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Riparian Landscape Suitability for Urban Tourism: A Case Study at Ciliwung River in Central Jakarta, Indonesia

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Abstract
To meet community needs, riparian zones of rivers are widely developed as recreational areas in major cities. Jakarta has the potential for riparian tourism development as it is traversed by 13 rivers. However, before being developed as riparian recreation areas, several assessments of the site are required. This study aimed to assess three distinct segments of the Ciliwung River in Central Jakarta for their potential as urban tourism sites. The evaluation was carried out by incorporating several parameters related to the suitability of riparian areas for tourism, including vegetation cover percentage, accessibility, and water quality. These parameters were measured using the Riparian Strip Quality Index (RSQI), proximity to public transportation hubs, and the Pollution Index, then categorized into four scoring levels. High scores indicate the suitability of riparian areas as tourist locations. Segments 1, 2, and 3 received scores of 6, 7, and 7 respectively out of 12, indicating that the riparian areas are still far from being ideal urban tourism sites. The findings also highlight weak land use regulations in these riparian zones and poor water quality in the Ciliwung River in Central Jakarta. The originality of this study lies in its combination of terrestrial ecosystem assessment parameters (vegetation cover percentage, accessibility) and aquatic ecosystem indicators (water quality), resulting in a comprehensive evaluation of the riparian landscape management.

Keywords: Land Use, Landscape Management, River, Urban Tourism, Vegetation Cover.

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1. Introduction

Urban communities have different characteristics compared to rural communities (Ayala-Azcárraga *et al*., 2019). High economic growths followed by long working times having an impact on mental health, such as depression and stress. To solve this problem, the urge of relaxation and recreation activities are very high for urban communities to maintain mental health. The existence of community connectivity with nature can provide recreational benefits by giving a relaxing effect so that the risk of mental illness can be reduced (Dzhambov *et al*., 2018; Garrett *et al*., 2019). Several water-related recreations such as fishing, swimming, and visiting water tourist attractions are options for people to relax. The water element is believed to have a relaxing effect on humans. Several studies show that the availability of green open space (GOS) and blue open space (BOS) in urban areas can reduce the risk of mental illness. The benefits of GOS as a place for people to socialise can help reduce the character of urban communities which tend to be individualistic and lack social cohesion. The existence of social cohesion among urban communities can also provide benefits for reducing mental health risks (Liu *et al*., 2020).

Several BOS, such as rivers and lakes, also provide tourism services in the form of interesting views that the public can enjoy for free. In contrast to lakes which provide a lentic ecosystem, rivers have flowing water features that providing calm and relaxation effect for visitors. Several elements of the river ecosystem can determine aesthetic value. Researchers have suggested that riparian landscapes can provide aesthetic value for tourist attractions. Forest and vegetation formations alongside the riverbank can provide the natural shape of rivers that support the tourist attraction (Saha *et al*., 2020). It is estimated that the presence of vegetation can maintain the sensitivity of riparian areas from erosion, flooding and ecosystem stability (Kruizse *et al*., 2019). Many land conversions also occur along the riverbank as a result of the high demand for built-up land. This damage has a negative impact on the river's recreational potential as a tourist location and reduces tourist services.

Meanwhile, several water quality parameters are often correlated with water clarity and odour, thus affecting the beauty of rivers, such as Biochemical Oxygen Demand, Total Suspended Solid, and Dissolved Oxygen (Deutsch *et al*., 2022; Fashae *et al*., 2019). Urban areas in lowland and coastal areas have a high risk of pollutant flows originating from upstream areas. The high residential area in urban areas also increases the risk of domestic waste flows and the lack of absorption areas. Contact between polluted water and human skin risks reducing human health (Singkran *et al*., 2019). Poor water quality will affect the suitability of the river ecosystem as a tourist location. Poor water quality also reduces people's interest in traveling.

Accessibility of tourist locations plays an important role in tourist interest. Previous research shows that many urban residents rely on public transport to reach the tourist locations. Apart from that, the distance between the nearest bus stop or station to the tourist location which can be reached on foot is preferred considering the high practicality and cost efficiency (Tjahjono *et al*., 2020). Walking distance from public transport to tourist locations also needs to be taken into consideration. In several countries that usually rely on motorbikes, interest in walking and the acceptable distance for walking are low. In Indonesia, acceptable walking distance ranges from 400-800 meters (Mulyadi *et al*., 2022). More than that, people prefer to use other, more practical modes of transportation such as motorbike taxis.

Currently, research on riparian areas primarily focuses on land use in terrestrial ecosystems, without considering the water quality (Olokeogun & Kumar, 2020; Saha *et al*., 2020). Some studies incorporate aquatic elements, but primarily from an aesthetic perspective (Li *et al*., 2022; Zhao *et al*., 2013). However, terrestrial and aquatic ecosystems in river landscapes are interconnected and mutually influential. The deterioration of river water quality in urban areas highlights the importance of including water quality analysis in the study of urban riparian landscapes. Integrating water quality assessments into riparian landscape research is expected to provide valuable insights into the overall quality of these landscapes in urban environments.

