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# Influence of Urban Morphological Challenges on the Travel Behaviour of Inland Waterway Users in Lagos Metropolis, Nigeria

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**ABSTRACT**
Urban development and transport systems share a well-established symbiotic relationship, with urban growth significantly impacting mobility worldwide. Lagos, Nigeria, exemplifies this with its rapid urbanization driven by diverse sectors and significant population growth. As cities expand due to population increases, economic activity, and shifting land use dynamics, sustainable transportation solutions become critical. This study investigates the relationship between urban morphology and the use of inland waterways, focusing on the impact of urban morphological challenges on the travel behaviour of users in Lagos Metropolis, Nigeria. The research utilized both primary and secondary data sources through questionnaires, observations, interviews, and ridership data from the Lagos State Inland Waterways Authority (LASWA). A sample size of 1,200 was determined using Krejcie and Morgan's table, with respondents purposively selected from an average daily ridership of 16,630 across 10 randomly selected jetties. Multiple regression analysis assessed the impact of morphologically induced challenges on travel behavior. The regression analysis revealed a negligible relationship between morphological challenges and the travel behavior of inland waterway users in Lagos Metropolis, with an R Square value of 0.002, indicating that only 0.2% of the variability in travel behavior could be attributed to morphological factors. The ANOVA results corroborated these findings, with the regression model showing no significant explanation of the variance in travel behavior due to morphological challenges. The study's coefficients further indicated that frequency of trips, average number of trips, and satisfaction level had no significant impact on morphological challenges. The study concludes that urban morphological challenges have a limited impact on the travel behavior of inland waterway users in Lagos Metropolis. It suggests the need for broader urban and transportation planning perspectives that incorporate various elements beyond physical infrastructure to enhance the efficiency and user satisfaction of inland waterways. Future research should explore additional variables that may better predict or explain the challenges faced in urban waterway transportation to inform more effective policy and planning decisions.

**Keywords:** Inland waterways, transportation planning, urban morphology, Lagos Metropolis
**Word count: 317**

## I. INTRODUCTION

Urban development and transport systems have a well-established symbiotic relationship, with the physical environment and urban growth patterns impacting mobility significantly worldwide. As cities expand due to population increase, economic activity, and shifting land use dynamics, the need for effective and sustainable transportation solutions becomes more critical. Excessive dependence on a single mode of transport, primarily road-based, has led to an overconcentration of services on the road subsector in many cities, particularly in emerging nations like Nigeria (Badejo, 2017; Oyesiku, 2020).

Despite the potential for more affordable passenger and cargo transportation via other modes, such as inland waterways, this unimodal approach has proven insufficient in meeting the complex transportation demands of expanding urban centers, exacerbating issues like traffic congestion, pollution, and limited accessibility. While much is known about the interplay between urban morphology and transport system especially road, rail, and air transport, the potential impact of the city form on sustainable transport and mobility option, particularly inland waterways remains underexplored.

Previous studies have examined the effects on urban development and morphology on transport sub-systems, focusing on roads, rail lines, and airways (Aderamo, 1990; Lisha et al., 2021; Marcin et al., 2018; Abraham et al., 2015; Aunurrofik, 2018; Aljoufieet al., 2011). Additionally, research has highlighted the socioeconomic benefits and urban mobility implications of water transportation (Ademiluyi et al., 2016; Owoputi & Owoputi, 2019; Usman &Animashaun, 2020). However, a significant gap remains in understanding the relationship between inland waterways and urban growth, particularly in terms of the urban morphological challenges and how it affects the travel behaviour of inland waterways user, with reference to Lagos metropolis.

Historically, riverbank settlements have been crucial to the establishment of major cities worldwide due to the role of water transportation in promoting growth, trade, and economic prosperity (Oyesiku, 2020). As urban areas continue to expand, residents seek quicker ways to navigate, with neighborhoods like Ijede, Langbasa, and Badore in Lagos evolving as locals prefer areas near waterways for ease of navigation. For instance, a boat trip from Ijede to Badore takes less than ten minutes, whereas traveling by road can take several hours. This preference has necessitated thoughtful construction along these waterways.

