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Flood Mitigation Management Practice: A Comparison Between Stormwater Management Road Tunnel (SMART) and Sponge City Methods

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Abstract

Flash flood in Malaysia urban is no longer a surprise incident as it has become a widespread natural disaster that frequently happened every year. The geographical of Malaysia with equatorial climate experiences consistently high temperatures with high relative humidity and influenced by the northeast and southwest monsoons have provided heavy rainfall during the monsoon season. Although the flood issue has been given an important focus under the disaster management implementation in Malaysia, there is critical demand to improve the present flood mitigation management practice to overcome unforeseen flood disaster issues over the long term. The annual occurrence of floods in Malaysia has caused a very big impacts to the lives of humans and other living beings that requires serious attention and better "solution alternative" measures in urban areas. Commentators have remarked that the current urban flood management method, i.e., Stormwater Management and Road Tunnel (SMART) has not been proven as the long-term best solution to overcome the unforeseen flood disaster issues over the long term. There have been suggestions from the scholars to explore and adopt a new method, i.e., Sponge City concept that is still scarce in Malaysia but has been substantially adopted in China to overcome the urban flood issues. Therefore, this paper is prepared to present the outcome of the study on the comparison between the present Stormwater Management and Road Tunnel (SMART) and the newly concept of Sponge City with specific reference to the urban flood mitigation management in Malaysia. This study employs a quantitative research strategy to collect primary data from fifty-eight (58) respondents that approximately represents 73% of the entire distributed questionnaires or a total of 80 potential respondents that was identified to meet the specified criteria, with the objective to get their opinions on the comparison between the two competing methods, i.e., the present SMART tunnel, and the newly Sponge City concept for urban flood mitigation management in Malaysia. The findings revealed that the majority of the respondents chose Sponge City because it is greater advantages than the SMART tunnel method to overcome the issues of flood disaster in the urban areas. Although the Sponge City concept could be deemed appropriate for consideration as the new and better flood mitigation management method in Malaysia, it demands a holistic assessment to view the relevancy of Sponge City implementation and its investment over the life span for achieving economic sustainability and Sustainable Development Goals (SDGs).

Keywords: Stormwater Management and Road Tunnel (SMART), Sponge City, flood management, urban flood

1.0 INTRODUCTION

Many commentators pointed out that flood has become the most common disaster issue affecting many low areas in Malaysia since the 1920s (Othman et al., 2014; Aliagha et al., 2015; Khalid and Shafiai, 2015; Tan et al., 2015). The annual occurrence of floods in the low urban areas has caused worrying to the communities. The high increase of migrations from rural to the city, the changes in the structure of soil caused by the uncontrolled development, poverty and other factors have threatened the communities living in the low land and floodplain areas (Mustaffa et al., 2014). Besides, the recent big flood disaster in December 2021 had submerged some parts of the urban areas in Malaysia, that include Shah Alam, Ulu Langat, Kuala Lumpur, Kuantan, and Lipis. After this recent flash flood disaster that hit some urban areas, the former Malaysia's Parliamentary Opposition Leader Anwar Ibrahim spoken out in the Information Session in the House of Representatives to demand the government to identify more comprehensive ways to overcome the issues of flood disaster, drainage problems and high cost of implementing the flood mitigation projects (Malaysia Post, 2022). Anwar Ibrahim (2022a, 2022b) urged the government to halt the mega-billion development projects and proposed a greater reallocating budget funds from these mega projects into the exploration of newly flood mitigation management method, i.e., Sponge City concept that has been substantially adopted in China to overcome the urban flood issues (Malaysia Post, 2022). Additionally, concerns have arisen whether the existing Stormwater Management and Road Tunnel (SMART) that was built more than 15 years ago can become the long-term best solution to overcome the unforeseen flood disaster issues and prevent property, vehicle, and belonging submersion in urban areas (City Planning Department, 2021; KPKT, 2021, 2022; Ibrahim, 2022a, 2022b; Malaysia Post, 2022; Anwar Ibrahim, posted in telegram and twitter on 20th January 2022; PLANMalaysia, 2023). Therefore, this paper is prepared to present the outcome of the study on the comparison between the present Stormwater Management and Road Tunnel (SMART) and the newly concept of Sponge City with specific reference to the urban flood mitigation management in Malaysia.

