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"Harmony in Spaces : Blending Heritage, Nature and Design"

E-PROCEEDING

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THE ACCLAIMED LANDSCAPE OF KNOWLEDGE SHARING
"Harmony in Spaces : Blending Heritage, Nature and Design"

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College of Built Environment
Universiti Teknologi MARA Selangor Branch
Puncak Alam Campus

CO-ORGANISED BY

Department of Built Environment Studies and Technology
Universiti Teknologi MARA Perak Branch
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24 JANUARY 2024

9 789672 776345

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UNDERSTANDING THE VITAL ROLE OF GREEN INFRASTRUCTURE IN STORMWATER MANAGEMENT FOR HYDROLOGICAL CONTROL IN PENANG

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ABSTRACT

Cities may greatly reduce water runoff volume by implementing features like vegetated swales, rain gardens, permeable pavements, and green roofs. This allows water to be absorbed and stored instead of overwhelming drainage systems. According to JPS Pulau Pinang, more than 50 areas in Pulau Pinang were hit by floods after heavy rain with water levels ranging from 0.1 meters to 0.4 meters. GeorgeTown is one of the locations involved in flooding. Thus, this paper aims to understand green infrastructure in stormwater management and residents' adaptability in GeorgeTown, Pulau Pinang. Green infrastructure is a vital component of sustainable urban and regional planning. Through the integration of natural systems into urban environments, the negative effects of heavy rainfall and urbanization are lessened. Qualitative data collection will be conducted for this research. The study contributes to the understanding of the relationship between green infrastructure, flash flood and community adaptability. Result of this study can prove that green infrastructure is needed in every aspect of hydrological control in terms of improving stormwater management in rapid growth of urbanization. However, it can be one of the supporting needs to educate the stakeholders about the importance of green infrastructure in Georgetown to face the crisis of environmental issues.

Keywords: *Flash Flood; Green Infrastructure; Stormwater Management*

INTRODUCTION

The growth of Penang, a lively urban center set against Malaysia's coastal beauty, faces the complexities of urbanization, heavy rainfall, and disruptions in its water systems. With the cityscape continually evolving and development booming, the strain on current drainage systems intensifies. Effectively handling stormwater becomes increasingly urgent. Floods are one of the environmental issues and water management threats that urban areas must deal with demographic vulnerability and dangers to the sustainability of urban areas. The rise in urbanization and climate change is anticipated to exacerbate the frequency and intensity of hydrometeorological extremes, worsening these issues, Ahmed, K. (n.d.). In response, green infrastructure emerges as a beacon of hope, presenting a harmonious fusion of natural elements within urban expansion to tackle these pressing challenges.

Based on JPS Pulau Pinang (Penang State Irrigation and Drainage Department), GeorgeTown is one area that needs to be wary because of the flood issues. This was reinforced by the high number of flood events that occurred in the GeorgeTown. By planning green open areas and preserving naturally occurring processes like the rainfall cycle and soil conditions, green infrastructure refers to a concept, endeavor, or method of environmentally sustainable environmental protection. Green infrastructure shapes the environment by preserving natural processes, encompassing rainwater and water quality management, as well as flood mitigation. The implementation of green infrastructure aims to bolster community development by enhancing environmental conditions and preserving verdant open spaces Muktiali, M., Sudharto Hadi, P., Purnaweni, H., & Mussadun, M. (2023).

This research aims to understand existing green infrastructure in study areas that helps in minimizing the volume of peak discharge by implementing efficient stormwater management methods and residents adaptability towards the flash flood in GeorgeTown. This study was conducted by using qualitative methods. By understanding the green infrastructure in the study area, researchers, and planners could understand how these impact the cause in helping to reduce the incidence of flash floods and how residents cope with it. The significance lies in establishing a greater sustainability and resilience community by implementing awareness and stakeholders can make new guidelines for residents to follow is an effective

way to reduce the flash flood issues.

LITERATURE REVIEW

Flash Flood in the Cities

Flash floods in cities occur when heavy rainfall overwhelms drainage systems or when water rapidly accumulates due to impermeable surfaces like roads and buildings, causing swift and intense flooding. Flash floods stand out as the most common and destructive hydro-meteorological occurrence in Malaysian urban areas. Especially within the city or urban areas, flash floods are happening more frequently than in the past. While flash floods may not always occur during monsoon seasons, they are more common in the city at this time. Rahman Bhuiyan, T., Reza, M., Choy Er, A., Jacqueline Pereira, J., Imam Hasan Reza, M., & Ah Choy, E. (2018). Flood waters can damage infrastructure such as roads, bridges, buildings, and utilities like electricity and water supply systems. This damage can disrupt normal life and take a time to repair, impacting communities and economies.

