Journal of Construction in Developing Countries

Manuscript Title	Investigation of Issues in Structural Flood Management Measures in Sri Lanka
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Submitted Date	16-Sep-2020 (1st Submission)
Accepted Date	17-Jan-2021

INVESTIGATION OF ISSUES IN STRUCTURAL FLOOD MANAGEMENT MEASURES IN SRI LANKA

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ABSTRACT

Floods can be identified as one of the devastating natural phenomena, which result a considerable amount of social, economic, and environmental impacts. Sri Lanka is a country that is highly vulnerable to floods due to its unique geographical location and topography. Many flood management measures, which mainly include structural and non-structural have implemented to reduce the impact of floods. Among them, structural measures play a vital role in flood management. However, the failures in achieving the expected performance of these existing structural measures urge the need to identify issues with them and overcome those issues to enhance the flood management process in Sri Lanka. Hence, this study focused to investigate the issues related to structural flood management measures in Sri Lanka to bridge this knowledge gap.

Initially, a literature review was conducted to gain a theoretical understanding of the research area. The research approach was qualitative, which was followed by two in-depth case studies. Semi-structured interviews were conducted with ten industry experts to gather data. Collected data were analysed via content analysis. Empirical research findings revealed that *structural measures play a prominent role in flood management. However, significant issues such as ageing of structural measures, leakages, construction faults, inadequate capacity, blocking of water flow and possibility of collapsing were identified in these existing structural flood management measures, which negatively impact the effectiveness of the overall flood management process within the country. The findings of this study will lead to gain a proper understanding of gaps and weaknesses in structural flood management measures in Sri Lanka and would influence the policymakers and other respective practitioners in disaster management to enhance structural flood management by using their novel ideas and concepts.*

Keywords: *Floods, Flood Management, Structural Measures, Issues, Sri Lanka*

INTRODUCTION

Severe flood events can occur due to various reasons such as heavy rainfalls, inadequate capacity of rivers, low permeability of the soil and insufficient drainage to carry away the excessive rainwater (Murray, 2017). These will lead to serious risks to millions of people and public property in any country (Shah et al., 2019). Hence, flood management is highly necessary to reduce the negative impacts on human life, property, and society (Tingsanchali, 2012). Further, as floods bring a considerable extent of social, economic, and environmental impacts, proper flood management helps to prevent floods from becoming a disaster (Wagenaar et al., 2019). Flood management can be identified as the process of managing floods properly to reduce the flood risks on human lives, and the natural and built environment (Murray, 2017). Different types of methods, namely structural and non-structural measures are used for effective flood management (Salvesen, 2010).

When it comes to the Sri Lankan context, the situation is the same. Sri Lanka can be identified as one of the flood-prone countries because of its unique geographical location and topography (Asian Disaster Preparedness Center [ADPC], 2019). The current situation has become more critical due to different reasons such as deforestation, urbanisation, illegal landfilling, and construction by blocking waterways (Wagenaar et al., 2019). Wickramaratne et al. (2012) stated that 103 river basins can be identified in Sri Lanka, which causes annual floods throughout the country. According to Ministry of Disaster Management [MDM] (2017), flooding is the most common disaster in Sri Lanka than other disasters. Further, a large number of deaths are reported in Sri Lanka annually due to floods (Wickramaratne *et al.*, 2012).

In this context, there is a higher necessity of different types of methods to combat the impact of floods in Sri Lanka. Similar to the global context, in Sri Lanka also both structural and non-structural flood management methods are available. However, the necessity of structural flood management measures is high as they act as a barrier for the spreading of water that would otherwise damage property and lives of the people (Velasco *et al.*, 2016). Further, since structural flood management measures are considered as the physical intervention for flood, for a flood-prone country like Sri Lanka, it is a must to have them in place (CCI, 2017).

Despite the importance, different issues have been raised with regard to the existing structural measures in Sri Lanka (Mudalige, 2011). As revealed by Mudalige (2011), the risk of floods has been highly increased due to the poor performance of structural flood management measures. This urges the need to investigate the issues in structural flood management measures in detail to take appropriate actions to improve their performance. Even though there are studies related to flood management (Palliyaguru and Amaratunga (2008), Wickramaratne *et al.* (2012), CCI (2017) and Wagenaar *et al.* (2019)), none of them have focus on the structural flood management in Sri Lanka. Hence, there is a dearth of knowledge in the area of structural flood management in Sri Lanka. This paper, therefore, aimed to investigate the issues related to structural flood management measures in Sri Lanka.

