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Total Word Count- 6534

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***Abstract*— This thesis investigates the development of an integrated Inland Water Transport (IWT) network system for the River Hooghly, focusing on the Kolkata Metropolitan Area (KMA). The study employs route optimization and carbon accounting techniques to analyze the existing IWT routes, coupled with Geographic Information System (GIS) techniques to analyze primary survey data and formulate outcome data. The research begins by assessing the current state of the IWT system in the KMA, highlighting its strengths and weaknesses. One significant issue identified is the lack of interconnectivity among ferry routes, limiting efficient transportation across the river. Additionally, the use of High-Speed Diesel (HSD) vessels in the IWT system contributes significantly to carbon emissions and poses environmental concerns. To address these challenges, route optimization techniques are applied to explore alternative connective routes between Ferry Ghats. Carbon accounting is utilized to understand the carbon emission scenario of the IWT system, providing valuable insights into its environmental impact. Through the implementation of GIS techniques, primary survey data is analyzed to formulate outcome data, enabling a comprehensive evaluation of passenger flow, travel patterns, and environmental impact. The study examines the feasibility of transitioning to Electric Vehicle (EV) modes of transportation within the IWT system to reduce carbon emissions and improve efficiency. The findings of this research contribute to the development of a more sustainable and efficient IWT network system for the River Hooghly in the KMA. By optimizing routes, reducing carbon emissions, and enhancing connectivity, the proposed integrated IWT system aims to meet the evolving transportation needs of the region while promoting environmental sustainability.**

Keywords— Inland Waterways Transport, IWT, India, Potential, Ferry Service, Sustainability

INTRODUCTION

India has 111 waterways with a length of 20186 km. Approximately 14,500 km of inland waterways, including river systems, canals, backwaters, canals, and tidal inlets, can be constructed and used as inland waterways in 24 states of the United States. About 5200 km of main rivers and 4000 km of canals are suitable for inland transport. Waterways are an efficient, ecological and cost-effective alternative to oil. Water transport is a safe, economical and lowcost means of transport.(Waterways & Of, 2022) This model is used in many countries for transportation purposes. In some developing countries (eg USA, China and some countries in Europe), the land transport (IWT) sector is larger than the IWT sector in India, which helps the economy.(Inland Waterways authority of India, 2021) It's a huge improvement over selfdriving. The IWT accounts for 8.5% of all goods movements in the United States, 8.3% in China, 38% in the Netherlands, 24% in Belgium, 13% in Germany and 0.5% in India of the total modal share within the country and 65% modal share in the road and 27% in rail transportation.(*Developing India's First Modern Inland Waterway*, n.d.)

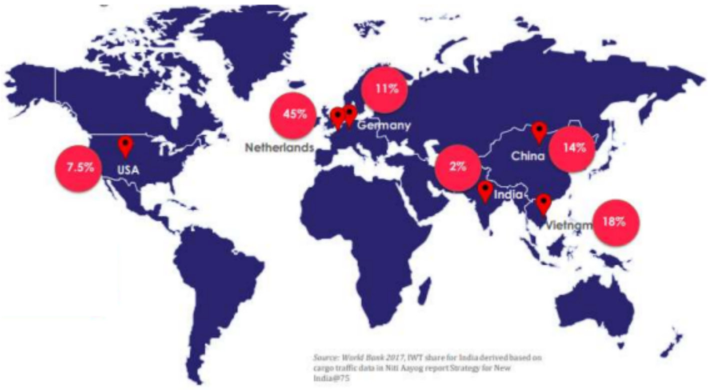


Figure 1World Scenario of IWT Cargo Infrastructure Share by World Bank 2017

Converting 1 billion tonne-km of cargo to IWT mode is estimated to reduce transportation fuel costs by $5 million and total transportation costs by $9 million.(S. Sriraman, 2010) A 10% share of IWT in all vehicles could reduce transport costs in India by 10 billion rupees ($1.8 billion). Despite the rich history of river transport and different river systems, the effects of inland waterways still result in poor IWT status in India.(Ministry of Ports Shipping and Waterways, 2021) The cost of traveling by this method was Rs 1.19 per tonne-kilometre compared to Rs 2.28 by road and Rs 1.41 by rail. The economic advantages of this type of vehicle compared to other types of vehicles have been selected by several highlevel committees, including the National Transportation Policy Committee, and it is the most environmentally friendly type of vehicle, which can move 105 tons at once liters of fuel compared to the IWT standard of 24 tonnes 85 tons by road and rail.(*Developing India's First Modern Inland Waterway*, n.d.)

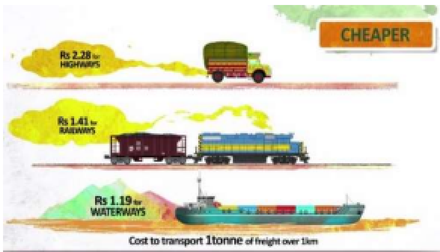


Figure 2 Cost Comparison

Figure 3 Fleet Percentage

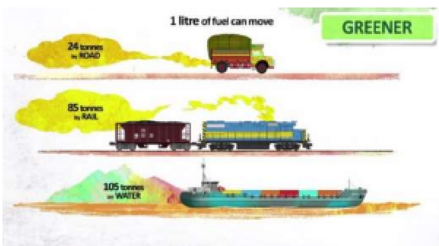


Figure 4 Fuel Comparison

River transport has been identified by the Government of India as an underdeveloped component of connectivity.(Justification, 2011) India has increased its traffic share from 0.5% to 2%, and cargo volumes have grown by 19% annually over the past five years. Globally, India ranks 2nd in shipbuilding and 21st in shipbuilding. India is one of the top five countries that send trained people, with a 17% increase in the number of seafarers in the last three years.(Ministry of Ports Shipping and Waterways, 2021) National Waterway-1 has been implemented through the Jal Vikas Marg Project (JVMP) and Arth Ganga, and will generate economic growth of over ₹1 billion over the next five years. Inland waterways will play an important role in achieving Prime Minister Narendra Modi's vision of making India a zero emission country by 2070.(*Inland Waterways Will Reshape Transportation - Hindustan Times*, n.d.) So, harnessing such potential opportunities and creating a sustainable approach to alternative transportation for Indian states rich in navigable water resources can be a major upliftment in a new sector of economic generation. And due to recent global warming scenarios we can analyze that Kolkata has become a silent killer due to its level of pollution and thus the report from urban emissions states that the yearly and month on month PM2.5 concentration is increasing day to day which have escalated the scenario in terms of transportation pollution and so thus the urban bodies have taken up the initiatives to reduce the carbon emissions through multi modal transport approach where an integrated planning approach have been initiated through route optimization of Sub Urban Train, Buses, Tram, Jettys, Auto and taxi. And thus integration will result in the formation of connecting the last mile and thus reducing over utilization of fuel.