Thus, understanding how large cities like Lagos especially the city's metropolitan urbanization/morphology contributed to inland waterways is critical. It is equally important to determine the impact of morphological changes on the travel habits of inland waterway users.

Addressing this knowledge gap and exploring the influence of the morphologically induced challenges on the travel bevaviour of inland waterways users in metropolitan areas like Lagos can inform more holistic and sustainable urban transport planning strategies. By expanding our understanding of the intricate relationships between land use development and transportation systems, including water-based systems, this study aims to provide valuable insights for urban planning and transportation policy.

## II. LITERATURE REVIEW

### 2.1.1 The Urban Form

Rodrigue (2020) defines urban form as the spatial arrangement of an urban transport system along with its associated physical infrastructure, creating a specific spatial layout for cities. Transportation infrastructure, including roads, transit networks, and walkways, has played a pivotal role in shaping urbanization, resulting in diverse urban forms and spatial configurations. The urban spatial structure, a subset of urban form, refers to the network of connections arising from the movement of people and goods within the urban framework, assessing the reachability of urban constructions via different transportation modes.

Urban spatial structure is categorized based on transportation developments and characterized by two main elements: centralization and clustering. Centralization pertains to the dispersion of activities across a metropolitan area, with centralized cities concentrating activities within a designated center, often driven by financial companies and large enterprises. Clustering involves the arrangement of activities around specific hubs, frequently connected to transportation facilities such as highway interchanges and transit hubs. Two structural elements, nodes, and linkages, intricately shape the urban form and spatial structure. Nodes, representing hubs of urban activity, are linked by transportation facilities facilitating movement, establishing functional connectedness crucial for interdependent urban operations like production, management, and trade (Rodrigue, 2020).

### 2.1.2 Evolution of Transportation and Urban Form

The development of urban transport systems is closely related to urbanization, particularly in terms of system capacity and efficiency. Historically, walking was the primary mode of urban transportation, leading to compact urban forms with clustered activity nodes. While these patterns still exist in some modern cities, they are no longer the norm. European and East Asian cities often have dense urban centers conducive to walking and cycling, whereas newer cities in America, Canada, and Australia exhibit dispersed structures promoting car dependency. Trade significantly influences the urban spatial form and economic vitality of port cities, with ports and airport terminals serving as crucial nodes within urban spatial organization(Antrop, 2004).

Urban form has evolved significantly with advancements in transportation technology, reflecting dramatic changes in urban structure. The formation of new clusters in suburban areas exhibiting unique urban activities and linkages is one such alteration. Central business districts (CBDs), once the primary hub for public transportation commuters, have transformed due to shifts in retail, manufacturing, and managerial practices(Garcia-López, 2012). Suburbanization of industry, office, and retail operations has altered urban structures, with essential transport hubs emerging in suburban regions to meet modern freight distribution demands. This transition from a nodal to a multi-nodal urban spatial structure requires new urban development patterns and connectivity to local, national, and international economic processes. Large road corridors initially facilitated suburban development, which gradually led to a consistent suburban landscape, significantly altering the activity structure of cities and promoting varied urban growth rates based on economic specialization(Feng et al., 2008; Nuissl&Siedentop, 2020).

### 2.1.3 Urban Land Use and Transportation

Urban land use reflects the spatial concentration and location of diverse activities, such as retailing, management, manufacturing, and residence, each generating flows supported by intricate transport systems. These urban environments sustain a broad spectrum of social, cultural, and economic activities dispersed across multiple locales, forming a complex network of activities. These activities range from regular events like traveling and shopping to sporadic endeavors driven by necessities or lifestyle choices. Production activities associated with distribution and manufacturing establish connections at local, regional, or international levels, driving the movement of goods. The spatial dispersion of activities stimulates passenger and freight movements, underscoring the link between land use and transportation (Rodrigue, 2020).

