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Elucidating the Environmental, Social and Governance Strategies towards Urban Resilience for Flood Disaster

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Abstract: Flood is a reoccurring disaster throughout the world. With the increasing effects of climate change, the occurrence of floods is predicted to increase, impeding development and growth. Moving forward towards 2030, the United Nations calls for a strategic recovery, rehabilitation and reconstruction that embodies the "build back better" approach. Existing disaster risk reduction efforts for floods have focused on restorative and preventive measures through an integrated architectural response that encompasses the experiential and inherited knowledge of communities living in flood-prone areas together with technological and disaster risk reduction operations for flood resilience. The study utilised current literature reviews to identify environmental, social and governance (ESG) domains for risk reduction and three key strategies from the ESG domains, extending towards urban design for disaster management opportunities. Results were collated and analysed through a thematic literature review from local and international knowledge. The findings suggested that it is vital to respond to and attend to the ESG-integrated approach to promote and sustain resilient urban design and architecture. The study presented a holistic urban design framework towards flood resilience.

Keywords: Climate change, Disaster risk management, Flood resilience, Sustainable architectural and urban design, Environmental, social and governance (ESG) domain

INTRODUCTION

Floods are one of the most recurring forms of natural disasters worldwide. Communities and governments suffer from immediate damages caused by floods, such as socio-economic loss due to disruptions of activities, environmental damages and the cost of rescue operations and repairs. There are also long-term effects relating to health, economic growth and the degradation of the environment. Rapidly developing countries in Southeast Asia are the most affected by floods. In Malaysia, about 9% of the land area that accommodates around 21% of the population is susceptible to flooding (Muhammad, Akashah and Abdullah, 2016). Malaysia is prone to flooding due to the availability of rainfall all year round, as it is located along the equator. Local knowledge and initiatives have been developed from on-the-ground experiences facing floods (Ainullotfi, Ibrahim and Masron, 2014). In the international context, floods also lead to massive losses and damage. International disaster risk reduction efforts follow the Disaster Risk Reduction Frameworks, developed by the United Nations Office for Disaster Risk Reduction (UNDRR), with the goal of reducing impacts resulting from a disaster. The current risk reduction framework is the Sendai Framework (UNDRR, 2015). The Sendai

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Framework promotes a culture of "building back better" where the contributions of architecture and urban design play an extensive role in disaster reduction efforts. It places a strong emphasis on a community-driven approach and an integrated approach between disciplines that recognise climate change and interface with technological advancements.

The application of resilient strategies is less effective, largely because of non-integrated approaches. In general, approaches for disaster resilience are divided into two categories: structural and non-structural. However, there is a lack of integrated applications for most approaches because tracks for implementation are widely missing. Therefore, the current study attempted to offer the approaches of environmental, social and governance (ESG) in the implementation strategies. This study illustrated a diversified set of strategies implemented or proposed for urban resilience in three folds of ESG recorded in literature (as shown in Figure 1). Later, the study illustrated how the three strategies were integrated in urban design. ESG, in this study, was translated as resource use, community impact and risk management, respectively.

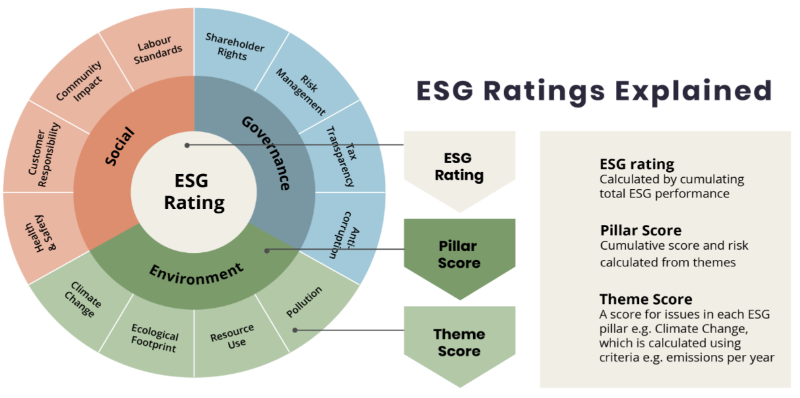

Figure 1. ESG pillars and scores
Source: Halker Engineered Solutions (2021)

METHODOLOGY AND MATERIALS

The study deployed a mixed research methodology through literature reviews. It used two methods of literature reviews, namely, systematic and traditional methods. Since the objective of the study dealt with integrated approaches, the literature review was performed through both qualitative and quantitative research content. Moreover, systematic literature reviews published within the previous five years and traditional reviews that involved policies, government papers, and historical and philosophical books were studied. A systematic literature review was done through the Scopus Search engine using the keywords "urban resilience for flood disasters".

ENVIRONMENTAL CONSIDERATIONS FOR DISASTER RISK REDUCTION

ESG principles prioritise environmental sustainability and stewardship. In the context of urban resilience, the use of ESG means implementing flood management strategies that minimise environmental harm and promote ecosystem health. For example, sustainable land use planning can help preserve natural habitats and mitigate the loss of green spaces in urban areas. This is because green infrastructure solutions, such as green roofs and wetland restoration, not only reduce flood risk but also enhance biodiversity and ecosystem services.

Macro Structural Interventions

Recent studies show that international disaster risk reduction efforts have focused on post-flood and pre-flood strategies. Strategies implemented are often direct responses to challenges imposed by physical exposure to floods. A study in the area of Ibadan metropolis (Salami, Giggins and Meding, 2017) and Katsina City in Nigeria (Mashi et al., 2020) found that low-lying flat lands and developments at riverbanks were areas with high exposure to floods. These areas were inhabited by the urban poor. These developments can be curbed through the planning of zones and land use along with the control of urban development (Munyai et al., 2021). A study in Southern Malawi implemented temporary migration as the solution and applied the concept further to their livestock to mitigate the loss of livelihood and income (Trogrlić et al., 2019).

In Malaysia, its government has implemented many projects as part of risk reduction and resilience to the community, particularly through the Department of Drainage and Irrigation (DID) Malaysia. DID is the designated Malaysian agency for flood disaster management (Chan et al., 2020). DID contributes towards river improvements through work such as widening, dredging and deepening existing river channels, besides constructing river embankments, river bunds, tidal control gates, dams and diversion relief channels. Diversion relief channels work together with flood gates to divert water away from flood susceptible areas located in uplands, while river bunds and embankments, as well as tidal gates, protect low-lying suspectable land from floods. It is also in charge of the enlargement and deepening of rivers to increase the river's water capacity benefit at low-lying and uplands. In the urban setting, retention ponds, retention tanks, water pump stations, and post-construction and floodproofing buildings are also built after floods.

Connectivity is the next important intervention for the provision of rescue operations that includes transportation and medical supplies in addition to food, clothing and communication which is critical as part of the flood relief supply (Ludin and Arbon, 2017). During floods, transportation may be cut off due to roads being submerged, as recorded in flood maps. Participants and volunteers then encounter challenges in reaching flood victims due to a lack of boats to reach them.

