International Journal of Social Science and Human Research

ISSN (print): 2644-0679, ISSN (online): 2644-0695

Volume 08, Issue 12 December 2025

DOI: 10.47191/ijsshr/v8-i12-113, Impact factor- 8.007

Page No: 10153-10156

Adaptive Waste Collection and Distribution Vessel for the Ciliwung and Pesanggrahan Rivers in Jakarta

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ABSTRACT: Jakarta's rivers have become highly polluted with waste, especially plastics, exacerbating urban flood risk. Conventional cleanup measures – such as floating trash booms, sediment dredging, and powered cleaning boats – often fail under strong currents or sudden water level rises. In this study, we use a qualitative case-study and design-research framework (observation, data collection, analysis, design recommendation) to develop an innovative, adaptive river-cleaning vessel. The proposed design adapts dynamically to changing flow and water height without obstructing the river, while emphasizing aesthetic form, sustainable materials, and environmental education. Initial results suggest this concept could significantly improve upon existing trash boats and serve as a practical solution for government and NGOs in urban waste mitigation and flood-reduction efforts.

KEYWORD: Adaptive, cleanup, flood, mitigation, river; waste

I. INTRODUCTION

Jakarta's chronic flooding is closely linked to heavy pollution in its river system, especially from plastic and domestic waste. The city is traversed by 13 main rivers that are vital for drainage but become major flood drivers when debris blocks the flow. In particular, the Ciliwung and Pesanggrahan rivers are critical for flood control yet highly vulnerable to overflow. Both rivers run through dense urban areas with much impervious ground, causing dramatic spikes in flow during heavy rainstorms. For example, the severe flood on November 30, 2023 – when runoff from these rivers inundated dozens of neighborhoods – highlighted how waste jams and increased surface runoff collectively precipitate flooding.

Government efforts to mitigate flooding and pollution have included installing floating trash nets, building polder basins, dredging sediments, and deploying mechanical cleaning boats. However, these conventional approaches have notable drawbacks. Static trash barriers can become clogged or detached in high flow, and traditional cleanup boats often struggle in strong currents or during rapid water level changes – in some cases even acting as obstructions that worsen flooding. This gap underscores the need for more adaptable solutions. Researchers have begun exploring advanced strategies to optimize river debris removal. For example, (Kim, 2025) describe a computer vision–based framework for adaptive trash collection along river barriers, reducing collection costs by 10–30% compared to fixed schedules . Similarly, various river-cleaning machines employ floating booms, nets, and conveyor systems to gather debris; these designs can continuously collect and sort floating waste to prevent it from reaching the sea . Building on these ideas, this study aims to design a novel adaptive waste-collection vessel tailored to Jakarta's conditions. The objective is to create a trash-collecting boat that operates effectively in changing currents and depths without blocking the river, while also using sustainable materials and serving an educational function.

II. METHODOLOGY

This research uses a qualitative case-study approach focused on product design to address Jakarta's river waste and flooding issues. The design research framework (Hendriyana, 2018) consists of four main stages: (1) observation of river and waste conditions, (2) data collection (field notes, waste surveys, existing technology review), (3) analysis of findings, and (4) design development with recommendations. Primary data were collected through on-site river observations and waste composition surveys on the Ciliwung and Pesanggrahan and nearby waterways. Secondary data came from literature on urban river management and existing cleanup technologies. The goal is to iteratively synthesize these insights into an innovative, adaptive trash-collecting boat design that is practical for urban flood-prone rivers.

III. RESULT

A. Waste Observation

Field observations confirmed that plastic pollution is pervasive in Jakarta's rivers, but a wide variety of other debris also contributes to flow blockages. In the Ciliwung and Pesanggrahan, we repeatedly saw floating and submerged waste, including plastic bottles, bags, food scraps, wood branches, Styrofoam, old tires, and household refuse. For instance, volunteer cleanup crews in East Jakarta's Ciliwung often collected large amounts of styrofoam, discarded textiles, and clothing, whereas in the Pesanggrahan river stretch plastic bottles, single-use plastic bags, and leftover food waste were most common . These bulky items, along with accumulated plastics, significantly slow water flow and heighten flood risk. The data indicate that urban river cleanup must handle not only lightweight plastic litter but also sizable debris (logs, furniture) to maintain open flow.