The diverse landscape of urban land use is shaped by the transportation system, which accommodates the numerous transport needs arising from urban activities. Urban activities are hierarchically distributed, with key locations developing due to institutional, political, economic, or cultural factors, resulting in high levels of spatial accumulation in sectors like retail and management(Bidandi& Williams, 2020). Peripheral regions, primarily residential and warehousing areas, show lower levels of accumulation. Individuals, institutions, and businesses influence land use through their site choices, reflected in both formal and functional land use typologies. Formal typologies emphasize qualitative characteristics like form and pattern, while functional typologies highlight economic aspects of activities such as production, consumption, dwelling, and transportation. Cities occupy around 3% of the world's landmass, with residential land use comprising 65-75% of a city's footprint, and commercial and industrial land uses accounting for 5-15% respectively. Car-dependent communities often have 35-50% of their total land area dedicated to parking lots and roadways (Rodrigue, 2020). Understanding the complex interactions between land use and transportation is crucial for comprehending urban dynamics and informing planning and policy decisions.

## 2.2 EMPIRICAL REVIEW

A number of studies have been carried out by researchers in the field of urban transportation, focusing on the impacts of various transport modes on urban morphology and economic development. A study by Bao et al., (2022) examined the spatial and temporal patterns of traffic congestion in Xining, a small city in China. Using multivariate least-square regression analysis on social-sensing hyperlocal travel data, findings reveal that Xining experiences traffic peaks in the mornings and evenings on weekdays and pre-weekends, and only evening peaks on weekends and holidays. Pre-weekend congestion is notably worse than on regular weekdays, suggesting the need for enhanced traffic management during this period. Educational and residential land use significantly contribute to congestion, exacerbating the issue. The study provides valuable insights for urban planners and policymakers to develop effective strategies for mitigating traffic congestion in small urban areas.

Chen et al., (2023) analyzed the effects of land-use changes on the ecosystem service value (ESV) in the Wuling Mountains from 2000 to 2020. The findings reveal that the Wuling Mountains experienced four stages of transport development, contributing to land-use changes. The spatial pattern of construction land growth evolved with transport development, while garden land gradually spread throughout the region. Policies from different periods significantly impacted ecological land and cropland. During the study period, the ESV initially increased and then declined, with cold spots forming around the transportation axis and hot spots along the Yangtze

River. These insights inform land-use policy and spatial planning under green development principles.

Nozdrovická et al., (2020) conducted a study on the landscape development, land-use changes, and transport infrastructure variations in Martin and Vrútky, Slovakia, over the past 70 years. It analyzes the landscape structures of the area during different periods (1949, 1970, 1993, 2003) and compares them with the current structure (2018). Special emphasis is placed on the evolution of landscape elements forming the transport infrastructure. The study highlights changes in traffic intensities and their impact on landscape formation. Findings show that transport significantly influences landscape changes, with railroad accessibility being crucial until the 1970s and a shift to road transport in recent decades.

Otuoze et al., 2020) in their study investigated the impacts of urban growth on transport space in Kano, Nigeria, over the past few decades to predict future space demands. Landsat images from 1984, 2013, and 2019 were processed, classified, and analyzed to identify land-use/land-cover (LULC) types, including transport space, built-up areas, vegetation, farmland, bare land, and water. The analysis involved model calibration, validation, and prediction using hybrid modeling techniques (cellular automata-Markov) in IDIRISI SELVA 17.0 and ARC-GIS 10.7 software. Results show significant expansion of transport and built-up areas, with predictive modeling indicating further expansion by 345 km² (3.9%) in 2030 and 410 km² (11.7%) in 2050. Kappa reliability indices were 85%, 86%, and 88% for 1984, 2013, and 2019, meeting the 80% minimum suggested for tracking and predicting urban growth.

Bala et al. (2018) conducted a study on road transport development and urban growth in Gombe Metropolis, revealing a significant increase in road network connectivity from 1996 through 2005 to 2014, positively affecting the pattern of urban growth in the study area. Similarly, the results from Duranton and Turner's (2012) study on urban growth and transportation revealed that a 10% increase in a city's stock of roads causes about a 2% increase in its population and employment and a small decrease in its share of poor households over 20 years, while a 10% increase in a city's stock of large buses causes about a 0.8% population increase.