Mirco-Structural Adaptations

Places are converted into flood relief centres for refuge during floods (Sach et al., 2018). This structural adaptation measure was taken in Johor was the selection and conversion of spaces in places of worship, schools and community centres. For example, the upper levels of two-storey homes in Segambut, Johor, were preferred by residents to reside in while waiting for floods to subside (Karki, 2016). Most communities living in one-story houses have adapted to living with floods with the construction of an additional storey (Asmara and Ludin, 2014). The community also installed latches in their cabinets and wardrobes (Diyana, 2022). These strategies manifest in places where historical flood records indicated one day for flood waters to subside.

Another approach towards floods is the adaptation of design based on the historical experiences of communities living in floodplains. Studies of community-driven approaches through the integration and adaptation of experiences and inherited local knowledge of living in flood plains were conducted (Akturk, 2022; Brisibe, 2018; Joseph et al., 2011; Trogrlić et al., 2019). Adaptations according to historical flood inundation levels have been directly translated regardless of community and locality. These adaptations respond to historical flood inundation levels simply by building floors above the levels. In Louisiana, USA, building codes required floor levels to be raised 900 mm above local flood elevations, while Christchurch, New Zealand, required floor heights to be built above the existing 200-year flood level (Brisibe, 2018).

In Cockermouth, England, modifications of electric service articulations were carried out in response to experiences and historical references of anticipated flood levels (Joseph et al., 2011). A similar strategy was observed in Semarang, Indonesia, at a larger scale, where damaged homes performed backfilling of floor levels to achieve a higher level of 30 cm above the road levels (Kurniawati, Mussadun and Nugraha, 2020). The raising of windowsills and doors was also observed in the two examples presented above. The performance of drain channels is another key focus area for disaster risk reduction (Munyai et al., 2021). Poor runoff of water due to drainage and blocked channels during extreme rainfall is a key contributor to floods (Munyai et al., 2021). Also, damage to buildings and materials increases with the duration of exposure to water and the increase of flood depth (Brisibe, 2018). As part of flood adaptation measures, communities improved drainage around their homes with the building of temporary dikes (Trogrlić et al., 2019). Similar strategies were implemented by communities in Limpopo, South Africa (Munyai et al., 2021). The introduction of drains along the roads was an active flood prevention strategy that reduced flood damage costs by 19% (Sohn et al., 2020).

SOCIAL CONSIDERATIONS FOR DISASTER RISK REDUCTION

Social resilience is a key aspect of ESG. It focuses on equity, social cohesion and adaptive structures. Urban resilience measures should prioritise the needs of vulnerable populations, such as low-income communities and marginalised groups, who are often disproportionately affected by floods and climate change impacts. Community engagement and participatory decision-making processes ensure that resilience strategies are inclusive and address the specific concerns of residents. Furthermore, investing in affordable housing and social infrastructure can help enhance the resilience of communities to flood events and other climate-related disasters.

Social Cohesion

Resilience is the ability to withstand and maintain the community's original functions during disaster impacts and the ability to return to its original functions pre-impact. The two key criteria from this perspective are robustness and speed. Among the four characteristics of resilience infrastructure: robustness, rapidity, resourcefulness and redundancy (Ahmad, Zin and Alauddin, 2020), robustness and redundancy are regarded as physical elements while rapidity and resourcefulness are non-physical elements.

The community of Kelantan regarded robustness and resourcefulness as the two main criteria, followed by rapidity and redundancy. In Kuala Lumpur, community-based organisations and community-based networks were formed post floods, especially in the illegal settlement areas (Zahari and Ariffin, 2013). These community-based organisations function as "flood early warning systems" through the public announcement system in local mosques. Zahari and Ariffin (2013) found that the community exhibited a sense of responsibility towards their neighbours and commitment during the rescue efforts working with the local Malaysian Red Cross Organisation, which was among the first in the disaster landscape.

The floods in 2007, 2011 and 2012 resulted in population displacement and damage to the built environment in Johor (Barau, 2013). The floods were caused by changes in wind flow characteristics arising from climate change and an increasing trend of floods is predicted. The community principle observed in Johor was *gotong-royong* (communal work) to maintain, upkeep and conduct restoration work at different stages of the floods. It is a form of community-based organisation that was formed as part of the community disaster risk reduction initiatives. *Gotong-royong* was based on ownership, selflessness and togetherness, similar to other case studies (e.g., Sach et al., 2018).

Adaptive Structures by Communities

Structural projects implemented by the government are effective upon implementation to maintain their original functions that require servicing and maintenance. Organised preventive maintenance and planned corrective approaches and the upgrading of existing systems, along with the availability of manpower to restore and reconstruct these structures post-disasters, are key for the continual operation of these systems (Ahmad, Zin and Alauddin, 2020; Chan et al., 2020).

The Sendai Framework on disaster risk reduction involve the local community in building resilience (UNDRR, 2015). Resilience through disaster risk reduction initiatives is enforced through resourcefulness and rapidity. The provision of awareness, training and involvement in project decisions as the local community is most familiar with the local context and is ever ready to respond. In addition, working together with local community stakeholders builds resilience through a community that is aware, skilled and alert and is ever ready to respond to disasters (Roosli, Nordin and O'Brien, 2018).

Besides the establishment of community-based organisations, the local community has adopted socially constructed adaptations to the built environments in response to floods. Historical knowledge of flood experiences and community information on flood inundation levels, together with the awareness of elevations, provided references for community adaptations to the environment. For example, the construction of shelves located at high elevations, half-height walls and raised platforms, and the selection of building materials concrete to replace timber plank walls.

Most communities living in flood-prone areas are from the low-income group; thus, requiring cost-effective methods. Homes are built of timber construction or non-plastered masonry finishes. However, Platt et al. (2021) found that plastered masonry walls were not as resilient as plastered and reinforced masonry walls. The study presented the strategic application of geogrid reinforcement in plasters for unreinforced masonry walls as an economical alternative to counteract lateral forces and velocity introduced by flood inundation waters. In addition to the selection of load-bearing and strategic reinforcement of materials, material type contributes to the physical vulnerability and resilience of homes located in flood inundation plains (Eggleston et al., 2021; Joseph et al., 2011; Salami, Giggins and Meding, 2017), namely different materials for traditional buildings, reconstruction technics for damaged buildings, UPVC for doors, wall boarding, furniture units, skirting and architraves in place of plasterboard. The increased resilience of communities significantly reduces anticipated recurring repair costs, which increase over time.

Kelantan and Terengganu are heavily affected by seasonal floods in Malaysia. Several well-developed measures were implemented by the community. The most prominent adaptation to the structure is *rumah rakit* (floating houses). *Rumah rakit* has been constructed as an adaptation of lifestyle and built environment to live with the rise and fall of flood inundation waters (Barau, 2013; Chan et al., 2020). Other adaptations were the use of the ground floor as garages and higher levels for storage. This was observed in the traditional home typology of the Malaysian *kampung* (village) houses constructed on stilts. On the other hand, residents constructed extensions at the ground level of traditional *kampung* homes for extra living space due to economic pressure, resulting in less resilient homes to floods.

