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Original Article

Comprehensive Planning and Structural Design Analysis for the Sorong Container Terminal Construction Project

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Abstract - *The Sorong City Port Container Terminal supports regional and international trade. Currently operating with a capacity of 50,000 TEUs per year, the terminal's capabilities are set to be surpassed by 2036, when container traffic is projected to increase to 71,823 TEUs. This study conducts a comprehensive structural and planning analysis for the proposed terminal expansion, focusing on structural specifications that accommodate larger vessel capacities and increased cargo demands. The analysis encompasses critical design aspects, such as pier structural resilience, load distribution, and reinforcement for diverse loads, including dead, live, berthing, mooring, and earthquake forces. Key infrastructure elements, such as the catwalk, pile cap, and dock beam reinforcements, are meticulously specified to ensure operational safety and efficiency. The structural design follows standards from Indonesian regulations, incorporating considerations for seismic activity and medium soil conditions. The results demonstrate a reinforced structure capable of sustaining significant loads and larger vessel sizes, ensuring long-term stability and efficient operations. This expansion plan provides a strategic response to the anticipated surge in maritime logistics demand, supporting economic growth in the region.*

Keywords - *Sorong container terminal, Structural design, Load analysis, Reinforcement, Vessel capacity, Maritime logistics.*

1. Introduction

The Sorong City Port Container Terminal is critical in facilitating regional maritime trade and logistics. Currently, the terminal operates at an annual capacity of 50,000 Twenty-foot Equivalent Units (TEUs), supported by a stacking area of 22,632 m2. Operating 24/7, the terminal is designed to meet local and international shipping demands. However, the escalating volume of container traffic presents significant challenges to the terminal's operational sustainability. Projections indicate a dramatic increase in container flows, reaching an estimated 71,823 TEUs by 2036. This substantial increase is expected to exceed the existing capacity, underscoring an urgent need for strategic planning and expansion initiatives. Upon examining future projections, it becomes evident that the current infrastructure will soon be inadequate to accommodate the anticipated growth in container traffic. Specifically, the projected required stacking area of approximately 23,020.35 m2 marginally surpasses the terminal's available space, highlighting a potential for operational bottlenecks. As container vessels grow and shipping volumes rise, the Sorong Container Terminal must evolve to meet these escalating demands. This necessitates the expansion of critical facilities, including the docking area and stacking zones, alongside the modernization of operational systems. The imperative further compounds the challenge of maintaining operational efficiency, as delays or inefficiencies could lead to significant economic losses. While the terminal has made notable improvements in operational efficiency, such as reducing port stay times from 72 hours to 24 hours and increasing productivity from 17 BSH to 30.34 BSH, these advancements alone may not be sufficient to address the projected rise in container volumes. Without proactive measures, the terminal risks include being unable to handle the influx of traffic, ultimately impacting the overall logistics network and trade activities in the region. Therefore, comprehensive planning and structural design analysis are essential to address immediate capacity challenges and lay a foundation for sustainable growth and development in the Sorong City Port Container Terminal. The urgency of research into comprehensive planning and structural design for the Sorong container terminal construction project is driven by the projected surge in container traffic from 50,000 TEUs to 71,823 TEUs by 2036. The existing terminal infrastructure, including the 22,632 m2 stacking area, is at risk of becoming insufficient, underscoring the immediate need for strategic expansion. Failure to address these limitations could result in operational bottlenecks, inefficiencies in cargo handling, shipping delays, and significant economic losses for the region. Expanding the terminal's capacity is thus crucial to meet future demand and avert operational disruptions. The global shipping industry's competitiveness mandates significant enhancements in port facilities to accommodate larger vessels and increased shipment frequencies. The rapid evolution of containerization and the demand for efficient cargo turnaround have intensified competition among ports, compelling them to modernize their infrastructure to maintain operational efficiency. Failure to invest in timely upgrades could jeopardize Sorong's strategic position as a vital hub in regional and international supply chains, as ports that do not adapt risk losing their competitive edge. Comprehensive planning and structural design solutions ensure the terminal's long-term viability and support Indonesia's broader economic development objectives. Moreover, integrating sustainable practices within port operations is increasingly recognized as a critical factor for competitiveness, aligning with global trends toward environmentally responsible logistics.