2.0 REVIEW OF STORMWATER MANAGEMENT AND ROAD TUNNEL (SMART)

SMART Tunnel is an innovative project implemented by the Malaysian government, that constructed from 1st January 2003 to 30th June 2007 to alleviate flooding problems in the Kuala Lumpur's City Centre (Kannapiran, 2005; Yusop et al., 2016). It was the first dual-purpose tunnel in the world, with 11.5 km length and 13.2m diameter to keep floodwaters away from the confluence of two rivers that flow through the drainage system in the city of Kuala Lumpur. The middle 3 km of the tunnel serves as a two-deck freeway to relieve traffic congestion at the city's main southern entrance (Mott Macdonald, 2020). The followings are the reasons that influenced the decision of the government to apply the SMART method in Kuala Lumpur's City Centre (Kannapiran, 2005; Yusop et al., 2016):

i. To solve the frequent flash flood in the Kuala Lumpur City Centre

The SMART method was chosen to be developed to reduce floods that caused by heavy rainfall during the monsoon season. The flooding in the Kuala Lumpur central city has costed the government a lot of money and disrupted the economy. By building a storage tunnel to operate as a water release mechanism, Kuala Lumpur may avoid the costs of flood damage and post-flood actions. Simultaneously, the companies and residents in Kuala Lumpur would not feel worried to go about their daily routines.

ii. To solve the traffic congestion at roads in Sungai Besi, Kuala Lumpur Southern Gateway

The SMART method was designed to relieve traffic congestion in Kuala Lumpur's primary southern routes to the city centre. Kuala Lumpur is a bustling metropolis with frequent traffic congestion issues. Due to the prevalence of toll roads in Malaysia, constructing a toll tunnel beneath an existing road allows commuters to bypass the clogged traffic by paying to utilise the tunnel that can help to reduce traffic on the above-ground highways as well.

The total construction cost of SMART tunnel project is RM 1.933 billion (0.48 billion US Dollars) that was constructed by a two-joint venture firms under a 40-year concession agreement, i.e., Malaysian Mining Corporation (MMC) Berhad and Gamuda Berhad, and assisted by the two government implementing agencies, i.e. Department of Irrigation and Drainage Malaysia and the Malaysian Highway Authority (Special Unit for South-South Cooperation, 2012; Yusop et al., 2016; MacDonald, n.d.; SMART, n.d.). The SMART tunnel project was also supported by the two professional engineering consultants, i.e., SSP Consultants and Mott MacDonald

(MacDonald, n.d.). The Malaysian government funded 340 million US dollars and the remaining 170 million US dollars were funded by the joint venture firms (Special Unit for South-South Cooperation, 2012). The SMART tunnel concessioner designed an open toll system to charge the tunnel users when enter the tunnel through the toll plazas over 40-year concession period to recoup the total development, operational and maintenance costs of SMART tunnel project (Kannapiran, 2005; Special Unit for South- South Cooperation, 2012; Yusop et al., 2016; MacDonald, n.d.; SMART, n.d.).

According to Azhar et al. (2021) the SMART tunnel has been successfully proven to prevent the Kuala Lumpur's city from incurring considerable costs of damages to public and private properties in the city centre due to flash flood, that save approximately RM100.8 million (about USD 24 million) a year or RM1.411 billion (around USD 337 million) since it was operated in 2007 over the course of 14 years (Azhar al., 2021). During the September 2020 flash floods, the SMART Tunnel kept 20 football fields, or 15 hectares, of the city centre from being under water (Babulal and Teoh, 2020 as cited in Azhar et al., 2021).

The SMART tunnel, including the 30 hydrological stations, floodgates, flood detection system, holding pond, and attenuation pond are periodically maintained by the Department of Irrigation and Drainage to keep the tunnel infrastructure systems function at the utmost level (Azhar et al., 2021). The said department has developed a preventive and corrective maintenance plan for the implementation of routine inspection and execution of maintenance repair to immediately resolve any defect detected or issues arise in the operational of SMART tunnel systems (Azhar et al., 2021). For examples, the wear-and-tear repair works are scheduled for completion within 14 days, whilst the emergency repairs are targeted to be resolved within a one-hour. The engineers on duty are required to be on call around-the-clock, seven days a week, to make sure the overall tunnel systems can be effectively operated at the utmost level (Azhar et al., 2021).