## III. METHODOLOGY

Lagos State, located between 2°42' and 3°42' East longitude and 6°22' and 6°52' North latitude in Southwestern Nigeria, covers 3,475.1 km². Its coastal plain features creeks and lagoons, accounting for 22% of the area, with elevations below 650 meters. Most land is under 320 meters, making it prone to flooding and erosion. Significant population growth saw the census count rise from 5,725,116 in 1991 to 9,113,605 in 2006, with projections of 12.5 million by 2016 (Nigerian Bureau of Statistics).

The transportation landscape in Lagos, a megacity, accommodates over 6 million daily passenger trips, with 70-77% relying on buses. Cars, tricycles, and motorcycles handle most of the rest, while rail and water transport account for less than 1%. Road transport dominates, moving 90% of passengers and goods (Ministry of Transport, 2019). Road transport contributes 27% to Lagos's GDP, yet the infrastructure remains overburdened. The government has focused on enhancing underutilized inland water and rail transport to alleviate congestion and promote sustainability (Ministry of Transport, 2019).

Recent initiatives like the Bus Rapid Transit (BRT), Lagos Bus Systems Ltd. (LBSL), and corporate taxi services aim to modernize the transport system and improve mobility, though challenges persist, including poorly managed bus stops that waste 3 billion hours annually (Ministry of Transport, 2019). This system includes routes like the Purple Line to Redemption Camp, Green Line from Lagos Island to Lekki, Blue Line from Okokomaiko to Marina, and Red Line from Iddo to Agbado. Revamping inland waterways and launching private ferry services are part of a strategy to transform Lagos's transport landscape. Despite water transport being only 0.8% in 2020, recent improvements increased it to 3.2% in 2021. The Lagos State Water Authority oversees 12 ferry routes, enhancing connectivity and transportation options (Ministry of Transport, 2019).

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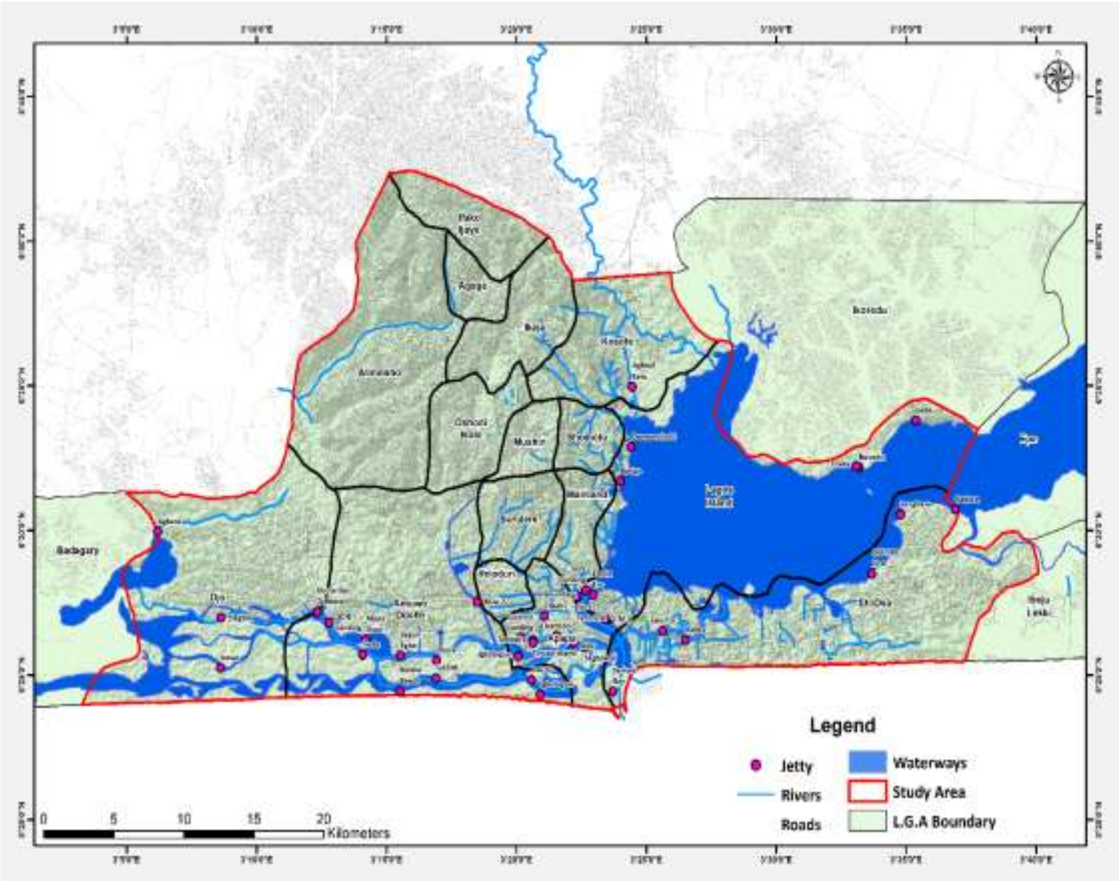