Awareness Programmes

According to Karki (2016) and Sach et al. (2018), the government plays an important role in educating the community on the damage caused by floods. The awareness of floods increases the knowledge and capacity of communities to deal with floods (Kamarudin, Rashid and Chong, 2022). Steps to take in anticipation of floods, flood evacuation and adaptation of houses to floods are some of the key trainings suggested (Karki, 2016). In addition, there is a need for an integrated platform where effective flood strategies developed by the communities can be shared and made readily available. Ludin and Arbon (2017) suggested the use of a scorecard to effectively determine those communities and stakeholders that were not aware of floods and arrange targeted activity and awareness programmes to build community resilience.

The psychological aspect of the community is also important for the effectiveness of early warning systems (Alias et al., 2019). This is because the preparedness of the community is key. Preparedness is developed through the psychological readiness of evacuees. Drills, training and awareness programmes provide predictability on evacuation procedures and build readiness. The other key element that affects the psychological aspect of early warning systems is the timeliness and accuracy of warning systems (Ainullotfi, Ibrahim and Masron, 2014). Also, having flood risk maps in local zoning maps is important.

GOVERNANCE CONSIDERATIONS FOR DISASTER RISK REDUCTION

Governance principles underpinning ESG emphasise transparency, accountability and ethical leadership. Effective governance structures are essential for implementing and coordinating urban resilience initiatives across different levels of government and sectors. This includes establishing clear regulatory frameworks, allocating resources equitably and encouraging collaboration between public, private and civil society actors. Strong governance ensures that resilience efforts are aligned with broader sustainability goals and that decision-making processes are guided by principles of fairness and social responsibility.

Equity to Resources

A community-based approach is an approach where the community, authorities and organisation cooperate to resolve communication, investigation and effective dissemination of information. Evacuation drills, training and campaigns involving evacuation bodies, such as firefighters, police and the medic, together with the local community leaders, will provide awareness to communities and prepare both the community and evacuation bodies for actual events (Alias et al., 2019; Zahari and Ariffin, 2013).

Provided post-flood solutions can also contribute to improving the resourcefulness of the community. Resourcefulness consists of the ability to identify, analyse and determine priorities to which resources are allocated (Ahmad, Zin and Alauddin, 2020). To ensure safe participation and effective capacity building, the selection of local stakeholders and the provision of adequate training along with the machinery and tools are important considerations. Through the supply of materials, machinery and training, local stakeholders could contribute effectively within the timeline of these fast-paced projects.

Besides the storing of food and medicine as emergency supplies during floods, the provision of technology is an additional implementation found in Kelantan (Hassan et al., 2020). Communication is key to disaster risk management activities. For example, Hassan et al. (2020) suggested the provision of power banks as part of provisions for disaster efforts to ensure communication is secured between evacuees and facilitators. Another strategy is to provide standalone phones with their generator to district quarters for communications. A study conducted by Ludin and Arbon (2017) found that satellite phones and walkie-talkies were useful in areas away from the city centres where mobile phone coverage was not as high. Another suggestion was to improve social security and protect communities purchasing houses in these areas through the implementation of flood insurance (Asmara and Ludin, 2014; Sarkar et al., 2014).

Structural Schemes

In the Netherlands, the Flood Protection Act was established for the government to effectively manage the integrity of infrastructures to be responsible for the operation, maintenance and training of personnel and volunteers involved throughout the country's 41 district administrations (Pilarczyk, 2008). A curation of a standard assessment to identify areas requiring repair measures before failure limits, completed maintenance works, damaged areas and mapping of existing conditions of infrastructure and controls to ensure ongoing awareness of the systems. At a residential and communal level, communities contribute to preventive maintenance through scheduled cleaning and sanitation tasks such as drain jetting and clearing of rubbish in their compounds and village areas (Joseph et al., 2011). This culture that upholds prevention and maintenance reduces the cost and damages of floods.

The Malaysian National Security Council and Malaysian Public Works Department (JKR) have built post-flood relief homes. Roosli and Collins (2016) suggested the involvement and provision of opportunities to the local flood victims, communities, nongovernmental organisations (NGOs) and organisations. This increases the income, skills and human capital of affected communities and prepares them for post- flood reconstruction and restoration of buildings. In short, community involvement improves the resilience of the local community rather than creating a donor-dependency culture (Roosli and Collins, 2016).

A culture for flood resilience is another key factor that supports strategy implementation. Drain channels and permeable surfaces require maintenance to continue to remain effective (Sohn et al., 2020; Joseph et al., 2011; Brisibe, 2018). Governments, institutions and communities have contributing roles. Governments contribute to flood resilience through large-scale investments in infrastructures and perform periodic maintenance to ensure systems maintain their intended operations (Munawar, Hammad and Waller, 2021). Delayed maintenance and overlooked allocation for maintenance were some of the risks leading to floods. Over time, drainage and permeable surfaces may lose their absorbing properties (Sohn et al., 2020). Debris and soil may fill up these surfaces and clog drain channels leading to compromised performance. Asset management and ongoing maintenance plans were recommended as part of the culture for flood resilience to ensure these systems do not decay and continue to remain effective (Munawar, Hammad and Waller, 2021). Maintenance exercises such as visual inspections and scheduled drain jetting are some of the activities that build a culture of preventive maintenance.

The housing scheme, Rumah Kekal Baru (RKB), is one of the projects implemented by JKR in Kuala Krai, Kelantan (Hanafi et al., 2021). Through RKB, houses were built over the flood victim's land. However, these adaptations pose risks to occupants who dwell in low-lying spaces at the stilt level (Asmara and Ludin, 2014; Sach et al., 2018). Thus, knowledge and awareness of safe adaptation are required (Chan et al., 2020; Ludwig and Poliseli, 2018). As an added advantage, the flood relief supply could include the supply of construction materials for post-disaster works. In many cases the cost of construction during restoration works post floods is high. The community could be trained to identify debris that may be reused as parts of building works during post-disaster operations to improve the economic viability of post-disaster restoration works (Roosli and Collins, 2016).

Technology Driven Structural Schemes

At their most basic form, water barriers are similar to makeshift sandbags and boards that are used as temporary measures to prevent water flow into homes or living areas (Proverbs and Lamond, 2017). Nonetheless, technological solutions have been implemented for renovations and repairs in response to rising flood inundation levels during floods in the areas with the high-income group. The most common modification was the use of water-tight and barrier technology that responded during floods (Brisibe, 2018; Joseph et al., 2011; Proverbs and Lamond, 2017). This technology consists of automatic barriers that respond and rise upon the detection of floods and slot-in barriers that slide into position during floods (Brisibe, 2018).

In 1991, Hong Kong developed remote sensing technology through the implementation of real-time technology at stations, equipped with real-time tipping bucket rainfall gauges, ultrasonic water level probes and tide gauges that collected and analysed hydrological data and flood warning systems (Chui, John and Chu, 2006). A wireless real-time flood monitoring system was also implemented in Ulleung-d, Korea, where sensor information on upstream and downstream river areas was recorded (Lee et al., 2008). Flood forecasting allows for planning and decision-making that occurs pre-floods through predictions (Noymanee and Theeramunkong, 2019).

