The main barriers to the implementation of NbS for urban adaptation are related to (Castelo et al., 2023):

a) Spatial issues—NbS often need more space than conventional "grey" solutions, and urban land is highly valuable, with many competing uses (Fratini et al., 2012; Skrydstrup et al., 2020).

b) Governance—Lack of knowledge and capacity within city councils. City governments also typically operate within traditional, sector-based structures, limiting the adoption of cross-disciplinary and intersectoral approaches like NbS (Kabisch et al., 2016). Urban planning and policies must be revamped to integrate NbS (Castelo et al., 2023; Nalau et al., 2018; Seddon, 2022) and incorporate them into viable governance and business implementation models (Albert et al., 2019). Urban planning must be grounded on evidence and needs to adapt flexibility and collaboration to integrate NbS effectively (Frantzeskakiet al., 2022).

c) Assessment—NbS' benefits are often difficult to quantify. Research suggests that for NbS to gain traction, their transformative potential must be acknowledged as superior to traditional grey infrastructure (Frantzeskaki, 2019).

d) Finance—The absence of clear monetary outcomes from NbS implementation can pose a hurdle to their adoption, despite efforts to increasingly monetize their benefits (Castelo et al., 2023).

e) Sociocultural issues—The failure of humans to acknowledge the value of non-human nature is an obstacle to the adoption of NbS (Murphy et al., 2021).

The main opportunities offered by NbS in terms of urban adaptation are in the sphere of 1) systems change, 2) social resilience, 3) mitigation and adaptation synergies, and 4) funding-knowledge support system nexus (Castelo et al., 2023). Addressing the climate and biodiversity crises requires transformative systems change, which transforms existing structures and underlying support mechanisms (Wamsler et al., 2022). This aligns with transformational adaptation, benefiting society while averting further climate damage (Castelo et al., 2023) as NbS work in harmony with nature, fostering resilience and a green economy (Sowińska-Świerkosz and García, 2022). Recent research has shown that participation in NbS projects is correlated with sustainable behavioral change (Cárdenas et al., 2021). NbS projects have also been identified as promoting social resilience, as involving local communities and indigenous groups in NbS implementation can reduce vulnerability beyond income generation, enhancing capacity, fostering innovation, and bolstering adaptation (Castelo et al., 2023; Seddon, 2022). In terms of mitigation and adaptation synergies, NbS can be particularly important for the developing world. Vast carbon reserves in ecosystems like peatlands and mangroves near the equator are at risk of permanent loss, which could trigger uncontrollable climate change, a concern recognized as a top priority for mitigation efforts (Goldstein et al., 2020). Mangrove forests, which protect coastal cities in adapting to rising sea levels, offer a strong potential for synergy between adaptation and mitigation. Many cities, particularly in Southeast Asia, home to the world's largest and most diverse mangrove forests, stand to benefit from this integrated approach (Siman et al., 2021). Finally, in terms of the funding-knowledge support system nexus, funding for NbS for urban adaptation could benefit from being associated with a knowledge support system. This knowledge support system can assist in identifying and filling in gaps while facilitating global knowledge exchange.

2.4. Systems of innovation and change theory

The concepts discussed in this section are innovations, systems innovation, systems of innovation, and change theory. Innovations are human adaptations to

changing needs and new socio-economic conditions, which are necessarily embedded in social processes (Rodima-Taylor et al., 2012). It consists of the process of creating, developing, and implementing new or improved devices, products, processes, or systems that bring about positive change and provide value (Edwards-Schachter, 2018). Systems innovation is about transforming entire systems to address complex challenges; it is an intensively collaborative endeavor, depending on alliances and requiring political, financial, and technical innovation (Mulgan and Leadbeater, 2013). It is a relevant concept, as the most pressing societal challenges today are associated with complex innovation systems (Dougherty, 2017). Systems of innovation consist of all the important factors, such as economic, social, political, institutional, organizational, and others, that influence the development, diffusion, and use of innovations (Edquist, 2009). In other words, systems of innovation refer to the broader framework of interconnected elements that facilitate and support the process of innovation within a society, industry, or organization. These elements may include institutions, organizations, policies, research and development activities, education and training systems, infrastructure, and more. A system of innovation helps create an environment where innovation can thrive by providing resources, collaboration opportunities, and structures for innovative activities to take place. Finally, change theory relates to the theoretical and empirically grounded knowledge about how change in general occurs, beyond specific projects (Reinholz and Andrews, 2020).

The systems of innovation approach have been endorsed for climate-related challenges by multiple institutions, including the United Nations Organization (UNFCCC, 2023; Watson, 2000). It acknowledges that institutions and actors operate within interdependent complex networks of relationships, in which causal relationships are frequently counterintuitive and non-linear. At a theoretical level, it analyses the potential for social, political, economic, environmental, and behavioral forces to interact as part of a complex system and assist in identifying leverage points within that system to bring about dynamic change (Meadows, 1999). Different components must be engaged in systems of innovation, such as policy, finance, scientific knowledge, skills, and human resources. In developing nations, public policy will likely need to take a bigger role in stimulating the development of systems of innovation (Lundvall, 2006; Lundvall, 2007). For climate-related challenges, institutional innovation is most likely crucial for achieving adaptive urban governance systems (Eakin et al., 2017; Larsen et al., 2016; Noble et al., 2014; Patterson and Huitema, 2018; Rodima-Taylor et al., 2012). Developing a systems of innovation approach means building a network of relationships with different types of interactions, exchanges, and periodic outputs. It is, however, necessary to make some room for spontaneity, as research has shown that systems of innovation mostly evolve in an unplanned way (Lundvall, 2007).

Addressing global challenges through innovation necessarily involves change (Matos et al., 2022). Transformation (or change) is regarded as key for municipal adaptation to develop more innovative and collaborative governance models, which will be able to help municipalities adjust to changing socio-economic and environmental conditions and contexts (Brooks et al., 2015; Frantzeskaki, 2019). While examining change theory, it is important to look for insights into the mechanics

of change, searching for principles, concepts, and guidelines that can help understand, manage, and, above all, facilitate change. Some change theories have reached a stage of maturity, underpinned by robust empirical evidence, others might have sprouted from specific contexts, being substantiated by more constrained proof (Reinholz and Andrews, 2020). In this paper, four change theories (Lewin's change model, Kotter's 8-step change model, Roger's diffusion of innovations theory, and Senge's five disciplines model) are briefly examined.