LITERATURE REVIEW

Floods can be identified as overflowing and rising water onto dry land (Emberga, 2014). Indeed, floods are considered as a general and temporary condition in dryland areas, in which the inland water overflows due to the rapid increase of water (Sivakumar, 2016). Wagenaar et al., (2019) identified floods as one of the significant environmental crises because of their severe impact on human activities and the environment. Floods can happen in different ways due to various reasons (Salvesen, 2010). Many short-term and long-term reasons can affect the occurrence of floods in any area (Emberga, 2014). In the hydrological terms, flooding can be identified as a natural phenomenon; nevertheless, human activities and socio-political factors also contribute to flooding (Adekola & Lamond, 2017). When moving to the Sri Lankan context, the situation has become more critical because flood events highly occur throughout the year (Sivakumar, 2016). Guruge (2017) further strengthened the crucial situation by stating that 15 of 25 districts in Sri Lanka are affected by severe floods due to the heavy rainfall from monsoons every year. According to MDM (2017), the majority of people are affected by floods in Sri Lanka during two monsoon seasons, which affect the country throughout the year.

Flood management can be effectively achieved with the combined use of non-structural and structural measures (Shah *et al.*, 2017). Non-structural measures refer to the methods, which can be used to reduce the damages from floods by not involving physical constructions but implementing different types of precautions (Bridges, 2014). These measures include flood forecasting and warning, establishing laws and regulations, reconstruction and rehabilitation planning, flood insurance system and flood-related databases (Kang, Lee and Lee, 2018). Although the non-structural measures can be identified as effective flood management methods, they would be less successful without improving structural measures (Heidari, 2009). According to Salvesen (2010), structural measures seek to reduce the impact of floods, while non-structural measures seek to keep people away from the floods. Therefore, rather than keeping people away from the hazard, it is better to move or tame the water flow to a considerable level with reduced risk. Therefore, it is obvious that implementing structural measures plays a vital role in flood management (Salvesen, 2010). Various structural measures developed nowadays for flood management can be identified as dams, reservoirs, levees (bunds), floodwalls, diversions, drainage systems, and channel improvements (CCI, 2017).

Although these structural measures stand for effective flood management within the country, presently their performance has become slightly poor due to many types of issues involved (JICA, 2013). As further stated by the study, ageing of the structural measures with time mainly leads to extensive damages and losses during floods. Some of these structural measures desperately need replacements or rehabilitations to ensure their functions in the event of a flood, as most of them were implemented before the 1980s (JICA, 2013). Moreover, a study by Wickramaratne et al. (2012) mentioned that the non-functionality of some structural measures encourages the possibility of turning flood events into major disasters. They also argued that the inadequacy of structural flood management measures within the country has discouraged the performance of overall flood management process as the flood occurrence in Sri Lanka is significantly high. Accordingly, it is obvious that different issues can be identified with existing structural flood management measures resulting poor performance of them. This situation severely affects the entire flood management process within the country and therefore, it emphasises the need to investigate and overcome those issues in a detailed manner.

METHODOLOGY

When considering the research philosophy, three types of assumptions can be identified as epistemology, ontology and axiology (Smith, Thorpe and Lowe, 2012). This study requires to investigate the issues pertaining to existing structural flood management measures in Sri Lanka. In order to fulfil this aim, it is needed to explore the ideas regarding types of structural flood management methods available in Sri Lanka and their issues from people, who are involved in flood risk management. Accordingly, this research takes social constructionism as the epistemological assumption of this study. Further, as the investigation of issues in existing structural measures were conducted in its everyday setting, this study favours the idealistic nature under the ontological assumption. Furthermore, the nature of the subject matter requires the researcher to be undertaking, where the subject matter is analysed by the researcher by being a part of the study (Saunders, Lewes and Thornhill, 2009). As the nature of the study required to conduct an in-depth inquiry on the issues related to structural measures and the possible ways of improving them, qualitative research approach has been followed. Within the qualitative research approach, as the researcher acquired and interpreted the data, value-laden stance was taken in terms of the axiological assumption.

The research under consideration focuses on a contemporary phenomenon (i.e. investigating issues with existing flood management measures) and the researcher does not aim to control the behaviour or perceptions concerning the phenomenon. Accordingly, as asserted by Yin (2015), case study research strategy is more appropriate for such research. Case selection for a case study need to be theoretical since case studies enable to build novel theoretical versions by theoretical analysis of cases (Brereton *et al.*, 2008). In this study, since the study has performed in flood-prone areas, multiple case studies have been carried out by selecting two cases (refer to Table 1). Flood-prone areas were selected as the case study boundary for this study. Accordingly, structural flood management measures used within the selected flood-prone areas have been identified as the unit of analysis of this study. Two different geographical areas that have been identified as the main flood-prone areas in Sri Lanka were selected as the case studies. The profile of the cases is presented in Table 1.