However, there have been concerns whether the SMART Tunnel that was built more than 15 years ago is methodically enough to serve as a long-term and optimal solution to overcome unforeseen flood disaster issues in Klang Valley urban areas (City Planning Department, 2021; KPKT, 2021, 2022; Ibrahim, 2022a, 2022b; Malaysia Post, 2022; Anwar Ibrahim, posted in telegram and twitter on 20th January 2022; PLANMalaysia, 2023). For example, the recent flash flood in 2021 that hit parts of Kuala Lumpur had affected thousands of road users and residents that lived in the marginalized areas (Ibrahim, 2022a, 2022b). Indeed, the former Malaysia's Parliamentary Opposition Leader Anwar Ibrahim also had demanded more comprehensive actions to be taken by the government to prevent the recurrent big flood disaster that happened in Shah Alam in December 2021. It has been a critical demand to identify more comprehensive ways and better solutions to address the common urban disaster issue of flooding in the country (City Planning Department, 2021; KPKT, 2021, 2022; Ibrahim, 2022a, 2022b; Malaysia Post, 2022; Anwar Ibrahim, posted in telegram and twitter on 20th January 2022; PLANMalaysia, 2023).

2.1 Latest Innovation of SMART Method

The Malaysia government had announced in 2022 to conduct a feasibility study in developing a proposal of SMART 2, a new innovated flood mitigation management to lessen the flush flooding issues frequently occurred in Shah Alam, Selangor. The study was conducted by a regional engineering and construction firm, i.e., Gamuda Berhad, the present concessioner of SMART 1 tunnel in Kuala Lumpur, Malaysia. The proposed SMART 2 underground tunnel is a hybrid tunnel that will be designed 22-kilometer length and embedded with "Sponge City" concept (Gamuda Berhad, 2022; Hazim, 2022). The hybrid design of SMART 2 tunnel is proposed to build over five flood-prone areas that incorporates with different flood mitigation techniques, e.g., river enhancement works for Sungai Klang, powerful pumping system development etc. (Gamuda Berhad, 2022). However, the proposed SMART 2 tunnel will not be designed for traffic management like the previous SMART tunnel (Gamuda Berhad, 2022). The SMART 2 hybrid concept will be designed as meant to collect precipitation and surface runoff through interception and infiltration, and then to store the enormous water volume in the underground infrastructure storage system before releasing the collected water in a controlled manner to the sea or reservoir (Gamuda Berhad, 2022; Hazim, 2022). Besides, the Director General of Town and Country Planning has announced that the newly Sponge City concept has been included in the Fourth National Physical Plan (NPP-4) of Twelfth (12th) Malaysia Plan 2021 to 2025 for flood mitigation management and municipal water management (PLANMalaysia, 2021; Rameli, 2023; Taib and Mahyuddin, 2023). The objective of Twelfth Malaysia Plan 2021-2025 is to pave the way forward to achieve a prosperous, inclusive, sustainable Malaysia, and according to EPU (2021) there is a need to explore the newly Sponge City concept that can be applied to store rainwater infiltrates into the ground in the urban aquifers to overcome unforeseen flood disaster risks in the country (Rameli, 2023; Taib and Mahyuddin, 2023).

3.0 REVIEW OF SPONGE CITY

Sponge City is a city with a water system that is highly adaptable to environmental changes and natural disasters that acts like a sponge, absorbing, storing, infiltrating, cleaning, and purifying rainwater before releasing it for reuse (Wu, 2015 as cited in Zhang, 2017; Li et al., 2017; Xia et al. 2017 as cited in Chan et al., 2018). Figure 1 shows the concept of Sponge City water system.

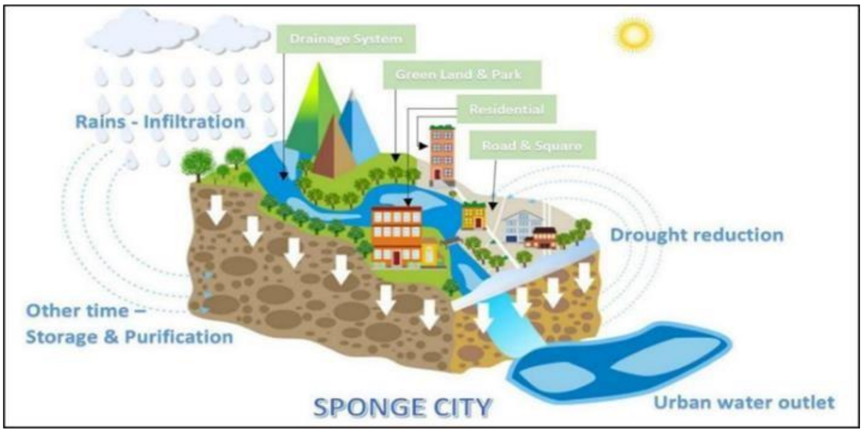

Figure 1. Schematic diagram of the Sponge city concept (Chan et al.,2018, pg. 775)