Lewin's change model is a three-step process, emphasizing three stages of change, unfreezing, transition/change, and refreezing. Unfreezing involves creating awareness and recognition of the need for change. It requires individuals or organizations to break free from their existing routines and beliefs. In the transition/change stage, actual changes are implemented. New processes, structures, or behaviors are introduced and adopted. In the final stage of refreezing, after the change has been implemented, it is necessary to stabilize the new state and make it the new norm. This often involves reinforcing the new behaviors and systems to ensure they are sustained (Kritsonis and Hills, 2012).

Kotter's 8-step change model provides a more detailed approach to managing change, with eight steps that guide organizations through the change process. Kotter's model provides a comprehensive and systematic approach to managing change within institutions. Its eight sequential steps are a) creating a sense of urgency, b) forming a guiding coalition, c) developing a vision and strategy, d) communicating the change vision, e) empowering broad-based action, f) generating short-term wins, g) consolidating gains and producing more change, and h) anchoring new approaches in the culture (Kotter, 2012). This model is well-suited for larger institutions requiring significant and sustained change (Tang, 2019). It provides a straightforward approach to introducing change in a process, project, or organization.

Roger's diffusion of innovations theory explains how new ideas or innovations spread through societies and organizations. This theory identifies four key components of the diffusion of innovations a) innovation, b) communication channels, c) time, and d) social system (Sahin, 2006). It also categorizes individuals into different adopter groups based on their willingness to embrace change. Roger (2003) characterizes adoption as a decision of committed use of an innovation as the best course of action present and rejection as the decision of not adopting an innovation. Diffusion is the process in which an innovation is communicated through particular channels over time among the members of a specific social system (Roger, 2003). The innovation-decision process is particularly important and involves five sequential stages: i) knowledge, ii) persuasion, iii) decision, iv) implementation, and v) confirmation (Roger, 2003). This theory is particularly useful for understanding the process of innovation and how to integrate its mechanisms into new structures and frameworks.

Senge's five disciplines model presents a comprehensive framework for organizational evolution, focusing on personal and organizational learning to facilitate change. This model underscores the interdependence of different disciplines that, when integrated, can transform a conventional organization into a dynamic "learning organization" that can thrive in intricate environments (Bui, 2020). The five disciplines are: 1) Systems thinking. Encouraging a comprehensive perspective,

systems thinking prompts organizations to perceive challenges and situations as components of a larger interconnected system. It involves discerning relationships, patterns, and feedback loops that shape behaviors and outcomes. This approach facilitates the identification of fundamental issues and the creation of solutions that address underlying structures instead of just treating issues on the surface. 2) Personal mastery. Focused on continuous personal growth and learning, it emphasizes individual development, clarifying personal visions and aspirations, and striving for excellence. When individuals commit to personal mastery, it contributes to an atmosphere of perpetual improvement and advancement. 3) Mental models. They encompass assumptions, beliefs, and perceptions that influence how individuals understand and interact with the world. It requires recognizing and challenging these mental models to foster new possibilities of thinking and decision-making. Adjusting mental models allows organizations to overcome biases and facilitate effective communication and problem-solving. 4) Shared vision. It represents a compelling, collectively embraced image of an organization's envisioned future. It provides a sense of purpose and direction. Cultivating a shared vision nurtures commitment and collaboration, propelling the organization toward its goals. 5) Team learning. It revolves around enhancing the collective abilities of a group to collaboratively solve problems, innovate, and make decisions. It emphasizes creating an environment that encourages open dialogue, constructive feedback, and joint reflection. Effective team learning enhances the organization's collective learning and adaptability. The five disciplines are intended to work harmoniously, with each discipline reinforcing and complementing the others. By cultivating these disciplines, organizations can foster a culture of continuous learning, adaptability, and innovation. Senge's model has significantly impacted fields such as organizational development, leadership, and change management, offering a holistic approach to tackling the complexities of continuously evolving environments (Bui, 2020). Senge's model provides useful guidance for complex systems in the process of change.

The systems of innovation framework can assist in organizing an arrangement of interconnected actors, institutions, policies, and practices which can lead to new outcomes as a result of change (Nikas et al., 2017). Collaborative governance can make a difference in achieving the desired results (Ansell and Gash, 2007). Research has shown that, specifically for climate policy-making processes, different societal groups should be included in a process that is structured and transparent (Nikas et al., 2017).

When discussing innovation and the need for change in the context of climate change, it is important to note that there are relevant issues related to ethics and values that should be considered, such as global, local, and intergenerational justice. In the study on the emergence of values in organizations by Gehman et al. (2013), it is suggested that a variety of stakeholders and institutions can influence an organization's values in a meaningful way and that interactions, and especially networks, between different groups of stakeholders, can be of substantial positive consequence, particularly when involving events and practices. Perspectives from different sectors of society, including the most vulnerable groups, should therefore be introduced to organizations that have policy-making responsibilities. Gehman et al

(2013) also highlight the role of concerned stakeholders in precipitating events related to changes in values. Four key processes were identified as being involved in the emergence of new values practices: a) dealing with pockets of concern—as different concerned actors interact, spillovers are likely to occur, the practices of one group of stakeholders concerned are adopted by uninvolved actors, leading them to become involved; b) knotting local concerns into action networks—the importance of integrating local concerns into broader action networks, which leads them to gain momentum; c) performing values practices—how adopting the new values must be effectively put into practice; and d) circulating values discourse, about how the new values tend to expand within each organization (Gehman et al., 2013).

3. Methods

The focus of this paper is to develop a model for accelerating knowledge transfer to promote urban adaptation in Malaysia, based on the Penang program. The methodology used for the conceptualization of the model is based on a literature review focused on urban adaptation in Malaysia, knowledge transfer case studies, barriers, and opportunities to the use of NbS for urban adaptation, and systems of innovation and change theory. These subjects were considered important for the development of a model for knowledge transfer. The review on urban adaptation in the country covers challenges related to flooding due to rainfall or extreme weather events, heat, and public health. Sea level rise is excluded, as it was not identified as a threat in the case of Penang Island (Adaptation Fund, 2021).

The focus on systems of innovation and change theory addresses the need for innovation and change associated with climate adaptation. Climate adaptation is a new field of work in Malaysia, and innovation in institutions and governments has been highlighted as crucial for improvement in the adaptive capacity associated with the most vulnerable societies and communities (Adger et al., 2003). For climate adaptation to be addressed, a substantial amount of change needs to take place (Díaz et al., 2019). The literature review on systems of innovation and change theory seeks to select specific mechanisms to assist the creation of a framework for the knowledge transfer model.

To understand the knowledge that is to be transferred, the PNBCAP, its components, and its governance system are introduced, as well as Penang Island's main climate vulnerabilities to climate impacts.