METHODOLOGY

For objective 1 the criteria to be worked on are the literature studies, site analysis, primary and secondary data sources and thus the resulting in understanding the site context, understanding the IWT network and IWT route optimization. For objective 2 the criteria to be analyzed are the literature and secondary resources study which will be resulting in GHG inventory, establishment of carbon emission of IWT with other comparisons. For objective 3 and lastly the criteria to be observed under this objective are the route optimization, GHG inventory, SUMP and URMP which will result in the formulation of guidelines for IWT movements, sustainable transport practice, river conservation through URM indexing

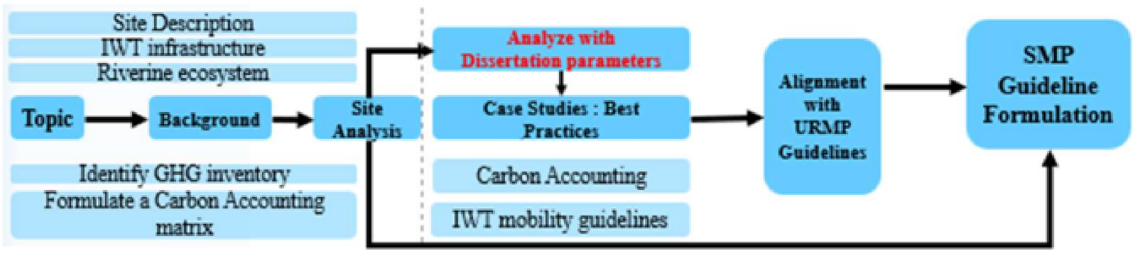


Figure 5 Methodology FLow Chart

LITERATURE STUDY

Inland water Transportation can be defined as an extensive system or network of transportation through the medium of water like rivers, lakes/ponds or canals.(Rejuvenation, 2022) They are the major contributors of the overall transportation sector carrying goods and passengers simultaneously. They act as major economic boost for the country as its an only cheapest and efficient medium for the import and export business of the country. The river system of India have been classified under 4 major categorisation as per the geographical location and they are the Himalayans rivers, Deccan rivers, Costal Rivers and the rivers of inland drainage basin.(*Press Release: Press Information Bureau*, n.d.) For example Himalayan rivers are the Ganges, Indus, Chenab, Brahmaputra, Bhagirathi, Jhelum etc those originates from the river basin of Himalayan range, and The deccan rivers are Godavari, Krishna, Cauvery, Mahanadi etc which generally flows towards the east direction to Bay of Bengal.(*Profile - Rivers - Know India: National Portal of India*, n.d.) The coastal rivers are Savitri, Subarnarekha, Vaigai etc and lastly the rivers of inland drainage are basically Ghaggar river, Aksai Chin, Luni etc which are either dried up to some point or ends up in a lake before reaching the sea.(*Advantages And Disadvantages Of Water Transportation - Navata 2021*, n.d.) From the historic evidence we can analyze that transportation through water provides major evidences of transportation. Water was considered to be the only source of movement from place to place which is cheapest mode of transportation of people goods and animals. Waterways movement can be further classified into two major types of transportations that is inland waterways and ocean or sea transportation and inland transportation is further classified into canal or river transportation.(Ghosh, Nilanshu, Abhinav Soman, Harsimran Kaur, 2023)

SITE ANALYSIS

The Kolkata Metropolitan Area has an area of 1850 sq km with an amalgamation of 38 municipalities and 4 municipal corporations with a population of 1.58 cr. Within which the transportation pressure can be observed as about 2450 vehicles covering about 1 km of road space. KMA has majorly 5 different modes of transportation which majorly connects from one end to another.

Figure 6 Diffrent Transport Mode of Kolkata

- In 1690, Job Charnok, an agent of the East India Company chose this place for a British trade settlement. The site was carefully selected, being protected by the Hooghly River on the west, a creek to the north, and by salt lakes about two and a half miles to the east. There were three large villages along the east bank of the river Ganges, named, Sutanuti, Gobindapur and Kalikata. These three villages were bought by the British from the local land lords.
- Later after independence gradually various parts of south and north 24 parganas gets along in the formation of Kolkata Municipal corporation area.
- Later Kolkata metropolitan district was legally defined in the schedule of the Calcutta Metropolitan Planning Area (Use and Development of Land) Control Act, 1965.

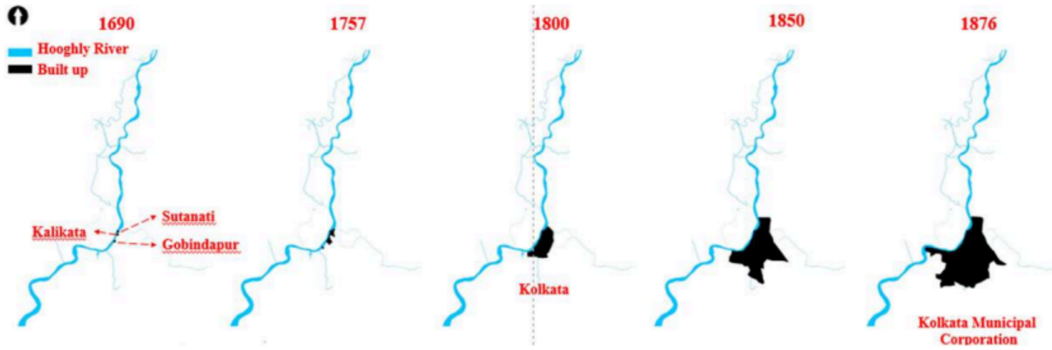


Figure 7 Urban Decadal Growth

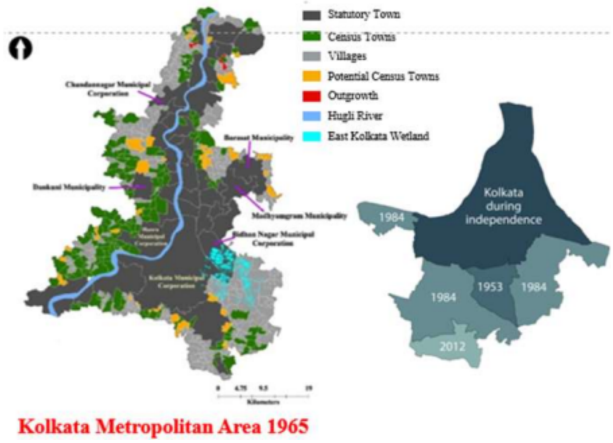


Figure 8 KMA and KMC area 1965

- Kolkata Metropolitan Area has around 1850 sq. km of spatial area boundary which consists of 38 municipalities and 4 municipal corporations.
- Along which 25 Municipalities and 3 Municipal corporations share the boundary with the river Hooghly and thus cater for the major footfalls for the IWT
- Kolkata metropolitan district was legally defined in the schedule of the Calcutta Metropolitan Planning Area (Use and Development of Land) Control Act, 1965