Scholars have pointed out several points below as the important goals of adopting Sponge City concept in the urban development for promoting environment sustainability in urbanization, conserving nature and ecological system, and supporting for the wellbeing of communities and future generations (Zhang, 2017; Jia et al., 2017; Chan et al., 2018; Liang, 2018; Khor, 2018a, 2018b; Nguyen et al., 2020; Yuming Su et al, 2020; Taib and Mahyuddin, 2023):

- To focus on the storm water management strategies that employed natural solutions to control around 70% of runoff in 20% of urban areas by 2020, and 80% of urban lands by 2030.
- To maximise infiltration and limit surface runoff in a metropolis by absorbing and releasing rainwater as appropriate,
- To create a high-quality living environment with a well-balanced water circulation system in effort to achieve urban sustainability at a reasonable development cost.
- Treat rainwater as a resource and set aside sufficient water conservation areas for urban development.
- To lessen the influence of building on the urbanisation process by retaining an area's hydrological features both before and after construction.
- To increase the storage capacity of urban water resources and maximise the environmental value of wetlands to safeguard cities from floods.
- To balance peak discharges and eliminate extra storm water, old drainage systems should be upgraded by adopting more flood-resistant infrastructure.
- To address the 'heat island' impact and climate change-related challenges.
- To guarantee that urban water ecosystem services are provided.

Money and expenses may be characterised as the primary basis for financing the project from the development, execution operation phases (Nuruljannah, 2017). The preliminary estimation has projected that the total investment of Sponge City is between 100 and 150 million Yuan RMB (RM 64 million to RM 96 million) per square kilometre, or a total of 10 trillion Yuan RMB (RM 6.4 trillion) for the 657 cities across China (Jia et al., 2017). In comparison with the Sponge City development cost, higher budget was spent more than 160 billion Yuan RMB (RM 103 billion) to remedy the adverse impacts and economic damages after the flood disasters in more than 150 cities in China in between 2006 and 2010 (Li et al., 2015 as cited in Chan et al., 2018; Khor, 2018). Beijing was devastated by a flash flood on 21st July 2012, and it was reported that a total of 56,933 persons were evacuated and 79 deaths. While on July 6, 2016, a large area of Wuhan city was flooded by precipitation, causing an economic loss of around 2.2 billion RMB (RM 1.4 billion) and affecting 10 million people in the city (Zhang, Zevenbergen, Rabé, & Jiang, 2018). To prevent the recurrence of flood disaster in China, the government has placed greater emphasis to improve the urban storm water and drainage management system (Su et al., 2020). The government has decided to make an important commitment to adopt and implement the "Sponge City" concept in China because the total development cost is lesser than the whole costs of loss and economic impacts that affected by flood disasters (Chan et al., 2018; Taib and Mahyuddin, 2023). Changde, a city in the northwest of Hunan Province of China was chosen amongst the first set of demo pilots for the implementation of Sponge City programme in 2015. The Changde water projects were evaluated with cost benefit analysis to determine the economic, environmental, and financial viability of the projects (Liang, 2018; Taib and Mahyuddin, 2023). The outcome of the cost benefit analysis revealed the total benefits of Sponge City programme is more worthy, feasible and the benefits outweigh the downsides rather than the traditional methods of flood mitigation management, but there is no financial instrument or mechanism that can facilitate the programme developer to determine their affordability to pay the hidden operational and maintenance costs throughout the entire service life span (Liang, 2018). Additionally, Taib and Mahyuddin (2023) pointed out the two identified limitations that have hindered the implementation of Sponge City development in China that include limited Sponge City expertise in the local government agencies and financial management constraint.