Table 1: Profile of the Cases

	CASE A	**CASE B**
District	Colombo District	Matara District
Description	A highly urbanised area with some rural areas	Consists with many rural areas and some urbanised areas
Population	Approximately 2.5Mn	Approximately 1Mn
Area	Approximately 700km2	Approximately 1300km2

Semi-structured interviews were identified as the most appropriate method to gather data for this study because of the flexibility they provide the researcher to research in an in-depth manner. Purposive sampling was used to select most knowledgeable respondents within the selected cases (Creswell, 2007). Due to the data saturation (Faulkner and Trotter, 2017), data collection was limited for a sample size of 10 respondents. Respective managerial personnel were interviewed over the operational level personnel from the two case studies to gather strategic viewpoints (refer to Table 2). As stated by Saunders, Lewes and Thornhill (2009), a study can cross sectional or longitudinal in terms of the time horizon. As this study was conducted within a single point of time, it belongs to cross sectional studies.

Table 2: Profile of the Respondents

CASE	RESPONDENT	DESCRIPTION
Case A (Colombo District)	A1	Research Engineer with 5 years work experience in the industry
	A2	Civil Engineer with 8 years work experience in the industry
	A3	Civil Engineer with 10 years work experience in the industry
	A4	Senior Engineer with 13 years work experience in the industry
	A5	Technical Officer with 10 years work experience in the industry
Case B (Matara District)	B1	Divisional Irrigation Engineer with 10 years work experience in the industry
	B2	Civil Engineer with 9 years work experience in the industry
	B3	Chief Irrigation Engineer with 22 years work experience in the industry
	B4	Technical Officer with 8 years work experience in the industry
	B5	Technical Officer with 5 years work experience in the industry

In addition to the interviews, documentary reviews were carried out as a supplementary data collection method (Yin, 2015) within the case studies to support the viewpoints of the respondents. Document reviews were carried out mainly to familiarise with the existing situation with regard to the case studies. Accordingly, annual reports and survey documents related to structural flood management of the case studies were referred.

Content analysis, which was identified by White and Marsh (2006) as a research technique of developing replicable and valid inferences through the text, has been adopted in this study to analyse data. In content analysis, there are different categories of coding namely, open coding, axial coding, and selective coding (Cho and Lee, 2014). As further mentioned by them, open coding refers to the first level coding of examining, conceptualising, and categorising the collected data, where the axial coding refers to deriving themes by grouping the similar interpretations discovered in level one. Selective coding includes derived key themes from the analysis of axial coding. Further, coding can be carried out inductively (inductive coding) by deriving codes with prior establishment of categories based on the research area or deductively (deductive coding) by deriving codes from the data itself (Kulatunga, Amaratunga and Haigh, 2007).

In this study, firstly, the data gathered through semi-structured interviews were transcribed. Thereafter, main themes were identified by carefully examining the interview transcripts as open coding. Subsequently, main themes were further categorised into themes assigned with an axial code, with the use of both deductive and inductive coding. That means that some themes were derived by comparing with literature following deductive coding and other themes were derived from the data itself following inductive coding. Coding was continued until no new codes emerged through the findings. According to Zamith and Hermida (2013), manual content analysis is regarded as a better way to handle manageable datasets. As ten (10) interviews were carried out within the study, manual content analysis was used as the data analysis technique. Further, the use of manual content analysis provided the opportunity for the researcher to be more familiar with the data set.

CASE STUDY FINDINGS AND ANALYSIS

Case Study Backgrounds

Case A is based on the Colombo Metropolitan area. Reviewing existing survey documents revealed that Colombo has been more vulnerable to flooding since it consists of many areas with low-lying land. In this area, riverine floods occur annually, when heavy rains affect the river streams and urban areas due to southwest monsoons. These riverine floods especially occur due to the overflowing of water in the Kelani river and Diyawanna Oya. The same situation can be identified in Case B, where riverine floods have become the most common type of flood, resulting primarily due to the overflowing of the Nilwala river. Accordingly, riverine flood occurrence in both areas is at the same level due to the frequent rainfall for the river areas of the selected cases. However, the situation is somewhat different with local floods. In both cases, these local floods have occurred mainly in urban areas. As Case A is more urbanised than Case B, the possibility of occurring local floods is considerably high in Case A. Therefore, although the same types of floods have happened in both cases, the way of occurring floods is somewhat different based on the urbanisation level of the two areas. The factors above prove that the overall flood occurrence in both areas is significantly high. Therefore, it can be argued that it is very imperative to have structural flood management measures in both areas to reduce flood risks.