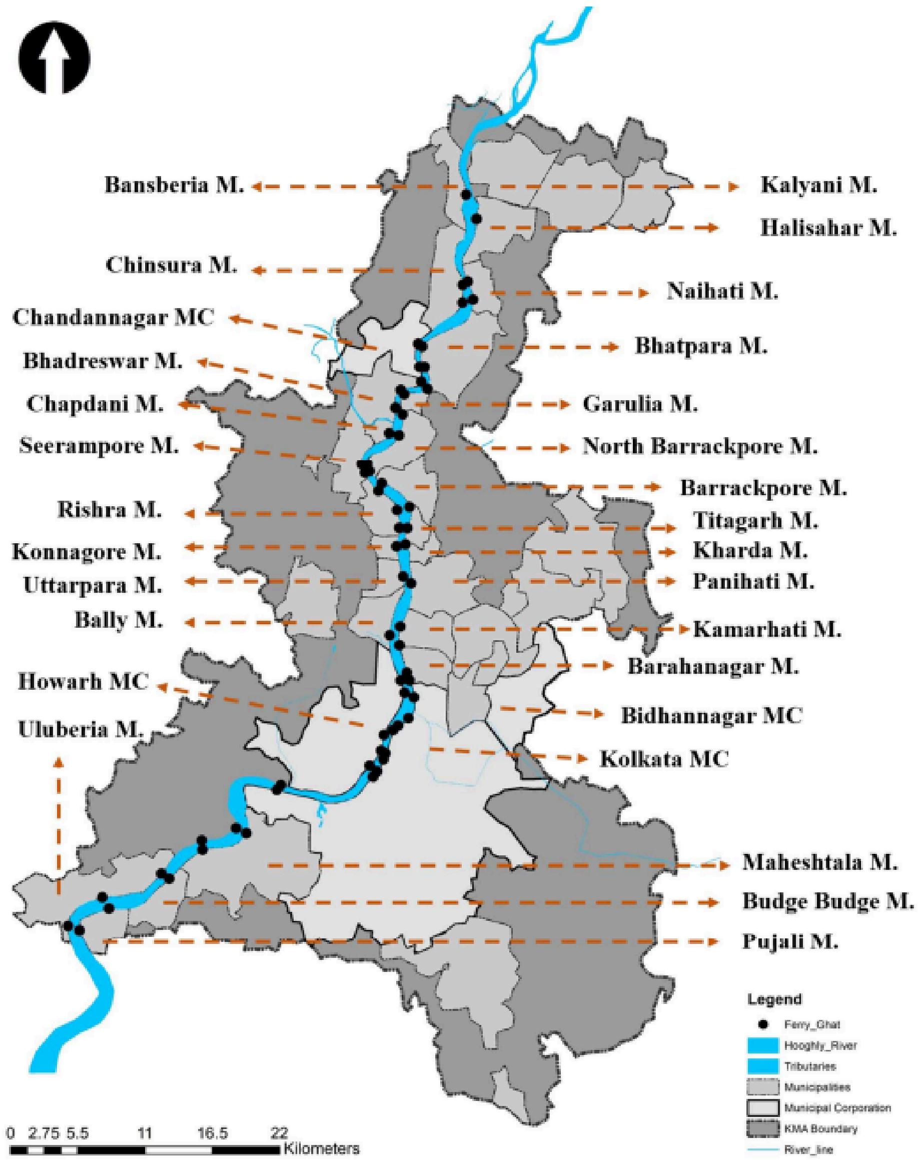


Figure 9 Urban Amulgamation areas of diffrent Municipalities and Municipal Corporation

We can observe from the demographic chart above that Chapdani, being an outskirt from the center of Kolkata, has the highest density. Kolkata MC and Howrah MC both have approximately 20,000 people per square kilometer. This high density in both central and outskirt areas indicates significant urban congestion, which can lead to challenges in providing adequate infrastructure, public services, and housing. The data underscores the need for effective urban planning and development strategies to manage population growth and ensure sustainable living conditions in these densely populated regions.

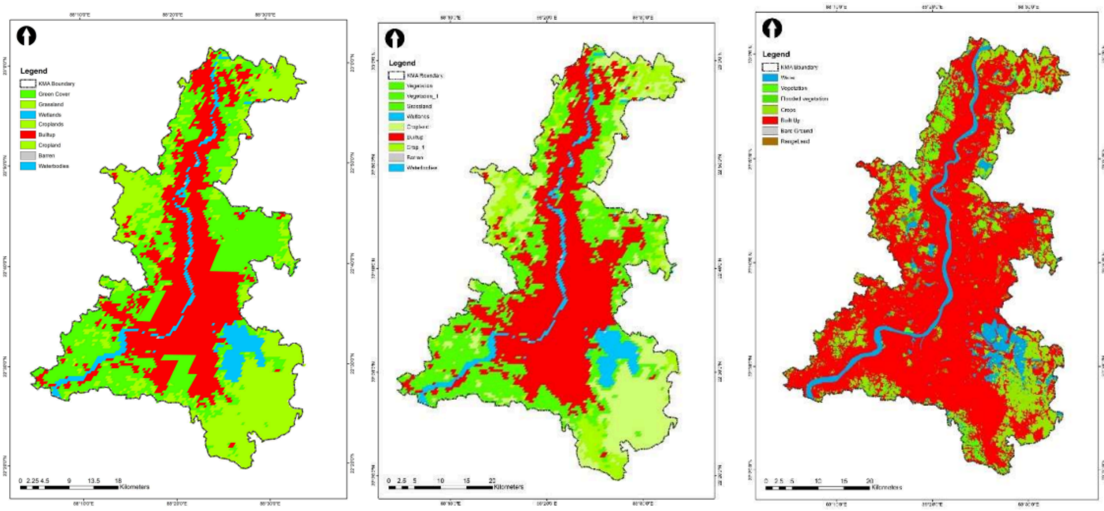


Figure 10 Decadal LULC KMA 2001, 2011, 2021

Table 1 LULC DECADAL CHANGE

LULC DECADAL CHANGE OF KMA in %			
LULC Type	**2000**	**2010**	**2021**
Built Up	30.11	37.28	66.3
Vegetation	28.35	27.7	6.94
Cropland	35.22	29.17	16.16
Waterbodies	3.48	3.48	6.8
Wetlands	2.72	2.29	1.7
Barren	0.12	0.08	2.1
Total	100	100	100

Population Scenario

- As per the LULC decadal map we can observe that there is a growth towards the outer wards of the river profile due to the advancement of road and rail transportation.
- But the fact is that there are only 4 cross bridges along the river within KMA and thus major river cross traffic uses the ferry transportation.
- As per the population and density map we can observe that the people and not well distributed on the left bank of the river due to its connectivity issue and hence there is a scope of work regarding the IWT network efficiency.