It was reported the anticipated Sponge City construction cost per square kilometre is between 14 and 26 million USD, and the total development cost is between 0.2 and 1.6 trillion USD (Guotai Junan Securities, 2016 as cited in Yuming et al., 2020). In Wuhan, the total development cost of Sponge City is less expensive (i.e., about US$ 600 million or CNY 4 billion) rather than the alternative flood mitigation methods, e.g., grey infrastructure (based method), reservoirs, dykes, river courses, water gates and drainage infrastructure etc. (Lucy Oates et al., 2020; Lucy Oates et al., 2020; Yunfei et al., 2021). The facilities to be built in the Sponge City programme are include the construction of permeable roads, the development of wetlands and man-made lacks, rooftop gardens, community gardens, and planting trees including bioretention (Yin et al., 2021). A quality maintenance programme for the constructed facilities in the Sponge City programme is designed to enhance the stormwater runoff control capabilities, performance, and efficacy (MHURD, 2014 and Macedo et al., 2017 as cited in Yin et al., 2021). Table 1 below shows the outcome of comparison study on the investment and maintenance costs between Sponge City and conventional model that reported by Ma et al. (2017). The results revealed that the investment cost of Sponge City (184.26 million Renminbi (RMB) or Yuan (Y)) is lower than the conventional model (218.6 million Renminbi (RMB) or Yuan (Y)). In addition to this, the total maintenance cost of Sponge City (8310 million Renminbi (RMB) or Yuan (Y)) is lower than conventional model (8760 million Renminbi (RMB) or Yuan (Y)). Therefore, based on the investment and maintenance costs reported in Table 1, it is not misconception to state that the total life cycle cost of Sponge City is more cost efficiency rather than the conventional model in the flood mitigation management practice. However, according to Arfah Juneena (2022) that the initial development cost for the implementation of Sponge City concept in Malaysia can be higher if there is limited expertise in the construction industry, high land acquisition cost, and long-time research required for the development of Sponge City proposal.

Table 1. Breakdown of investment and maintenance costs of Sponge City
(Ma et al., 2017, pg. 107)

Content of Sponge City Construction			Investment cost (10,000 RMB/y)		Maintenance cost (10,000 RMB/y)	
			Conventional model	**Sponge city model**	**Conventional model**	**Sponge city model**
Total			**21,860**	**18,426**	**876**	**831**
1)		Construction and operation maintenance in residential area	3960	5576	96	144
	a)	Roof greening	0	200	0	18
	b)	Pavement (hard/permeable)	1440	2160	15	30
	c)	Green space (traditional/ecological)	2160	2520	65	72
	d)	Green belt (traditional/grass plating ditch)	360	396	16	18
	e)	Rainwater storage device	0	300	0	6
2)		Construction and maintenance of rainwater pipe network and pump station	6500	3900	360	340
3)		Watercourse ecological construction and maintenance	5100	4500	270	250

4)		Construction and operational maintenance of wastewater pipeline and wastewater treatment plant	4500	3250	141	91
5)		Construction and operational maintenance of waterlogging prevention facility	1800	1200	9	6

Content analysis was carried out to review the similarities and differences between SMART tunnel and Sponge City methods. The outcome is presented in summary as shown in Table 2 below.

Table 2. Summary of similarities and differences between SMART Tunnel and Sponge City methods

SIMILARITIES BETWEEN SMART TUNNEL AND SPONGE CITY	
• Aim towards Sustainable Development goals (SDGs). • The concept towards more sustainable, resilient, and inclusive development. • Flood control and water resources management. • Strengthening infrastructure to support economic expansion.	
DIFFERENCES BETWEEN THE SMART TUNNEL AND SPONGE CITY	
Stormwater Management and Road Tunnel (SMART)	**Sponge City**
• Has been launched in Malaysia in 2007	• Not yet constructed in Malaysia
• To solve the frequent flash flood • To solve the traffic congestion	• To absorbs, store, infiltrate, clean, and purify rainwater before releasing it for reuse, much like a sponge
• The total cost is US$510 million • The proposal for future construction of SMART 2 by Gamuda Berhad is RM20 billion	• The cost per square kilometre is between US$14 million - US$26million. • Wuhan - US$ 600 million
Components • Flood Detection System • 'Flood By-pass' tunnel • 'Motorway' tunnel • Storage reservoir • Twin box culvert • Holding pond	Components • Construct permeable roads. • Build wetlands and man-made lacks. • Construct rooftop gardens • Build community gardens and plant trees. • Bioretention
Maintenance • Carried out according to its operations manual • Monthly maintenance works for watertight-doors, motorway tunnel and software checks are compulsory	Maintenance • Costly which is 10.000 RMB per year. • Facilities covered by vegetation layers should be studied. • Litter cleans up and structural layer functions tests. • Evaluated after maintenance to see if they match the design criteria. • Consider whether the facility should be utilised or decommissioned.

4.0 METHODOLOGY

A quantitative research strategy was chosen rather than qualitative and mixed method research strategies due to the accessibility of the original data in the study that can be collected through questionnaire interview survey and statistically analysed. Additionally, the data can be presented in table forms for the "generalisation" and comparison of the opinions between one participant with another. The questionnaire interview survey was designed to collect quantitative data by interviewing respondents on the comparison between two exclusive variables, i.e., the present SMART practice and newly Sponge City methods with specific reference to the issues of urban flash flood and flood mitigation management solution in Malaysia. The survey was carried out through online platform, i.e., Google Form that enables a wider and inexpensive distribution of surveys to a high number of respondents. It facilitates the study to collect replies from the respondents in the organization of numerical data responses, without having to decode and count responses on a sheet of paper (Wolber, 2018; Adedoyin, 2020).

