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ASSET MANAGEMENT USING PESTLE-SWOT ANALYSIS: STRATEGIC ASPECTS FOR INTEGRATED DAM CATCHMENT MANAGEMENT

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Abstract

Dam is generally utilised for flood control, water supply, recreation, and minimising the effects of increasing runoff due to changes in land use brought about by real estate developments. However, it is found that current work practice is only focusing on dam's operations and overlook on the dam catchment activities such as land encroachment, land use activities, and other possibility of being polluted by surrounding land use activities. Due to various activities surround catchment, it is important for management to discover strategic aspects for integrated dam catchment management to ensure any issues pertaining catchment area are integrated into the planning process. Therefore, this study aims to discover strategic aspects for dam catchment management to be more integrated in managing dam assets including its land and buildings using PESTLE-SWOT analysis. A mixed-method approach is adopted, involving focus group discussions with stakeholders and analysed using content analysis and descriptive analysis. The findings highlight technological and legal factors as the most critical dimensions for ensuring long-term dam sustainability and effective governance. This study provides a framework that bridges dam operations, asset management, and environmental planning, contributing to more resilient and sustainable dam catchment management practices aligned with national water resource and sustainability goals.

Keywords: Dam catchment, asset management, PESTLE-SWOT, real estate

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INTRODUCTION

Real estate covers a huge scope of functions, including operational real estate. Within Malaysian context, Machap Dam is owned by the government which has prompted to manage their assets in a more systematic and effective way since their operations plays a significant role in the infrastructure of the Johor state and brought impacts on the state's economy and its inhabitants. Generally, Machap dam is utilised for flood control, water supply, recreation, and minimising the effects of increasing runoff due to real estate developments. In this context, dam can be considered as an entity of physical asset that can create, sustain, or destroy values at any stage in its life cycle.

Apart from the benefits, there is also a possibility where the water can be polluted due to human activities on land which could create dam issues, especially from the land use activities (Ayman, 2021; Yaacob, 2021). The complexity of managing these assets that lies in their engineering operations have overlook on the supervision of the land and ecosystem that surrounds them, which are often subject to competing land uses, encroachment, and environmental degradation. This concludes that dam catchment activities also need to be monitored to avoid any possibility of being polluted by surrounding land use activities, while making its communities a part of the overall effort through a structured SWOT analysis (Ghorbani & Hamidifar, 2021), complemented by a PESTLE framework to assess the external opportunities and threats (Srdjevic et al., 2012; Buye, 2021).

This supports Malaysia's Twelfth Malaysia Plan (2021–2025), the National Water Resources Policy (2012), and the Malaysia Dam Safety Management Guidelines (2017) by employing PESTLE–SWOT framework that allows policymakers to systematically link macro-environmental drivers such as political, legal, economic, social, technological, and environmental factors with operational realities at the site level including its building and land. This integration enhances the government's capacity to align dam management practices with broader national sustainability objectives such as the Sustainable Development Goals (SDG 6: Clean Water and Sanitation) and Malaysia's National Water Sector Transformation 2040 (WST 2040) agenda. In a meantime, Ijlil et. al (2025) highlighted that Integrated Water Resources Management (IWRM) is a crucial process for sustainable and equitable water resource use, by using SWOT analysis to reveal the current water management framework, including local stakeholders' perceptions.

From this, there is a urgent need for the government to implement specific measures to maximise the management effectiveness of its assets by establishing specific department of units to control or supervise management functions relating to real estate assets (Abdullah et al., 2011). Dam asset management involves the systematic evaluation of dams as physical assets,

considering their lifespan, criticality, operational history, maintenance, and long-term financing (Quader & Kabir, 2025). It concludes that role of dam asset management in supervising an assets and involvement of day-to-day operations at the site surround dam catchment area is significant to identify possibilities of risk or problem that bring negative impacts to all parties concerned related to dam catchment.