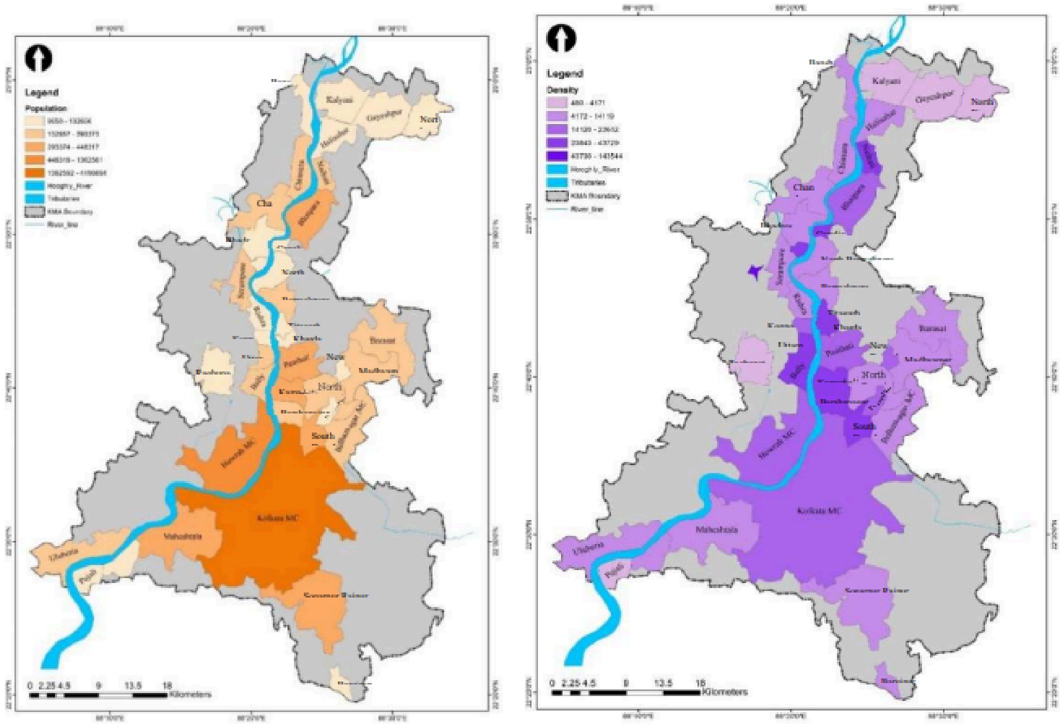


Figure 11 Population and Density Thematic Map

The LULC decadal map clearly illustrates a significant expansion towards the outer wards of the river profile, driven primarily by improvements in road and rail infrastructure. However, the limited number of cross bridges within the Kolkata Metropolitan Area (KMA) poses a significant challenge, as only four bridges span the river, necessitating heavy reliance on ferry services for cross-river traffic. This bottleneck in infrastructure not only affects daily commutes but also impacts economic activities and the overall connectivity of the region. The population and density map further reveal a notable disparity in population distribution, particularly on the left bank of the river, where connectivity issues are more pronounced. This uneven distribution underscores the potential for enhancing the Inland Water Transport (IWT) network's efficiency. By addressing these connectivity challenges and improving the IWT infrastructure, there is an opportunity to promote more balanced regional development, facilitate smoother transit, and ultimately foster more equitable growth across both banks of the river.