4. Results

The development of the model for knowledge transfer was informed by a literature review, adjusted to the specific characteristics of the PNBCAP.

4.1. The Penang program

4.1.1. Vulnerability to climate impacts

Penang, a Malaysian state located on the northwest coast of Peninsular Malaysia, lies approximately five degrees north of the equator. It encompasses an area of 1049 km^2 and is governed by two local authorities: one overseeing Penang Island, Majlis

Bandaraya Pulau Pinang, the City Council of Penang Island (MBPP), and the other managing the mainland (Majlis Bandaraya Seberang Peral). The state is further subdivided into five administrative districts, each comprising several mukims (sub-districts), which include George Town and Bayan Lepas. As shown in **Figure 1**, the surface temperatures in Penang state are significantly higher in urban areas than neighboring natural or rural areas by approximately 8 °C due to the UHI effect.

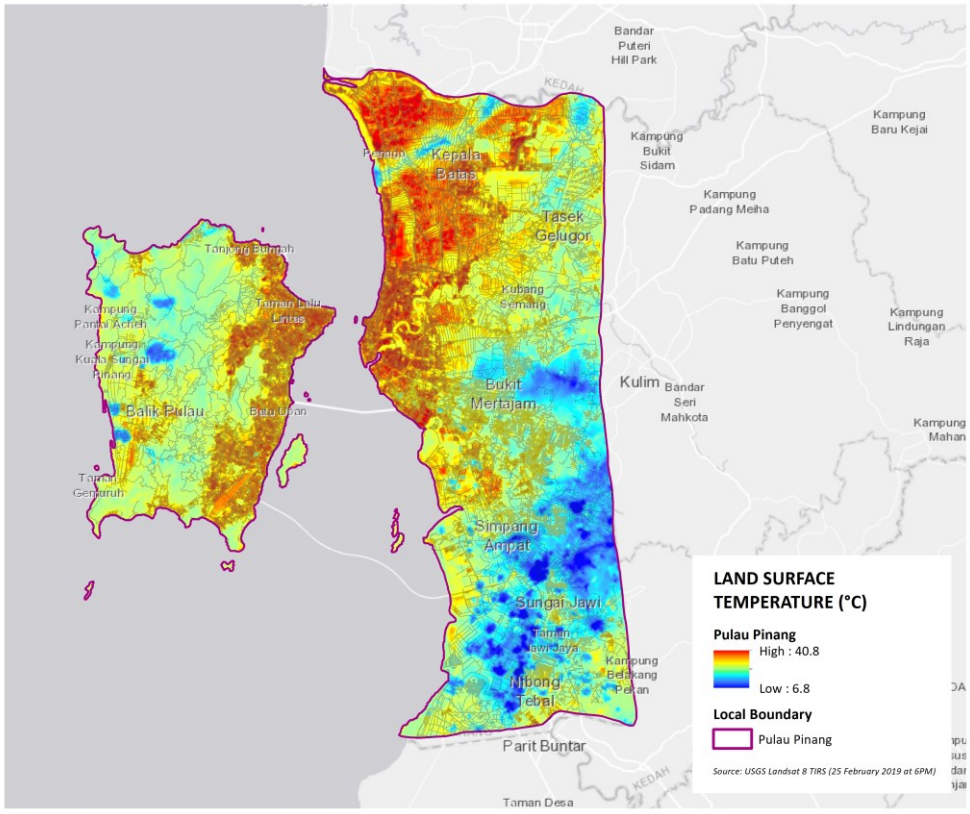

Figure 1. Remote sensing (Landsat 8) for surface temperatures in Penang Island.
Source: Image retrieved by Think City, 2019 (Adaptation Fund, 2021).

George Town, the state's capital, covers an area of 2501 hectares and has a population of 198,298 as of the last census in 2010, equating to 79 people per hectare. The land usage in this area is a mix of residential, commercial, and mixed-use shop lots. The historical center of George Town has been recognized as a UNESCO World Heritage Site since 2008. It has substantial vulnerability to rising temperatures and flooding, particularly due to a significant flood-prone area coinciding with a high concentration of elderly residents. Bayan Lepas, a larger area spanning 2898 hectares, encompasses Penang's airport and a sizable manufacturing zone. While it is not as susceptible to severe flooding, Bayan Lepas experiences a pronounced UHI effect, as indicated by remote sensing surface temperatures (Adaptation Fund, 2021): a significant increasing trend was found in both the annual and monthly mean temperatures from 1951 to 2018 at 95% confidence level (**Table 1**), with a mean temperature increase from 1951 to 2018 of 1.50 °C.

Table 1. The magnitude of changes of annual and monthly mean temperatures at Bayan Lepas climate station during the 1951–2018 period.

	Mean Temp Change (°C)
Jan	1.53
Feb	1.50
Mar	1.66
Apr	1.24
May	1.45
Jun	1.71
Jul	1.86
Aug	1.52
Sep	1.38
Oct	1.34
Nov	1.50
Dec	1.34
Annual	1.50

Source: Produced by the Geography Department of Universiti Sains Malaysia (USM), 2019 (Adaptation Fund, 2021).

Households in Penang are particularly vulnerable to the effects of climate change due to their heightened exposure, such as outdoor labor, and their limited capacity to safeguard themselves from overheating food scarcity, and natural hazards like floods and droughts. Penang Island comprises several vulnerable communities, including a) communities residing in flood-prone areas, which coincide with the highest concentration of elderly residents in Penang; b) low-income groups lacking access to air conditioning; c) women and girls, who are disproportionately impacted by climate change (Allen, 2022), with women primarily serving as caregivers, as evidenced by their low labor force participation rate of 59% (Adaptation Fund, 2021).

Malaysia is vulnerable due to its location, as Southeast Asia was identified as one of the three regions in the world most severely affected by climate change (Adaptation Fund, 2021). In Malaysia, the primary impacts include rising temperatures, more frequent and severe extreme weather events, and sea level rise (NAHRIM, 2017). The intensifying temperatures pose a significant challenge, as the tropical rainforest climate characterized by consistently high temperatures and humidity year-round is already extreme. The UHI effect amplifies the impact, increasing urban temperatures by up to 8 °C (Velazquez-Lozada, 2006) compared to the surrounding natural or rural areas, with notable implications for public health. However, it's worth noting that the country's hospitals currently lack a systematic approach to identifying and coding heat-related health issues, instead categorizing them as respiratory or cardiac conditions (Adaptation Fund, 2021). Malaysia is already experiencing shifts in weather patterns, with long-term estimates suggesting a potential 12% reduction in GDP per year due to climate change (in a scenario of a 3 °C increase by 2100) (Kompas et al., 2018). In comparison, the study estimates a 1% reduction in GDP per year for Australia, 0.6% for the USA, and 0.2% for Canada, indicating an exacerbation of the economic disparity between Malaysia and developed countries. Additionally,

changes in temperature and rainfall patterns are predicted to reduce crop yields by 10 to 15%, potentially raising food costs and disproportionately affecting vulnerable communities (Firdaus, 2013). Research focused on Penang has shown a correlation between the increase in the UHI effect and expanded urbanization and reduced forest cover (Rahaman et al., 2022).