**Figure 3.1 Map showing the Lagos Metropolis and the jetties/terminals/landings within the metropolis. Source: LASWA (2023).**

The study focused on the users of Inland waterways and the jetties in the research region, leveraging both primary and secondary sources of data to ensure a comprehensive and well-rounded exploration, thereby enhancing the validity and robustness of generalisations drawn from the study's findings. The primary sources encompassed the use of questionnaires, observations, and interviews, strategically designed to offer a detailed understanding of the sampled respondents. Complementing these primary sources, secondary data were harnessed, with a focus on the ridership details of inland waterways user, as obtained from the governing body, Lagos State Inland Waterways Authority (LASWA). The Krejcie and Morgan's (1970) table for determining sample size from a given population was incorporated, utilizing a sample size of 1,200 from an average daily ridership of 16,630. This sample size was derived based on a population size range of 10,000 to 25,000, a 99% confidence level, and a 3.5% margin of error, as specified in the Krejcie and Morgan table. To refine the selection process, a purposive sampling technique was employed to select participants based on specific characteristics relevant to the research, such as usage of inland waterways transportation. Additionally, 10 jetties within the Lagos metropolis were selected randomly to ensure a comprehensive representation.Ridership details, presented in Table 3.1, offer a comprehensive view of the context within which the dataset was chosen. This detailed ridership data for the year 2022 served as a foundational element for the research, providing critical insights into the commuting patterns within Lagos Metropolis. Furthermore, to enhance transparency and understanding, the study includes Table 3.2, which visually outlines the randomly selected jetties along with their corresponding sample sizes. A total of 1,200 questionnaires were distributed across these 10 selected jetties, as detailed in Table 3.2.

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**Table 4.1: Ridership Details, 2022.**