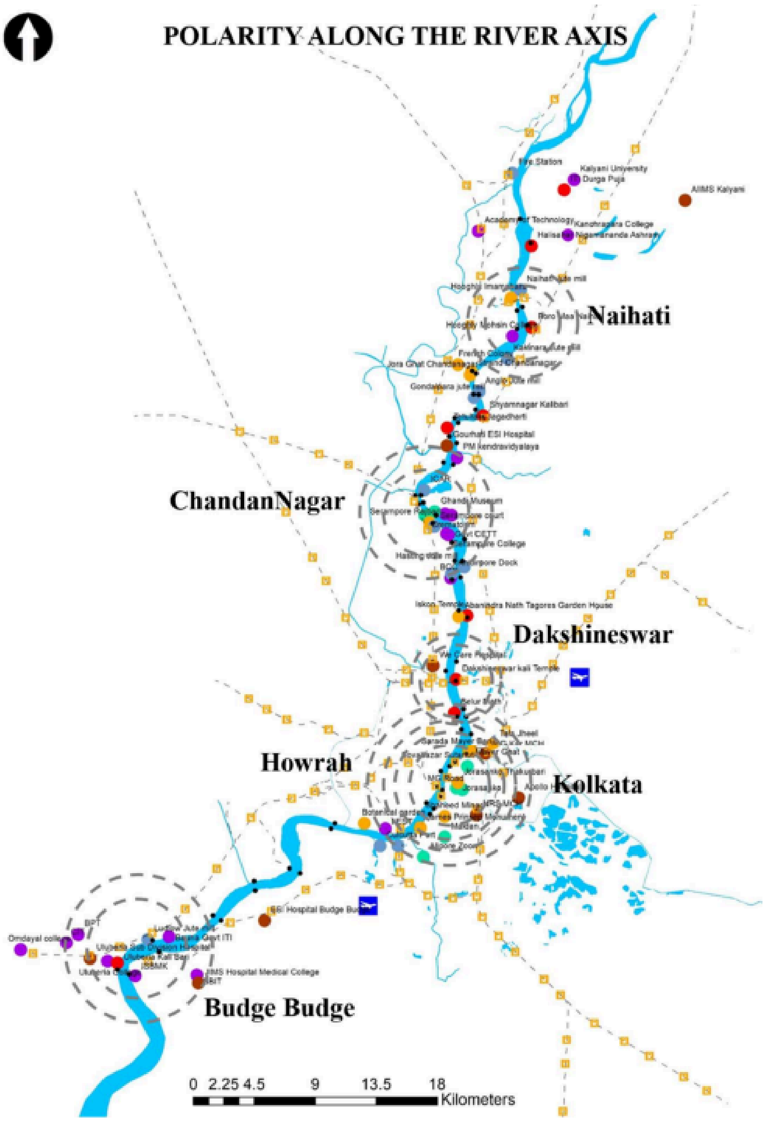


Figure 12 River Polarity

Transportation Infrastructure of KMA

- The Hooghly River, with its numerous ghats, serves as a key axis for analyzing urban polarity and the socio-economic dynamics of the region. These ghats, with their unique historical and cultural significance, form distinct poles that either pull or push various population segments. Central Kolkata stands out as the area with the highest polarity, serving as the primary hub for the working class and the Central Business District (CBD) of the Kolkata Metropolitan Area (KMA). This region's robust infrastructure, employment opportunities, and commercial activities make it a focal point for daily commuting and economic interactions.
- Additionally, areas like Naihati and Dakshineswar are significant due to their religious importance, drawing large numbers of devotees and tourists. These regions act as secondary poles, providing a spiritual pull that complements the economic activities of central Kolkata. Chandannagar, with its colonial heritage and scenic beauty, functions as a tourist magnet, enhancing its polarity through cultural and recreational appeal.
- On the other hand, Uluberia demonstrates a different type of polarity, attracting populations involved in industrial and educational sectors. The presence of various factories, industrial units, and educational institutions on both sides of the river facilitates a steady influx of workers and students, creating a vibrant economic and academic environment.
- Overall, the Hooghly River's ghats play a crucial role in shaping the urban landscape and demographic patterns of the KMA. By understanding these polarity axes, urban planners and policymakers can better address the needs of different regions, ensuring balanced development and efficient utilization of resources along the riverbanks.

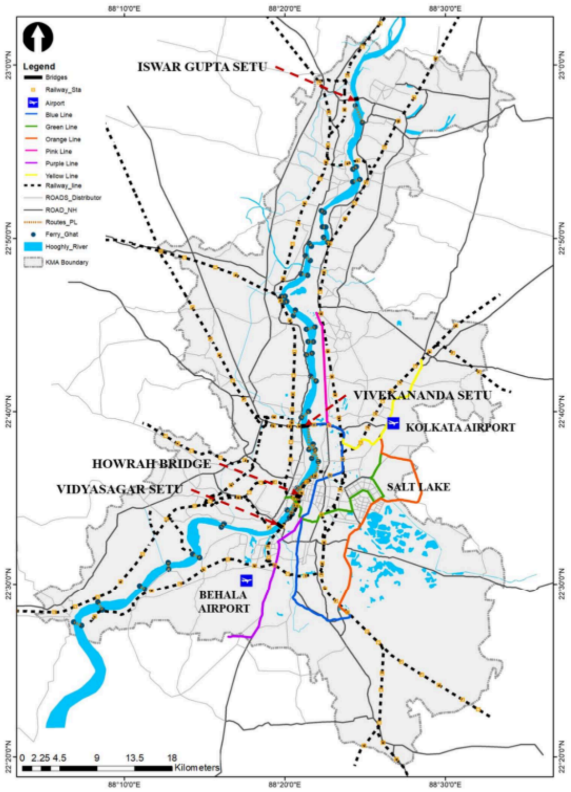


Figure 13 Transportation Network of KMA

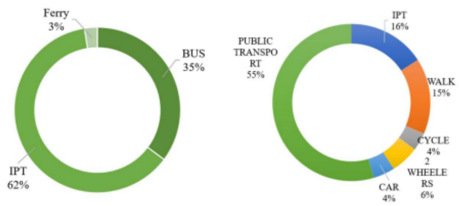


Figure 14 Modal Split

Table 2 Public Transport Mode vs cost,capacity,speed

Public Transport Mode								
Mode	**Rail**	**Metro**	**Bus**	**Tram**	**Ferry**	**IPT Auto**	**IPT Auto Shared**	**IPT rikshaw**
Cost/km/pax trip	0.4	2	1	1	2.5	12	4	5
Capacity pax/hr/direction	15000	40000	5000	5000	1000	-	-	-
Speed (kmph)	30	30	20	15	10	30	25	10

As per the 2017 report of the Integrated Sustainable Development Plan (ISDP), we can infer that 55% of the total population relies on public transportation, while 16% uses Intermediate Public Transport (IPT). Within this framework, only 2.5% of the population utilizes Inland Water Transport (IWT), which is notably less than the percentage of people who prefer to walk.

When conducting a comparative study of various types of public transportation in terms of cost, capacity, and speed, we observe several interesting trends. Among these, ferry services stand out as an exceptionally cost-effective option for crossing the river. Ferries charge only Rs 2.5 per kilometre per trip, making them significantly cheaper than other modes of transportation, particularly when considering the cost and time efficiency for river crossings.

In terms of cost, ferries offer unparalleled affordability. This low fare is especially beneficial for daily commuters who seek budget-friendly transportation options. Compared to buses, taxis, or auto-rickshaws, which can be considerably more expensive, ferries provide a viable and economical alternative.

From a capacity perspective, ferries can accommodate a large number of passengers per trip, which helps reduce congestion on roads and bridges. This high capacity is particularly advantageous during peak hours, alleviating pressure on other forms of public transport and contributing to a more balanced and efficient transportation network.

Regarding speed, ferries provide a relatively swift mode of transit across the river, often bypassing traffic jams and road delays common in urban areas. This time-saving advantage further enhances their appeal to commuters looking to avoid the unpredictability of road transport.

In summary, the 2017 ISDP report highlights the underutilization of IWT despite its cost-effectiveness and efficiency. Promoting ferry services could lead to more balanced transportation usage, easing the burden on other public transport systems and offering a sustainable solution for urban mobility. Encouraging greater adoption of IWT can optimize transit times, reduce travel costs, and contribute to a more sustainable and efficient transportation infrastructure.