Despite the clear need for expansion and modernization, a significant research gap exists in detailed structural design modifications tailored to the Sorong Container Terminal's projected growth demands. Existing literature often focuses on broad port management strategies or general capacity planning without providing specific structural design adaptations for accommodating increased Deadweight Tonnage (DWT) capacities for vessels in a rapidly growing regional port. Previous studies, such as Solvoll et al. (2020) and Pelindo (2023), identify the quantitative need for increased stacking area and projected TEU growth. However, they do not investigate the engineering specifics required to achieve these expansions.

Furthermore, while Sakib et al. (2021) highlight economic losses due to inefficiencies and Hales et al. (2017) discuss the need for modernized infrastructure in competitive environments, there is a lack of practical application of structural analysis for a specific port expansion project like Sorong. The novelty of this work lies in its specific focus on modifying the structural design of the Sorong container terminal dock to accommodate ships with capacities of 50,000 DWT and 10,000 DWT, a direct response to the identified future operational demands. This goes beyond general capacity planning by providing concrete structural calculations and design modifications using established engineering principles and software. Considering the broad scope of planning involved in this final project, as well as time constraints and limitations in the discipline of knowledge, this study focuses on several key problem boundaries: (1) The structural calculations will be concentrated on the dock structure, mooring dolphin facilities, and catwalk; (2) The formulas employed will strictly follow existing literature without the derivation of new formulas; (3) The structural design modifications will aim to determine the dimensions, perform structural analysis, and conduct necessary control checks, without delving into cost analysis; and (4) The structural analysis will be conducted using SAP 2000 software. The objective of this final project is to modify the design of the Sorong container terminal dock to accommodate ships with capacities of 50,000 DWT and 10,000 DWT, directly addressing the need for expanded infrastructure to meet future operational demands.

2. Method

2.1. Description of the Research Location

The Sorong Container Terminal was officially inaugurated in Sorong, Papua, on September 20, 2021. The terminal features a 450-meter-long pier and an existing container yard area of 22,632 m². Operating 24 hours a day, 364 days a year, the port has modern facilities, including shipping lanes, berths, storage warehouses, and advanced handling equipment such as container cranes and reach stackers. The terminal has a yearly capacity of 50,000 Twenty-foot Equivalent Units (TEUs). However, with significant projected growth in container traffic, it is estimated that by 2036, the required capacity will increase to around 71,823 TEUs, with a container yard area demand of 23,020 m².

Fig. 1 Sorong container terminal location

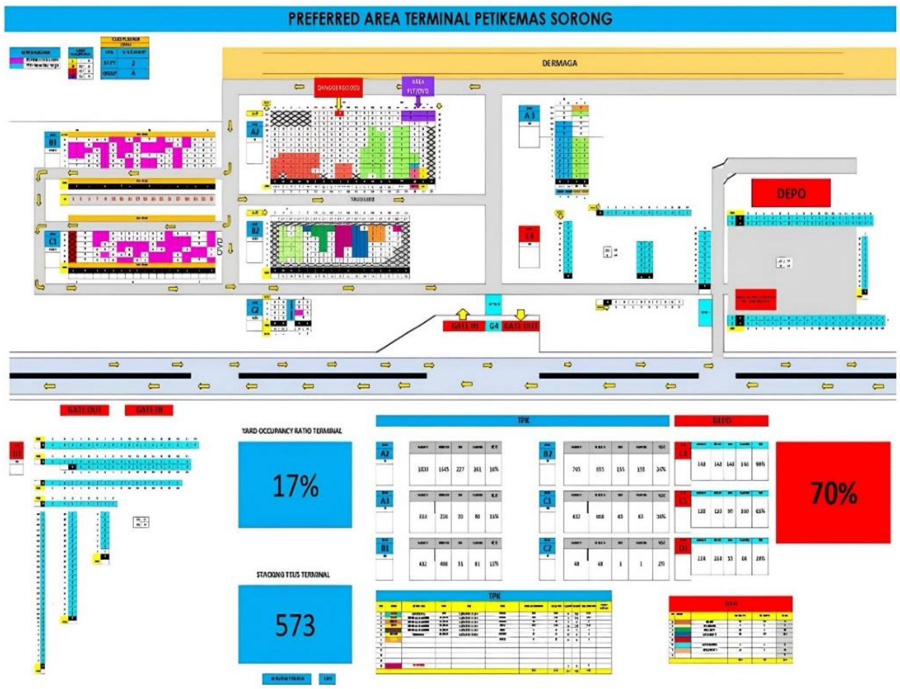

Fig. 2 Sorong container terminal location

The image shows the layout of the Sorong Container Terminal, highlighting various operational zones and facilities. The terminal consists of distinct areas for container stacking, labeled A1, A2, B1, B2, and C1, along with a designated depot area. The terminal includes gates for vehicle entry and exit (Gate In and Gate Out) and has a marked "Dangerous Goods" area. The current yard occupancy ratio is 17%, with a stacking capacity of 573 TEUs. The depot area, which handles container storage and related activities, has a yard occupancy ratio of 70%. The layout also illustrates traffic flow and the arrangement of container blocks across the terminal, ensuring efficient container handling and movement throughout the facility.