Table 1: Characteristics of Waste Types in Observed Rivers

No	River Name	Dominant Waste Type	Description
	Ciliwung river, Jakarta.	Plastic waste, wood, vegetation, styrofoam, vehicle tires, household waste, domestic waste	Major river crossing Jakarta, Bogor, and Depok (±120 km); main contributor to urban flooding and waste accumulation.
	Pesanggrahan river, South Jakarta	Plastic waste, wood, vegetation, styrofoam, vehicle tires, household waste,	It crosses Depok, Jakarta, and Tangerang (±66.7 km); it flows through dense residential areas.
	Dadap river, Tangerang	Plastic waste, wood, vegetation, styrofoam, vehicle tires, household waste, domestic waste	A tributary connected to Ciliwung accumulates waste from upstream areas.
	Jurumudi river, Tangerang	Plastic waste, wood, vegetation, styrofoam	Drainage output of Dadap river. Smaller scale but continuous waste input

B. Current System Evaluation

Existing automated river-cleaning systems were assessed to inform our design. For example, The Ocean Cleanup's Interceptor units use long floating barriers to direct trash toward a conveyor-equipped boat . The Interceptor 001 and the newer Interceptor 020 "Neon Moon II" both employ barriers that funnel debris onto a rear conveyor, which lifts the trash into an onboard container. These systems have large daily capacities (about 50–90 tons) and can operate in fairly strong currents . However, they require significant infrastructure and struggle with very large objects: their conveyors and barriers can jam on oversized debris, and solar-powered components have limited output under heavy load.

By contrast, smaller community-led vessels like the Pandawara boat are simpler: it has a steel hull with a front conveyor to pull in trash and can carry only about 2–3 tons per outing . Its advantages are lower cost and agility, but its capacity is very limited and it relies entirely on human operation. In summary, The Interceptor excels in throughput and automation but at very high cost and with difficulties for oversized debris, whereas the Pandawara craft is inexpensive and flexible but low-capacity and labor-intensive. No existing system perfectly combines large capacity, moderate cost, adaptability, and ease of use. Previous research notes that river-cleaning machines often incorporate floating booms, conveyor belts, and other mechanisms to prevent debris from reaching downstream environments. Our evaluation confirms that an ideal design should blend these proven elements with enhancements to overcome their limitations.

C. Proposed Adaptive Design

The proposed adaptive cleanup vessel is a hybrid electric-diesel boat with modular collection systems designed for Jakarta's rivers. Its key features include:

- Hybrid Power System: Equipped with photovoltaic panels and a small diesel engine, the boat can generate electricity consistently. Solar panels power onboard systems and the conveyor during normal conditions, while the diesel generator automatically assists under low sunlight or heavy loading. This hybrid approach ensures reliable operation in varying weather and waste-load conditions.

- Anti-Jam Conveyor: A forward-rising conveyor belt fitted with spikes and adjustable panels continuously lifts trash from the waterline into the boat. This design (Chandra Prakash, 2024) accepts both lightweight plastic litter and heavier debris without jamming, ensuring continuous collection. Its modular sections can be reconfigured for different river widths.
- Detachable Waste Containers: Unlike fixed internal bins, the vessel carries multiple quick-release waste containers of different sizes. When full, these modular containers can be swapped out by a small crane or winch, allowing for rapid offloading ashore. This expedites disposal and lets the boat resume cleaning with minimal downtime.
- High Capacity Hull: The boat's hull is made of corrosion-resistant material (marine-grade aluminum or stainless steel) with a shallow draft (<1.5 m) suitable for Jakarta's often-silted rivers. It is designed to safely carry roughly 30–50 tons of collected waste per day , balancing the large throughput of Interceptor boats with a lower construction cost.
- Autonomous Assist Systems: Basic automation features include GPS navigation, current and depth sensors, a forward camera, and an autopilot mode. These assist functions reduce crew workload and allow the vessel to maintain an optimal cleaning path, while an operator retains manual control. Such autonomy minimizes personnel needs without fully removing human oversight .
- Educational Design: The vessel's superstructure has a modern, attractive design painted with environmental graphics. It includes an observation deck and public viewing area. This aesthetic focus aims to engage local communities and serve as a floating classroom about river health, thereby raising awareness as it operates.

These features together enable the boat to balance efficiency, technology, and cost. In particular, the modular containers and anti-jam conveyor allow it to handle large debris that would stall other systems. The hybrid energy system and automation make operations more flexible under different conditions. Overall, the design offers comparable capacity to The Interceptor but at a much lower cost (targeting a mid-range budget) and with greater adaptability. It integrates proven mechanical solutions (e.g. conveyors, barriers) in a refined form and adds sustainability and educational value.