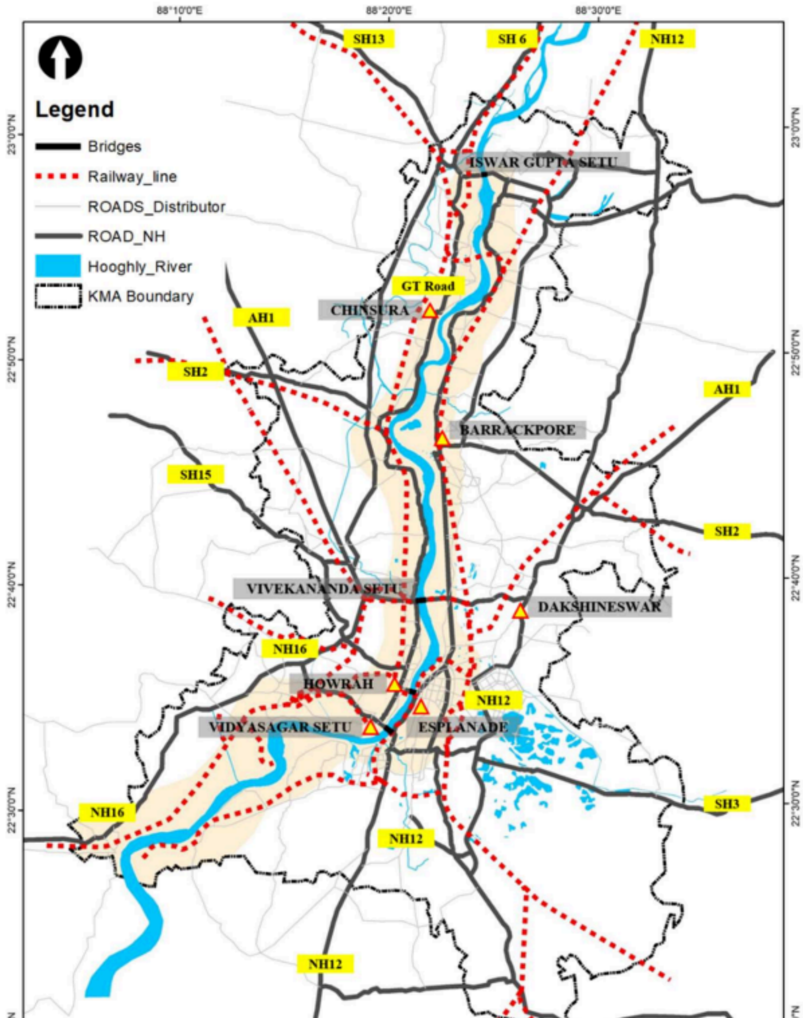


Figure 15 Major Transport Node and Infrastructure

The region has an extensive network of public and private buses, with routes covering almost all major road networks in the Kolkata Metropolitan Area (KMA). Howrah and Esplanade are the major terminals for the bus network, connecting the intra- and interstate transport network as well as the KMA area. This extensive bus network ensures comprehensive coverage and connectivity across the region, facilitating easy movement for daily commuters and long-distance travelers alike.

The Intermediate Public Transport (IPT) connectivity of KMA is also robust, featuring various modes such as auto-rickshaws, cycle rickshaws, yellow cabs, and hand carts. These modes operate along almost every distributive road, providing crucial last-mile connectivity that bridges the gap between bus or train stops and final destinations. This network is essential for maintaining the fluidity of urban mobility and ensuring that all areas, even those not directly served by larger public transport systems, remain accessible.

Suburban railways have a significant impact on connecting KMA from every corner of the city. Running almost parallel to the Hooghly River, these rail lines link the north to the south of either bank, making them a vital component of the region's transport infrastructure. The suburban rail system enhances accessibility, reduces travel time, and eases congestion on roads by offering a reliable and efficient alternative for longer commutes.

Inland Water Transport (IWT) ferry services play a crucial role in cross-bank river connectivity, given the limited number of cross-bank road and rail connections. These services operate primarily on point-to-point routes, connecting two ferry ghats on either side of the river. Key road networks for IWT connectivity include GT Road, Strand Road, and BT Road, which support about 80% of ferry services. Additionally, suburban rail lines such as the Howrah to Bardhaman and Howrah to Kharagpur lines on the left bank, and the Sealdah to Budge Budge and Sealdah to Chakdah lines on the right bank, integrate seamlessly with IWT services, enhancing overall connectivity and transportation efficiency in the region

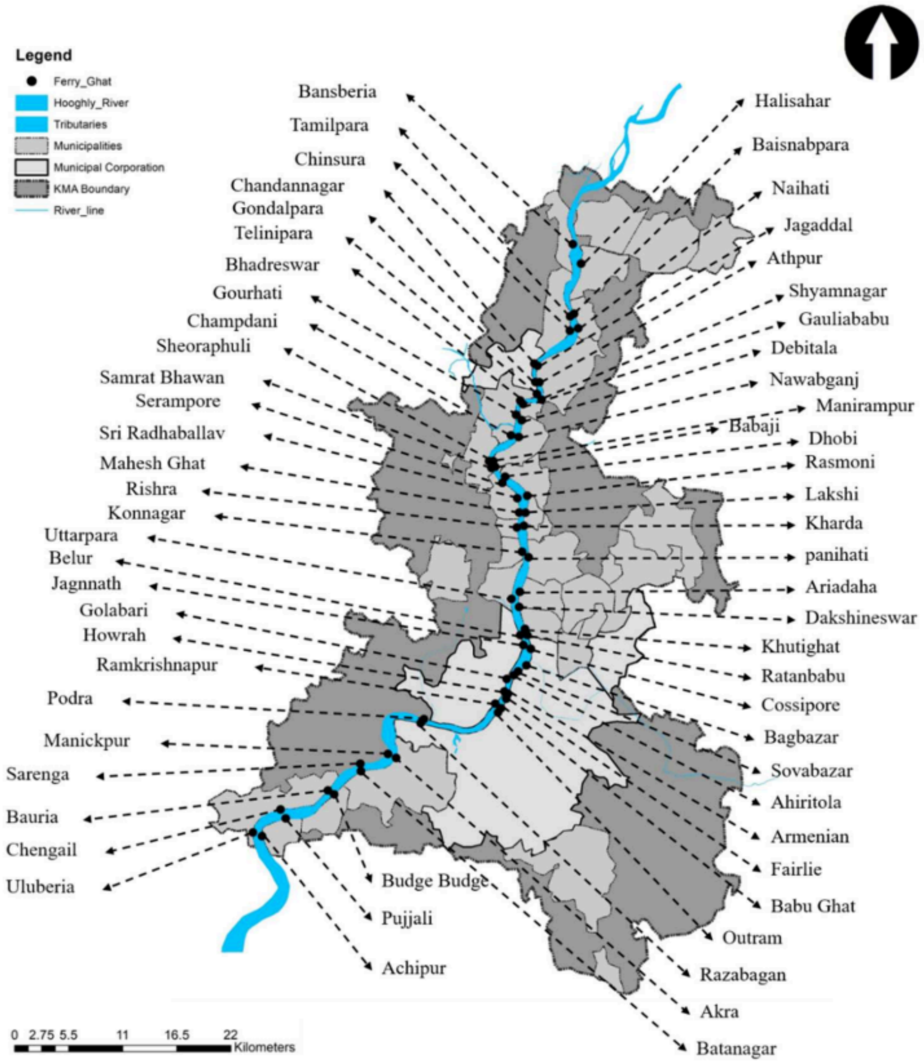


Figure 16 Different Ferry Ghats of KMA

- Inland Water Transport (IWT) network is a defining feature in West Bengal and in the KMA region specifically, has substantial potential for development.
- The IWT network in the identified study area, between Kalyani to Uluberia, as depicted in the adjoining figure, includes a riverine length of -120 km and includes several Ghats across the region providing cross-river ferry services for passengers. • However, it attracts less than 1% of passenger traffic and negligible cargo traffic, thereby playing a negligible role in the economy of the region.
- Poor connectivity and infrastructure has negatively impacted the growth of the IWT network.
- A reason for low inland waterway modal share can be insufficient and piecemeal investments in the sector.
- Development of IWT can play an important role given the region's geographic conditions. IWT is an efficient, cost-effective, and environmentally friendly mode of transport.