2.2. Data Collection

For the Sorong Container Terminal construction project, essential data collection for the pier's structural design includes wind data to evaluate atmospheric impacts, wave and current data to understand dynamic forces from the water, and tidal data to account for water level variations.

Additionally, bathymetric data is necessary for analyzing underwater topography, while soil data is crucial for assessing geotechnical properties to ensure a stable foundation. This comprehensive data will inform a robust design that meets safety and operational requirements.

2.3. Vessel Specifications

On the seaside, the vessels have a carrying capacity of 50,000 DWT, with a total length (LOA) of 266 meters, a width (B) of 32.3 meters, and a loaded draft of 13 meters. On the landside, the vessels are designed with a carrying capacity of 10,000 DWT, a total length (LOA) of 139 meters, a width (B) of 22 meters, and a loaded draft of 7.9 meters. These specifications are critical for ensuring the terminal can effectively accommodate various vessel sizes and types.

2.4. Structure Specifications

This section outlines the structural specifications for the Sorong Container Terminal, focusing on the design and dimensions of key components essential for its operation.

The specifications ensure the terminal can effectively accommodate vessels of varying capacities while addressing environmental conditions.

- Jetty Length: 252 meters
- Catwalk Length: 36 meters
- Mooring Dolphin Length: 6,5 meters
- Jetty Width: 43 meters
- The foundation structure uses steel pipe pile foundations.
- It is designed to serve vessels with a carrying capacity of 50,000 DWT on the seaside and 10,000 DWT on the landside. Tidal conditions:
    - Highest Water Spring (HWS): +2.98 meters
    - Lowest Water Spring (LWS): +0.00 meters

2.5. Structural Planning Analysis

The structural planning analysis of the jetty includes:

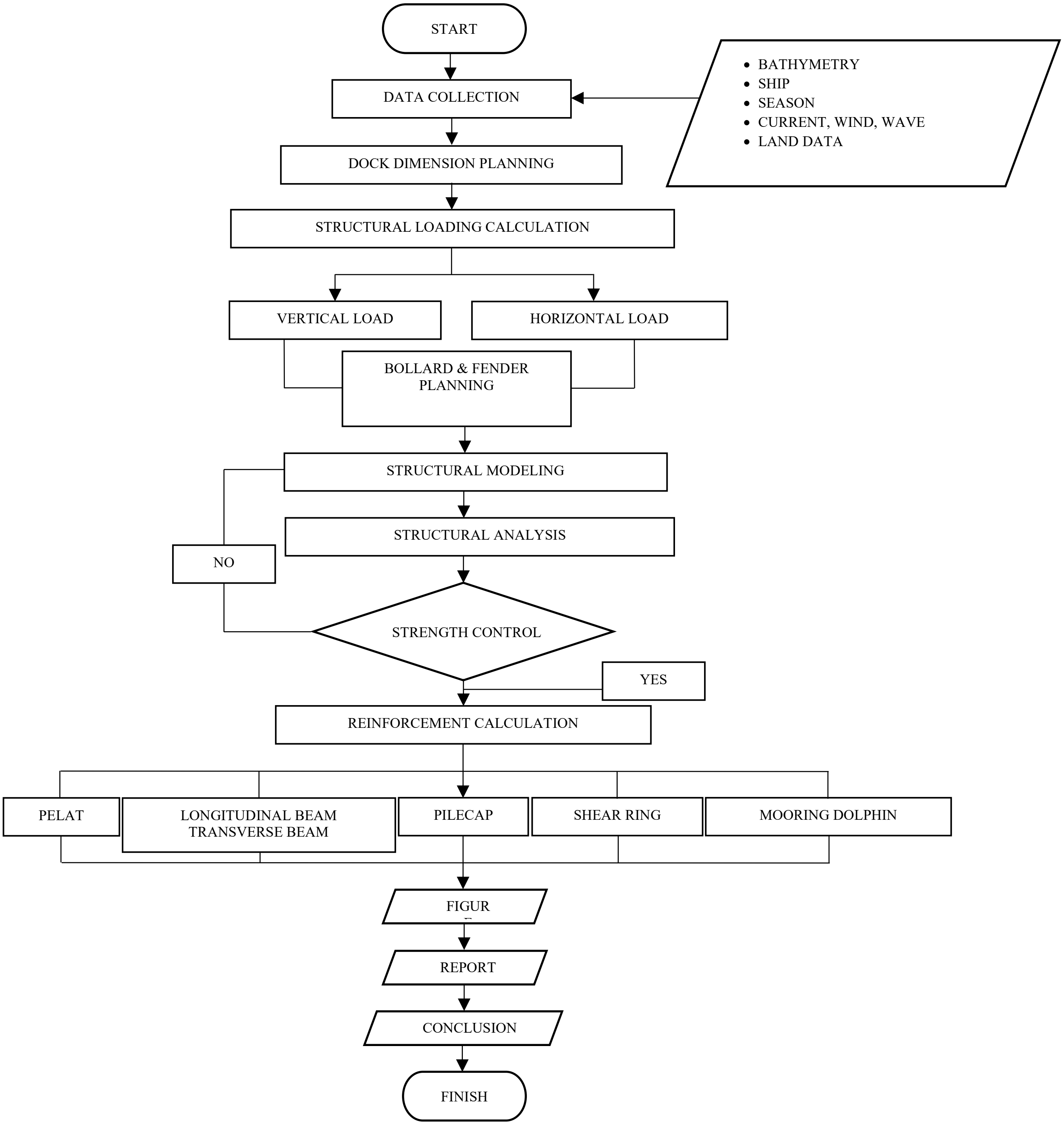

Fig. 3 Structural depiction

2.5.1. Structural Dimension Planning

The first step in planning the jetty structure involves determining the structural dimensions, including the apron dimensions, jetty slab thickness, longitudinal and transverse beam dimensions, and pile cap and pile dimensions.

This comprehensive dimension planning is crucial for ensuring the structural integrity and functionality of the jetty.

2.5.2. Loading

The loads acting on the jetty structure include vertical and horizontal loads and a combination.

- Vertical Loads: Dead load and Live load
- Horizontal Loads: Berthing force (vessel impact load), Mooring force, wave and current loads, and Seismic load
- Load Combination

2.5.3. Fender Planning

Fender planning is essential to ensure safe and efficient vessel berthing at the jetty, as fenders act as cushions to absorb impact energy between the vessel and the structure.

This planning involves calculating the impact energy generated by the largest vessel expected to berth, determining the energy absorption capacity of the jetty, selecting the appropriate fender type and size, and strategizing the optimal placement of fenders to maximize protection during vessel docking.

2.5.4. Boulder Planning

A boulder or mooring device is used to secure a vessel when moored to prevent any shifting or movement caused by waves, currents, and wind.

- Calculation of the forces received by the boulder.
- Dimension planning of the boulder.

2.5.5. Structural Analysis

Structural analysis of the jetty is conducted using the SAP 2000 program to determine the forces acting on the planned jetty structure.

2.5.6. Stability and Strength Control

Stability control is necessary to ensure adequate structural behavior under working load conditions. This control includes monitoring for cracks and deflections.

2.5.7. Reinforcement

Reinforcement is carried out on the concrete structures in jetty construction, such as slab reinforcement, longitudinal beams, transverse beams, secondary beams, and pile caps.

2.6. Structural Depiction

Once the structural calculations are complete, the structure is depicted using AutoCAD software.

3. Results and Discussion

3.1. Presenting the Results

3.1.1. Regulations Used

In planning the structure of the jetty, the following regulations are used:

1) Standard Design Criteria for Ports in Indonesia, 1984.
2) SNI 2847-2002, Reinforced Concrete.
3) SNI 03 - 2833 - 2013, Earthquake Planning Procedures for Bridges.
4) Technical Standards and Commentaries for Port and Harbour Facilities in Japan.