| S/N | Name of Terminal/Jetties | JETTY TOTAL |
|---|---|---|
| **1** | AbuleOsun Jetty | 328,160 |
| **2** | APA JETTY | 87,816 |
| **3** | Agbara Jetty | 163,531 |
| **4** | AgboyiKetu Jetty | 1,294,735 |
| **5** | Ajegunle Boundary Jetty | 711,155 |
| **6** | Alex Jetty | 1,127,301 |
| **7** | Badore Terminal | 472,319 |
| **8** | Baiyeku Jetty | 497,159 |
| **9** | Bariga Terminal | 32,667 |
| **10** | Coconut Jetty | 363,069 |
| **11** | Commando Jetty | 286,569 |
| **12** | Addax | 354,691 |
| **13** | EbuteEro | 1,198,210 |
| **14** | Ijon landing | 689,750 |
| **15** | Mile 2 | 987,560 |
| **16** | EbuteIpakodo Terminal | 1,712,701 |
| **17** | EbuteOjo Terminal | 1,253,416 |
| **18** | Elegbata Jetty | 1,390,857 |
| **19** | EpeAyetoro Jetty | 126,613 |
| **20** | Etegbin Jetty | 420,610 |
| **21** | EyinOsa Jetty | 271,653 |
| **22** | Falomo Terminal | 741,984 |
| **23** | GbajiYekeme | 270,583 |
| **24** | Ibese Jetty | 120,415 |
| **25** | Igando Jetty | 662,974 |
| **26** | Ijede Jetty | 670,861 |
| **27** | IjegunEgba Jetty | 1,243,542 |
| **28** | Ijora Jetty | 125,536 |
| **29** | Imore Jetty | 625,255 |
| **30** | IsashiItekun Jetty | 1,165,346 |
| **31** | Ishashi Jetty | 778,494 |
| **32** | IyaAfin Jetty | 463,037 |
| **33** | Langbasa Jetty | 88,871 |
| **34** | Liverpool Jetty | 1,576,949 |
| **35** | Offin Jetty | 465,333 |
| **36** | Oke Ira Nla Jetty | 455,845 |
| **37** | Oluwo Jetty | 216,312 |
| **38** | Pashi | 100,858 |

| | | |
|---|---|---|
| **39** | Sagbokoji Jetty | 326,465 |
| **40** | Slave Route Jetty | 133,328 |
| **41** | Temidire Jetty | 1,115,419 |
| **Total** | | 21,887,738 |

Source: LASWA (2023)

The research looked into how morphologically-induced obstacles affected the way inland waterway users in Lagos Metropolis travelled, incorporating Multiple Regression analysis which is a well-established statistical technique for exploring relationships between a dependent variable and multiple independent variables. In this context, the dependent variable (morphologically-induced challenges) represents the challenges faced by waterway users, while the independent variables (travel behaviour of respondents in the sampled jetties) capture various aspects of their travel patterns, such as frequency of use, average recorded Trips and Satisfaction level.

## IV. RESULTS AND DISCUSSION

The regression analysis conducted on the impact of morphologically-induced challenges on the travel behaviour of inland waterways users in Lagos Metropolis indicates a negligible relationship between the variables. The R Square value, which represents the proportion of the dependent variable's variance explained by the independent variable, is found to be 0.002. This value suggests that approximately 0.2% of the variability in the average number of trips and satisfaction level of inland waterways users can be attributed to morphologically-induced challenges. In other words, the morphological factors considered in the analysis have a limited explanatory power in understanding the variations observed in the travel behaviour of individuals using inland waterways in this specific area.

Statistically, the observed data do not offer conclusive evidence of a significant influence of these challenges on the travel behaviour of inland waterways users in Lagos Metropolis.

**Table 4.1: Model Summary of Regression**

| **R** | **R Square** | **Adjusted R Square** | **Std. Error of the Estimate** |
|---|---|---|---|
| 0.046(a) | 0.002 | 0.000 | 0.498 |

Source: Author’s Analysis, (2024).

The ANOVA results further reinforce these findings, indicating that the regression model, utilising Frequency of trips, Average number of Trips, and Satisfaction Level as independent variables, does not significantly explain the variance in Morphology challenges ($F(3, 1196) = 0.861$, $p = 0.461$). The low R-squared value (0.213%) implies that the included independent variables do not collectively have a substantial impact on predicting Morphology challenges, reinforcing the lack of justifiable reasons to reject the null hypothesis. This suggests that other unexamined factors may play a more significant role in influencing Morphology challenges within the study area.

**Table 4.2: ANOVA**

| | **Sum of Squares** | **Df** | **Mean Square** | **F** | **Sig.** |
|---|---|---|---|---|---|
| Regression | 0.640 | 3 | 0.213 | 0.861 | 0.461(a) |
| Residual | 296.259 | 1196 | 0.248 | | |
| Total | 296.899 | 1199 | | | |

Source: Author’s Analysis, (2024).