As it is advisable to integrate asset management to apply a holistic planning on the preservation of an asset throughout its whole life cycle, it is important for management to discover strategic solutions for integrated dam catchment management as part of a preventive measures and holistic approach in ensuring any issues pertaining to catchment area are integrated into the planning process. Therefore, this study aims to discover dam catchment management to be more integrated in managing dam assets including its land and buildings using PESTLE-SWOT analysis. There are two objectives outlined in this study which are 1) To identify PESTLE factor towards dam catchment management, and 2) To assess PESTLE-SWOT effect for integrated dam catchment management. Overall, this study is significant in bridging the gap between dam operations and dam assets governance including its land and buildings through a multi-dimensional analytical framework.

LITERATURE REVIEW

Dam Management Guidelines

In Malaysia, Department of Irrigation and Drainage (JPS) has established a national guideline on dam safety management for a safe governance of dams and resilient community surrounding the dams in Malaysia, which is Malaysia Dam Safety Management Guidelines (MyDAMS) in 2017. This guideline includes dam safety aspects comprising legal requirements, potential hazards, safety principles, safety management system, investigation, design, construction, commissioning, operation and maintenance, surveillance and safety review, rehabilitation, emergency preparedness, changes and decommissioning of dams.

To add, MyDAMS also noted the encouragement of dam owners to view proper dam safety management as a key element of their overall risk and asset management strategies whilst must be sustained since it is an important long-lasting asset to the society. However, Toh et al. (2020) in their study highlighted that there is still a major gap towards MyDAMS implementation into the dam industry and proposed a way forward framework to be carried out with various stakeholders.

Apart from that, Finland, New Zealand, Auckland also have established dam safety guidelines namely as Dam Safety Guide (2012) produced by the Centres for Economic Development, Transport, and the Environment, Dam Safety Guidelines (2015) published by the International Commission on Large

Dams (ICOLD), as well as Dam Safety Guidelines published by Auckland Regional Council (n.d.), respectively. All guidelines are also highlighted dam safety aspects comprising legal requirements, potential hazards, safety principles, safety management system, investigation, design, construction, commissioning, operation and maintenance, surveillance and safety review, emergency preparedness, and lifecycle management.

However, Okhovat (2021) claimed that there is a gap pertaining to New Zealand Dam Safety Guidelines whereby there is absence of comprehensive legal binding scheme to monitor and maintain the structural integrity of dams. Furthermore, the dam assets in Finland are believed to ageing and more education relating to dam safety is needed to upgrade and improvise the dam development (Isomaki, 2021). From this point of view, these scenarios contribute to the advancement of strategic planning in sustaining the existing dam by appointing an asset manager to handle, control, and conduct dam work practices to achieve dam owner's goal.

PESTLE-SWOT Analysis Relating to Dam Operations

In the process of decision making and the development of strategic plan, it is important to identify key elements that affects the business or situation. As claimed by Gurel (2017), SWOT and PESTLE analysis provide highly effective analysis tools which could assist an organisation during the process of strategic planning development. SWOT analysis could interpret the findings for the business to determine the strengths and weaknesses, as well as opportunities and threats. As for the PESTLE analysis, it considers the broad environmental context that affects the business and the changes occur which aims to guide the planning and strategic decision making, as well as to determine the potential issues or events that could impact the organisations (Buye, 2021).

PESTLE analysis facilitates the inclusion of diverse stakeholder perspectives by highlighting the social and political dimensions of dam management. This engagement is crucial for achieving consensus and ensuring that the decisions made are socially acceptable and politically feasible (Song et al., 2021). Economic and financial factors identified through PESTLE analysis also could assist in assessing the cost-effectiveness of different management strategies. This includes evaluating the long-term financial implications of maintenance, rehabilitation, and potential upgrades or decommissioning of dams (Anggarini et al., 2022; Quader & Kabir, 2025). This could be simplified that SWOT and PESTLE analysis significantly enhances decision-making in dam asset management by providing a structured approach to evaluate a wide range of factors. This comprehensive analysis ensures that decisions are well-informed, balanced, and sustainable, ultimately leading to improved management and operation of dam assets.

There are several studies focusing on SWOT analysis which has been applied in real estate asset management field, especially relating to dam as report in various case studies. For instance, SWOT is used to examine factors of development strategies of the rubber dams (Ghorbani & Hamidifar, 2021), evaluate the potential for SWOT data to improve reservoir operations in the upper Niger river basin (Munier et al., 2014), as well as determine the management strategy of Rendani River catchment area, Indonesia (Sadsoeitoeboen et al., 2021).