3.1.2. Planned Vessel Criteria

This jetty structure is planned to accommodate container ships with a maximum weight of 50,000 DWT on the seaside and 10,000 DWT on the landside. The specifications are as follows:

Table 1. Planned vessel specifications (Seaside)

Specification	50,000 DWT Vessel
Dead Weight Tonnage (DWT)	50,000 tonnes
Length Overall (LOA)	266 metres
Beam (B)	32.3 metres
Loaded Draft (D)	13 metres

Table 2. Planned vessel specifications (Seaside)

Specification	10,000 DWT Vessel
Dead Weight Tonnage (DWT)	10,000 tonnes
Length Overall (LOA)	139 metres
Beam (B)	22 metres
Loaded Draft (D)	7,9 metres

Based on the Standard Design Criteria for Ports in Indonesia, 1984, regarding vessel berthing speed, a ship with the above specifications is estimated to berth at a speed of 0.15 m/s, assuming standard berthing conditions (moderate berthing velocity).

3.1.3. Materials

The materials used in the design are specified as follows:

- The concrete used is standard reinforced concrete, referring to SNI 2847-2000. The concrete has a compressive strength of f'c = 35 MPa at 28 days.

Reinforcement Steel The quality of the reinforcement steel used is as follows:

- Steel Pipe Piles: The steel pipe piles used are by ASTM A 252 / JIS A 5525 specifications. The steel pipe piles used for the jetty, catwalk, and mooring dolphin have 1422.4 mm, 1016 mm, and 508 mm diameters, with corresponding thicknesses of 22 mm, 16 mm, and 14 mm.

Table 3. Reinforcement steel

Reinforcement Ø < 12 mm; U24	fy =	240 MPa
	Ea =	210000 MPa
	σa =	140 MPa
Reinforcement D ≥ 13 mm; U39	fy =	390 MPa
	Ea =	210000 MPa
	σa =	225MPa

Table 4. Steel pipe piles

Specification	Mooring Dolphin, Catwalk, Dock
Steel Grade	BJ 55
Tensile Strength Min (fu)	(550). MPa
Yield Strength Min (fy)	410 MPa
Young's Modulus (E)	200,000 MPa
Shear Modulus (G)	80,000 MPa
Poisson's Ratio (μ)	0.3
Coefficient of Thermal Expansion (α)	12 x 10^{-6} °C

Based on Law Number 23 of 2014, Regional Governments are given the authority to regulate and manage their government affairs to improve the community's welfare.This is done through autonomy, assistance, democracy, equity, justice, speciality, and specificity. As regional diversity within the system and principles of the Unitary State of the Republic of Indonesia. Given the increasing environmental damage, disasters, and degradation of ecological functions due to spatial and regional development, budgeting for environmental interests is recognized as a regional policy instrument. To overcome these problems, regional budget politics can be focused on efforts to prevent, restore, overcome, and improve environmental protection and management by the community [1]. A local government's financial budget is a plan that sets revenue and expenditure targets over a specified period [2]. The budget plays a vital role in ensuring the smooth functioning of local government and the provision of public services. Programs and policies implemented by the government are aligned with its financial capabilities, and the budget sets spending limits. In addition, the budget also serves as a management coordination tool within the government and as a political document that demonstrates commitment between the executive and legislature on the use of public funds [3], and organized based on priorities in providing public services to the community [4].