In the first step of the questionnaire design process, the questions were developed and formulated based on the research objectives and the outcome of literature review. The questionnaire was piloted with the research supervisor, peers, and few respondents to identify mistakes in the questions and wording, and to improve reliability and answerability of the questions in answering the study objectives. The questionnaire was reviewed, corrected, and validated for satisfaction based on the outcome of pilot questionnaire before distributing to the respondents. The questionnaire is divided into four sections, i.e., Sections A to D. Section A is designed to collect demographic information of the respondents, Section B is designed to obtain expert opinions on the SMART flood management method, Section C is designed to ask opinion of the respondents on the newly Sponge City flood management method. Section D is designed to procure expert opinion on which method that is more competitive advantage between the two exclusive flood mitigation management methods, i.e., the present SMART and newly Sponge City methods.

The convenience sampling method was chosen to collect survey data in the study. The potential survey respondents were identified through literature search. The respondents were contacted individually through a linked website, e-mail, or online messenger. The respondents were chosen based on the following criteria:

i. The respondent possesses degree or certification in the field of built environment such as architecture, engineering, quantity surveying, project management, town planning, landscape architecture, facility management, etc.
ii. The respondent possesses knowledge and/or experience in flood mitigation management.
iii. The respondent is readily available and committed to participate throughout the study.

The survey data was analysed using descriptive statistical analyses, i.e., mean, and standard deviation (SD). The mean score was calculated to determine which item response(s) that is/are essential to be included in the answer set to the relevant questions (Ayob, 2014). The item responses that obtain mean scores of more than 3.75 are regarded as very essential (Sandrey & Bulger, 2008 as cited in Ayob, 2014). Whereas the standard deviation score was calculated to determine the agreement levels amongst the respondents (Grobbelaar, 2007; Al-Mabrouk & Soar, 2009; Shah & Tillman, 2011 as cited in Ayob, 2014). The standard deviation values are used as the judgement criteria to ascertain the level of consensus achieve amongst the respondents (see Table 3). The higher the level of the consensus amongst the respondents is achieved when the lower the score value of the standard deviation, and it is high level of consensus attained when the standard deviation score lesser than 1.0 (Ayob, 2014).

Table 3. Standard deviation and level of consensus (Grobbelaar, 2007 as cited in Ayob, 2014)

Standard deviation (SD)	**Level of consensus achieved.**
$0 \leq X < 1$	High level of consensus
$1 \leq X < 1.5$	Reasonable/ fair level of consensus
$1.5 \leq X < 2$	Low level of consensus
$2 \leq X$	No consensus

5.0 RESULTS

A total of 80 people was identified as potential respondents for the study. However, only 58 people provided their agreement to become respondents and completed the interview survey, that approximately represents 73% of the entire distributed questionnaires. Table 4 shows in brief the demographic information of respondents in the study.

Table 4. Demographic information of respondents in the study

Organization	Questionnaire distributed	Questionnaire received	Percentage completed (%)
Engineer	40	35	87.5
Quantity Surveyor	10	5	50
Contractor	5	2	40
Architect	5	1	20
Student	2	2	100
Others	18	13	72.22
TOTAL	80	58	72.5

For Section B of the questionnaire, the respondents were required to state their opinion on the degree of agreement on the advantages of SMART tunnel flood management method for flash flood mitigation in Malaysia. Table 5 presents the outcome of statistical analyses based on the calculated mean and standard deviation (SD) scores on the advantages of SMART tunnel flood management method. A majority of the respondents agreed that the top three ranked advantages of SMART tunnel with the highest mean score more than 3.75 are: to improve flood management (mean 4.17), the second rank is shared by environmental benefits and sustainable development (mean: 4.10) and then followed by social benefits (mean: 3.97). The standard deviation scores of these three top ranked advantages of SMART tunnel are less than 1.50 that indicate reasonable level of consensus were achieved amongst the respondents. Whilst for Section C, the respondents were required to state their opinion on the degree of agreement on the advantages of Sponge City. Table 6 shows that the majority of the respondents agreed the top three ranked advantages of Sponge City with the highest mean score more than 3.75 are: to improve flood management (mean 4.21), sustainable development (mean 4.10), and the third rank (mean 3.97) is shared by economic benefits and environmental benefits. These three top ranked advantages of Sponge City possess standard deviation scores more and less than 1.00 that indicate high level of consensus were achieved amongst the respondents.