Another key contributor to the flood resilience of the community is the availability and effectiveness of early warning systems (EWS) (Ainullotfi, Ibrahim and Masron**,** 2014). In its basic form, EWS consists of detection, dissemination of information and the application of historical data from experiences of floods (Alias et al., 2019). Technological advancements provide automation and off-site monitoring of hydrological data such as frequency and intensity of rain, discharge rates of rivers and levels of water bodies. Although so, modern EWS faces challenges the communities are not fully aware of (Alias et al., 2019; Roosli, Nordin and O'Brien, 2018). Not all areas were implemented with EWS (Zahari and Ariffin, 2013). This requires leveraging local knowledge through a community-based flood mitigation plan, requiring a cooperative and participatory approach to enhance existing EWS (Ainullotfi, Ibrahim and Masron, 2014). Community leaders are the trusted people who can directly inform community members of flood warnings. Thus, communication or EWS were sent to DID, the National Disaster Control Centre, the state national security councils and the district centres (Alias et al., 2019). The current process is a top-down approach.

Summary of Literature Review

A set of ESG domains was identified as: (1) social inclusivity by culture and history, (2) environmental resourcefulness through materials and drainage and (3) technologically integrated governance through data and forecasting. Culture refers to community practices performed by the local population. Meanwhile, historical interventions are where the local communities react directly to their rich historical experiences, data and knowledge of the recurrence of floods. Materials are about the selections and how they are placed together, which affects the performance of the built environment when dealing with floods. Drainage is about effective water management.

Moreover, the implementation of technology contributes towards flood resilience among the local community. As technology continues to advance, special devices are developed to respond to floods. Forecasting is made possible through accurate data collection made available through early warning systems and remote sensing (refer to Table 1 and Figure 2).

Table 1. Domains of strategies for flood risk reduction

Domains	ESG Strategies
Social Inclusivity	
Culture	Seasonal migration, relocation, planned preventive maintenance, training of volunteers and maintenance personnel, multifunction safe-to-fail public spaces
History	Raised porch, raised level of electrical switches and plugs, raised windowsills, enhancement of walls below inundation level, damp proofing of foundations
Environmental Resourcefulness	
Material	Use of load-bearing materials, low porosity and less permeable material, water resistant material, reinforcement of low-lying walls, no air gaps between wall details
Drainage	Addition of drainage, drainage enlargement, rainwater collection, on-site detention tank, perimeter dikes
Technologically Integrated Governance	
Technology	Early warning system, automated flood barriers, flood control valves, on-site detention tank, record keeping of hydrological data
Forecasting	Machine learning

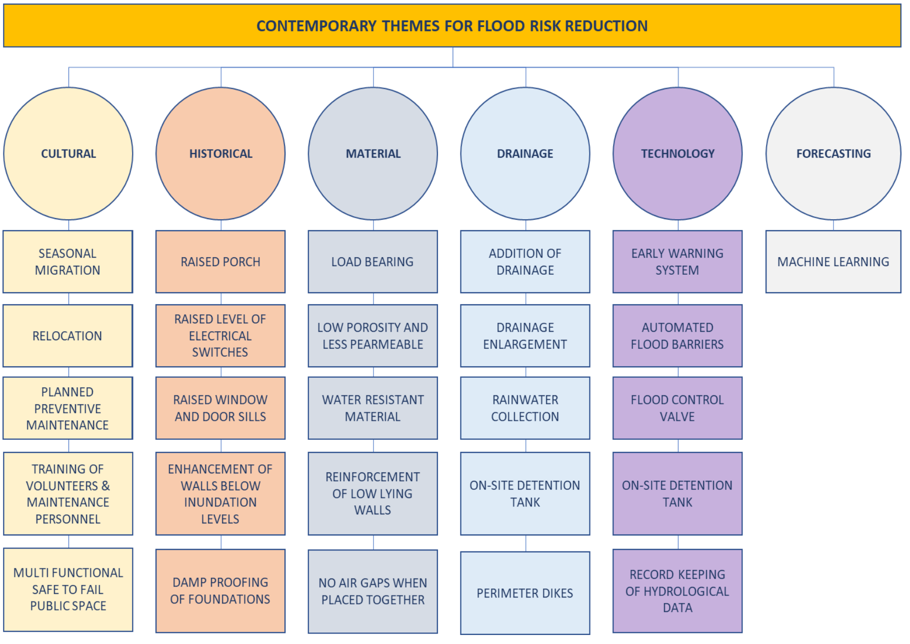

Figure 2. Domains of strategies for flood risk reduction

ESG INTEGRATION TO URBAN DESIGN PRINCIPLES FOR FLOOD RISK REDUCTION

Figure 3 displays the recent shift in architectural paradigm that emphasises largely on regenerative design integrating human and ecological systems (Kishnani, 2021).

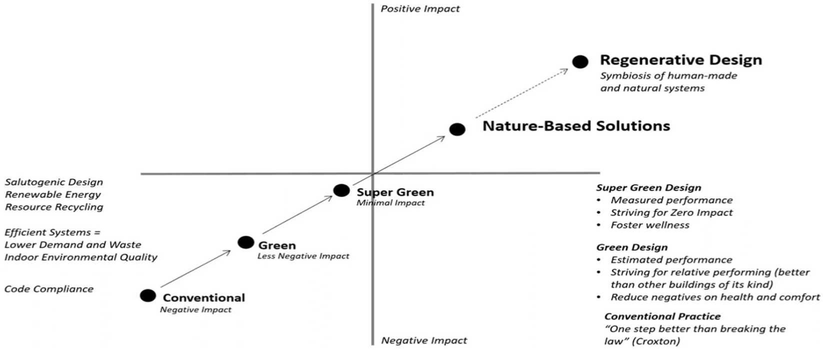

Figure 3. Contemporary paradigm in architecture and urban design
Source: Kishnani (2021)

Urban design as a field of practice has the power to create "resilience in cities" by promoting integrated approaches of ESG domains. With the understanding of ESG domains from literature reviews, this study attempted to present case studies from urban designs that had deployed an integrated approach. The three macro concepts for a sustainable urban design to create resilience in cities are:

1. Social inclusivity,
2. Environmental resourcefulness and
3. Technologically integrated governance.

Social Inclusivity

Planned flooding in urban spaces could be implemented with the concept of designing "safe to fail" public spaces (Palazzo, 2019). A successful implementation of this space is found at Zollhallen Plaza in Friedberg, Germany, where a public space was designed to be inundated from time to time. On a larger scale, this strategy can be implemented throughout urban spaces through the development of multiple landscape spaces where the collection of water is expected and retained before being redistributed at safe rates. A housing development located in Arkadien Winnenden, Stugart, Germany, implemented this solution as it directed rainwater toward a central water retention reservoir (Wojnowska-Heciak and Janus, 2016). Water was retained at the reservoir before overflowing into the local stream. Also, the detention tank Tai Hung of Hong Kong (Chui, John and Chu, 2006) was designed to cater to 50-year rainstorms predicted to introduce 100 mm/hour of rain to the area.

The most prominent urban design theory in response to providing better resilience towards floods is the concept of resilient cities. Resilient cities are cities that are designed with the capacity to learn and respond to disruptions through preparation and adaptation without losing their existing functions (Figueiredo, Honiden and Schumann, 2018; Bejtullahu, 2017). Resilient cities absorb, adapt and transform accordingly in response to disruptive events. Disruptive events may occur at any point in time and consist of changes arising from natural disasters, economic, pandemics and demographics. These events may be categorised into the environmental, economic, social and institutional dimensions.