Since Case A is a highly urbanised area than Case B, the damages resulting from flood events can be significantly high in Case A. That means that even minor flood events can lead to extensive damages and losses. This was endorsed by the findings from document reviews as well. Thus, proper flood management is essential. In Case B, this situation can be identified from a different perspective. The livelihoods of the people in both cases can vary due to the diversity of their lifestyles. People who cultivate are more in Case B than Case A. These cultivations are mostly done in downstream areas that are positively affected by floods. Therefore, any flood event in these areas can lead to a considerable amount of losses due to the inundation of these cultivations. Accordingly, though the urbanisation level of Case B is not the same as Case A, the impact of floods is significantly high and it elaborates the critical need for mitigating floods in Case B.

Even though the non-structural measures and some structural measures are implemented in both cases, they are not sufficient to mitigate the impact of floods. This indicates the importance of the need for effective structural flood management measures for both cases. Proper flood management can be successfully achieved with the presence of adeqaute performance of structural measures. Consequently, it can be argued that the necessity of having structural measures is essential for effective flood management in any flood-prone area of the country.

Existing Structural Measures in Selected Cases

In Case A, different types of structural measures were identified by the respondents as follows. According to A1, levees, flap gates (flood gates), pump houses, and drainage systems were identified as the most common structural measures. Accordingly, different types of levees are located in line with the Kelani river in Case A. Regarding the levee construction, pump station was identified as another structural measure in Case A. Pump station constructed at St. Sebastian South Canal near Maradana was identified as an example by the respondents in Case A. adding to this, flood control gates were also identified as another common structural measure in Case A. A3 commented that malfunctioning of flap gates could result in seepage of water to the canal leading to water overflowing. Also, as local floods are widespread in Case A, it is vital to have a proper drainage system as a structural measure in this area because they are highly beneficial in local flooding to immediately discharge the storm-water after a rain.

As further stated by A2, underground flood tunnels and bottle-neck removing are not common structural measures, but they are also constructed for flood mitigation with the requirement. That means these structural measures are being built with the situation and the need for flood mitigation. For example, underground flood tunnels are usually constructed in urban areas, where there is no space for surface canals or storm-water channels. Therefore, they are highly appropriate for flood mitigation in Case A since local floods are most common in this area. Torrington tunnel, which runs along Bauddhaloka Mawatha, was identified as an example of such an underground flood tunnel. Further, bottle neck removing is done by considering the river area's location as a specific aspect of channel improvement.

A3 and A5 identified canal diversions as another critical structural measure, referring to Kolonnawa canal diversion. It is constructed to mitigate flood events during periods of high water levels in Kelani river. Moreover, as mentioned by A4, gabion walls were identified as another type of structural measure in Case A. Although they are purposely constructed as retaining structures for soil stabilisation in riverbanks, they can also be identified as a structural measure for flood mitigation because they act as a type of flood-wall during floods.

In Case B, flap gates, pump houses and flood bunds were identified as the most common structural measures for flood management, as disclosed by B1. As the occurrence of the riverine floods in Case B is considerably high, flap gates are constructed as a structural measure to mitigate floods. Flap gates constructed in Nilwala river in Akuressa area can be identified as an example. Flood bunds were also identified as one of the main structural measures for flood mitigation in Case B. Nadugala and Piladuwa bunds are examples of such flood bunds. In line with flood bunds, pump stations are constructed in Case B, similar to Case A. As per the views of the respondents, such a pump station can be seen in Thudawa area. Moreover, as stated by B3 and B5, drainage systems are constructed as structural measures to reduce the storm-water and water runoff from domestic and industrial works, similar to Case A. Additionally, spill paths were also identified as one of the important structural measures for flood mitigation in Case B, especially at the occurrence of riverine floods, common in Case B, as stated by B2.

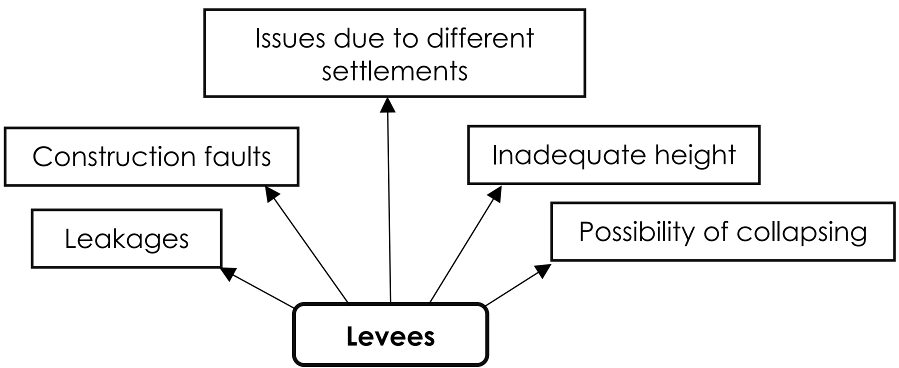
Issues in Structural Measures and their Impact on Flood Management Process

After identifying the currently available structural measures for flood management in both cases, issues regarding those structural measures were properly investigated to understand the impact of those issues on the entire flood mitigation process.