However, there is synergy between SWOT and PESTLE which provides an extensive and more accurate analysis of a complex system and its multidimensional interaction with the environment. For example, Vorthman (2008) argues that SWOT serves to recognise the positive and negative internal and external factors of a system, but that it is necessary to use PESTLE for any further analysis of these factors.

Previous study by Srdjevic et al. (2012) performed an approach for specific class of management of water problems. In their study, SWOT-PESTLE analysis is used and has been evaluated by invited expert to discover the internal and external environment. All aspects of the problems and factors is considered according to the domain factor of the effects including political, economic, social, and so forth that could be applied to real-life problem. The obtained SWOT-PESTLE analysis is then representing the possible criteria for multicriteria analysis which is one of the approaches to favour the factors to maximise the opportunities and minimise the weaknesses in the hydro system. The result revealed the top ranked factors based on SWOT-PESTLE analysis which aimed to select the best practice during the decision-making process.

Within Malaysia context, none of related studies considering SWOT-PESTLE approach in day-to day decision making and operation context with stakeholders. It can be seen that there is still a major gap towards MyDAMS implementation into the dam industry and proposed a way forward framework to be carried out with various stakeholders (Toh et al., 2020).

Since PESTLE analysis provides an effective tool to analyse the catchment and other external environmental factors that will influence the business, the domain factors of Machap Dam must take into considerations to discover a strategic plan by looking into political, economic, social, technological, legal, and environmental aspects.

METHODOLOGY

Study Area

This study mainly focuses on Machap dam, Kluang, Johor, completed in 1982 and has been gazetted by the government. The water body is about 9.1 km² while the basin area is 77 km². Machap dam basin lies in three local authorities, namely Majlis Perbandaran Kluang, Majlis Daerah Yong Peng and Majlis Daerah Simpang Renggam. The dam is initially designed for flood mitigation, but latter is used to regulate the flow at downstream for water supply intake.

Data Collection & Data Analysis

Objective 1: To identify PESTLE factor towards dam catchment management

Interview survey in the form of FGD sessions is conducted and analysed using NVIVO tools. FGD provides in-depth discussion which aims to obtain data from a purposely selected group of individuals rather than from a statistically representative sample of a broader population. In this study, it is conducted among panels who have knowledge and experience in dam management and its surroundings, as well as its effect towards dam catchment. Consent has been obtained during FGDs and surveys. A total of 20 sample sizes has been collected, as in **Table 1** below.

Table 4: FGD Panel

No.	Organisation	No. of Panel
1.	Department of Irrigation and Drainage (JPS)	8
2.	Badan Kawalselia Air Johor (BAKAJ)	1
3.	Suruhanjaya Perkhidmatan Air Negara (SPAN)	1
4.	Ranhill SAJ Sdn Bhd	3
5.	National Water Research Institute of Malaysia (NAHRIM)	1
6.	Majlis Perbandaran Kluang (MPK)	1
7.	Majlis Daerah Yong Peng (MDYP)	1
8.	Malaysia Office of the Chief Government Security Officer (CGSO)	2
9.	Village Head Machap	1
10.	Secretariat of Village Head Ayer Hitam	1
Total sample size for FGD		20

To achieve this objective, the list of PESTLE factors for the dam management is derived through FGD. It is then assessed to obtain the effect of each PESTLE factors either provides the positive or negative effect towards the Machap Dam. Since Vorthman (2008) claimed the positive and negative internal and external factors can be recognised by SWOT analysis, hence, the positive and negative effect derived from each of the PESTLE factors become the outcome for this analysis which is the list of SWOT classification from each PESTLE factors for the Machap dam either it provides positive or negative effects. The positive factor is classified under Strength (internal factor) and Opportunity (external

factor), meanwhile the negative factor is classified under Weakness (internal factor) and Threat (external factor).

The outcome is then used to assess the impact over time for each PESTLE factors whether it provides short, medium, or long-term impact for the Machap Dam. FGD session is concurrently performed together with the previous activity and analysed using content analysis through NVIVO tools.