The main factors affecting the rainfall volume that runs off are soil, the cover land or land use and the vegetation. It is well-known the importance of vegetation cover in improving soil permeability. Vegetation cover affects soil infiltration by changing the hydrological process of rainfall-infiltration on slopes and modifying the soil pore spaces Quagliolo, C., Comino, E., & Pezzoli, A. (2021). Trees and vegetation act as natural sponges, absorbing water and reducing runoff. Strategic planting of trees and creation of green spaces in urban areas can help regulate water flow, decreasing the intensity of flash floods by increasing water absorption.

The Importance of Green Infrastructure

Green infrastructure plays a vital role in our communities and environments for several reasons. It is a strategically planned network of natural and semi-natural areas, including green and blue spaces and other ecosystems, designed and managed to deliver a wide range of ecosystem services at various scales. Apart from the ecological functions, green infrastructure, as a planning tool, contributes to social and economic

benefits, leading to the achievement of sustainable, resilient, inclusive and competitive urban areas. Monteiro, R., Ferreira, J. C., & Antunes, P. (2020).

Green infrastructure helps in several ways, particularly in the context of stormwater management, green infrastructure practices reduce the volume of stormwater entering conventional drainage systems and minimizes the risk of urban flooding Golden, H. E., & Hoghooghi, N. (2018). Hydrological implications of urbanization are typically translated through alteration of natural water systems such as increasing runoff rate and volume, decreasing infiltration and groundwater recharge and increasing flood risks. (e.g., Brun and Band, 2000, Wang et al., 2003, Brandes et al., 2005), (Konrad, 2014)

Stormwater Management Functions

Stormwater management is the process of controlling and directing rainfall runoff to prevent flooding and reduce its impact on the environment. It involves various techniques and systems to collect, store, treat, and release excess rainwater in a controlled manner in many places. Water scarcity is becoming a serious problem and sometimes prevents rainwater from penetrating the earth. Arya, S., & Kumar, A. (2023).

Managing stormwater during floods is critical to mitigate their impact on communities and the environment. Inadequate stormwater management can lead to flooding in urban areas. When there's excessive runoff and the drainage systems are overwhelmed, streets, properties, and even entire neighborhoods can become inundated. According to Guo, J. C. Y. (2017), urbanization, characterized by the expansive growth of infrastructure such as roads, buildings, and parking lots, significantly amplifies impervious areas. The concerning consequence lies in flood damage and residents willingness to change in order to suit the issues conditions. Researchers and water managers have started to investigate the effectiveness of green stormwater infrastructure, such as bioswales, retention and detention basins, rain barrels, green spaces, wetlands, green roofs, permeable pavements, and deep infiltration wells to reduce flooding (Roy et al 2008, Dhakal and Chevalier 2016).

METHODOLOGY

There are two types of analysis conducted in this research, site observation and analysis data from unstructured interviews with few stakeholders from Majlis Bandaraya Pulau Pinang (MBPP), Penang Development Corporation (PDC) and two residents - the data obtained are analyzed descriptively.

Site Selection

Georgetown is the capital city of the state of Penang in Malaysia. It is situated on the northeastern coast of Penang Island and is known for its rich cultural heritage, historical significance, and vibrant atmosphere. Figure 1 shows the key plan and location plan of the site selected.

Figure 1. Key plan (left) and location plan (right) of Georgetown, Penang
Source: https://iplan.townplan.gov.my/public/geoportal?view=semasa

The research has been conducted at Georgetown, Penang. There is a Sungai Pinang in the middle of this site. The area chosen is an area where floods often occur in the middle of the city and this area is located in a residential area which is Taman Wangi. The study employed two primary data sources for investigation: primary data and secondary data. In the primary data collection phase, the researcher conducted on-site observations, data collection, and conducted interviews with landscape architects. In the secondary data analysis, online research papers and government reports were used. These sources serve as reservoirs of information, both contributing to the study's objectives, offering insights, and yielding suggestions and findings. The study applies the site observation, qualitative approach and unstructured interview with the residents as instruments for data collection in a qualitative approach.