Ciliwung is one of the rivers that divides Jakarta and crosses various important sites in the heart of the city (Permatasari *et al*., 2017). The strategic location gives the river high tourism potential. The Jakarta walking tour has become one of the tourism concepts currently being promoted by the local government (Musthofa & Arif, 2020). Several locations with historical value can be visited on foot and are located around the Ciliwung River in Central Jakarta, such as the National Monument, Istiqlal Mosque, and Independence Square (Aryanti & Achmadi, 2024). On the other hand, land conversion in the Ciliwung riparian area and increasingly degraded river water quality can become obstacles to developing the Ciliwung River as an urban tourism area (Aprilia *et al*., 2023).

This study aimed to evaluate three segments in Ciliwung River for tourism potential by using some criteria including land use, public transportation, and water quality. This analysis will not only determine the best locations for current tourist activities but will also guide future efforts to enhance and expand river tourism, ensuring sustainable growth, and improved experiences for visitors. The findings will be instrumental in shaping strategies for long-term development, maximizing both the environmental and economic potential of these river segments.

2. Methods

2.1 Study area

This research was carried out on the Ciliwung River, Central Jakarta, Jakarta Province in May-August 2024. Ciliwung River is one of the most important rivers in West Java, Indonesia, particularly for the capital city, Jakarta, as it flows through its urban areas. The river empties into Jakarta Bay, part of the Java Sea, in North Jakarta. The river mouth lies in a heavily urbanised region, making it susceptible to pollution, sedimentation, and tidal effects. Three segments of the Ciliwung River in Central Jakarta Municipality were chosen as research locations considering their strategic location and are located between several important buildings in the capital such as government offices, national mosques, national hospitals, etc. Segment 1-3 were sorted from upstream to downstream (south to north). In each river segment, the riparian area was delineated to 50 meters outward (both left and right) from the water body boundary. The decision to select a riparian width beyond the standard requirement (up to a maximum of 30 meters) was intentionally made to assess land use conditions within the riparian zone and explore the potential for other land uses that could serve as borrowed landscapes at the study site.

The three quality sampling points were located on the border of each segment. Sampling points were chosen at each end of the segment to assess the water quality after it has flowed through the segment. The Ciliwung River in Central Jakarta is connected to other rivers in the surrounding area such as Cideng and East Kalibaru. Map of study location can be seen on Figure 1. The analysis was performed by evaluating various parameters that influence tourist interest in visiting a river segment as an attraction. Each parameter was assessed using a scoring system with a range from 1 to 4, resulting in four distinct assessment categories. The aggregate score for each river segment, calculated as the sum of its scores across all parameters, ranges from a minimum of 3 (indicating the lowest performance) to a maximum of 12 (indicating the highest performance).

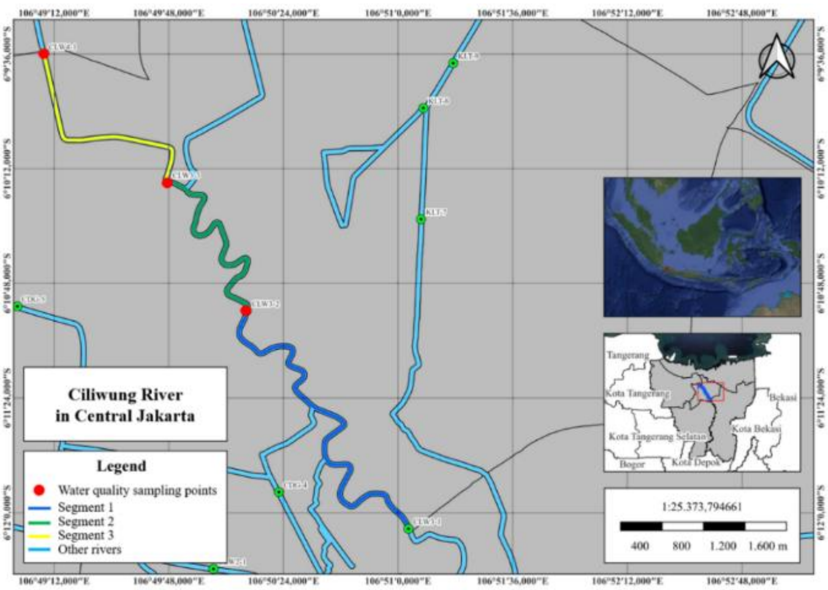

Figure 1. Study Location

2.2 Vegetation Percentage

Land use data was acquired from Landsat satellite imagery in 2024 and utilised to analyse land use within each river segment of the research area. The suitability of riparian zones for tourism was assessed based on the extent of forested or green space coverage, with higher percentages indicating greater suitability (Saha *et al*., 2020). The percentage of vegetation cover was calculated using the following Riparian Strip Quality Index (RSQI) formula (Equation 1). Weight of the i^{th} land use class can be seen on Table 1 and score of RSQI value can be seen on Table 2.

$$RSQI = \frac{\sum(\%LU_i \times W_i)}{10} \quad (1)$$

Where LU_i = land cover percentage in the riparian strip of the i^{th} land use class and W_i = weight of the i^{th} land use class.