The other substantial problem identified in Penang is flooding due to increased volumes of rainfall, and the number of extreme weather events. Penang had an average annual rainfall of 2434 mm over the past decade. During this period, from 2010 to 2018, there was an unusually substantial increase in average annual rainfall (**Table 2**), that surpassed the National Water Research Institute of Malaysia (NAHRIM) projections by 29.6% (**Table 3**) (Adaptation Fund, 2021). The increase in precipitation in the Penang state is substantial, although more significant in the mainland than in the Island (Tan et al., 2022).

Table 2. Average annual rainfall for Penang Island (2010–2018) shows an increasing trend.

Year	Average Annual Rainfall (mm)
2010	2088.65
2011	2260.38
2012	2359.86
2013	2519.10
2014	2389.98
2015	2453.13
2016	2493.41
2017	2642.25
2018	2706.76

Source: Data provided by JPS (Adaptation Fund, 2021).

Table 3. Observed and projected rainfall in Malaysia.

Parameter	Observed (1970-2000)	Projected for 2030	Projected for 2050
Average Annual Rainfall			
Peninsular Malaysia	1891-2619 mm	1998–2663 mm (1 to 6% increase)	2068–2805 mm (7 to 11% increase)

Source: Malaysia Third National Communication and Second Biennial Update Report to the UNFCCC (2018) (Adaptation Fund, 2021).

The escalating rainfall and shifting weather patterns are already causing substantial harm in Penang. The worst floods in the history of the state took place over a weekend in November 2017, leading to the loss of seven lives, with a total of 159 neighborhoods reported as being affected by floods, 68 of which had never previously flooded (Adaptation Fund, 2021). Losses were substantial in multiple sectors (Adaptation Fund, 2021; Federation of Malaysian Manufacturers, 2017; Penang Institute, 2019).

4.1.2. Introduction to the program and its components

The main scope of the PNBCAP is to improve urban resilience in George Town

and Bayan Lepas, urban sub-districts of Penang Island. In this paper, the definition adopted for urban resilience is the one provided by Meerow et al. (2016): "Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity". Disturbances to be considered are related to climate change. The main threats are identified and NbS are proposed to address them, and the main vulnerabilities, in terms of social vulnerability and institutional capacity are identified and targeted with specific projects. The introduction of NbS seeks to reduce the UHI effect and overall temperatures and to improve stormwater management to reduce flooding while strengthening social resilience and building institutional capacity. As the reduction and management of climate impacts are crucial, a science-driven approach was adopted to guide the program's design. This type of approach must accommodate for some uncertainty, which exists at different levels, in terms of the degree of impacts and of RCP scenarios, which vary depending on collective global action. Some impacts are, however, confirmed in all scenarios for Malaysia: increasing temperatures, increasingly frequent and severe extreme weather events, as well as sea level rise (NAHRIM, 2017). The PNBCAP, being the first of its kind in the country, poses some challenges, as no NAP has been developed, so there was no available framework to adopt (Castelo et al., 2023b). An alternative would be to wait for the Federal Government to develop the NAP, but climate impacts are already taking place and action must be taken to protect the population. TC was well positioned to develop the project and reach out to local and international stakeholders, having its origins and headquarters in Penang. The organization functions as a neutral platform, facilitating partnerships between the community, the private sector, and different arms of government to deliver high-quality and impactful outcomes, focusing on making cities more livable, sustainable, and socially and environmentally resilient. Aware of the climate-related challenges cities face, the organization launched a community of practice focusing on climate in 2019, by initiating the design of the PNBCAP and by launching and hosting the first climate action week in Malaysia (Penang Climate Action Week, 2019; PCAW, 2019). A decision was made by the parties involved to move ahead. Extensive knowledge and capacity were drawn together almost from scratch to design, develop, and initiate the program. The financial resources and knowledge gathered ought to be as beneficial as possible for the country, so the PNBCAP should become a national pilot project for urban climate adaptation (Yong et al., 2023; Zen et al., 2019). The execution of the 5-year program was launched in September 2022.

NbS were adopted in PNBCAP due to being repeatedly highlighted as a key concept in policy and management for aligning with environmental and societal goals (Castelo et al., 2023b). Being a possible central solution for climate change, they are now recommended for implementation at a global scale (Griscom et al., 2017), supported by multiple international organizations, including the United Nations Organization. The benefits extend beyond climate change, as NbS impact is multifunctional and advantageous at many different levels, such as social, public

health, biodiversity and financial, having been proven to be highly beneficial in terms of cost-benefit ratios. In cities, NbS have an instrumental role in transitioning to a more livable and sustainable future high-density model (Emilsson and Sang, 2017). Introducing green spaces, particularly strategically placed street trees, has proved to be the most effective strategy to control rising temperatures (Kardan et al., 2015). The introduction of vegetation can play an essential role in changing the urban climate closer to a state prior to climate change impacts (Cohen-Shacham, 2016). Microclimate regulation achieved by planting green spaces will also reduce the impact of heat waves (Lindén et al., 2016).

Urban Greening will be executed by MBPP, except for the Built Structures projects, which will be under Think City. This includes the introduction of street trees, greening car parks, urban agriculture, and pocket parks/vacant spaces. The Built Structures sub-component will address private property through a Grants Program. Analysis and planning play an important role, as green spaces must be introduced in strategic locations to achieve optimized results, taking advantage of parameters such as solar orientation, air circulation and others. Strategic planting includes choosing the most beneficial typology of space, planting, and species, in general, as well as for each specific location. With street trees for example, leaf organization and canopy shape have the biggest impact (sparse crowns with large leaves have a higher cooling capacity) (Kardan et al., 2015). has a natural advantage in terms of NbS implementation due to its equatorial climate, as vegetation growing ratios are significantly higher compared to other climates. Of all NbS urban typologies for adaptation to increased temperature, street trees are the most impactful (Donovan et al., 2013; Kardan et al., 2015). They require a limited area at ground level (which is convenient in an urban setting) and provide the broadest protection from radiation exposure to people, animals, structures, and their materials, hence reducing the UHI effect (Lenzholzer, 2012). Adding even just a few trees has proved to significantly reduce excessive heat (Lindén et al., 2016). Furthermore, the positive impact of green spaces in urban contexts is well documented in terms of public health. Urban green spaces provide cooling effects that can contribute to reducing stress factors that stem from overheating, leading to health-related impairments that may result in increased mortality rates (Emilsson and Sang, 2017). Additionally, they have been proven to reduce obesity, cardiovascular diseases, blood pressure, respiratory diseases, and diabetes (Ulmer et al., 2016). Other benefits include the improvement of social cohesion, and economic and aesthetic added values (Soares et al., 2011).