Site observation

Site observations are one of the methods used in this study that aims to understand the areas that have green infrastructure, green areas and places that are related to stormwater management. The site study was conducted to identify the existing numbers of green areas and the green infrastructure which are built by local residents. The frequency of floods causing damage and destruction of residents' property will be identified to get the differences between severe areas and less severe areas when flooded. Observing the site is crucial for developing a comprehensive, enduring plan. Understanding the existing green infrastructure allows for meaningful engagement with communities. It helps in raising awareness about the importance of green spaces, involves residents in conservation efforts, and encourages participation in initiatives aimed at enhancing or preserving these areas. In essence, understanding the existing green infrastructure serves as a foundation for creating sustainable, resilient, and livable communities by guiding decision-making, resource allocation, environmental management, and community engagement efforts. The final product of the study will determine the areas needed for green infrastructure to reduce the water runoff.

Characteristic of Georgetown site area

To study the characteristics of Georgetown, the researcher went to the site and collected a little data about the site's condition. In this method the researcher has made a study about the current situation in the site area. stated in the plan and map below some pictures and locations that show the existence of green infrastructure. can be seen where the existence of green infrastructure in this area is relatively less.

Figure 2. Location plan of the area analyzed in site study Georgetown, Penang

(Source: Author, 2023)

Figure 2 shows eight locations on the plan that have been inventoried, serving as references for studying the state of existing green infrastructure. Pictures 1 and 2 showcase street road vegetation, while picture 3 highlights the lack of vegetation and plants in the housing area. Pictures 4 and 5 reveal poor vegetation and drainage along the main road, and picture 6 depicts an area with inadequate vegetation and drainage systems. Picture 7 illustrates impermeable pavement used along the walk, while picture 8 reveals the poor condition of permeable pavement at Jalan Sungkai.

Examining pictures 1 to 8, we can draw conclusions about the present conditions of the site in the affected flash flood area. These images collectively indicate that the green infrastructure in this area is still unsatisfactory and requires improvement. The analysis suggests the Georgetown area experiences flooding due to insufficient green infrastructure exposure in the population, leading to high volume water runoff, compounded by low

topographical factors.

Qualitative Approach

This study adopts a qualitative approach to gain a deeper understanding about the vital role of green infrastructure in stormwater management for hydrological control in Georgetown, Penang. This method consists of interviews with four respondents, two of them are Landscape Architects from PDC and MBPP, while the other two are the residents. Qualitative research allows for exploring the experiences, perspectives, and suggestions of the green area and methods for ensuring in reducing the coefficient water runoff from the residents and landscape architects. Through the utilization of both open-ended and closed-ended questions. There are twelve questions including their personal background. This method enables thorough discussions, fostering the creation of extensive and detailed insights. The software that has been used to analyze the interview is Atlas Ti.

Data collection

Data will be collected through open-ended and close-ended interviews conducted with the selected respondents at Georgetown, Penang. The interview will be conducted via online meeting (Teams meeting) and face-to-face following an interview guide that includes questions related to flash flood, green area and suggestion of awareness about the vital role of green infrastructure. Participants' consent will be obtained prior to audio-recording the interviews, ensuring precise data capture. The findings will provide valuable insights for enhancing the city adaptability through flash flood incidents.

RESULT & DISCUSSION

When conducting interviews with respondents about green infrastructure, we gain valuable insights and results that contribute to a better understanding of perceptions, challenges, and opportunities associated with these sustainable practices.

Analysis of unstructured interview

The analysis of unstructured interviews was conducted via a Teams Meeting, because of the rising number of COVID-19 cases. This process unveiled diverse perspectives on the challenges of implementing green infrastructure, with recurring themes centered around funding constraints and community engagement. These findings are intricately linked to the root causes of why Georgetown is among the cities in Penang facing a high number of flood issues. The data collected from respondents is organized, analyzed, and graphically represented using Atlas Ti. The thematic analysis conducted through Atlas.ti revealed six prominent themes emerging from the interviews that have been made in Teams meeting platform, highlighting key sentiments towards green infrastructure.
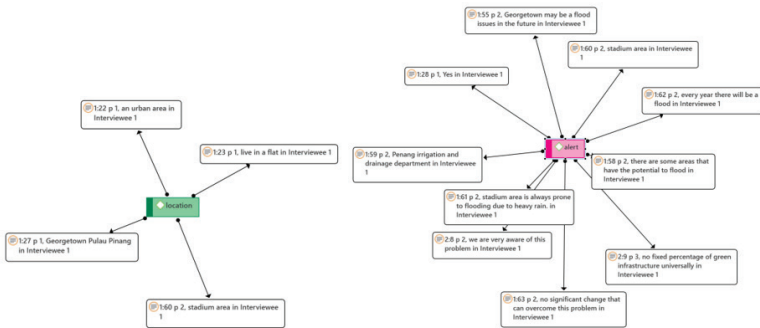
Figure 3. Keyword (location & alert) of analysis using the Atlas Ti