Figueiredo, Honiden and Schumann (2018) found that urban resilience requires an adaptive and forward-looking approach to city design. Resilient cities are made up of systems and communities that respond towards changes, easily reorganise and plan for future disruptions from past experiences. To design systems that generate resilience, key urban design principles are required to be investigated in their respective environmental context. A mix of quantitative and qualitative approaches has been required to uncover and reflect on the risks and challenges experienced by urban spaces, followed by the study of resources and capacity to handle anticipated challenges.

A comprehensive understanding of the contextual situation of the urban fabric from documented records of environment profiles and inventory of building assets, including records containing information on building performance during past disruptions, is needed to carry out a study of cost and benefit analysis to evaluate the effectiveness of adaptation or mitigation techniques. This record and document reviews support the mechanism for reflectivity and preparation to 'build back better'. Urban flooding results from a very large volume of stormwater that exceeds the capacity of existing drainage systems (Kipkirui and Kageche, 2020).

The drained city concept (as shown in Figure 4) is a traditional concept of managing rainwater where drains are designed to respond to anticipated rapid water levels and volume increase and discharge through technical requirements based on the allocation of the volume of water build-up and discharge at the time of design.

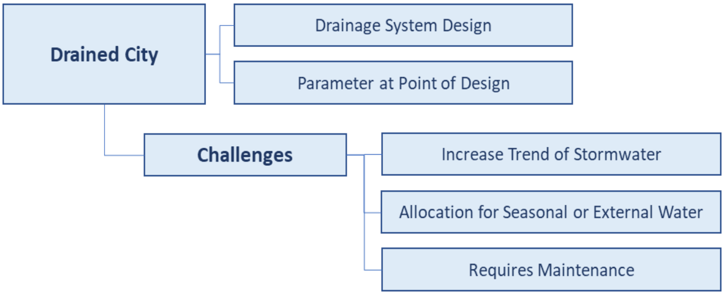

Figure 4. Drained city concept

Environmental Resourcefulness

Sponge cities are a new water management concept to improve flood disasters, making the cities more resilient and sustainable. The concept is based on an understanding of the amount of water introduced during the seasonal peak rain period. The sponge city development (SCD) concept was introduced in 2014 in China as a national urban design policy for flood resilience disaster risk reduction initiatives (Ma, Jiang and Swallow, 2020). SCD was targeted to improve other challenges faced in urban cities such as water scarcity, water pollution and degradation. Eco-system-based approach and low-impact development strategies were implemented through advancement in stormwater management, deviating from traditional engineered drainage solutions. SCD solutions focused on the natural hydrological cycle consisting of storage of water, infiltration, purification and reuse of water. Some of the completed infrastructures were green roofs, rain gardens, bio-swales, stormwater retention basins, modular rainwater storage and permeable pavements (Nguyen et al., 2019). As a result, an estimated investment of CNY39.9 billion was invested for three years in 30 cities in China to promote the construction of SCD (Qiao, Liao and Tandrup, 2020).

However, the implementation of SCD was found challenging due to the lack of space in existing urban fabrics for the incorporation of green infrastructure that requires a large area to be effective, along with the challenge of quantifying objectives and post-implementation performances (Qiao, Liao and Tandrup, 2020). Moreover, where a lack of space occurs, the upgrading of grey infrastructure was implemented, such as the renovation of existing pipe networks, construction of pump stations and construction of drainpipes and wastewater treatment plants (summarised in Figure 5). Accordingly, studies (e.g., Nguyen et al., 2019; Qiao, Liao and Tandrup, 2020) suggested the integration of green and conventional grey infrastructure for water resilience. Green infrastructure contributes to adaptability and resistance to climate change, while grey infrastructure traditionally copes with managing the influx of developments quickly. Nguyen et al. (2020) defines traditional grey infrastructure as a centralised system, while green infrastructure is decentralised. Applying both systems allows cities to take advantage of new and existing strategies that build over existing infrastructure to make improvements to reduce the water run-off load to existing infrastructure. Nguyen et al. (2020) found infiltration into the ground and retention can be reduced by up to 40% reduction in water run-off.

The implementation of SCD requires a holistic approach that integrates into its context (Ma, Jiang and Swallow, 2020). A systemic approach from analysis of urban water and environmental issues followed by identifying available low-impact development and nature-based strategies, evaluating their contribution to the existing environment and, most importantly, organising community participation is important to jointly develop an integrated SCD solution for its community. Community and stakeholder participation is crucial to building long-term sustainable management for SCD solutions as research findings found that challenges faced by most completed SCD initiatives are mainly related to the poor or lack of long-term management and maintenance of the design and build environment (Qiao, Liao and Tandrup, 2020).

The projects were constructed successfully but long-term contributions towards completed solutions faced challenges as cities did not receive any maintenance funding throughout the training on the introduced systems (Ma, Jiang and Swallow, 2020). Thus, rapid implementation was challenging as there was limited expertise required to implement and maintain SCD projects (Nguyen et al., 2019). This study proposed improvements by providing training to relevant stakeholders, including maintaining clear ongoing records of performance indicators for completed SCD projects versus its initial design objectives.

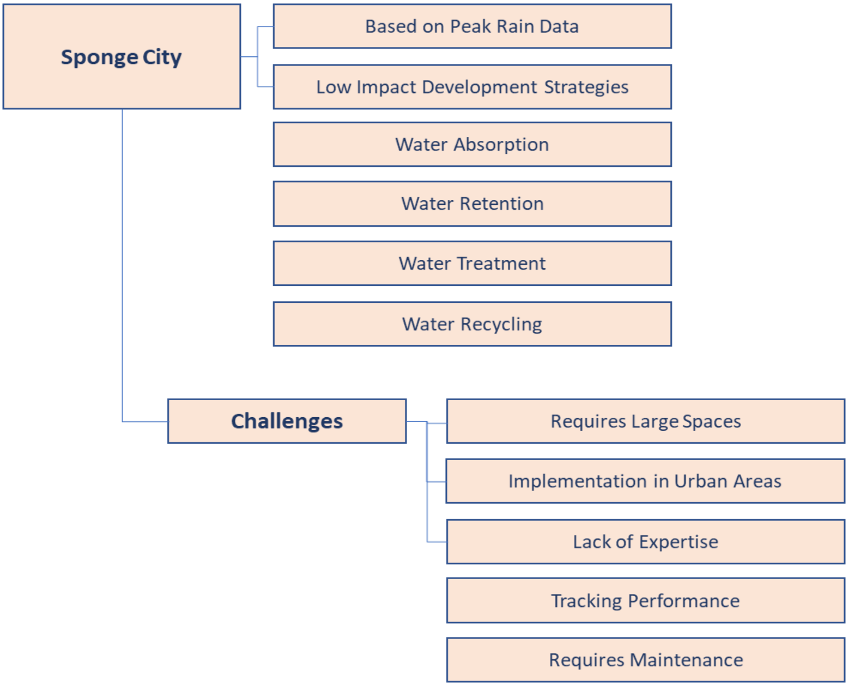

Figure 5. SCD and challenges

Technologically Integrated Governance

Intentional and context-sensitive solution is required, as a part of the advancements and responding to flood challenges. Technology advancements allow for an analytical and informed approach through computer-aided processes involving geographic information system (GIS) modelling, spatial data and simulation analysis before the implementation of SCD strategies. Some key models include wastewater collection, wastewater treatment, rainfall rate, surface runoff models, river models, water distribution models, environment assessment models, economic assessment models and social assessment models (Nguyen et al., 2020). Computer-aided water management models do not include environmental, social economic and ecosystem aspects of SCD (Nguyen et al., 2020). Existing models were based on water infrastructures and macro-scale developments.