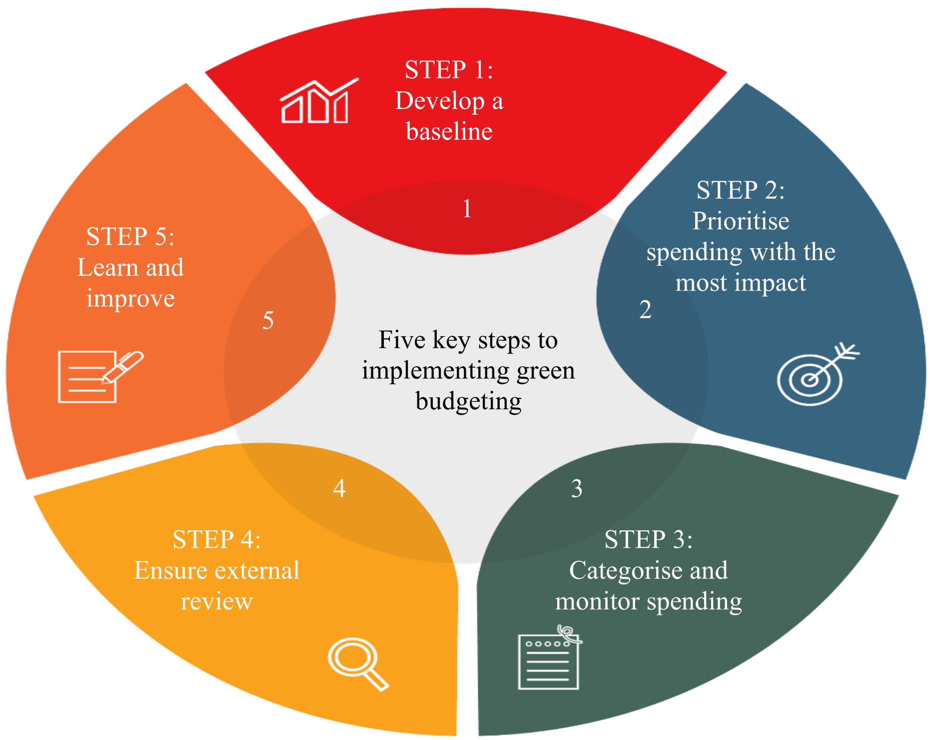

Fig. 4 Five key steps to green budgeting

Local government budgets are essential in monitoring their financial condition and operations. It informs the public about the use of funds for public service functions and provides transparency to the public on planned and actual revenues and expenditures [5]. In addition, local government financial budgets reflect financial conditions regarding revenues, expenditures, and financial support. To ensure efficient and effective spending in meeting the community's needs, local governments must establish good strategies for resource control [6].

From this explanation, the functions of government financial budgets that can be identified are planning tools, fiscal policy tools, control tools, work assessment tools, motivation tools, political tools, tools for creating public space, and coordination and communication tools. Local governments can improve their financial condition by optimizing resource allocation efficiently and effectively. Berne and Schramm (1986) define the economic condition of a local government as referring to the local government's ability to fulfill its financial obligations to stakeholders when due [7].

This includes the solvency of local governments to fund their services sustainably. Cash solvency is the ability to generate sufficient cash within a short period (one to three months) to pay off liabilities. Budgetary solvency refers to raising enough revenue to finance existing or desired service standards. Long-term solvency indicates meeting all expenditure activities, including recurrent and non-routine expenditures. Service level solvency is the ability to maintain desired service levels. These factors contribute to the overall financial solvency of local governments. Wang et al. (2007) also defined local government financial condition as the level of economic solvency, which includes the same factors of cash solvency, budget solvency, long-term solvency, and service level solvency [7]. Green budgeting in local development refers to an environmentally focused budget that includes local revenue and expenditure components.

It complements Corporate Social Responsibility programs by incorporating environmental objectives into corporate budgeting. The ultimate goal is ensuring companies prioritize ecological issues in their business policies. Green budgeting involves incorporating green principles into various aspects of revenue and expenditure, such as allocating a percentage of the budget to finance environmental needs.

For example, budget policies for the energy sector should prioritize renewable energy power generation over electricity subsidy programs. In addition, the construction and development of mass transportation should be prioritized over toll roads. However, budget priorities for environmental management programs should also consider other infrastructure programs to maintain environmental quality. This requires government, local governments, legislators, and the public support.

4. Research Design

This study collected data from primary and secondary sources. Primary data was collected through random sampling in the field, with 10 samples taken. Meanwhile, secondary data was obtained from literature, related agencies, and previous reports. Secondary data consists of pre-existing data collected by other parties, including statistical data, government reports, and prior research related to environment-based local budget policies. The external data analysis in this study will involve a comparative analysis of the measured parameters. The findings from this data analysis will be presented descriptively through tables, graphs, and diagrams to effectively convey the information collected in this study.

5. Results

Referring to the objectives and methods of this study, a practical approach to green budgeting is supported by four key mutually reinforcing foundations (Figure 2): a strategic framework, tools for evidence generation and policy coherence, reporting to facilitate accountability, and a transparency and budget governance framework. Green budgeting tools are used to gather evidence on the impact of budget actions on environmental and climate goals. These tools should be based on each country's existing Public Financial Management (PFM) frameworks. These tools introduce them and gather information to support more informed budget analysis and decision-making. This helps governments ensure that budget decisions are aligned with strategic and policy priorities.