Above figure 3, showing that the respondents are alert and aware of the flood problem in Georgetown. As supporting evidence, in (1:60) and (1:62) they confirmed that there was a flood in the City Stadium Penang area and there will potentially be another flood in the future when it comes to heavy rain seasons, said Participant 2 in quotation (1:61). Participant 2 in quotation (1:63) also mentioned that there are no significant changes to overcome stormwater management issues in the area.
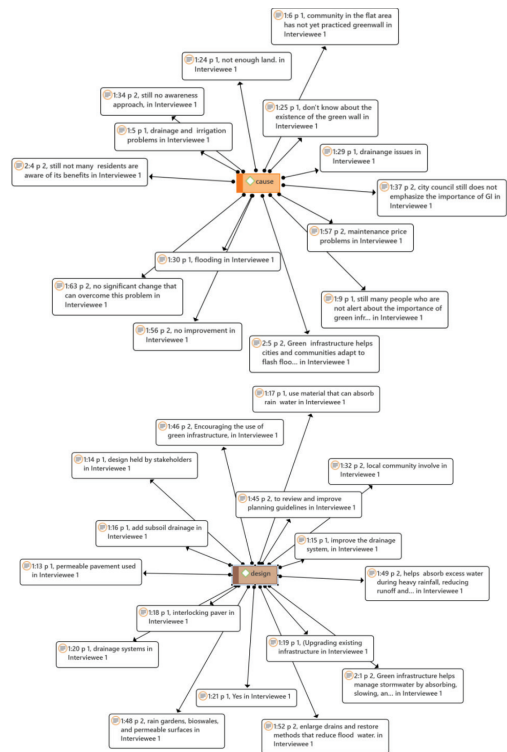
Figure 4. Keyword (causes & design) of analysis using the Atlas Ti

In Figure 4, the relationship between causes and design is depicted based on insights gathered from the interviews. In (1;5), respondents indicated that the causes of flash floods stem from issues with the drainage and irrigation system. This perspective is reinforced by (2:4), highlighting that residents are still not fully aware of the benefits of green infrastructure in the city for mitigating flash floods. The implementation of designs by stakeholders is limited, and notably, Interviewee 3 emphasized the use of water-absorbing materials, such as previous concrete.

States (1:13), (1:18), and (1:16) indicate that landscape architects are adopting nature-friendly methods and materials for sustainable development. This suggests a positive trend in incorporating environmentally conscious approaches in design and planning for the area.
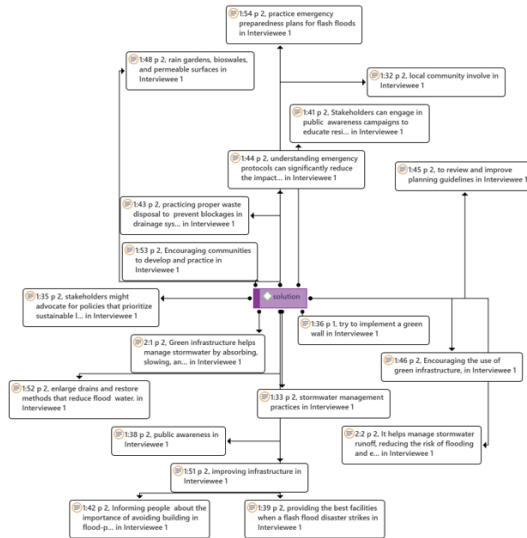
Figure 5. Code group of keywords (Solutions) in Atlas Ti

As depicted in Figure 5, it illustrates some of the solutions and opinions provided by respondents regarding how to address the flash flood problem in the future. In (2:1), it is stated that green infrastructure plays a crucial role in managing stormwater by absorbing water runoff. Additionally, (1:15) suggests that improving the city's infrastructure can lead to a reduction in the coefficient level, indicating a potential strategy for flood mitigation.

Furthermore, the perspective presented in (1:45) emphasizes the need for governmental action. The interviewee suggests that the government should prioritize enforcing laws and revising planning guidelines for each city. This, in turn, would raise awareness among the public and authorities, fostering a more proactive approach to addressing the flood issue.