- There are 62 Identified Ghats within KMA study area and 33 number IWT routes running cross ferry service along river Hooghly.
- There are 38 Municipalities and 3 Municipal corporations that share boundaries and provide potential passengers for the IWT sector.

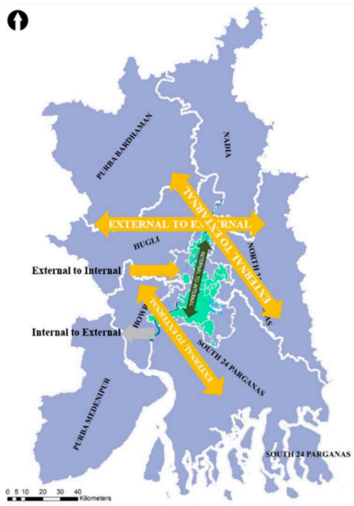


Figure 17 TAZ

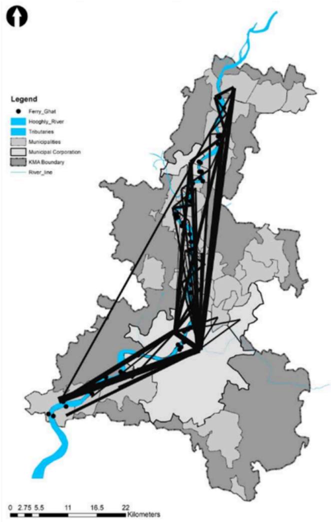


Figure 18 OD Matrix

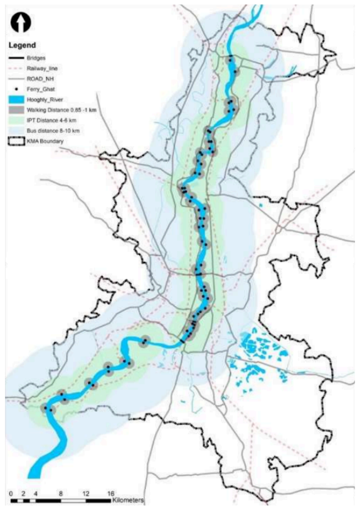


Figure 19 Human perspective range

To facilitate an understanding of traffic flows between different parts of the study area and its hinterland, the subject area is divided into several Traffic Analysis Zones (TAZs). These TAZs are further elaborated into a two-level zoning scheme. The primary zone encompasses the entire study area, while the secondary zone influences the peripheral areas of the primary zones. This zoning system enables a detailed analysis of traffic patterns and movement dynamics within the region. The Origin-Destination matrix map is developed based on survey results, providing valuable insights into major population traffic flows. It is evident that a significant portion of the population's traffic movement is from residential zones to their workplaces, such as Howrah, Kolkata, Uluberia, and Kalyani. Another substantial movement is observed from residential areas to religious or recreational zones. This analysis sheds light on the primary travel needs of the population, emphasizing the importance of commuter routes and the distribution of essential services and amenities across the study area. Lastly, the spatial area capturing map with different modes of transport represents the population served by each area, taking into account various transportation options, including Inland Water Transport (IWT). Areas highlighted on this map where IWT is prevalent indicate potential users of this mode of transportation. By identifying these areas, planners can target infrastructure development and service improvements to better accommodate the needs of current and potential users of IWT, enhancing overall transportation efficiency and accessibility within the region. This comprehensive analysis of traffic flows, origin-destination patterns, and mode preferences provides valuable insights for urban planners and policymakers to optimize transportation networks and enhance the overall mobility experience for residents and visitors alike.

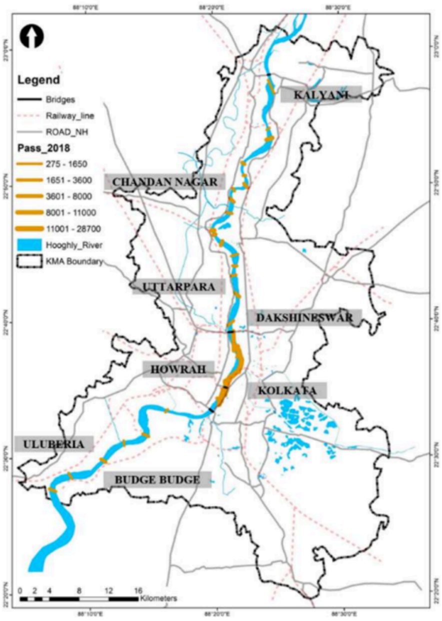


Figure 20 Passenger Footfall 2018

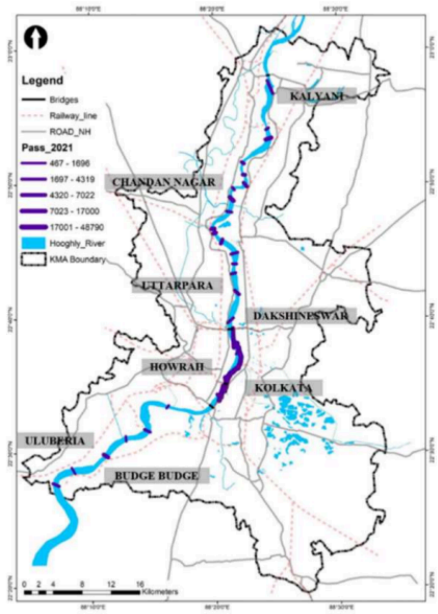


Figure 21 Passenger footfall 2021

According to the footfall data per route per day of 2018, analysis from the map reveals that the central Kolkata area experiences the highest footfall rate compared to the rest of the region, with an estimated range of 11,000 to 28,700 passengers per day. However, when comparing this data with the 2021 figures, calculated based on traffic demand analysis optimistic values, we observe a notable growth in passenger numbers, with the footfall in the central Kolkata area increasing to a range of 17,000 to 48,700 passengers per day. This significant increase in footfall demonstrates a substantial growth in passenger demand, particularly in the central Kolkata area. However, it also highlights a negative growth rate in three ferry routes, primarily due to the lack of adequate infrastructure. To better understand the magnitude of daily passenger traffic crossing the river, it is essential to recognize that this traffic can be increased with the improvement of infrastructure and route optimization. By investing in infrastructure development, such as constructing additional terminals, enhancing docking facilities, and increasing the number of ferries, we can accommodate the growing passenger demand more effectively. Furthermore, route optimization strategies can play a crucial role in maximizing the efficiency of ferry services and catering to more passengers. By identifying and addressing bottlenecks, adjusting schedules to match peak demand periods, and implementing better integration with other modes of transportation, we can enhance the overall effectiveness of the ferry system. Overall, the observed growth in passenger footfall underscores the need for proactive measures to improve ferry infrastructure and optimize routes. By investing in these areas, we can ensure that the ferry services meet the increasing demand and provide efficient and reliable transportation options for the residents and commuters of the region.