An integrated approach requires local context data input containing physical topography, urban development and local infrastructure, together with soft data containing climatic and socio-economic data. Bill Hiller's Space syntax systemic tool provides an analysis of tangible and intangible aspects of space (Yamu, Van Nes and Garau, 2021). Space syntax performs special analysis through convex mapping, axial mapping, isovist mapping and visibility graphs. Space syntax measures the logic of extrinsic spatial qualities through mathematical relationships.

Convex mapping measures the mathematical accessibility of spaces where open spaces or rooms are represented with a convex outline of the space and connections to adjacent spaces are recorded. The number of access axial lines determines the connectivity level and the hierarchy of the street, being the most dominant with more connections (Esposito and Pinto, 2014). Isovist graphs measure the visibility of a space through the overlapping of the volume of space measured from a vantage point or a panoptic view of a space from multiple points. The most strategic visual points are determined from the volume with the most overlapping field of vision demonstrated by the calculation of overlapping isovists. The application of space syntax to evaluate the addition of a new ring road in Pontianak, Kalimantan, Indonesia, and how it related to disaster preparedness was conducted by Gultom, Zaneta and Javiera (2022). The local community preferred to select roads with the least turns with the shortest paths as these involved shorter turning angles and distances.

The effects of floods and damage can be analysed to visualise the impact of floods. Gil and Steinbach (2008) found the need for the decentralisation of resources at main road networks and opportunities for an intentional and balanced distribution of resources on road networks performing with and without disasters where road hierarchy shifted. In another study, an interesting parameter was added during the study of evacuation routes using space syntax (Irsyad and Hitoshi, 2022). In Haeundae District, Busan, Korea, a study was conducted to determine the location of evacuation routes and the incorporation of open green spaces as refuge areas (Jeong et al., 2021). With GIS, space syntax study of axial maps along with the study on rainfall index and the topographical wetness index, the study integrated an evacuation route with existing open green spaces to form a green infrastructure network, applying the concepts of low-impact developments like SCD. Another study conducted in Stockholm incorporated space syntax with ArcGIS, open street maps, location of amenities from the local council and hydrological data measurements of river flow from the Swedish Metrological and Hydrological Institute (Abshirini, Kock and Legeby, 2017).

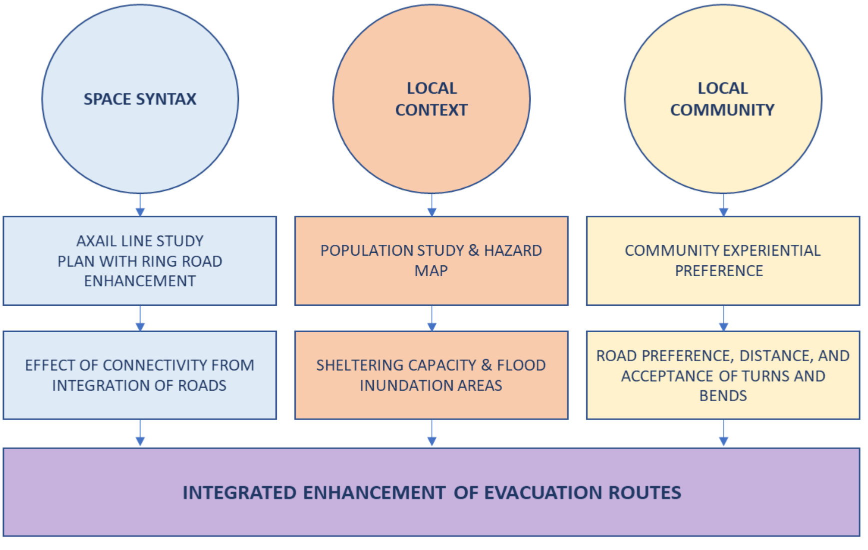

Figure 6. Integrated enhancement of evacuation routes

The contributions of space syntax in disaster risk reduction were divided into three main themes (as shown in Figure 6). The most prominent contributions were to ascertain evacuation routes before and after floods, conduct damage diagnostic, resilience measurement and integration of key nodes for refuge areas and amenities. The understanding of community, physical and hydrological factors of a place was the key repeating parameter.

CONCLUSIONS

This study delved into the critical concept of urban resilience concerning climate change and flood issues viewed through the lens of ESG principles. Urban resilience is defined as a city's capacity to endure and adapt to various challenges, with a particular emphasis on climate-related risks like flooding. By incorporating ESG considerations, cities can develop holistic strategies that address environmental sustainability, social equity and effective governance. Environmental aspects involve implementing green infrastructure solutions to mitigate flood risks while enhancing biodiversity. Social resilience requires inclusive approaches that prioritise vulnerable communities and invest in social infrastructure. Governance principles ensure transparent, accountable and ethically driven decision-making processes, essential for effective resilience planning.

In short, adopting an ESG perspective on urban resilience for climate change and flood issues underscores the interconnectedness of environmental, social and governance considerations. By integrating these principles into resilience planning and implementation, cities can build more sustainably and communities can be more equitable to better equipped to withstand and adapt to the challenges of flood disasters. The study concluded with case studies on urban design with an integrated approach, considering all three ESG dimensions simultaneously, offering the integrated path forward, fostering sustainable and equitable urban environments prepared to face the challenges of climate change and flooding. Through case studies and examples, the current study illustrated successful urban resilience initiatives that embody ESG principles and underscored the importance of adopting such perspectives in resilience planning for cities worldwide. The key concepts for urban resilience are identified as inclusivity, resourcefulness and technology.