Table 5. Opinion of respondents on the advantages of SMART tunnel flood management method

Code	Advantages of SMARTmethod	Degree of agreement					Total	Mean	SD	Mean Rank
		SD (1)	D (2)	N (3)	A (4)	SA (5)				
10	Economic cost	2	5	10	9	4	*30*	**3.27**	**1.11**	**9**
20	Economic benefits	3	1	10	9	7	*30*	**3.53**	**1.20**	**7**
30	Environmental benefits	1	2	5	10	13	*30*	**4.10**	**1.03**	**2**
40	Social benefits	0	3	6	10	11	*30*	**3.97**	**1.00**	**3**
50	Sustainable development	1	0	6	11	12	*30*	**4.10**	**0.96**	**2**
60	Improve flood management	1	0	5	11	13	*30*	**4.17**	**0.95**	**1**
70	Improve traffic management	1	3	3	14	9	*30*	**3.90**	**1.06**	**4**
80	Produce more skilledworkers	2	2	9	10	7	*30*	**3.60**	**1.13**	**6**
90	Data is transferred faster	3	5	9	9	4	*30*	**3.20**	**1.19**	**10**
100	Easier for physicalactivities	1	5	8	10	6	*30*	**3.50**	**1.11**	**8**
110	Proper controlling and monitoring environment	1	2	5	14	8	*30*	**3.87**	**1.01**	**5**
120	Easier for maintenance	1	4	10	8	7	*30*	**3.53**	**1.11**	**7**

Table 6. Opinion of respondents on the advantages of Sponge City flood management method

Code	Advantages of Sponge City flood managementmethod	Degree of agreement					Total	Mean	SD	Mean Rank
		SD (1)	D (2)	N (3)	A (4)	SA (5)				
130	Economic cost	1	4	2	5	2	14	**3.21**	**1.25**	**8**
140	Economic benefit	0	0	5	5	4	14	**3.93**	**0.83**	**3**
150	Environmental benefits	0	1	3	6	4	14	**3.93**	**0.92**	**3**
160	Social benefits	0	2	4	2	6	14	**3.86**	**1.17**	**4**
170	Sustainable development	0	0	5	4	5	14	**4.00**	**0.88**	**2**
180	Improve flood management	0	1	3	2	8	14	**4.21**	**1.05**	**1**
190	Lack of readiness	1	3	4	4	2	14	**3.21**	**1.19**	**8**
200	Inadequate creation of high value-added jobs	2	2	7	2	1	14	**2.86**	**1.10**	**9**
210	Inadequate internet speedand connectivity	2	0	7	2	3	14	**3.29**	**1.33**	**7**
220	Unproven adoption of new technologies	2	1	5	3	3	14	**3.29**	**1.27**	**7**
230	Lacks skilled labour	2	3	3	2	4	14	**3.21**	**1.48**	**8**
240	Lack of public information sharing from government	1	0	6	2	5	14	**3.71**	**1.20**	**5**
250	Technical issues and development issues	1	1	6	3	3	14	**3.43**	**1.16**	**6**
260	Cybersecurity risks	4	1	5	1	3	14	**2.86**	**1.51**	**9**
270	Easier for maintenance and physical activities	1	1	6	3	3	14	**3.43**	**1.16**	**6**

In Section D, the respondents were asked to provide their opinion on which method that is more competitive advantage between the two exclusive flood mitigation management methods, i.e., the present SMART and newly Sponge City methods. The infographic chart in Figure 2 shows that the majority of respondents chose the Sponge City flood management method (56.4%) as more competitive advantage rather than SMART tunnel (43.6%) for consideration in the implementation of flood mitigation management in Malaysia urbans.

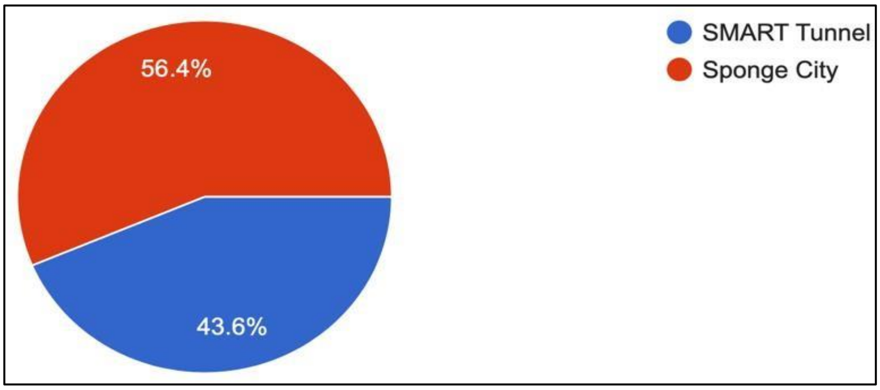

Figure 2. Respondents' opinion on which flood mitigation management amongst the two competing methods that is superior and more competitive advantage