Table 1. Weight of Land Use Class

Landuse	Value
Forest	10
Shrubs	8.2
Herbaceous vegetation	5.8
Crops	1.9
Pastures	3.0
Bare soil	1.7
Infrastructure	1.9
Bed rock	3.8
Logging area	4.3

Source: (Saha *et al*., 2020)

Table 2. Score of RSQI Value

Class	Percentage	Score
High	>80	4
Moderate	60-80	3
Low	40-60	2
Very Low	<40	1

Source: (Saha *et al*., 2020)

2.3 Accessibility

Accessibility of riparian areas was quantified by measuring the proximity to public transportation nodes, such as bus stops and train stations. Data on bus stops and train stations were sourced from Google Maps. The suitability of a river segment for tourism was determined by the proximity of riparian zones to these transportation nodes, with shorter distances indicating higher suitability (Mulyadi *et al*., 2022). The acceptable walking distance was adjusted according to the walking willingness standard observed in urban communities in Indonesia. The score of riparian area accessibility can be seen on Table 3.

Table 3. Score of Riparian Area Accessibility

Distance (meters)	Category	Score
0-400	Highly acceptable	4
400-600	Acceptable	3
600-800	Moderately acceptable	2
>800	Not Acceptable	1

Source: (Stanesby *et al*., 2021)

2.4 Water Quality

Water quality is a critical factor in assessing river tourism suitability in urban areas. Data of water quality was collected from Jakarta Provincial Environmental Services in the 2022-2023. Each year, data was analysed from 4 periods those described 4 different seasons (rainy, rainy-dry transition, dry, and dry-rainy transition). For a river segment to be deemed appropriate for tourism, it must meet Class II standards for several water quality parameters as outlined in Attachment VI of Government Regulation of Indonesia Number 22 of 2021. Key parameters, including Total Suspended Solids (TSS), pH, Dissolved Oxygen (DO), ammonia, total phosphate (TP), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD), are commonly used to evaluate water quality, as detailed in Table 4.

Table 4. Water Quality Standard for Tourism Activity

Parameters	Unit	Standard
TSS	mg/L	50
pH	-	6-9
DO	mg/L	4
Ammonia	mg/L	0.2
TP	mg/L	0.2
BOD	mg/L	3
COD	mg/L	25
H_2S	mg/L	0.002
MBAS	mg/L	0.2
Fecal Coliform	MPN/100 mL	5000
Total Coliform	MPN/100 mL	1000

Source: Government Regulation of Indonesia Number 22 of 2021

In addition, other important parameters include hydrogen sulfide (H_2S), Methylene Blue Active Substances (MBAS), fecal coliform, and total coliform. H_2S is a toxic gas produced by the breakdown of organic matter in anaerobic conditions, and its presence in water can indicate poor water quality and a risk to human health due to its toxicity and foul odour. MBAS is used to measure the concentration of anionic surfactants, such as those found in detergents, and high levels can indicate pollution from domestic wastewater. Fecal coliform and total coliform are indicators of microbiological contamination, particularly from sewage or animal waste. Elevated levels of these bacteria suggest the presence of pathogenic microorganisms, which can pose significant health risks to humans, especially in waters used for recreational activities (Effendi, 2003). Therefore, monitoring these parameters is crucial to ensuring the safety and attractiveness of river tourism in urban areas.

The Pollution Index (PI) serves as a tool for evaluating water quality across various environments, including rivers. By aggregating measurements of key water quality parameters, the PI provides an estimate of contamination and degradation levels within aquatic ecosystems, thus aiding in the development of management and mitigation strategies. In Indonesia, the PI is essential for guiding regulatory frameworks, shaping water management policies, and enhancing stakeholder collaboration. The assessment of water pollution status using the PI is outlined in the Decree of the Minister of the Environment of Indonesia Number 115 of 2003 (Equation 2).

$$PI = \sqrt{\frac{(Ci/Lij)^2_M + (Ci/Lij)^2_R}{2}} \qquad (2)$$

Where, C_i is concentration of water quality parameters (i) analysis results; L_{ij} is concentration of water quality parameters (i) quality standard for water allocation (j); $(C_i/L_{ij})_M$ is maximum value of C_i/L_{ij}; and $(C_i/L_{ij})_R$ is average value of C_i/L_{ij}.

The Pollution Index (PI) is calculated by comparing measured water quality parameters against the Class II river water quality standards specified in Attachment VI of Government Regulation of Indonesia Number 22 of 2021. Based on PI values, water quality is categorised into four distinct criteria, as detailed in Table 5.