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REFERENCES

Abshirini, E., Kock, D. and Legeby A. (2017). Flood resilient cities: A syntactic and metric novel on measuring the resilience of cities against flooding, Gothenburg, Sweden. *Journal of Geographic Information System*, 9(5): 505–534. https://doi.org/10.4236/jgis.2017.95032

Ahmad, E.F., Zin, I.M. and Alauddin, K. (2020). Criteria of resilience infrastructure in flood-prone areas in Kelantan: A pilot study. *Malaysian Journal of Sustainable Environment*, 7(1): 171. https://doi.org/10.24191/myse.v7i1.8917

Ainullotfi, A.A., Ibrahim, A.L. and Masron, T. (2014). A study on integrated community-based flood mitigation with remote sensing technique in Kota Bharu, Kelantan. *IOP Conference Series: Earth and Environmental Science*, 18: 012133. https://doi.org/10.1088/1755-1315/18/1/012133

Akturk, G. (2022). How a rainy climate has shaped the artifacts and communities of Fındıklı and Rize in Türkiye. *Blue Papers*, 1(2): 122–131. https://doi.org/10.58981/bluepapers.2022.2.12

Alias, N.E., Salim, N.A., Taib, S.M., Mohd Yusof, M.B., Saari, R., Adli Ramli, M.W., Othman, I.K., Annammala, K.V., Yusof, H.M., Ismail, N., Yuzir, A. and Blenkinsop, S. (2019). Community responses on effective flood dissemination warnings: A case study of the December 2014 Kelantan flood, Malaysia. *Journal of Flood Risk Management*, 13(Supp. 1): e12552. https://doi.org/10.1111/jfr3.12552

Asmara, T.A.T. and Ludin, A.N.M. (2014). Mapping perception of community preparedness towards flood in Muar River, Johor Malaysia. *IOP Conference Series: Earth and Environmental Science*, 18: 012126. https://doi.org/10.1088/1755-1315/18/1/012126

Barau, A.S. (2013). Patterns of flood-induced population displacement and its management in Southern Peninsular Malaysia. Paper presented at the Hamburgh Conference: Actions for Climate-Induced Migration. Hamburg, Germany, 18 July. https://doi.org/10.13140/2.1.1631.7441

Bejtullahu, F. (2017). Role of the architects in creating building and urban resilience. *Journal of International Business Research and Marketing*, 2(5): 14–17. https://doi.org/10.18775/jibrm.1849-8558.2015.25.3002

Brisibe, W.G. (2018). Assessing architects' knowledge of flood resilient and adaptable buildings in Yenagoa, Nigeria. *Journal of Architecture and Construction*, 1(2): 16 –24.

Chan, N.W., Ghani, A.A., Samat, N., Hasan, N.N.N. and Tan, M.L. (2020). Integrating structural and non-structural flood management measures for greater effectiveness in flood loss reduction in the Kelantan River Basin, Malaysia. In F.M. Nazri (ed.), *Proceedings of AICCE'19 Transforming the Nation for a Sustainable Tomorrow*. Vol. 53. Cham, Switzerland: Springer, 1151–1162. https://doi.org/10.1007/978-3-030-32816-0_87

Chui, S.K., John, K.Y. and Chu, C.K. (2006). The development of a comprehensive flood prevention strategy for Hong Kong. *International Journal of River Basin Management*, 4(1): 5–15. https://doi.org/10.1080/15715124.2006.9635270

Diyana, F.A.N. (2022). Attitude and flood preparedness of households in Pasir Mas, Kelantan, Malaysia. *IOP Conference Series: Earth and Environmental Science*, 1091: 012022. https://doi.org/10.1088/1755-1315/1091/1/012022

Eggleston, J., Parker, J.C., Striegel, M.F., Stynoski, P.B. and Wellock, J. (2021). Testing the flood resilience of traditional building assemblies. *The Journal of Preservation Technology*, 52(1): 15–26.

Esposito, A. and Pinto, V. (2014). Urban resilience and risk assessment: How urban layout affects flood risk in the city. In B. Apduhan, A.M. Rocha, S. Misra, D. Taniar, O. Gervasi and B. Murgante (eds.), *2014 14th International Conference on Computational Science and Its Applications*. Danvers, MA: IEEE, 204–207. https://doi.org/10.1109/iccsa.2014.46

Figueiredo, L., Honiden, T. and Schumann A. (2018). *Indicators for Resilient Cities*. OECD regional development working papers, no. 2018/02. Paris: OECD Publishing.

Gil, J. and Steinbach, P. (2008). From flood risk to indirect flood impact: Evaluation of street network performance for effective management, response and repair. *WIT Transactions on Ecology and the Environment*, 118: 335–344. https://doi.org/10.2495/friar080321

Gultom, B.J., Zaneta, J. and Javiera, E. (2022). Flood risk of today and tomorrow spatial analysis of flood vulnerability in Pontianak City. *International Review for Spatial Planning and Sustainable Development*, 10(3): 170–187.

Halker Engineered Solutions (2021). ESG pillars and scores. Available at: https://www.halker.com/esg/?utm_medium=websiteandutm_source=archdaily.com [Accessed on 1 November 2023].

Hanafi, N.N.H., Juliza, M., Aisyah M S. and Zain, M.H.K.M. (2021). Lessons learned from the adaptations of post-flood housing reconstruction in Kuala Krai, Kelantan. *Environment–Behaviour Proceedings Journal*, 6(17): 227–234. https://doi.org/10.21834/ebpj.v6i17.2820

Hassan, M.S., Abdul Jaffar, M., Abdulameer, S.K., Mohd Radzi, S.F. and Kanasan, V. (2020). Preparedness for disaster risk management (DRM), case studies: Kelantan flood, Malaysia. *Advances in Social Sciences Research Journal*, 7(5): 382–392. https://doi.org/10.14738/assrj.75.8296

Irsyad, H.A.W. and Hitoshi, N. (2022). Flood disaster evacuation route choice in Indonesian urban riverbank kampong: Exploring the role of individual characteristics, path risk elements and path network configuration. *International Journal of Disaster Risk Reduction*, 81: 103275. https://doi.org/10.2139/ssrn.4075919

Jeong, D., Kim, M., Song, K. and Lee, J. (2021). Planning a green infrastructure network to integrate potential evacuation routes and the urban green space in a coastal city: The case study of Haeundae District, Busan, South Korea. *Science of the Total Environment*, 761: 143179. https://doi.org/10.1016/j.scitotenv.2020.143179

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2011). An analysis of the costs of resilient reinstatement of flood affected properties: A case study of the 2009 flood event in Cockermouth. *Structural Survey*, 29(4): 279–293. https://doi.org/10.1108/02630801111162350

Kamarudin, K.H., Rashid, M.F. and Chong, N.O. (2022). Local community knowledge for flood resilience: A case study from east coast Malaysia. *International Journal of Built Environment and Sustainability*, 9(2): 21–34. https://doi.org/10.11113/ijbes.v9.n2.922

Karki, T. (2016). How capable are local residents and local governments at coping with and adapting to flood disasters in Malaysian cities? A case study of two cities from Johor state. Malaysia Sustainable Cities Program working paper series. Available at: https://malaysiacities.mit.edu//sites/default/files/documents/Karki.pdf [Accessed on 1 November 2023].

Kipkirui, E. and Kageche, K.D. (2020). Developing towards flood resilient cities: Opportunities for sponge infrastructure. *International Journal of Scientific and Research Publication*, 10(2): 9888. https://doi.org/10.29322/ijsrp.10.02.2020.p9888

Kishnani, N. (2021). *Ecopuncture: Transforming Architecture and Urbanism in Asia*. Jakarta: BCI Asia.