From this, the list of SWOT impact over time from each PESTLE factors for the Machap dam are derived. As a result, the situation for Machap Dam is obtained by looking into their effect either it provides positive or negative (SWOT), and their impact over time whether provides short-term, medium-term, or long-term effect towards dam catchment management.

Objective 2: To assess PESTLE-SWOT effect for integrated dam catchment management

Primary data is obtained in this stage using questionnaire survey. The purpose of this stage is to examine the obtained PESTLE factors by dynamics whether it provides an important effect to Machap dam or not, and how important it is. PESTLE factors are ranked from ‘very not important’ [1], ‘not important’ [2], ‘important’ [3], and ‘very important’ [4] using questionnaire survey during FGD session, as in **Table 2** below. It is then analysed using descriptive analysis through SPSS tool to determine importance level and term effect of each PESTLE factor towards dam catchment management.

Table 5: Questionnaire design

No.	PESTLE Factor	1	2	3	4
Political Aspect					
1.	Press freedom for public information and awareness				
2.	Involvement of local community within dam catchment				
Economic Aspect					
1.	Local economic activities opportunity				
2.	Ecotourism/Edutourism opportunity				
3.	Local economic activities within dam catchment cause water pollution				
4.	Ecotourism/Edutourism activities cause pollution and encroachment issue				
Legal Aspect					
1.	Water Act 1920 (Act 418)				
2.	Water Services Industry Act 2006 (Act 655)				
3.	Protected Areas and Protected Places 1959 (Act 298)				
4.	Occupational Safety and Health Act 1994 (Act 514)				
5.	Environmental Quality Act 1974 (Act 127)				
6.	National Land Code 1965 (Section 62); Reservoir area				
Technological Aspect					
1.	Regular dam safety inspection				
2.	Security gate control and CCTV utilisation within dam operation area				
3.	Drone utilisation within catchment and dam operation area				
4.	Study on decision making based on GIS for dam optimisation				

No.	PESTLE Factor	1	2	3	4
5.	Unavailability of CCTV coverage within dam catchment area				
Environmental Aspect					
1.	Land clearing determination for soil erosion control				
2.	Research on integrated catchment management plan				
3.	Integration of water pollution management control with community				
4.	Research on <i>Neptunia Oleracea</i> threat towards dam management				
5.	Community involvement in maintaining dam ecosystem cycle				
6.	Study on water inflow forecasting				
7.	Small distance between commercial crops and dam catchment area				
8.	Significant flood occurrences due to dam capacity				
9.	Climate change effect				
10.	Uncontrolled <i>Neptunia Oleracea</i> growth				
Social Aspect					
1.	Local people's water lifestyle consumption				
2.	Increment in local population size				

As a result, the level of importance and term effect of each PESTLE factor towards dam catchment management is obtained and will be integrated with SWOT effect to discover an integrated dam catchment management in managing dam assets including its land and buildings using PESTLE-SWOT analysis.

FINDINGS

Table 3 and **Figure 1** below presents the results based on FGD's panel experts for Objective 1 and Objective 2 regarding the dam catchment management effect on Political, Economic, Legal, Technological, Environmental, and Social factor towards dam catchment management that integrates with the importance level and term effect for each factor, as well as the SWOT categorisation. In terms of importance level, this study excludes 'Not Important' aspect as it is not assisting in encouraging the management to be more advanced in delivering current dam work practice.