Table 5. Score of Water Quality based on the Pollution Index (PI)

Class	Score	Criteria	Score
1	0 ≤ PI ≤ 1.0	Good water quality	4
2	1.0 < PI ≤ 5.0	Lightly polluted	3
3	5.0 < PI ≤ 10	Moderately polluted	2
4	PI > 10	Extremely polluted	1

Source: Government Regulation of Indonesia Number 22 of 2021

3. Results and Discussion

3.1 Vegetation Cover Percentage

Based on the comprehensive results of the land cover analysis, the three river segments under study indicated a very minimal percentage of vegetation cover. The landscape in these segments is overwhelmingly dominated by land use dedicated to various forms of infrastructure. Specifically, the tree vegetation classified as forest occupies only a small fraction of the area, reaching proportions of just 3.61% in Segment 1, 5.14% in Segment 2, and 6.00% in Segment 3. These figures underscore the limited presence of natural forested areas, which could have significant implications for local biodiversity and ecological balance (Figure 2).

In addition to the scarce forest cover, the research location revealed a marked absence of other land use types, such as bare soil, crops, pasture, bed rocks, and logging area, which are typically found in rural areas. The overwhelming dominance of infrastructure is a key characteristic of the area. This infrastructure includes a variety of critical and culturally significant buildings, with government offices playing a central role as hubs of public service. The segments are further characterised by densely populated settlements, educational institutions like schools, as well as museums and buildings of cultural heritage, which highlight the area's historical significance.

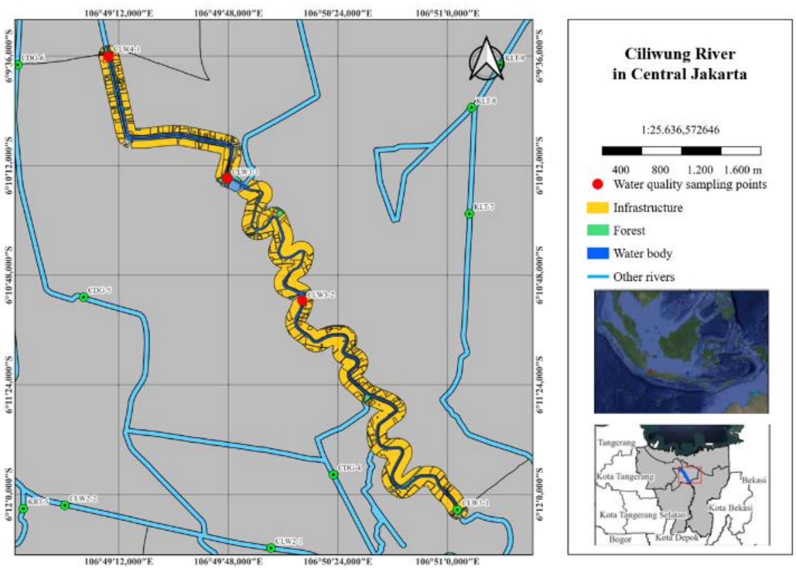

Figure 2. Landuse Map

The spatial distribution of these land uses is detailed in Table 6, providing a clearer understanding of how each river segment is utilised. This distribution not only illustrates the extent of human activity and urbanisation but also emphasises the challenges in balancing development with environmental conservation in these areas.

Table 6. Proportion of Landuse in Each Segment

Landuse	Segment 1	Segment 2	Segment 3
Forest	3.61	5.14	6.00
Infrastructure	96.39	94.86	94.00
Total	**100.00**	**100.00**	**100.00**

The relationship between vegetation cover in riparian areas and the Riparian Strip Quality Index (RSQI) is well established: the greater the vegetation cover, particularly in the form of trees or forested areas, the higher the RSQI value. Conversely, lower vegetation cover, particularly when it is sparse or consists of less dense types like shrubs or herbaceous plants, results in a lower RSQI value. In the three river segments under study, it is noteworthy that no vegetation cover in the form of shrubs or herbaceous vegetation was detected. This absence of varied vegetation types contributes significantly to the minimal overall vegetation cover observed in these segments, which in turn has a direct impact on the RSQI values calculated for each area.

The low RSQI values across the three segments highlighted the ecological consequences of limited vegetation growth. Segment 3 stands out as having the highest RSQI value among the three, attributable to the relatively more extensive tree cover present around the water body in this segment. This tree cover, although still limited, provides a degree of soil stabilisation and ecological support that is reflected in a somewhat improved RSQI value compared to the other segments. However, even this segment's RSQI value remains low, emphasising the overall deficiency in vegetation cover across the research area.

Furthermore, all three segments received a value of 1, the lowest possible RSQI rating, due to the overwhelming dominance of infrastructure in the land cover (Table 7). This predominance of built environments over natural vegetation significantly reduces the potential for soil and ecological quality improvements that vegetation typically provides. The extensive infrastructure in these areas, including residential buildings, public facilities, and other constructed features, not only replaces natural land cover but also impairs the ability of the landscape to support diverse plant life, further compounding the low RSQI values observed.

Table 7. Score of RSQI Value

Segment	RSQI Value	Score
1	21.92	1
2	23.16	1
3	23.86	1

In recent decades, the Jakarta Province has seen a predominance of infrastructure development due to increasing demand for built-up land (Richards *et al*., 2017; Wilonoyudho *et al*., 2017). Rapid population growth, coupled with inadequate land use regulations along riverbanks, has led to the encroachment of riparian areas by residential and service developments (Wen *et al*., 2021). This trend is contrary to the ideal use of these areas, which should include the provision of green open spaces along riverbanks. For embanked rivers in urban areas, a minimum green open space width of 3 meters is recommended. For unembanked rivers, the required green open space ranges from 10 to 30 meters, depending on the river's depth.