Flooding is another challenge for Penang. Studies (Hartman et al., 2018) have recommended the increase of green spaces to reduce flooding by developing strategies for stormwater retention and creating a linear park with retention areas in the Pinang River. However, a more flexible approach to stormwater management is needed to address the challenges associated with changes in rainfall patterns. City managers must introduce a more resilient approach combining soft and hard infrastructures. A sustainable drainage systems' approach is behind the concept of the sponge city, which has achieved remarkable results in reducing floods (Chan et al., 2018). The Stormwater Management component will be executed under JPS. This will include upstream retention areas, blue-green corridors, swales, and infiltration wells. The

program will be executed in the two targeted pilot project areas, the George Town and Bayan Lepas mukims (sub-districts). These areas, particularly George Town, are densely built downstream, making upstream retention critical, as well as swales and downstream infiltration wells.

The main PNBCAP components and sub-components are illustrated in **Figure 2**. Strategies and actions address social resilience and institutional capacity. They differ from built projects in the sense that their outcome is not constructed, and instead of reducing negative impacts, they focus on strengthening society and institutions. The program incorporates a community-focused strategy and places a strong emphasis on knowledge transfer to enable the widespread adoption of this methodology by other cities in Malaysia and the broader region in the near future (Castelo et al., 2023b; Zen et al., 2019).

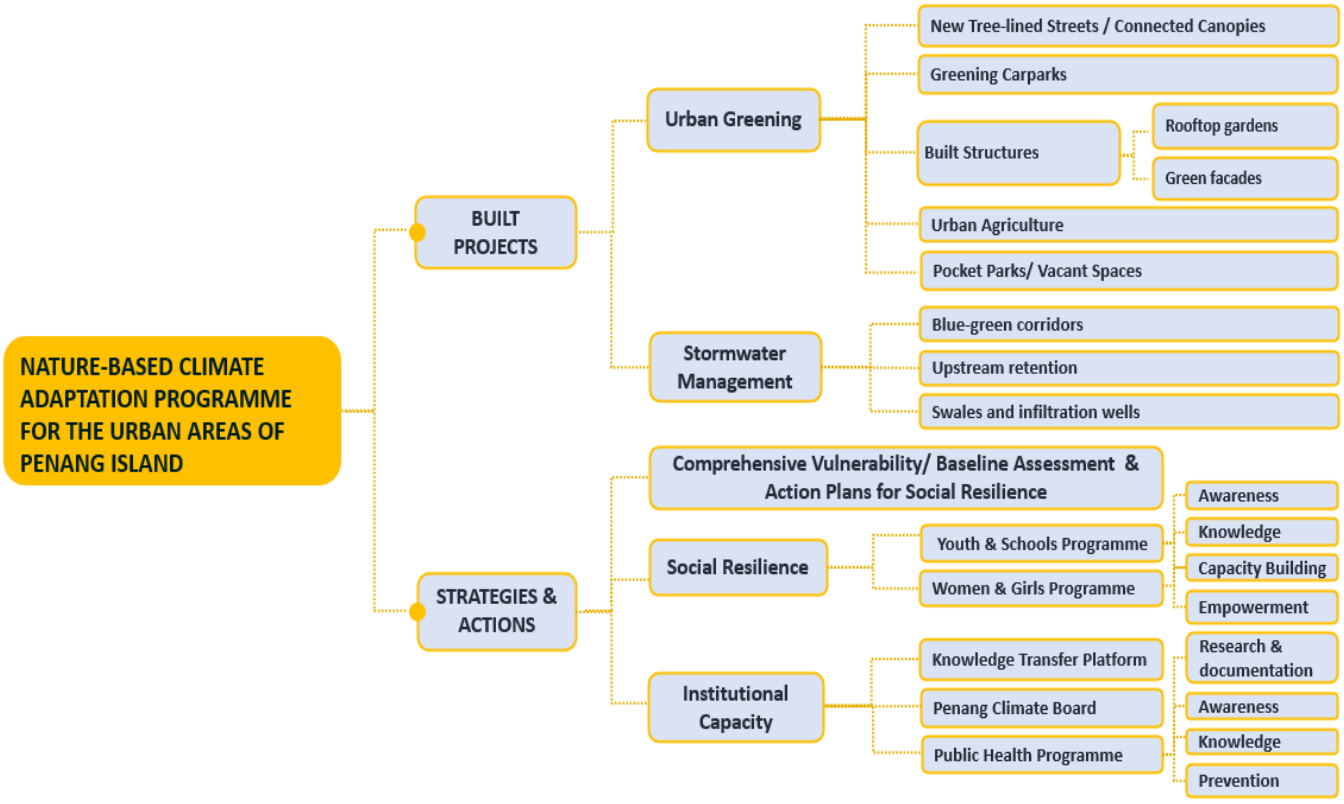

Figure 2. PNBCAP components and sub-components (Castelo et al., 2023b).

Strategies and actions will be executed by TC, which will include the comprehensive vulnerability/baseline assessment and action plans, social resilience, and institutional capacity. In terms of social resilience, the goals are to identify specific vulnerabilities in a baseline study and to develop two programs targeted at particularly vulnerable demographics, women and girls, and youth. According to Keck and Sakdapolrak (2013), social resilience is rooted in ecological systems thinking, particularly in the concepts of persistability, adaptability, and transformability, and is not only a dynamic and relational concept but also a political one. Definitions of social resilience focus on social entities', whether they are individuals, organizations, or communities, aptitude or capacity to endure, assimilate, deal with, and adapt to diverse environmental and social threats (Keck and Sakdapolrak, 2013). Keck and

Sakdapolrak's (2013, p. 5) literature review identifies three important dimensions of social resilience: (1) Coping capacities—the ability of social actors to cope with and overcome all kinds of adversities; (2) Adaptive capacities—their ability to learn from past experiences and adjust themselves to future challenges in their everyday lives; (3) Transformative capacities—their ability to craft sets of institutions that foster individual welfare and sustainable societal robustness towards future crises. The following four proposed stages were created to address these three dimensions: 1) awareness, 2) knowledge, 3) building capacity, and 4) empowerment (Castelo et al., 2023b).