Table 3: PESTLE-SWOT effect towards dam catchment management

No.	PESTLE Factor	SWOT Effect				Mean Value	Level of Importance		Term Effect			
		Strength (S)	Positive Opportunity (O)	Negative Weakness (W)	Threat (T)		Important	Very Important	Short-term	Medium-term	Long-term	
Political Aspect												
1.	Press freedom for public information and awareness	/				3.14	/		/			
2.	Involvement of local community within dam catchment				/	3.57		/				/
Economic Aspect												
1.	Local economic activities opportunity		/			3.29	/					/
2.	Ecotourism/ Edutourism opportunity		/			2.90	/					/
3.	Local economic activities within dam catchment cause water pollution			/		3.29	/					/
4.	Ecotourism/ Edutourism activities cause pollution and encroachment issue				/	2.90	/					/
Legal Aspect												
1.	Environmental Quality Act 1974 (Act 127)	/				3.81	/					/
2.	Protected Areas and Protected Places 1959 (Act 298)	/				3.67	/					/
3.	Water Act 1920 (Act 418)	/				3.57		/				/
4.	National Land Code 1965 (Section 62); Reservoir area	/				3.57	/					/
5.	Water Services Industry Act 2006 (Act 655)	/				3.48	/					/
6.	Occupational Safety and Health Act 1994 (Act 514)	/				3.38	/					/
Technological Aspect												
1.	Regular dam safety inspection	/				3.36		/	/			
2.	Security gate control and CCTV utilisation within dam operation area	/				3.36		/	/			

No.	PESTLE Factor	SWOT Effect				Level of Importance		Term Effect		
		Strength (S)	Positive Opportunity (O)	Weakness (W)	Negative Threat (T)	Mean Value	Very Important	Short-term	Medium-term	Long-term
3.	Drone utilisation within catchment and dam operation area	/				3.36	/	/		
4.	Unavailability of CCTV coverage within dam catchment area			/		3.36	/	/		
5.	Study on decision making based on GIS for dam optimisation	/				3.27	/			/
Environmental Aspect										
1.	Land clearing determination for soil erosion control	/				3.91	/			/
2.	Research on integrated catchment management plan	/				3.91	/			/
3.	Integration of water pollution management control with community management control	/	/			4.00	/			/
4.	Research on <i>Neptunia Oleracea</i> threat towards dam management		/			3.91	/			/
5.	Community involvement in maintaining dam ecosystem cycle		/			3.64	/			/
6.	Study on water inflow forecasting		/			3.55	/			/
7.	Small distance between commercial crops and dam catchment area				/	3.91	/			/
8.	Significant flood occurrences due to dam capacity				/	3.73	/			/
9.	Climate change effect				/	3.55	/			/
10.	Uncontrolled <i>Neptunia Oleracea</i> growth				/	3.45	/		/	
Social Aspect										
1.	Local people's water lifestyle consumption	/				3.23	/		/	
2.	Increment in local population size				/	3.46	/			/

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Asset Management Using PESTLE-SWOT Analysis: Strategic Aspects for Integrated Dam Catchment Management