The insufficient green open space in riparian zones not only diminishes the aesthetic value of rivers as tourist attractions but also negatively impacts their ecological functions. Riparian areas serve as buffers and water absorbers, mitigating pollutants and regulating water discharge into rivers. Additionally, these areas act as transitional zones between aquatic and terrestrial ecosystems, supporting diverse biodiversity. Development-dominated riparian zones risk increasing water, sediment, and pollutant loads in rivers and reducing biodiversity (Nikolaus *et al*., 2022; Oertli & Parris, 2019).

The prevalence of built-up areas in riparian zones limits tourists' opportunities for relaxation typically provided by green spaces. While water bodies are key elements in urban green open spaces (GOS), combining GOS with blue open spaces (BOS) enhances the relaxation benefits for visitors (McDougall *et al*., 2021; Smith *et al*., 2021). Furthermore, green open spaces can mitigate the high air temperatures often found in urban environments (Davtalab *et al*., 2020). Tourist areas dominated by concrete are susceptible to higher temperatures, which can detract from visitor comfort.

In addition to government and public service buildings, the extensive built-up land cover in certain segments of the Ciliwung River in Central Jakarta is influenced by numerous cultural and tourism-related structures, including museums, national mosques, squares, churches, and performance venues (Aryanti & Achmadi, 2024). These landmarks support river tourism activities related to historical and cultural exploration. Protecting the cultural heritage status of these buildings is essential, as they have been integral to the Ciliwung River's historical narrative. Similar concepts of integrating rivers into historical tourism have been successfully implemented in Kuala Lumpur’s River of Life and Jakarta’s Old Town area (Nayan *et al*., 2020).

However, land use planning along the Ciliwung riparian area is very necessary considering the ecological conditions of the river that are declining every year. Priority of replacing buildings with green open spaces needs to be done with careful consideration to meet the minimum limit of green open space in urban areas of 30%. Currently, the area of green open space in Jakarta is still far below that standard. The provision of green open space in Jakarta not only functions to increase tourist attractions but also to improve ecological functions such as flood prevention, pollutant absorption, microclimate regulator, and human wellbeing.

3.2 Accessibility

A detailed mapping of bus stops and stations within a 400-meter radius was conducted at the three study locations, revealing a well-established network of public transportation options in these areas (Figure 3). The mapping identified more than 10 bus stops and 2 stations within a closer radius of 50 to 200 meters from the study locations. This dense distribution of stops and stations underscores the high level of accessibility to public transport across the three segments, making it convenient for residents, workers, and visitors alike to reach these areas using public transportation. The dominance of Busway stops among the various types of public transport options is particularly notable, highlighting their crucial role in the public transportation network of the area.

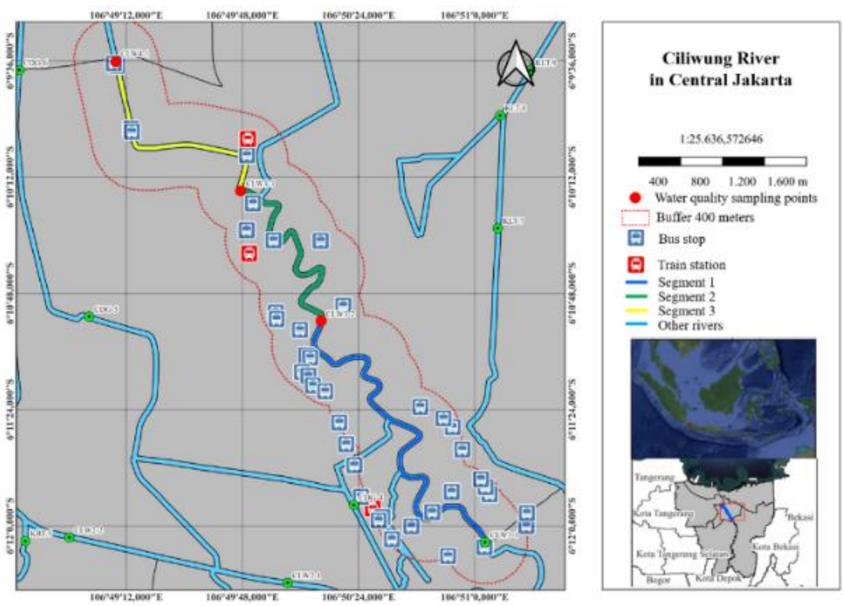

Figure 3. Map of Bus Stop and Train Station

In addition to the Busway stops, commuter line stations were also identified within a 400-meter radius from Segment 2 and 3, further enhancing the accessibility of this segment by providing direct connections to regional rail services. However, other modern transportation modes such as the MRT (Mass Rapid Transit) and LRT (Light Rail Transit) were notably absent from the stops around the study locations. This absence suggests that users of the MRT and LRT systems would need to transfer to alternative forms of transportation, such as the Busway, city buses, or the Jaklingko service, to reach these areas, indicating a potential gap in the direct connectivity of these modes to the study locations.