Table 4.3 displays the regression coefficients, which indicate that all three independent variables, the frequency of trips, the average number of trips, and the satisfaction level do not significantly influence the prediction of Morphology challenges. This is supported by the p-values for each variable, which are as follows: p = 0.222 for frequency of trips, p = 0.747 for average number of trips, and p = 0.314 for satisfaction level. These findings suggest that the regression model's morphology problems are not significantly impacted by any of the independent variables. Consequently, it is not evident from the data that morphological difficulties have a major impact on travel frequency, average number of trips, or satisfaction in Lagos Metropolis.

In summary, the regression analysis results suggest the need for further exploration into additional variables that could better predict or explain Morphology challenges in Lagos metropolis. This exploration may include factors related to organizational structure, training, or environmental conditions.

**Table 4.3: Coefficients of Regression**

| **Dependent Variable**: Morphology challenges | **Unstandardized Coefficients** | | **Standardized Coefficients** | **t** | **Sig.** |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | B | Std. Error |
| (Constant) | 0.628 | 0.066 | | 9.502 | 0.000 |
| Frequency of trips | -0.020 | 0.016 | -0.044 | -1.222 | 0.222 |
| Average number of Trips | -0.001 | 0.003 | -0.012 | -.323 | 0.747 |
| Satisfaction Level | -0.032 | 0.032 | -0.029 | -1.007 | 0.314 |

Source: Author's Analysis, (2024).

## V. DISCUSSION OF FINDINGS

The study revealed a very weak correlation (R-squared = 0.002) via regression analysis between morphological challenges and trip behaviours/satisfaction. Morphological variables accounted for only 0.2% of the variance in user journeys and satisfaction. Analysis of variance revealed that morphological challenges did not substantially predict migratory patterns (F=0.861, p=0.461), supporting the null hypothesis that there was no significant impact. Regression coefficients for none of the trip/satisfaction indicators were statistically significant.

These results are consistent with those of Edeaghe et al. (2020), who discovered no discernible relationship between trip rates, access times, and infrastructure availability for waterway users in Port Harcourt, Nigeria. In contrast to the current analysis, studies conducted in Dhaka, Bangladesh, discovered that vessel access points, waterway width, and depth did affect usage and congestion levels (Asaduzzaman & Ringler, 2013). These variations might result from Lagos' inland channels' lower susceptibility to changes in natural morphology than the biologically active and prone to silt in Dhaka's rivers.

Morphological influence is further mediated by cultural acceptance and familiarity with transportation constraints. Salon and Aligula (2012) discovered that the majority of Nairobians were okay with crowded commutes. There may be differences between Lagos inland transit users and commuters who drive private vehicles that might be further examined in terms of social and behavioural subtleties. Overall, the poor statistical connections imply that, despite their importance, morphological features are overshadowed by other, as of yet unstudied elements such as income, climate, demographics, and so on. Morphological construct isolation did not produce meaningful predictiveness.

## VI. CONCLUSION AND RECOMMENDATIONS

The study highlights the limited impact of urban morphological challenges on the travel behavior of inland waterway users in Lagos Metropolis. While morphological factors have some influence, they are not the primary determinants of travel patterns. This insight emphasizes the need for a broader perspective in urban and transportation planning, incorporating various elements beyond physical infrastructure to enhance the efficiency and user satisfaction of inland waterways. Further research should delve into other potential influences to better inform policy and planning decisions aimed at improving urban transportation systems.

Based on the conclusion that urban morphological challenges have a limited impact on the travel behavior of inland waterway users in Lagos Metropolis, it is recommended that urban and transportation planners adopt a holistic approach to improve the efficiency and user satisfaction of inland waterways. This should involve exploring other potential influences on travel patterns, such as organizational structure, training, and environmental conditions. Additionally, enhancing infrastructure, increasing public awareness, and integrating water transportation with other modes of transport could further optimize the system. Policymakers should also consider regular feedback from users to continually adapt and improve services, ensuring the development of a sustainable and user-friendly urban transport network.

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