As for the fourth and final component of the PNBCAP, institutional capacity, the main goal is to reduce, and if possible, eliminate, previously identified gaps. This will be partially achieved through the development of a knowledge codification process to document the know-how acquired during the PNBCAP including the preliminary scientific climate vulnerability assessments, NbS techniques, and the program's outcomes and impacts. Its principles should be adopted by executing entities as their standard practices. The introduction of a climate-conscious approach in the design of green spaces in the urban areas of Penang is hopefully set to become one of the standard practices for both MBPP and JPS. The mission is also to have these lessons transferred to other local government authorities in Malaysia.

4.1.3. Governance structure

The PNBCAP governance structure is based on a partnership with six main stakeholders, TC, MBPP, JPS, the Ministry of Natural Resources, Environment and Climate Change (NRECC), UNH and the AF. As mentioned in the introduction, the program was initiated and designed by TC, who brought on board MBPP and JPS as executing partners, and UNH as the MIE for the AF. The National Designated Authority (NDA) for the AF was also contacted by TC, to provide feedback, as well as to obtain their support and endorsement of the program. The National Designated Authority (NDA) in Malaysia has changed since 2019 due to changes in government. Originally it was the Ministry of Energy, Science, Technology, Environment and Climate Change, in 2020 became the Ministry of Environment and Water, and currently it is NRECC.

All partners agreed that a multilevel governance framework was to be adopted together with a systems of innovation approach. The multilevel governance framework is useful not only because of the challenges the PNBCAP faces by being the first of its kind in Malaysia, but also because research shows it is vital for both adaptation and NbS projects, assisting in developing proactive adaptation measures and overcoming obstacles to adaptation (Amundsen et al., 2010). A collaborative approach is suggested to be at the core of NbS initiatives which lead to innovations (Frantzeskaki, 2019).

The program was discussed in detail with the main partners listed above, and also with the community, in extensive local community engagements which took place from 2019 to 2021 (Castelo et al., 2023b). Changes were made according to feedback from all; further minor changes are expected to take place during execution, as PNBCAP was designed to accommodate adjustments resulting from inputs from the community and from Monitoring and evaluation. Beyond the main partners, the program is supported by an unprecedented collaboration between stakeholders at local,

regional, national, and international levels (including government agencies, scientific support institutions, and civil society) (Castelo et al., 2023b). There is a particular focus on engaging with the most at-risk groups of society in order to assess their main vulnerabilities in a collaborative effort (including, women, disabled, migrants, and low-income households, designated as B40 in Malaysia, i.e., the bottom 40% of Malaysian households by income). PNBCAP was discussed in different types of platforms, having been presented at more than 30 conferences, webinars, and other types of events, at both national and international arenas. The repeated presentation of the program and its evidence-based approach has contributed to creating awareness to climate change in Malaysia, obtaining the endorsement and adoption by many national organizations, institutions, and groups of citizens.

4.2. Urban adaptation knowledge transfer model

4.2.1. Background of the Proposal

The Penang program has a multilevel governance system and a multidisciplinary and multisectoral nature, combining physical interventions to address climate impacts with projects addressing social resilience and institutional capacity gaps. This approach was highly praised by local and international stakeholders and was mentioned as one of the reasons for the program to win the Climathon Global Cities Award in 2020, an award given by EIT Climate-KIC. Developing a model to mainstream this framework to other cities in the country has been a matter of concern since the early stages of the program and is highlighted above as objective number 8 at the national level in the AF framework (Adaptation Fund, 2021).

The PNBCAP has already introduced technological innovation with ACResT, an online platform created in 2022 for sharing climate-resilient urban tree species in the country. Research suggests that studies on innovation in climate change are mostly focused on technology (Kotter, 2012). The innovation being sought for the knowledge transfer will include technology, but it is mostly procedural, relational, and institutional, within the sphere of governance. The main goal is to accelerate adaptation. Although urban climate adaptation involves addressing unprecedented risks, most impacts are well known, as well as the strategies to reduce them. City governments in developing nations, however, may not be familiar with either the challenges or the best policies to address them. This is also the case with combating the accentuation of pre-existing environmental challenges, social vulnerabilities, and inequalities (Kraas et al., 2016; Kritsonis and Hills, 2012; UN-Habitat, 2017).

The knowledge transfer platform's crucial role in PNBCAP is facilitating the capture and dissemination of the program's knowledge in a format that can be easily transferred to other Malaysian municipalities (Adaptation Fund, 2021) with the support of NRECC. It will share the program's methodology, evaluation and assessment of different strategies, and the program's effectiveness, including in terms of flood impacts and temperature reduction. Knowledge tools are vital, as they can play an important part in supporting adaptation measures aimed at having a systemic impact (Castelo et al., 2023a). Digital tools should be further incorporated into climate adaptation planning, advancing data-driven decision-making, while simultaneously reducing the likelihood of failure and enhancing planning efficiency (Balogun et al.,

2020). They can also be decisive in acquiring data to support decision-making processes (Molina-Perez, 2023) and to assess the effectiveness of climate adaptation programs, particularly in what concerns stakeholder engagements (Carneiro et al., 2022). Knowledge-sharing platforms can help different climate adaptation components and policies to be integrated into a framework of multi-level governance (Panenko et al., 2021). As many knowledge gaps remain in adaptation (Castelo et al., 2023a; Kabisch et al., 2016), a platform can greatly facilitate data collection and contribute to being filled, enhancing the potential for replication of successful strategies. According to Keibach et al. (2022), however, the benefits of digital technologies for climate adaptation planning have not yet materialized.

To ensure good communication and full transparency, all stakeholders will be informed of the implementation process, monitoring and evaluation tools, and results, through the platform and via monthly reports. It is, nonetheless, clear that an online platform with knowledge tools available will not be enough. Effectively disseminating knowledge and promoting the adoption of new adaptation-related policies in other cities in Malaysia is a substantial challenge, particularly in the context of Asia, where government institutions tend to work in silos (Scott, 2020), while climate adaptation is multisectoral. Developing a model to achieve this goal was acknowledged by TC to be the core of the knowledge transfer platform, to which systems of innovation and change theory contributed. Systems of collaborative governance were also a reference, as they can produce substantial results as long as specific circumstances are at play, such as the prior history of collaboration (with the absence of conflict), incentives for stakeholders to participate, reduced power and resource imbalances, and the quality of leadership and institutional design (Ansell and Gash, 2007). Ansell and Gash (2007) have identified some crucial factors for success: face-to-face dialogue, trust building, development of commitment, and a common, shared understanding of the challenges faced and the structure of the collaboration. Small wins in the context of collaborative forums were identified as promoting a virtuous cycle, building trust, and deepening common understanding and commitment. The fact that PNBCAP uses NbS also presents an opportunity, as research suggests they allow for different forms of institutional arrangement to be tested and promote the development of more innovative and collaborative governance models (Frantzeskaki, 2019).