While the study locations were not yet fully integrated into the entire spectrum of Jakarta's transportation network, the existing bus stops and stations adequately meet the needs of public transport users in accessing these areas. The nearly equal distribution of stops in each segment makes it challenging to determine which segment boasts the highest accessibility value, as the number of stops is almost identical across the three. Additionally, all three segments are strategically located near significant public facilities, which likely contribute to a high volume of visitors (Table 8). For instance, Segment 1 is situated near major attractions such as the national hospital, a prominent art area, and the historic Proclamation Building. Segment 2 is in close proximity to cultural landmarks like the national gallery and a museum, while Segment 3 is located near the iconic national mosque and the National Monument.

Table 8. Score of Accessibility

Segment	Public transport hub within 400 meters radius		Score
	Bus Stop	Train Station	
1	27	1	4
2	8	1	4
3	5	1	4

This favorable positioning near key public facilities enhances the potential for these riparian areas to attract visitors, particularly if they are developed into tourist destinations in the future. The existing public transportation infrastructure, combined with the proximity to popular attractions, ensures that visitors would find it relatively easy to access these areas, further supporting their viability as accessible and attractive locations within the city.

The high traffic congestion in major cities such as Jakarta has prompted local governments to develop diverse public transportation options for residents. The goal is to reduce the number of private vehicles on city roads, thereby alleviating traffic density. Additionally, enhanced public transportation is intended to shorten travel times and decrease fossil fuel emissions. In Jakarta, the government has introduced various modes of public transport, including Transjakarta (public buses), Jak Lingko (feeder taxis), mass rapid transit (MRT), light rail transit (LRT), and Commuter Line, to improve citizen mobility (Hasibuan & Mulyani, 2022).

Besides commuting to work, urban dwellers also use public transportation to visit tourist attractions. Public transit is preferred for tourism due to factors such as avoiding traffic congestion, convenient access to tourist sites, comfort, and the opportunity to travel with family (Nagari *et al.*, 2020; Sarker *et al.*, 2020). High accessibility from the nearest bus stops or stations can significantly boost visitor numbers to tourist destinations. Although the three river segments in question are not yet established tourist sites, the presence of public transportation facilities nearby makes these rivers strategically located and easily accessible from the nearest bus stops.

In developing countries with limited walkability, tourist attractions that are distant from the nearest bus stops or stations may see reduced visitor interest. Factors such as poor pedestrian infrastructure, conflicts between pedestrians and cyclists/motorcyclists, and inadequate safety measures can hinder access (Mulyadi *et al.*, 2022). In Jakarta, efforts have been made to enhance walkability in several areas through the development of pedestrian-friendly infrastructure. However, in study locations, pedestrian pathways that meet comfort standards for pedestrians are still lacking.

3.2 Water Quality

Water quality in each period and segment shows fluctuating results. In the rainy season, TSS (Total Suspended Solids) tends to be high, primarily due to increased runoff, which washes more particles into the river, and this is accompanied by a decrease in DO (Dissolved Oxygen), as the higher sediment levels can inhibit oxygen diffusion. Throughout each period, BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) values remain elevated and consistently exceed the established quality standards. High BOD and COD indicate excessive organic matter and pollutants in the water, contributing to further reductions in DO, as the decomposition of these substances consumes oxygen. On the other hand, the level of fecal and total coliform also exceeded the water quality standard due to the poor sanitation system and high anthropogenic activities in study location without appropriate wastewater treatment plant. Public awareness among communities living along the riverbank regarding the importance of clean living is still weak, as reflected in littering behavior.

The Pollution Index (PI) values in each period and segment were dominated by the "moderately" and "extremely polluted" categories, indicating poor river water quality across the three segments during all periods (Table 9). This suggests that the river experiences significant pollution pressure, likely from both point and non-point sources, impacting its suitability for tourism and other uses. However, it is important to note that the average PI shows decreasing trends downstream, which indicates an improvement in water quality conditions toward the river's lower segments. This may be due to natural self-purification processes, such as sedimentation and dilution, that occur as the river flows downstream, reducing the concentration of pollutants.

Table 9. Score of Pollution Index (PI)

Segment	2022	2023	PI Average	Score
1	13,99	10,61	12,30	1
2	9,68	8,94	9,31	2
3	7,40	9,44	8,42	2

The combined score of the three riparian area suitability assessment parameters reveals that none of the river segments reached the maximum score of 12 (Table 10). Segment 1 scored the lowest with 6 points, while segments 2 and 3 each scored 7. All three segments achieved the highest possible score for accessibility, indicating their strategic location and the strong availability of public transportation. However, the vegetation cover percentage parameter yielded only 1 point for all segments, reflecting the limited presence of vegetation, a situation further confirmed by the extensive land use for infrastructure along the Ciliwung River riparian zone in Central Jakarta. Similarly, water quality received a low score, with a maximum of just 2 points, due to high levels of pollutants such as BOD and COD throughout the year, which significantly reduce the river's suitability as a tourist destination that requires good water quality.