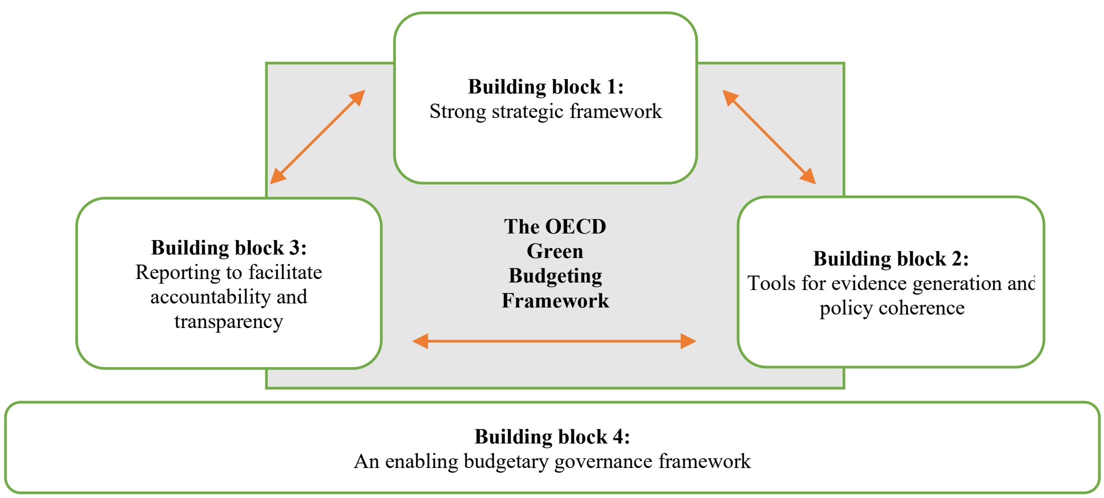

Fig. 5 Green budgeting framework

Overall, green budgeting is a practical approach that combines these four cornerstones to promote sustainable practices and decision-making in the budgeting process. The Mappi Regency's Regional Key Performance Development (RKPD) preparation process demonstrates alignment and divergence about the fundamental principles of effective green budgeting as outlined in the pertinent literature. The strategic framework component is primarily apparent in the RKPD's congruence with medium-term regional and national development plans, signifying the significance of coherence between local and national policy priorities. This finding is consistent with those reported by the OECD (2019) on strategic frameworks' role in integrating environmental considerations into budget planning. Adopting participatory and multi-stakeholder approaches (including technocratic, political, top-down, and bottom-up methods) echoes literature advocating inclusive policy-making processes [9]. Those processes stress that participatory governance can enhance policy coherence and legitimacy. Monitoring and evaluation stages in the RKPD preparation process align with the literature emphasizing accountability in budgeting processes. According to Curristine et al. (2007), robust evaluation mechanisms are conducive to transparent governance and performance assessment. Additionally, the RKPD's multi-stage formulation and finalization processes indicate a level of budget governance and transparency, aligning with recommendations by Yefriza (2015) on the importance of structured and transparent budget processes.

However, critical gaps emerge in the RKPD's approach. The absence of explicit evidence-generation tools for decision-making undermines one of the key foundations for green budgeting. As emphasized in the literature, such as that by Johnstone & Haščič (2009), Quantitative tools and methodologies are necessary for integrating environmental criteria into budgeting. Furthermore, the lack of emphasis on ecological or sustainability metrics in the reporting and evaluation stages diverges from the best practices outlined in studies such as those by the European Commission (2021), which advocates for green budgeting frameworks that monitor and report environmental outcomes.

Green budgeting underscores the use of instruments to generate evidence concerning the repercussions of budgetary actions on environmental and climate objectives. These instruments should be incorporated into the prevailing Public Financial Management (PFM) frameworks. These tools aim to inform budget analysis and decision-making, ensuring budget allocations align with strategic and policy priorities. However, an evaluation of the budget evaluation process in Mappi Regency, as mandated by Regulation No. 86/2017, reveals a misalignment with this concept. One area of alignment is using evaluation mechanisms to assess budget performance. Analyzing program achievements through performance indicators is consistent with monitoring and evaluating budget outcomes, a core component of effective PFM systems [10]. However, the exclusive emphasis on financial absorption rates and program achievements, devoid of integrating environmental and climate metrics, signifies a lacuna in implementing green budgeting principles. The literature emphasizes the incorporation of ecological indicators to measure the sustainability impact of budget actions [13].