In Case A, different issues were identified by the respondents with regard to current structural measures adopted. Drainage systems can be blocked due to various human activities and natural causes. As a result, excessive flow of water together with heavy rain causes immediate local flood events. Also, issues can arise for the structural measures due to different settlements in the area. As being a highly urbanised area, this has become more popular in Case A. It can be considerably identified, especially regarding flood bunds. Flood bunds can get damaged in numerous ways due to many constructions and settlements, resulting in poor performance. It is hard to retain water due to these settlements resulting in water overflowing. Leakages and construction faults are common issues with regard to levees, which result unexpected flood events. Also, lack of proper maintenance may lead to collapsing or breaching of levees due to heavy rain, and water can overflow, causing unexpected flood events for the opposite side of the bund. The respondents further identified the inadequate capacity of pump stations as another prominent issue in structural measures in Case A. It affects the rate of floodwater discharge in a severe flood event. As a result, flood water may remain for an extended period in a relevant area, causing more damage. Another issue, identified through data collection, is the non-functioning of flap gates. If the flap gates are not functioning correctly, canals can overflow due to heavy rains, resulting in major flood events. Further, two main issues were identified regarding flood tunnels, namely sand filling and blocking of water inside tunnels. If these issues occur, excess water flow through the tunnels can interrupt, and water can overflow resulting in unexpected flood events. Accordingly, due to the aforementioned issues of the structural measures in Case A, the flood mitigation process is not adequately performed resulting in extensive damages and losses.

The situation is the same in Case B, the situation is same as with Case A. According to the respondents, blocking of flap gates, inadequate capacity of pump stations, and blocking of drainage systems can be identified as the issues regarding existing structural measures in Case B similar to Case A. Additionally, not having the correct height to control floods was identified as another issue regarding flood bunds. When there is no adequate height for flood bunds, it causes flood events in protecting areas of the flood bunds. Hence, it can be a massive disaster as these floods affect vast areas resulting in many losses of human lives and inundation of properties.

Consequently, a number of issues can be identified in both cases regarding the existing structural measures due to different reasons and those issues can be summarised as illustrated in Figure 1.



DISCUSSION

Issues in structural flood management measures in Sri Lanka were investigated through this study to enhance the structural flood management measures for effective flood management. Existing structural flood management measures in Sri Lanka and their issues were identified during the study through a comprehensive literature review and two main case studies to provide recommendations with regard to implementing structural flood management measures.

By reviewing literature, the importance of having structural flood management measures was identified in a detailed manner. Those findings were in general, applicable to the Sri Lankan context as well. As disclosed by Wagenaar *et al.* (2019), floods can be identified as one of the major environmental crises that cause severe social, economic, and environmental impacts. This was further proven through the case study findings, where significant human and property damages occur due to floods throughout the year in Sri Lanka. Therefore, the need for proper flood management was evidently witnessed through the empirical research findings. Structural measures, which control the water flow floods and non-structural measures, which keep the people away from floods, are used for effective flood management, as revealed through the study. However, Salvesen (2010) pointed out that controlling water flow during flood events is more important than keeping people away from floods to reduce the risk. Accordingly, it is witnessed that structural measures play a prominent role than non-structural measures in flood management. Also, having identified the need for structural measures for selected cases, the case study findings proved that structural measures are crucial for effective flood management in any flood-prone area of the country.