Table 10. Aggregate Score of Three Parameters

Segment	Vegetation Cover Percentage	Accessibility	Water Quality	Total Score
1	1	4	1	6
2	1	4	2	7
3	1	4	2	7

Managing river water quality in DKI Jakarta presents significant challenges that stem from both its geographical location and the socio-environmental factors influencing the area. Positioned in a lowland region and at the confluence of 13 rivers, Jakarta is naturally vulnerable to water management difficulties. These rivers, which flow from upstream regions through various cities and provinces, bring with them pollutants, debris, and sediments from surrounding areas. As a result, effective water quality management in Jakarta is not an isolated task but one that requires collaborative efforts between the city and local governments responsible for upstream watershed regions. Given the interconnected nature of river systems, pollution originating upstream has a direct and often significant impact on water quality downstream in Jakarta (Asdak *et al*., 2018). Unfortunately, the lack of effective coordination among river managers across these regions exacerbates water quality challenges, making it difficult to implement and enforce consistent water management strategies.

For river-based tourism, maintaining water quality is paramount, as water quality must meet Class II standards to ensure safety and appeal. Rivers serve as a major attraction for tourists, but factors such as elevated turbidity, foul odours, and the visible presence of waste can significantly detract from the natural beauty and recreational potential of these water bodies (Lee, 2017). In addition to the aesthetic concerns, poor water quality poses serious health risks to visitors, who often engage in activities such as swimming, boating, or fishing. Contaminated water may lead to a range of illnesses, including skin diseases, gastrointestinal infections such as diarrhea and dysentery, and other waterborne diseases (Gwimbi *et al*., 2019; Lin *et al*., 2022). Moreover, fish and other aquatic species caught in polluted rivers may contain harmful toxins, rendering them unsafe for consumption and further diminishing the river's role in local food security and tourism.

In recent years, Jakarta has struggled with severe water pollution, a problem reflected in high Pollution Index (PI) levels. A major contributor to this pollution is domestic waste, which includes untreated sewage, household detergents, and other organic materials. These pollutants result in elevated levels of Biological Oxygen Demand (BOD), indicating an excessive amount of organic matter in the water, as well as high concentrations of *E. coli* bacteria, signifying the presence of fecal contamination (Aprilia *et al*., 2023). The city's inadequate sanitation infrastructure, coupled with the absence of widespread communal wastewater treatment facilities, exacerbates these water quality issues (Brontowiyono *et al*., 2022). This situation is worsened by rapid urbanisation, which increases the volume of wastewater generated without a corresponding expansion of water treatment capacity.

Water quality in rivers is significantly influenced by seasonal variations, particularly during the rainy and dry seasons. In Jakarta, as in many other tropical regions, the onset of the rainy season leads to notable changes in water quality due to increased runoff, while the dry season presents its own set of challenges related to water pollution and scarcity. During the rainy season, which typically occurs from November to March, Jakarta experiences heavy rainfall that dramatically affects the water quality of its rivers. One of the most prominent effects is the increase in Total Suspended Solids (TSS). The intense rainfall washes soil, debris, organic matter, and pollutants from urban areas into the rivers, significantly raising TSS levels. These suspended particles not only reduce water clarity but also increase turbidity, making the water appear cloudy and less appealing for tourism or recreational activities (Wirasatriya *et al*., 2023). High turbidity levels can also negatively affect aquatic life by blocking sunlight needed for photosynthesis and smothering habitats (Karbela *et al*., 2021).