6.0 DISCUSSIONS

The findings of the study have revealed the majority of the respondents have agreed that the top three advantages of SMART tunnel are to improve flood management, to provide environmental and social benefits, and to achieve sustainable development. As mentioned by Azhar et al. (2021), the SMART tunnel has prevented the Kuala Lumpur city from incurring considerable costs of damages to public and private properties, totalling RM100.8 million (about USD 24 million) year or RM1.411 billion (around USD 337 million) since it was operated in 2007 over the course of 14 years. These have proven the important function of SMART tunnel to overcome flash floods in Kuala Lumpur city and surrounding areas, e.g., Masjid Jamek and Dataran Merdeka etc. However, Azhar et al. (2021) contested that the tunnel may not adequate and methodically enough to serve as a long-term and optimal solution to overcome unforeseen flood disaster issues if there is a continuous heavy rainfall events in Klang Valley urban areas.

Meanwhile, for Sponge City, the "high level consensus" with standard deviation score less than 1.00 indicates that the majority of the respondents have mutually agreed that the main advantages of Sponge City are: to provide economic benefits, sustainable development, and environmental benefits. While the highest mean score is to improve flood management. For the economic benefit aspect, these findings support the earlier studies showing that the China's Sponge City strategy helped to reduce flood catastrophes and lower the total life costs associated with city growth (Khor, 2018a, 2018b). The Sponge City system makes use of less expensive green roofs, green revetment, and permeable pavement to increase the effectiveness of rainfall infiltration and avert flood disasters (Nguyen et al., 2020). Hence, these characteristics could help to increase the market value of Sponge City development area. The anticipated construction cost per square kilometre of Sponge City is between 14 and 26 million USD, with the total expenditure is between 0.2 and 1.6 trillion USD (Guotai Junan Securities, 2016 as cited in Su et al., 2020). Although the development cost is high, the nearby commercial and non-commercial properties can be economically and environmentally benefited from the development of green area in Sponge City.

Aside from that, the idea to construct a new SMART 2 tunnel project in Shah Alam that embedded with "Sponge City" is innovative because its hybrid design concept could provide more benefits to the communities living in the low land and floodplain areas rather than the present SMART tunnel. However, it was reported by Gamuda Berhad (2022), the SMART 2 development cost in Shah Alam may require higher budget than anticipated at about RM20 billion. The SMART 2 project in Shah Alam is located in a geographical low land area with high densely populated, therefore a comprehensive feasibility study is demanded to determine the economic sustainability of SMART 2 investment throughout the life span and the relevancy of SMART 2 hybrid design adoption for achieving the following three goal points of Sustainable Development Goals (SDGs):

i. SDG 9: Industry, Innovation, and Infrastructure – innovating flood management strategies through SMART 2
ii. SDG 6: Clean Water and Sanitation – enhancing sustainable environment in SMART 2 application.
iii. SDG 11: Sustainable Cities and Communities – improving lifestyle effectiveness amongst communities through SMART 2 application.

7.0 CONCLUSION

This paper has presented the outcomes of the comparative study between the existing SMART and newly Sponge City concept with specific reference to the issues of urban flash flood and flood mitigation management solution in Malaysia. The results of the study have established that the majority of the respondents proposed the Sponge City as more competitive advantage than the SMART method in overcoming the issues of flood in Malaysia's urban development. Although the development cost will be higher that requires long term studies, land procurement, and dedicated support from the government and stakeholders in the industry, it is not misconception to state that the benefits of Sponge City flood concept outweigh the downsides. Therefore, it could be deemed appropriate for consideration to adopt Sponge City concept into flood mitigation management application in the country. However, it demands a holistic assessment to view the relevancy of SMART 2 tunnel project development, land use planning and operation throughout the investment life cycle for achieving economic sustainability and three goal points of the Sustainable Development Goals (SDGs), i.e., SDG 9: Industry, Innovation and Infrastructure, SDG 6: Clean Water and Sanitation, and SDG 11: Sustainable Cities and Communities. There are limitations encountered in the study that include the limited availability and accessibility of information, and limited number of people that have established expertise and knowledge in Sponge City concept.

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