For the existing structural flood management measures in Sri Lanka, many types of structural measures were identified through literature findings and case study findings (refer to Table 3). When mapped with literature findings, dams, levees, flood walls, diversions, drainage systems, and channel improvements were identified as existing structural flood management measures (CCI, 2017). Adding to this, the empirical data analysis newly identified structural measures such as flap gates, pump stations, flood tunnels, bottleneck removing, spillways, and gabion walls. Furthermore, both literature and case study findings revealed many issues concerning structural measures. Based on the literature findings, the non-functionality of structural measures, inadequate structural measures, and ageing of them with time were identified as the main issues of the existing structural measures in Sri Lanka. Within the global context, also aforementioned issues were identified in structural flood controlling measures. For example, Aerts (2018)'s study revealed that the lack of functioning of drainage systems had created extensive damages and losses in the events of floods in Vietnam. Further, according to Noshin *et al.* (2018) and Myers and White (2010), the ageing of structural measures is one of the main issues in flood bunds in Mississippi river basins. Additionally, several newly identified issues related to structural flood control measures emerged from the case study findings (refer to Figure 1). They include blocking water flow, sand filling, inadequate capacity, the possibility of collapsing, insufficient height, construction faults, leakages, and issues due to unauthorised settlements. Accordingly, flood management process through the structural measures has become less effective in the selected cases due to these issues. Thus, the impact of floods has become more critical today, with the absence of effective structural flood management.

All the aforementioned findings from both literature review and data analysis can be tabulated as shown in below Table 3.

Table 3: Summary of literature and case study findings

Existing Structural Measures	Issues of Structural Measures
• Dams	• Aging of structural measures with the time
• Levees	• Non-functionality of structural measures
• Flood Walls	• Inadequate structural measures
• Diversions	• Blocking of water flow
• Drainage Systems	• Sand filling
• Channel Improvements	• Inadequate capacity of structural measures

• Flood Control Gates	• Possibility of collapsing
• Pump Stations	• Inadequate height of structural measures
• Flood Tunnels	• Construction faults
• Bottleneck Removing	• Leakages
• Spillways	• Issues due to unauthorised settlements
• Gabion Walls	

Literature Findings

Newly identified factors through case study findings

Moreover, as per the case study findings, the proposed recommendations to overcome the identified issues in structural flood management measures can be discussed as follows.

Implementing proper maintenance for the existing structural measures is particularly important to enhance their functionality by reducing possible issues. This includes carrying out relevant repairs, replacements, and rehabilitations for the structural measures according to the requirements. New monitoring and controlling systems can also be introduced for some structural measures to identify their existing issues. As insisted by the respondents, such monitoring and control systems can be used for structural measures like pump stations and flood control gates. Another proposed recommendation is establishing new rules and regulations for structural measures. Such kind of rules and regulations will significantly reduce the possibility of forming different issues. Further, new technologies and improved technical skills of the workers can be used to implement structural measures, and those can be designed for a higher return period of floods. Following these recommendations, the currently available issues regarding structural measures can be significantly reduced for an effective flood management process.

Those proposed recommendations can be illustrated as shown in Figure 2.