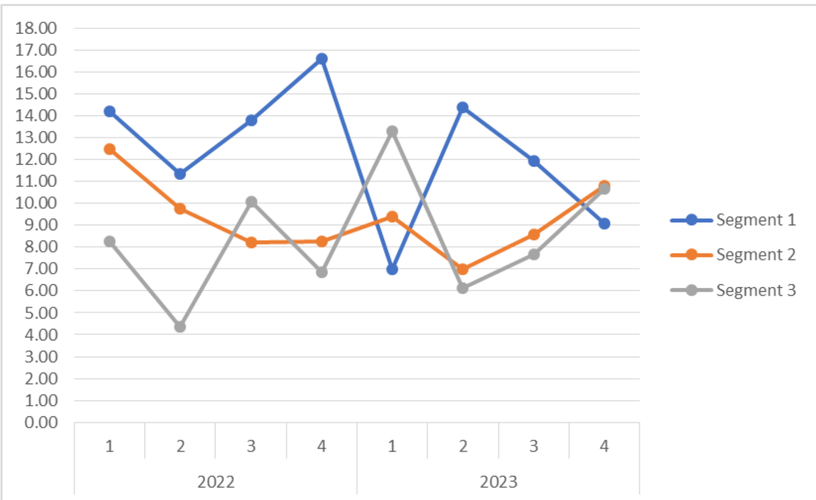

Figure 4. Seasonal Score of PI

Figure 4 shows the seasonal score of PI which indicated by high pollution in rainy season (period 1) and dry season (period 3) in each year. The rainy season is also associated with a decline in Dissolved Oxygen (DO) levels. As runoff carries organic pollutants into the rivers, the biological decomposition of this material by bacteria consumes large amounts of oxygen, leading to oxygen depletion. This can result in hypoxic conditions, which are harmful to aquatic organisms and further deteriorate the river's ecosystem (Aprilia *et al*., 2023). Furthermore, the rapid influx of water during the rainy season can cause localised flooding, which not only disrupts human activities but also introduces additional contaminants from overburdened sewage systems and stormwater drains into the rivers (Limthongsakul *et al*., 2017). These contaminants, including pathogenic bacteria, heavy metals, and nutrients like nitrogen and phosphorus, exacerbate water quality issues by promoting eutrophication (Aprilia *et al*., 2024) and increasing health risks for communities and tourists who come into contact with the water.

In contrast, the dry season, which occurs from April to October, presents different but equally concerning challenges for water quality. During this period, river flow rates typically decrease due to the lack of rainfall, leading to a reduction in the natural dilution capacity of the rivers. As a result, pollutants that enter the river—such as untreated domestic waste, industrial effluents, and agricultural runoff—become more concentrated. This concentration effect is particularly problematic for Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels, which tend to rise in the dry season as pollutants accumulate in the river without sufficient water flow to disperse them. The reduced flow also slows down the river's self-purification processes, allowing contaminants to persist for longer periods (Maulud *et al*., 2021).

Another critical impact of the dry season is the reduction in Dissolved Oxygen (DO) levels. With less water moving through the river, the capacity for natural aeration is diminished, which further exacerbates oxygen depletion (Aprilia *et al*., 2023). This can result in the proliferation of anaerobic conditions, especially in sections of the river where organic pollution is high. Under these conditions, bacteria break down organic material through anaerobic respiration, which produces harmful gases like hydrogen sulfide (H_2S), contributing to foul odours that make the river less appealing for tourism (Hamoda & Alshalahi, 2021). The combination of high pollutant concentrations and low DO levels creates an environment that is hazardous for both human health and aquatic life.

The seasonal variations in water quality also affect the Pollution Index (PI), which tends to fluctuate between the rainy and dry seasons (Aprilia *et al*., 2022). During the rainy season, the influx of pollutants from runoff and increased organic load results in higher PI values, indicating more severe pollution. However, downstream areas may experience some improvement in water quality during the dry season due to the settling of pollutants in upstream regions, where the river flow is slower. This phenomenon, known as pollutant stratification, often results in lower PI values downstream during the dry season, reflecting improved conditions in certain river segments (Brontowiyono *et al*., 2022).

Addressing these water quality challenges and improving conditions to a level where pollution is classified as light or minimal will require substantial efforts from a wide range of stakeholders. First and foremost, upgrading sanitation infrastructure—including the construction of communal wastewater treatment plants—is crucial to reduce the direct discharge of domestic waste into the rivers (Gwimbi *et al*., 2019). Additionally, public awareness and community involvement are key to preserving the river ecosystem and ensuring that policies and regulations designed to protect water quality are respected and adhered to. Encouraging local residents and businesses to engage in environmentally responsible practices, such as proper waste disposal and reduced use of harmful chemicals, can significantly mitigate the pollution problem. Moreover, regular monitoring and enforcement of water quality standards by governmental agencies are essential to sustaining long-term improvements. With a collective commitment to better water management, Jakarta's rivers can be restored to meet both environmental and recreational standards, promoting a healthier ecosystem and enhancing the city's potential as a destination for river-based tourism.

4. Conclusion

Segments 1, 2, and 3 received overall scores of 6, 7, and 7 respectively, out of a possible 12. The findings indicated that all segments are still far from ideal as urban riparian tourism sites, as evidenced by their low scores, particularly in vegetation cover and water quality. The high use of land for government, commercial, cultural, and tourism-related structures, dating back to the colonial era, has greatly limited vegetation in the area. Furthermore, much of the infrastructure was developed before regulations on building limits near riverbanks were in place, and many of these structures are considered national heritage, making it difficult to convert them into green spaces. The poor suitability of these river segments is also driven by low water quality, with high levels of pollutants from domestic and industrial activities, as well as runoff during the rainy season, as indicated by elevated BOD, COD, TSS, fecal coliform, and total coliform levels, which resulted in a drop in dissolved oxygen (DO). The lack of vegetation buffer strips around the river exacerbates the problem.

While these scores are far from ideal, the area shows potential for future development as a tourist destination. The high accessibility from public transportation hubs can attract visitors, and the presence of historical buildings and local cultural heritage could serve as unique tourist attractions. This concept has been successfully applied in waterfront tourist destinations in other ASEAN countries, such as Malaysia and Singapore. To realize ideal riparian tourism, cooperation between stakeholders is needed to create ideal riparian landscape management including spatial planning for riverbank and pollutants load regulation in the river so that the quality of the riparian and aquatic ecosystems can meet tourism activity standards. Providing green open space on riverbanks can improve the quality of land use while absorbing runoff pollutants before they enter the river.

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