The budget realization rates reported in Mappi Regency, with an average performance achievement of 21.15% and budget absorption of 20.49%, indicating inefficiencies and uneven budget execution. According to Johnstone & Haščič (2009), One of the critical roles of evidence-based budgeting is identifying inefficiencies and optimising resource allocation. The substantial variation in performance achievement among OPDs (ranging from 1.54% to 84.71%) underscores the necessity for enhanced alignment between budget allocation and strategic objectives, including sustainability goals. To achieve better alignment with green budget principles, it is recommended that the planning and budgeting process in Mappi District introduce evidence-based analysis and structured reporting mechanisms that focus on sustainability indicators. In addition, incorporating climate indicators into the budgeting process would align with OECD recommendations that emphasize the importance of integrating climate goals in the budgeting process to improve policy coherence and accountability.

6. Discussion

The budgeting process in Mappi Regency exemplifies a pronounced discrepancy between prevailing practices and the tenets of green budgeting, particularly regarding integrating environmental sustainability into fiscal planning. Even though the decision-makers in the region have been engaged in the formulation of the Regional Revenue and Expenditure Budget (APBD) for 22 years, there is a continued prioritization of development sectors, such as education, health, infrastructure, and economic development, to address the community's pressing demands for improvements in welfare. While these priorities are vital for socio-economic growth, they have resulted in environmental degradation, including a notable reduction in green spaces. This phenomenon highlights a persistent tension between the immediate demands of development and the imperative for long-term ecological sustainability. This challenge was previously identified by the OECD (2001) in its analysis of public financial management constraints.

A critical barrier to green budgeting in Mappi Regency is the limited budget allocation for environmental affairs, driven by fiscal constraints and competing development priorities. This phenomenon is not exclusive to Mappi Regency; extant literature consistently highlights that governments with limited resources often deprioritize environmental programs in favor of short-term socio-economic gains [12, 15]. The absence of binding regulations that mandate budget allocations for environmental programs further exacerbates the problem as the European Commission Emphasizes that establishing regulatory frameworks is pivotal in institutionalising environmental priorities within budgetary processes. The absence of such legal mandates may result in decision-makers lacking structural motivation to allocate resources toward environmental sustainability.

A further significant factor is the limited awareness among decision-makers regarding the importance of environmental conservation for regional sustainability. The literature emphasizes ecological literacy and capacity-building's pivotal role in cultivating policymakers' sustainability-oriented mindset [16]. When decision-makers are better informed about environmental conservation's long-term economic and social benefits, they are more likely to adopt green budget policies [16]. Additionally, the budgetary arrangements in Indonesia, which are centralized, further limit the Mappi Regency's discretion in allocating funds autonomously for environmental programs. In contrast, OECD and Litvack et al. (1998) posit that greater fiscal decentralization can empower local governments to allocate resources more effectively based on regional needs, including environmental priorities.

In order to align with green budgeting principles, Mappi Regency must introduce evidence-based analysis tools and structured reporting mechanisms focused on sustainability indicators. This approach is consistent with the recommendations of the OECD (2019), which underscores the significance of integrating climate objectives into budgetary processes to enhance policy coherence and accountability. Establishing performance-based budgeting frameworks incorporating environmental metrics would facilitate a more comprehensive evaluation of budget effectiveness [10]. Furthermore, establishing binding regulations for environmental budget allocations, as proposed by the European Commission (2021), Would ensure a more structured approach to sustainability. A further critical step is the integration of climate indicators into the planning and budgeting process. This would align Mappi Regency with international best practices and support Indonesia's broader environmental and climate commitments [8]. Initiatives to enhance environmental literacy among decision-makers are essential to a paradigm shift toward green budgeting. Sterner & Coria (2013) Knowledge dissemination and awareness-raising are critical for embedding environmental considerations into public policy and budget processes.

7. Conclusion

In order to transform Mappi Regency's budget process and align it more closely with green budgeting principles, a multifaceted approach must be adopted; this approach must include the adoption of evidence-based tools, the formulation of binding regulations, the enhancement of environmental literacy among policymakers, and the incorporation of climate indicators into budget planning. Such reforms would ensure the sustainability of the region's natural resources and contribute to a more resilient and balanced development framework, thus securing the environmental legacy for future generations.

However, we also highlight several limitations that hinder the integration of sustainability objectives into budget processes. Key constraints include the absence of comprehensive environmental data, insufficient policy and regulatory frameworks, and limited awareness among decision-makers about the importance of environmental sustainability. Addressing these limitations through data-driven approaches, regulatory reforms, capacity building, and decentralized budget authority would strengthen the alignment between fiscal planning and environmental sustainability objectives.

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