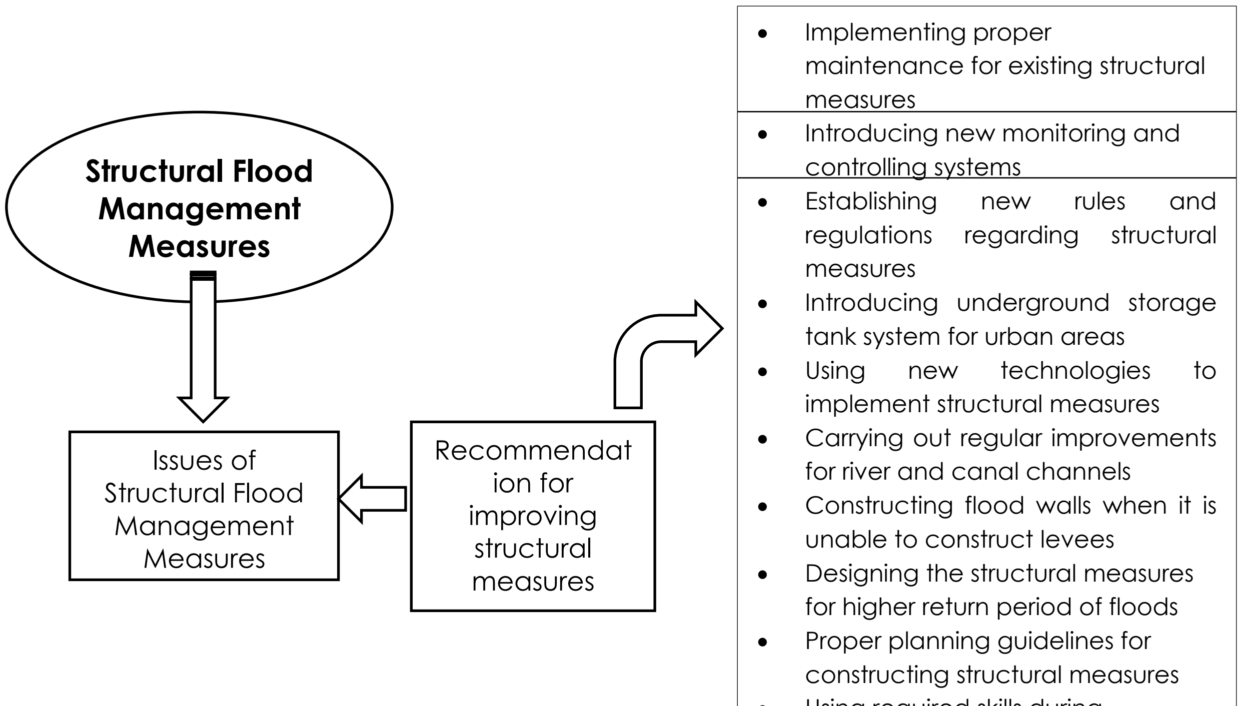


Figure 2: Recommendations for improving structural flood management measures

CONCLUSION

This study aims to investigate the issues related to structural flood management measures in Sri Lanka. As identified in both literature review and empirical data, Sri Lanka, being a flood-prone country, has a significantly high occurrence of floods due to many reasons. Every year, it causes considerable social, economic, and environmental impacts. In this context, flood management has become one of the priorities in the country. The study revealed that different structural and non-structural measures are used for flood management in Sri Lanka. Among them, structural measures play a vital role in the flood management process. Accordingly, various types of structural measures identified in Section 2 and Section 4.2 are implemented in Sri Lanka to mitigate the impact of flood events. However, the current flood management process has interrupted in a significant manner increasing the impact of floods day by day due to the poor performance of existing structural measures, as emerged through the study. This poor performance of structural measures has resulted due to many types of issues with them. This urged the need for investigating these issues in a detailed manner to enhance the flood management process by overcoming them. Accordingly, identified issues range from ageing of structural measures, non-functionality of structural measures, inadequate capacity, blocking water flow, leakages, construction faults, sand filling, inadequate height, and the possibility of collapsing (refer to Table 3). Finally, recommendations were proposed with the prospect of overcoming the above-identified issues in structural flood management measures to enhance the entire flood management process in Sri Lanka. Those proposed recommendations mainly include implementing proper maintenance plans, introducing new monitoring and controlling systems, establishing new rules and regulations, using new technologies, developing proper planning guidelines, and improving technical skills. The findings can be assisted by key policymakers in many ways to develop relevant policy mechanisms to attain effective preparedness during floods. On the whole, the findings of this study would influence on many respective industry practitioners to enhance the structural flood management in Sri Lanka by identifying and overcoming the issues and weaknesses of existing structural measures and fulfil the needs of the most vulnerable people for floods.

Although researches related to flood management is abundant, the literature on structural flood management pertaining to the Sri Lankan context is scarce. Therefore, this study contributes to the literature on enhancing structural flood management measures in Sri Lanka in a broader view. Further research directions are also available relating to the knowledge generated through this study.

REFERENCES

Adekola, O., & Lamond, J. (2017). A media framing analysis of urban flooding in Nigeria: current narratives and implications for policy. Cross Mark. https://doi.org/10.1007/s10113-017-1253-y

Aerts, J. C. J. H. (2018) 'A review of cost estimates for flood adaptation', *Water*, 10. https://doi.org/10.3390/w10111646.

Asian Disaster Preparedeness Center [ADPC] (2019) *Disaster Risk Reduction in Sri Lanka*. Bangkok.

Brereton, P. *et al.* (2008) 'Using a Protocol Template for Case Study Planning', in *12th International Conference on Evaluation and Assessment in Software*. Italy.

Bridges, D. (2014) 'Non-structural measures for water management problems', in Simonovic, S. P. (ed.) *Proceedings of the International Workshop*, pp. 471–475. https://doi.org/10.1007/978-94-007-6809-3_62.

Chamber of Construction Industry [CCI] (2017) *Seminar on Flood Control & Disaster Responsiveness in Proposed Western Megapolis*. Colombo.

Cho, J. Y. and Lee, E.-H. (2014) 'Reducing confusion about grounded theory and qualitative content analysis: similarities and differences', *The Qualitative Report*, 19(32), pp. 1–20. Available at: https://nsuworks.nova.edu/tqr/vol19/iss32/2?utm_source=nsuworks.nova.edu%2Ftqr%2Fvol19%2Fiss32%2F2&utm_medium=PDF&utm_campaign=PDFCoverPages.

Creswell, J. W. (2007) *An Introduction to Mixed Methods Research*. Umiversity of Nebraska. Available at: https://sbsrc.unl.edu/Introduction to Mixed Methods.pdf.

Doswell, C. A. (2003) 'Flooding', pp. 769–776.