Interview summary

The set of graphs below (figure 6) illustrates the level of agreement regarding green infrastructure among the interviewees.
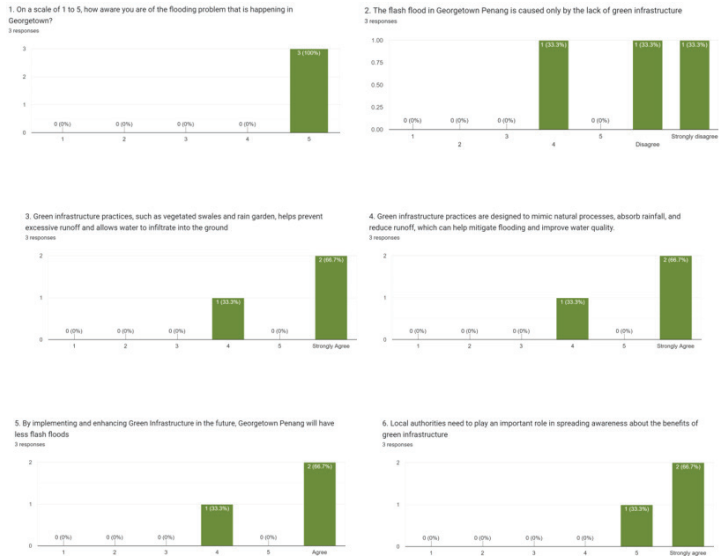
Figure 6. Level of agreement about Green infrastructure and issue on the site

From the graphs Figure 6, it illustrates that stakeholders are cognizant of the challenges at hand and are in consensus regarding the crucial need for green infrastructure in the Georgetown area. This collective awareness is driven by the understanding that implementing green infrastructure is imperative to diminish runoff and address the persistent issue of flash floods.
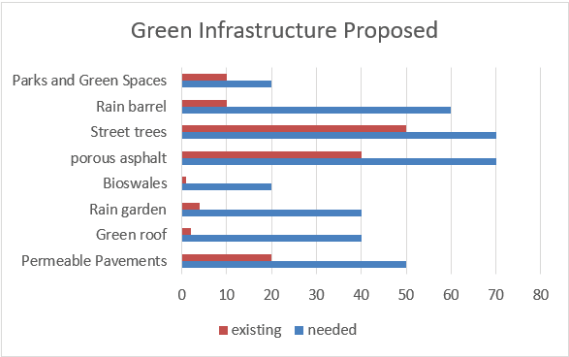

Figure 7. Graph percentage of existing green infrastructure and the suggested percentage supposedly implemented

From the figure 7, it shows the graph stems from an interview conducted by two landscape architects and a resident, providing an insightful estimate of the percentage of green infrastructure that should be integrated into the area. The comparative analysis drawn from this graph unmistakably highlights the notably low and feeble presence of green infrastructure in the region. This deficiency emerges as a crucial factor contributing to the delayed recession of floods in the area.

Individual experiences

During the flash flood, the resident faced many difficulties, highlighting the psychological effects on both the community and the individuals within it due its topography. This sets the groundwork for understanding the gravity of the situation and the extensive recovery efforts needed. "This area is frequent, it can be said every year. This area is one of the lower areas compared to other areas, that's why floods always happen when it rains heavily" (Interviewee 1)

"I don't practice any green earth initiatives, when the heavy rains occur, I am already prepared to move important items to higher storage to prevent my items from being damaged."

(Interviewee 3).

From the informal interview I can say that the residents in this area are still not alert and not exposed to the importance of Green Infrastructure in the city. Furthermore, as mentioned, the residents are more inclined to take quick steps every time there is a flood and do not practice evergreen measures which is to practice green infrastructure in their residential area.

CONCLUSION

In conclusion, the results of the findings underscored the pivotal role of green infrastructure in addressing various environmental challenges. The discussion illuminated the effectiveness of green infrastructure in mitigating issues like flash floods. The implementation of green infrastructure presents a promising solution for mitigating flash floods in urban areas. Through this research, it is evident that strategically designed green infrastructure,

such as permeable surfaces, green roofs, and rain gardens, plays a pivotal role in managing stormwater and reducing water runoff. The integration of nature-based approaches not only contributes to flood control but also fosters numerous ecological benefits (Interviewee 2).

The limitations of this study is lack of expertise to gain more detailed data and percentage of the green infrastructure and data about coefficient water when flash floods happened.

ACKNOWLEDGEMENT

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Sekian, terima kasih.

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setuju.

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