The model developed for knowledge transfer and acceleration of adaptation is materialized in a new institutional framework, the Malaysia Adaptation Sharing Hub (MASH), created as part of the knowledge transfer component. It constitutes a coalition of local governments, knowledge partners (universities and institutes), and civil society organizations. The model focuses on knowledge being socialized, and in the sharing of concerns by all stakeholders. Action is promoted, and specific policies are presented and discussed, backed by scientific evidence. This model presents an opportunity for other municipalities to develop their climate adaptation strategies and programs, extending to other cities in the country the benefits of the funding received. This framework will also allow us to think critically about the PNBCAP and proceed to the necessary adjustments to the 5-year program, assisting in developing a municipal model for urban adaptation for the country.

The selection of stakeholders to be part of MASH is key. The local governments

should have already shown interest in building climate resilience and the scientific institutions should ideally be interested in applied knowledge. The inclusion of civil society organizations is important, as it is known that for urban climate adaptation projects to be successfully implemented, they should be developed in close collaboration with the community (Pörtner et al., 2022). Furthermore, research has shown that local knowledge, socio-cultural and affective-emotive factors, as well as lay perceptions, can add vital information for the design of adaptation policies (Kotter, 2012). It is also important to note, for the design of the coalition, that power imbalances can lead to instability, which is not only present in the climate sphere at a global level but also within countries and communities (Dougherty, 2017). Finally, participation will be crucial at different levels, as with gathering the community's knowledge on impacts already taking place, especially in the case of vulnerable groups, who are not as buffered from climate effects as the rest of the population. Regardless of MASH, it is important to organize community engagements throughout the project's life cycle, to collect information, and feedback, and to ensure everyone is kept informed.

4.2.2. Malaysia Adaptation Sharing Hub (MASH)

MASH was developed by integrating concepts from systems of innovation and change theory, particularly from Kotter, Roger, and Senge's theories, and inputs from collaborative governance research. From Kotter's theory, the first five of the eight steps were of use: a sense of urgency was created, a coalition was established, a strategy was developed, the change vision was communicated, and broad-based action was targeted. Regarding Roger's diffusion of innovations theory, the communication channels for diffusion, as well as aspects of the components of time and social system influenced mostly the 3-step program and annual activities. Finally, from Senge's theory, aspects of the disciplines of mental models and team learning were of significant relevance to planning the fostering of a culture of continuous learning, adaptability, and innovation, particularly in relations between stakeholders and in fostering a shared vision.

To address climate-related challenges, it is important to have broad partnerships with multiple stakeholders, in which knowledge is co-produced (Dougherty, 2017). The relevance of systems of innovation is to provide a conceptual framework for understanding how innovation processes are shaped by the interactions and relationships among various actors and institutions within a specific context. This is particularly relevant for informing the design of networks with many stakeholders such as MASH, which are focused on promoting innovation and change. The PNBCAP being science-driven means that further research will likely impact aspects of the framework and the planning of annual activities. As an example, Reckien et al. (2023) study suggests the three weaker aspects of urban adaptation to be participation, monitoring, and evaluation, so special focus will be placed on them.

In **Figure 3** the MASH model, members, and main targets are presented. The MASH members include Malaysian local governments (i.e., city and state governments, 11–14 cities, and 4–5 state governments); scientific institutions (6–8); and civil society organizations (CSO) (8–12). The numbers listed are estimated for the organizations and local governments that are expected to be involved in the launch of

the coalition in 2024. MASH's 3-step program includes the following annual activities: one vulnerable community engagement meeting; one in-person 2-day meeting in Penang; one online meeting in which cities announce the two new policies to adopt the following year. MASH targets are a) sharing knowledge on the impacts felt by vulnerable communities in the country; b) sharing knowledge from the PNBCAP and obtaining feedback; and c) the adoption of two new climate-related policies/year by the city members of MASH.

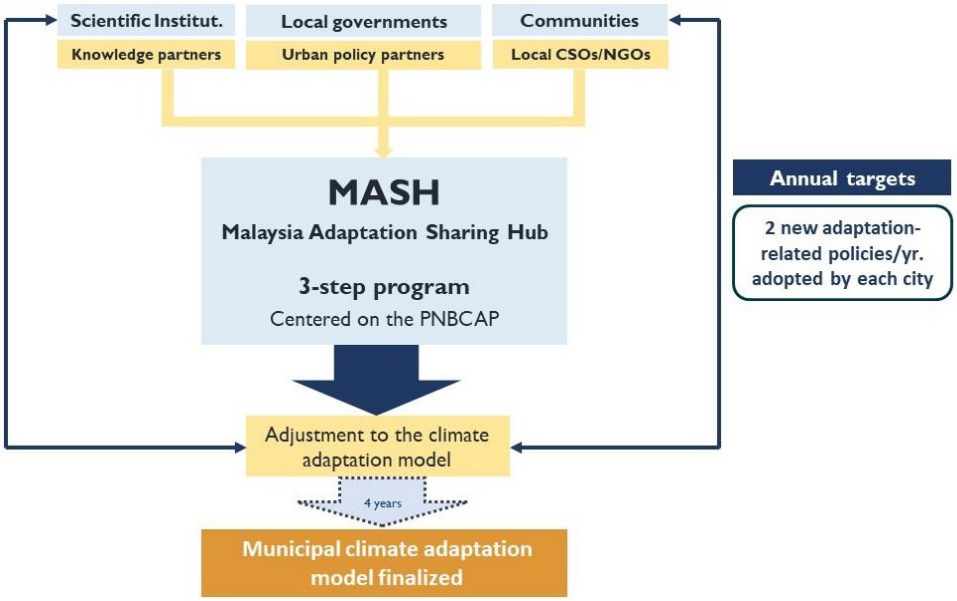

Figure 3. MASH model, members, and main targets.