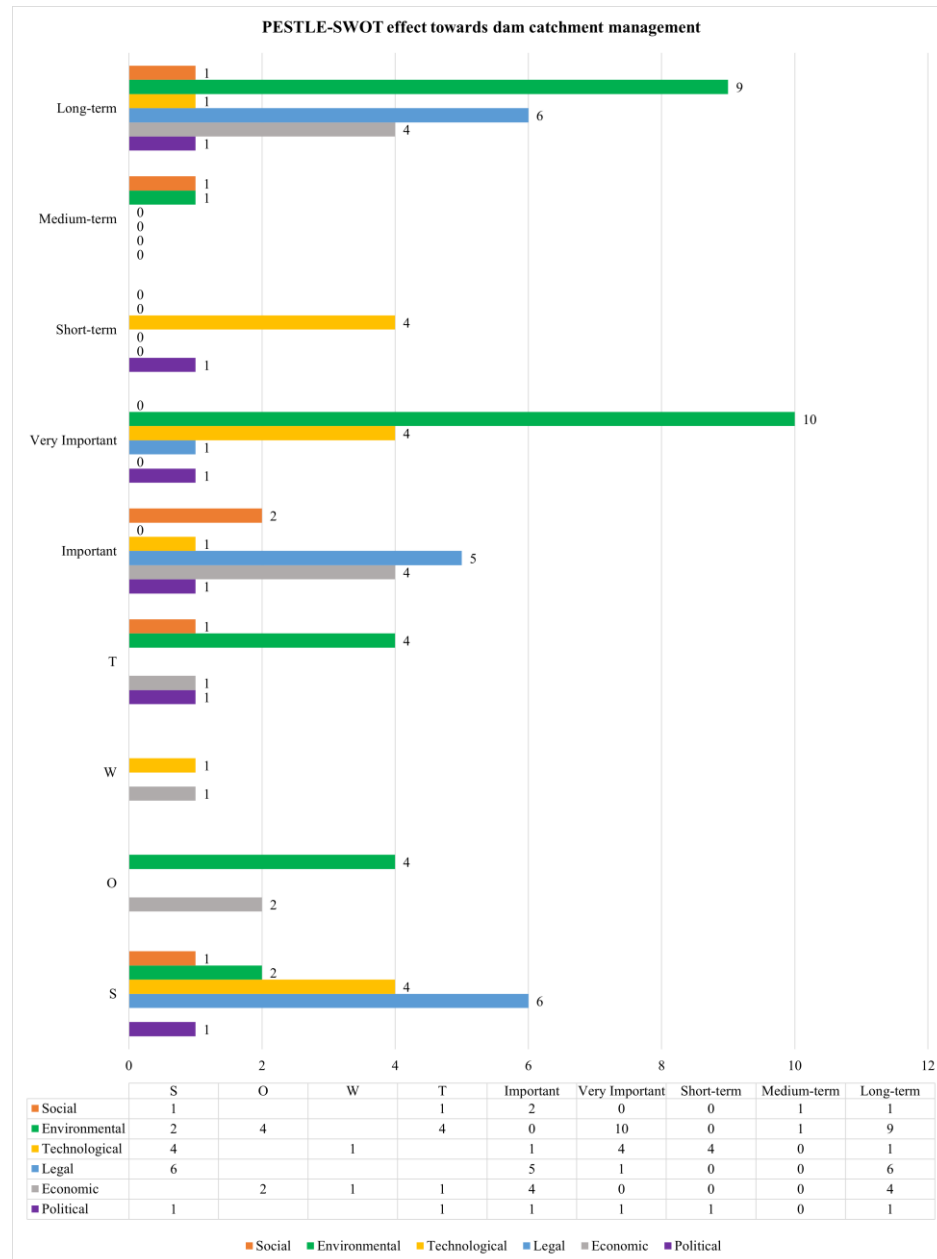


Figure 1: PESTLE-SWOT effect towards dam catchment management

Press freedom for public information and awareness contributes a short-term positive effect on dam catchment management. It strengthens transparency, promotes public oversight, and allows early detection of illegal or unusual activities around the catchment (Gurel, 2017). However, uncontrolled community involvement within the dam catchment area can create long-term negative effects, as it increases the risk of encroachment, land-use conflicts, and mismanagement (Yaacob, 2021). Effective governance and structured participation frameworks are therefore essential to ensure community engagement supports, rather than threatens, catchment protection.

Local economic development and ecotourism or edutourism initiatives provide long-term positive impacts by generating sustainable livelihoods and promoting environmental awareness (Gavrikova et al., 2020). Yet, economic activities within the catchment that resulted in encroachment may produce long-term negative effects (Ayman, 2021). These findings reveal the dual nature of economic growth is beneficial when it is properly managed, but potentially harmful without strong legal enforcement and environmental regulation.

Malaysia's comprehensive legal framework including the Environmental Quality Act 1974, Protected Areas and Protected Places Act 1959, National Land Code 1965, Water Services Industry Act 2006, Occupational Safety and Health Act 1994, and Water Act 1920 provides strong, long-term positive effects for dam catchment management. These laws serve as the foundation for preventing illegal land use, pollution, and encroachment. However, fragmented enforcement among agencies reduces their overall effectiveness, indicating the need for integrated legal coordination and stronger institutional collaboration (Toh et al., 2020).

Technological aspects including GIS-based decision-making, regular safety inspections, CCTV and gate control systems, and drone monitoring, have significant positive effects on dam operations (Quadier & Kabir, 2025; Selangor Journal, 2023; Srdjevic et al., 2012). These technologies improved early detection of erosion, encroachment, and illegal land use (Quaber & Kabir, 2025), as seen in Selangor and Melaka's implementation of drones and fencing (The Sun, 2021). Nonetheless, the lack of comprehensive CCTV coverage remains a short-term weakness that limits continuous monitoring. Investment in digital infrastructure and operator training is therefore vital for effective catchment management.