DISCUSSION

Urban river pollution in Jakarta is not merely a quantitative issue related to the volume of waste, but also a qualitative and structural problem associated with waste composition, river morphology, and the limitations of existing cleanup technologies. Field observations along the Ciliwung, Pesanggrahan, Dadap, and Jurumudi rivers indicate that although plastic waste dominates in frequency, bulky and heavy debris such as wood, tires, and discarded household furniture plays a more decisive role in obstructing water flow and triggering localized flooding. These materials tend to accumulate at narrow river sections, bends, and infrastructure interfaces, where conventional cleaning systems are least effective (Putra & Wijaya, 2020).

The evaluation of existing river-cleaning vessels highlights critical operational gaps. Large-scale automated systems, such as the Interceptor 020, demonstrate high daily collection capacity and technological sophistication; however, their reliance on fixed positioning, floating barriers, and linear conveyor systems limits adaptability to fluctuating water levels and strong currents. Furthermore, their reduced effectiveness in handling oversized debris necessitates additional support from heavy machinery, increasing operational complexity and cost. These findings align with previous studies that emphasize the vulnerability of rigid waste-collection infrastructures in highly dynamic river environments.

In contrast, smaller-scale vessels such as the Pandawara boat offer greater maneuverability and lower investment costs, making them suitable for community-led cleanup initiatives. Nevertheless, their limited waste capacity and dependence on manual labor significantly constrain their effectiveness in heavily polluted urban rivers. This trade-off between capacity and flexibility suggests that neither large automated systems nor small manual vessels alone can adequately address the complex waste conditions observed in Jakarta's rivers.

The comparative analysis underscores the need for an intermediate, adaptive solution that bridges this technological gap. An adaptive river-cleaning vessel, equipped with a modular waste-handling system, an anti-jamming conveyor mechanism, and a hybrid energy source, offers a promising alternative. Such a design would enable efficient handling of diverse waste sizes while maintaining operational flexibility under varying hydrological conditions. Moreover, reducing reliance on fixed barriers and heavy auxiliary equipment would enhance system resilience during peak flow events, when flood risk is highest.

From a broader perspective, the implications of this study extend beyond technical design. River-cleaning vessels in urban contexts should be viewed not only as waste management tools but also as integral components of flood mitigation strategies and public environmental education. An adaptive vessel with visible operation and educational features could reinforce public awareness of river pollution and encourage behavioral change, thereby supporting long-term sustainability goals.

CONCLUSION

This study demonstrates that effective river waste management in Jakarta requires a shift from conventional, rigid cleanup approaches toward more adaptive and context-sensitive solutions. While plastic waste remains the most visible pollutant, bulky debris poses a greater threat to river flow and flood risk, underscoring the limitations of existing river-cleaning technologies that are not designed to handle diverse waste compositions.

The analysis of current river-cleaning vessels reveals a significant gap between high-capacity automated systems and low-cost manual solutions. Large-scale systems offer efficiency but lack flexibility and cost effectiveness, whereas small-scale vessels provide adaptability but insufficient capacity. This imbalance highlights the need for an adaptive river-cleaning vessel that integrates moderate-to-high collection capacity, operational flexibility, and economic feasibility.

By synthesizing empirical waste observations and technological evaluation, this research concludes that a modular, hybrid-powered, and semi-autonomous river-cleaning vessel represents a viable direction for improving urban river management. Such a system has the potential to enhance waste collection efficiency, reduce flood risk, and support sustainable river restoration efforts. Future research should focus on prototype development, performance testing under real river conditions, and integration with urban waste management and flood control policies.

ACKNOWLEDGEMENT

Authors would like to convey their heartfelt appreciation to everyone who contributed to the completion of this research. Particular thanks are given to the lecturers of the Product Design Study Program, Faculty of Art and Design, Universitas Trisakti, for their valuable guidance, academic assistance, and insightful feedback throughout the research and writing stages. Authors also express their gratitude to the representatives of River's Impact group for kindly providing insights and practical information related to their cleanup boat and waste management. In addition, the authors acknowledge the unwavering support and encouragement from family members and colleagues during the research process. This research could not have been accomplished without the collaboration and contributions of all parties involved.

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