Emberga, T. (2014) 'An Assesment of causes and effects of flood in Nigeria', *Standard Scientific Research and Essays*, 2(7), pp. 307–315.

Faulkner, S. L. and Trotter, S. P. (2017) 'Data Saturation', in. United States. doi: https://doi.org/10.1002/9781118901731.iecrm0060.

Heidari, A. (2009) 'Structural master plan of flood mitigation measures', *Natural Hazards and Earth System Sciences*, 9(1), pp. 61–75. https://doi.org/10.5194/nhess-9-61-2009.

Japan International Cooperation Agency [JICA] (2013) *Data Collection Survey on Disaster Management Program in Sri Lanka*.

Kang, S., Lee, S. and Lee, K. (2018) 'A Study on the Implementation of Non-Structural Measures to Reduce Urban Flood Damage - Focused on the Survey Results of the Experts'. https://doi.org/10.3130/jaabe.8.385.

Kulatunga, U., Amaratunga, D. and Haigh, R. P. (2007) 'Structuring the unstructured data: the use of content analysis', pp. 498–509.

Ministry of Disaster Management [MDM] (2017) *Sri Lanka Rapid Post Disaster Needs Assesment; Floods and Landslides*. Colombo.

Mudalige, J. (2011) *Comparison Study of Existing Flood Research Activities :*

Murray, A. (2017) *Natural Flood Management Adopting ecosystem* *approaches to managing flood risk*. Dublin 2.

Myers, M. F. and White, G. F. (2010) 'CHALLENGE O F TI-', 35(10), pp. 37–41. https://doi.org/10.1080/00139157.1993.9929131.

Noshin, S. *et al.* (2018) 'Stability analysis of flood bunds : A study on geotechnical health evaluation of embankments', in *IOP Conf. Series: Materials Science and Engineering*. https://doi.org/10.1088/1757-899X/414/1/012035.

Palliyaguru, R. and Amaratunga, D. (2008) 'Managing disaster risks through quality infrastructure and vice versa', *Structural Survey*, 26(5), pp. 426–434. https://doi.org/10.1108/02630800810922766.

Salvesen, D. (2010) 'Structural Approaches to Flood and Coastal Hazard Mitigation; Assessing Structural Approaches', *Breaking the Disaster Cycle: Future Directions in Natural Hazard Mitigation*, (6). Available at: https://www.hsdl.org/?view&did=471126%0A.

Saunders, M., Lewes, P. and Thornhill, A. (2009) *Research methods for business students*. 5th edn. New Delhi: Dorling Kindersely (PVT) Ltd.

Shah, A. A. *et al.* (2017) 'Determinants of flood risk mitigation strategies at household level: a case of Khyber Pakhtunkhwa (KP) province, Pakistan', *Nat Hazards*, 88, pp. 415–430. https://doi.org/10.1007/s11069-017-2872-9.

Shah, A. A. *et al.* (2019) 'Factors affecting flood-induced household vulnerability and health risks in Pakistan: The case of Khyber Pakhtunkhwa (KP) Province', *International Journal of Disaster Risk Reduction*. doi: https://doi.org/10.1016/j.ijdrr.2019.101341.

Sivakumar, S. S. (2016) 'Flood mitigation strategies adopted in Sri Lanka', *International Journal of Scientific & Engineering Research*, 6(2).

Smith, M. E., Thorpe, R. and Lowe, A. (2012) *Management Research: An Introduction*. 4th edn. London, England: SAGE Publication Ltd. Available at: https://books.google.lk/books?id=EczlVa2192gC&pg=PA13&source=gbs_toc_r&cad=4#v=onepage&q=philosophy&f=false.

Velasco, M. *et al.* (2016) 'Assessment of the effectiveness of structural and nonstructural measures to cope with global change impacts in Barcelona', *Journal of Flood Risk Management*. https://doi.org/10.1111/jfr3.12247.

Wagenaar, D. J. *et al.* (2019) 'Evaluating adaptation measures for reducing flood risk : A case study in the city of Colombo , Sri Lanka', *International Journal of Disaster Risk Reduction*, 37, pp. 101–162. https://doi.org/10.1016/j.ijdrr.2019.101162.

White, M. D. and Marsh, E. (2006) 'Content analysis: A flexible methodology', *Library Trends*, 55. https://doi.org/10.1353/lib.2006.0053.

Wickramaratne, S. *et al.* (2012) 'Ranking of natural disasters in Sri Lanka for mitigation planning', *International Journal of Disaster Resilience in the Built Environment*, 3(2), pp. 115–132. https://doi.org/10.1108/17595901211245198.