Kurniawati, W., Mussadun and Nugraha, M.F. (2020). Spatial expression of Malay Kampung Semarang in facing flood disaster. *IOP Conference Series: Earth and Environmental Science*, 409(1): 012049. https://doi.org/10.1088/1755-1315/409/1/012049

Lee, J., Kim, J., Kim, D., Chong, P.K., Kim, J. and Jang, P. (2008). RFMS: Real-time flood monitoring system with wireless sensor networks. In *2008 5th IEEE International Conference on Mobile Ad Hoc and Sensor Systems*. Atlanta, GA: IEEE. https://doi.org/10.1109/mahss.2008.4660069

Ludin, S.M. and Arbon, P.A. (2017). Improving community disaster resilience through scorecard self-testing. *Disaster Prevention and Management: An International Journal*, 26(1): 13–27. https://doi.org/10.1108/dpm-08-2016-0177

Ludwig, D. and Poliseli, L. (2018). Relating traditional and academic ecological knowledge: Mechanistic and holistic epistemologies across cultures. *Biology and Philosophy*, 33(5): 43. https://doi.org/10.3410/f.734596979.793553970

Ma, Y., Jiang, Y. and Swallow, S. (2020). China's sponge city development for urban water resilience and sustainability: A policy discussion. *Science of the Total Environment*, 729: 139078. https://doi.org/10.1016/j.scitotenv.2020.139078

Mashi, S.A., Inkani A.I., Oghenejeabor, O. and Araen A.S. (2020). Community perception, response and adaptation strategies towards flood risk in a traditional African city. *Natural Hazards*, 103(60): 1727–1759. https://doi.org/10.1007/s11069-020-04052-2

Muhammad, N.S., Akashah, A.I. and Abdullah, J. (2016). Analysis of extreme rainfall indices in peninsular Malaysia. *Jurnal Teknologi*, 78: 15–20. https://doi.org/10.11113/jt.v78.9677

Munawar, H.S., Hammad, A.W.A. and Waller, S.T. (2021). A review on flood management technologies related to image processing and machine learning. *Automation in Construction*, 132: 103916. https://doi.org/1010.1016/j.autcon.2021.103916

Munyai, R.B., Chikoore, H., Musyoki, A., Chakwizira, J., Muofhe, T.P., Xulu, N.G. and Manyanya, T.C. (2021). Vulnerability and adaptation to flood hazards in rural settlements of Limpopo Province, South Africa. *Water*, 13: 3490. https://doi.org/10.3390/w13243490

Nguyen, T. T., Ngo, H. H., Guo, W. and Wang, X. C. (2020). A new model framework for sponge city implementation: Emerging challenges and future developments. *Journal of Environmental Management*, 253: 109689. https://doi.org/10.1016/j.jenvman.2019.109689

Nguyen, T.T., Ngo, H.H., Guo, W., Wang, X.C., Ren, N., Li, G., Ding, J. and Liang, H. (2019). Implementation of a specific urban water management: Sponge City. *Science of the Total Environment*, 652: 147–162. https://doi.org/10.1016/j.scitotenv.2018.10.168

Noymanee, J. and Theeramunkong, T. (2019). Flood forecasting with machine learning technique on hydrological modelling. *Procedia Computer Science*, 156: 377–386. https://doi.org/10.1016/j.procs.2019.08.214

Palazzo, E. (2018). From water sensitive to floodable: Defining adaptive urban design for water resilient cities. *Journal of Urban Design*, 24(1): 137–157. https://doi.org/10.1080/13574809.2018.1511972

Pilarczyk, K.W. (2008). Flood Protection and Management in the Netherlands. In Vasiliev, O., Van Gelder, P., Plate, E. and Bolgov, M. (eds.), *NATO Science Series: Extreme Hydrological Events; New Concepts for Security*. Dordrecht: Springer, 385–407. https://doi.org/10.1007/978-1-4020-5741-0_26

Platt, S.L., Ranasinghe, G., Jayathilaka, G.S., Jayasinghe, C., Jayasinghe, T., Walker, P. and Maskell, D. (2021). Retrofitting and rehabilitation of vernacular housing in flood prone areas in Sri Lanka. *Journal of Building Engineering*, 41: 102420. https://doi.org/10.1016/j.jobe.2021.102420

Proverbs, D. and Lamond, J. (2017). Flood resilient construction and adaptation of buildings. In *Oxford Research Encyclopedia of Natural Hazard Science*. Oxford: Oxford University Press. https://doi.org/10.1093/acrefore/9780199389407.013.111

Qiao, X.J., Liao, H. and Tandrup, T.B. (2020). Sustainable stormwater management: A qualitative case study of the Sponge Cities initiative in China. *Sustainable Cities and Society*, 53. https://doi.org/10.1016/j.scs.2019.101963

Roosli, R. and Collins, A.E. (2016). Key lessons and guidelines for post-disaster permanent housing provision in Kelantan, Malaysia. *Procedia Engineering*, 145: 1209–1217. https://doi.org/10.1016/j.proeng.2016.04.156

Roosli, R., Nordin, J. and O'Brien, G. (2018). The evaluation of community participation in post-disaster housing reconstruction Projects in Malaysia. *Procedia Engineering*, 212: 667–674. https://doi.org/10.1016/j.proeng.2018.01.086

Sach, A., Wild, A., Hoeun I., Nicholas, Y., Baynard-Smith, R., Mohd Hanif, K., Muhammad Hazwan, M., Mohd Fakhruddin, F. and Umi Salaman, M.Z. (2018). Mitigation and adaptation to floods in Malaysia: A study on community perceptions and responses to urban flooding in Segamat. Available at: https://www.monash.edu.my/__data/assets/pdf_file/0007/2236516/Flooding-in-Segamat.pdf [Accessed on 1 November 2023].

Salami, R., Giggins, H. and Meding J. (2017). Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria. *Journal of Disaster Risk Studies*, 9(1): a371. https://doi.org/10.4102/jamba.v9i1.371

Sarkar, M.S.K., Begum, R.A., Pereira, J.J., Jaafar, A.H. and Saari, M.Y. (2014). Impacts of and adaptations to sea level rise in Malaysia. *Asian Journal of Water, Environment and Pollution*, 11(2): 29–36. https://doi.org/10.3233/AJW-2014-11_2_05

Sohn, W., Samuel, B., Kim, J.H. and Li, M.H. (2020). How effective are drainage systems in mitigating flood losses? *Cities*, 107(7): 102917. https://doi.org/10.1016/j.cities.2020.102917

Trogrlić, R.Š., Wright, G.B., Duncan, M.J., van den Homberg, M.J.C., Adeloye, A.J., Mwale, F.D. and Mwafulirwa, J. (2019). Characterising local knowledge across the flood risk management cycle: A case study of Southern Malawi. *Sustainability*, 11: 1681. https://doi.org/10.3390/su11061681

UNDRR (United Nations Office for Disaster Risk Reduction) (2015). Sendai framework for disaster risk reduction 2015–2030. https://doi.org/10.1163/2210-7975_hrd-9813-2015016

Wojnowska-Heciak, M. and Janus, A. (2016). Landscape solutions for small retention. *Structure and Environment*, 8(2): 116–124.

Yamu, C., Van Nes, A. and Garau, C. (2021). Bill Hillier's legacy: Space syntax: A synopsis of basic concepts, measures and empirical application. *Sustainability*, 13(6): 3394. https://doi.org/10.3390/su13063394

Zahari R.K. and Ariffin R.N. (2013). Risk communications: Flood-prone communities of Kuala Lumpur. *Procedia Environmental Sciences*, 17: 880–888. https://doi.org/10.1016/j.proenv.2013.02.106