Environmental findings highlight both opportunities and threats. Positive factors include land-clearing control for erosion prevention, research on integrated catchment management, community-based pollution management, studies on *Neptunia oleracea*, and water inflow forecasting. These initiatives strengthen long-term ecosystem resilience. However, close proximity of agricultural areas to dams, recurring floods, climate change, and uncontrolled *Neptunia oleracea* growth pose significant long and medium term threats to

catchment sustainability (Munier et al., 2014). Adaptive environmental management and continuous monitoring are therefore essential.

Local water-use behaviour provides a medium-term positive effect by promoting responsible consumption and supporting sustainable dam operations. In contrast, population growth presents a long-term negative effect in which increase the water demand and pressure on dam infrastructure. Integrating social awareness campaigns and water-use education into management strategies can may reduce long-term strain on the catchment system.

Overall, this study concludes that technological and legal aspects serve as the strongest pillars of sustainable dam governance. However, their success depends on cross-sector collaboration, community participation, and evidence-based decision-making. Moving forward, Malaysia's dam management strategies should prioritise policy integration, technological modernisation, and adaptive management within its catchment including land and building to maintain ecological resilience while supporting socio-economic growth.

From this, SWOT analysis can be addressed in the form of PESTLE-SWOT analysis for integrated dam catchment management as an assessment and advancement for current work practices to sustain the existing assets from land encroachment issues and decision making process, as in **Figure 4** below.

	STRENGTH (S)	WEAKNESS (W)	OPPORTUNITY (O)	THREAT (T)
Long-term	Very Important: - Water Act 1920 (Act 418) Important: - Water Services Industry Act 2006 (Act 655) - Prohibited Areas and Prohibited Places Act (Act 298) - Occupational Safety and Health Act 1994 (Act 514) - Environmental Quality Act 1974 (Act 127) - National Land Code 1965 (Section 62): Reservoir area - Study on decision making based on GIS for dam optimisation - Land clearing determination for soil erosion control - Research on integrated catchment management plan		Very Important: - Integration of water pollution management control with community - Research on <i>Neptunia Oleracea</i> threat towards dam management - Community involvement in maintaining dam ecosystem cycle - Study on water inflow forecasting Important: - Local economic activities opportunity - Ecotourism/ Edu tourism opportunity	Very Important: - Involvement of local community within dam catchment - Significant flood occurrences due to dam capacity - Effect of climate change - Small distance between commercial crops and dam catchment area - Local community activities within dam catchment area cause water pollution Important: - Ecotourism/ Edu tourism activities cause pollution and encroachment issue - Increment in local population size
Medium-term	Important: Local people's water lifestyle consumption			Very Important: Uncontrolled <i>Neptunia Oleracea</i> growth
Short-term	Very Important: - Regular dam safety inspection - Security gate control and CCTV utilisation within dam operation area - Drone utilisation within catchment and dam operation area Important: - Press freedom for public information and awareness	Very Important: Unavailability of CCTV coverage within dam catchment area		

Figure 5: SWOT analysis for integrated dam catchment management

CONCLUSIONS

This study discovered that Technologies and Legal factor are the important strategic aspects for dam catchment management to be more integrated in managing dam assets including its land and buildings using PESTLE-SWOT analysis. Those nine factors are necessary to be focused to achieve long-term dam sustainability, particularly related to law and regulations, as well as the enhancement of technological directions.

PESTLE–SWOT framework may enable related agencies to systematically monitor external pressures, assess internal management capacities, and prioritise interventions across short-, medium-, and long-term planning horizons. It also provides a structured means of coordinating multi-agency responsibilities, particularly in contexts where jurisdictional overlaps exist between water authorities, local governments, and environmental regulators.

Situational analysis within dam catchment area is recommended to be carried out to review any possibilities of dam failure and illegal activities by third parties, as well as enable decision makers to secure sustainable dam management and water resources. From this, dam asset manager may integrate asset management planning processes into current work practices to enhance the deliverables of dam functions and its catchment area, especially land use and encroachment matters.

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