The 3-step annual activities program, shown in **Figure 4**, is initiated with a vulnerable communities' engagement, as these communities are on the frontlines of impacts and it is of utmost importance to document the challenges they face. This can be carried out by any member of the coalition. The resulting report will be shared in the second and most important step of the annual activities, the 2-day in-person meeting in Penang. Different members will take charge of different sessions, to promote taking ownership of the coalition. Stakeholders from PNBCAP will update on the progress of the program; scientific institutions will present the latest research on impacts in Malaysia and CSOs will share the communities' main concerns. City governments will be encouraged to present their most successful initiatives in this field. One of the sessions will be focused on workshopping different alternatives for the two new policies to be adopted by city governments for the following year. It is important to avoid local governments feeling pressured, so policies presenting different levels of commitment will be introduced. Finally, the third step consists of an online meeting, which will include a short presentation with the outcomes of the meeting in Penang but will be mainly focused on the announcement by city governments of the two new adaptation-related policies that have been chosen for implementation in the following year. A post-project review (PPR) will be carried out a couple of months later to identify areas for improvement and opportunities for development, which will lead to adjustments of the events to take place in the following year.

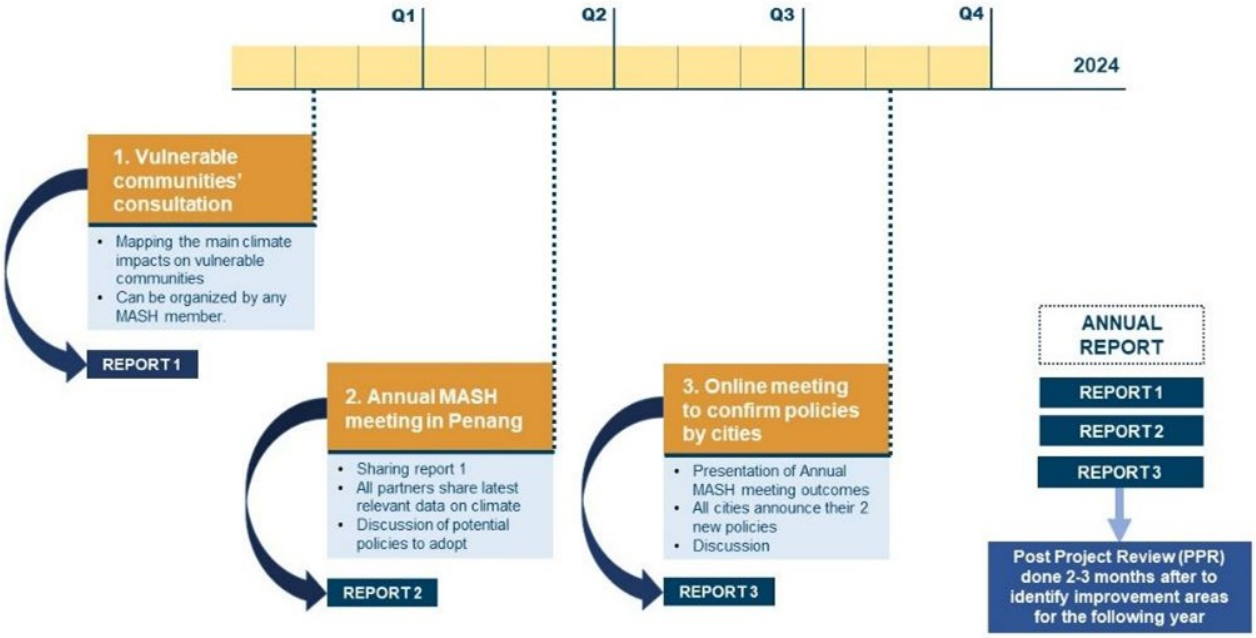

Figure 4. MASH annual cycle.

5. Discussion

The design of MASH incorporates flexibility, to allow spontaneity and further innovation to take place; this will ideally prompt stakeholders to take ownership of different parts of the partnership and even build new initiatives on their own. MASH is initially focused on incremental results, to have each city member adopt two new adaptation-related policies per year. The intention, however, is that the coalition's framework design, namely the annual adjustments to the structure resulting from PPRs, results in improved ambition with each passing year, hopefully leading to systemic change.

Research has shown that communication is one of the main causes of project failure (Herz and Krezdorn, 2021), therefore it is important to ensure that this is not the case with the MASH coalition. Bringing all stakeholders together in the support of a project and developing new associated policies is always a challenge, and even more so in a new field, which is the case of climate adaptation in Malaysia. Being able to support the different strategies proposed with clear evidence is key. The climate challenges faced by cities in the country and the strategies proposed to address them must be analyzed, synthesized, and communicated clearly with easily understood data during the annual event in Penang and throughout the annual cycle. Special attention will be placed on:

1) Presentation of scientific evidence, which should be communicated in a way that can be understood by all, not only by an audience of experts.
2) Full transparency of processes focused on building trust.
3) The different members of the coalition must feel they are equal partners and not subject to a hierarchy of power.
4) All members of the coalition will be encouraged to take charge of different components or sessions of annual events to build commitment and ownership

The knowledge acquired during the annual activities will also contribute to adjust the PNBCAP, targeting its effectiveness, resulting in an improved municipal model for urban adaptation to Malaysia at the end of the 5-year program. One of the main opportunities identified in previous studies in the use of NbS for urban adaptation is the synergy with climate mitigation (Castelo et al., 2023a). MASH can contribute to filling knowledge gaps in what concerns synergies between climate adaptation and mitigation in the context of NbS (Kabisch et al., 2016). One potential measure to be considered is the measurement of carbon sequestered by the NbS being implemented, and the monitoring of its progress, as plants, particularly trees, grow.

6. Conclusions

The importance of identifying this model is so that Nature-Based Climate Adaptation Programs for Urban Areas can adequately respond to climate-related challenges, leading to the identification of knowledge transfer as one of its main components.

A literature review, or case study of the pilot project and the changing ecosystem, makes it possible to identify the need for more collaborative approaches to climate adaptation programs. The pilot project being implemented in Malaysia supports the promotion of an alliance between the government, scientific institutions, and civil society as the vector for the success of the two programs. MASH seeks to maximize the potential of knowledge and financing to achieve the greatest possible number of possibilities that allows its replication in different cities and regions in collaboration with all interested parties.

The model developed further promotes, on the part of knowledge and concerns, to build trust between all those involved, increasing collaborative capacity and quality of results. The identified results of priority actions, both as challenges and opportunities in the use of NbS for urban adaptation, lead to cities approving new policies related to adaptation measures in each year following the start of implementation.

Finally, more studies should be carried out, focusing on specific cases of knowledge transfer models and scaling up of adaptation, in the Southeast Asian region and beyond.

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