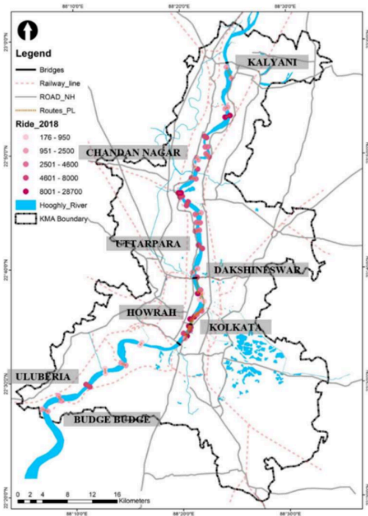


Figure 22 Ferry Ridership 2018

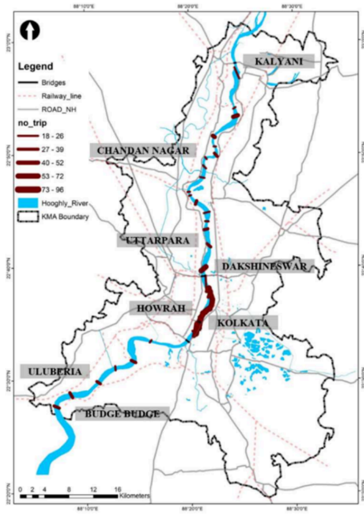


Figure 23 Number of Trips

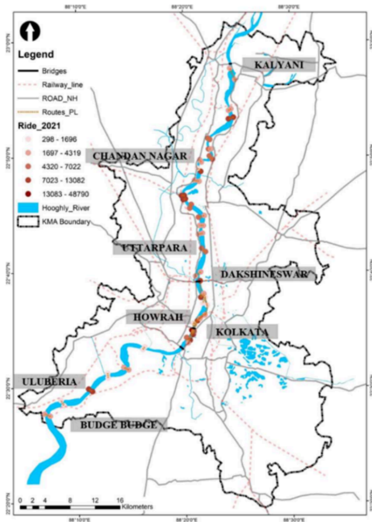


Figure 24 Ridership 2021

The maps of 2018 and 2021 depict the footfall at each ferry ghat, which can differ slightly from the number of passengers per route due to some ferry ghats serving multiple route directions. This distinction allows us to identify several major ghats experiencing significant passenger traffic pressure. Analyzing the number of trips per route provides insights into the maximum frequency of ferry services available in specific areas, while the travel time required to cater to the routes implies the demand matrix of the ferry routes. By examining these factors, we can identify key ghats with high passenger demand and operational significance. Central Kolkata, Chandannagar, Budge Budge, and Naihati ferry routes emerge as having both the maximum number of passengers and the highest number of trips. These ghats serve as critical transportation hubs, connecting densely populated residential areas with key commercial, industrial, and recreational zones. The high footfall and frequency of trips at these ghats highlight their strategic importance in the ferry network. Optimizing the infrastructure and services at these important ferry points is crucial for enhancing the overall efficiency and effectiveness of the ferry system in the region. By developing these key points, we can better manage the flow of passengers, reduce congestion, and improve overall commuter experience. This optimization strategy involves improving facilities, increasing the number of ferries, enhancing docking and embarkation processes, and implementing better scheduling and route management practices. Investing in the development of these critical ferry points not only addresses immediate transportation needs but also supports the long-term goals of improving connectivity, promoting sustainable mobility, and fostering economic growth in the region. By prioritizing the enhancement of these key ferry points, we can optimize the ferry network to better serve the evolving needs of the population and contribute to the overall development and prosperity of the area.

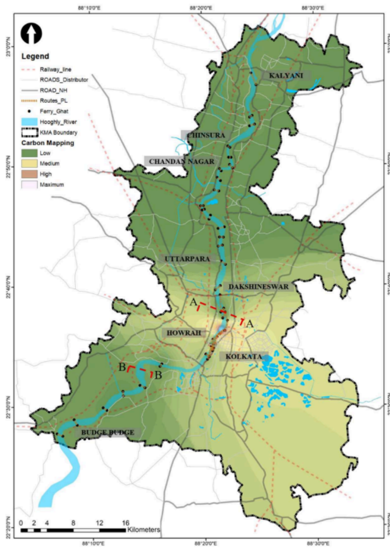


Figure 25 Carbon emission thematic map

The implications of carbon emissions from the Inland Water Transport (IWT) infrastructure vary significantly, with emission levels ranging from 33 kg of CO2 per day to as high as 3300 kg of CO2 per day. This wide range underscores the environmental impact of IWT operations and highlights the need for effective mitigation measures.

By mapping the range of environmental pollution using interpolation techniques, we can gain valuable insights into the spatial distribution and severity of carbon emissions across the region. This mapping approach allows us to visualize the areas most affected by IWT-related carbon emissions, guiding targeted intervention strategies and policy decisions to mitigate environmental pollution.

In total, the annual CO2 emissions from IWT infrastructure amount to 2,991,027.963 kg. This significant level of carbon emissions emphasizes the urgent need for implementing sustainable practices and adopting cleaner technologies within the IWT sector. By addressing these emissions, we can minimize the environmental impact of water transportation and work towards a more eco-friendly and sustainable transport system.

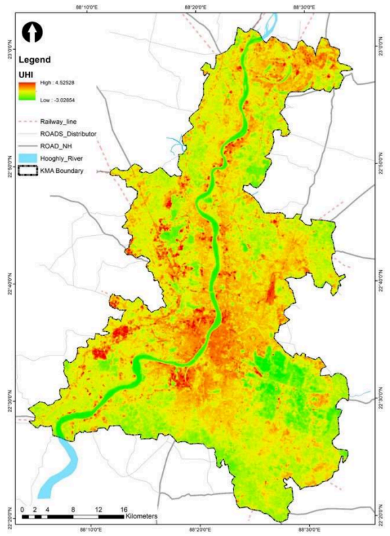
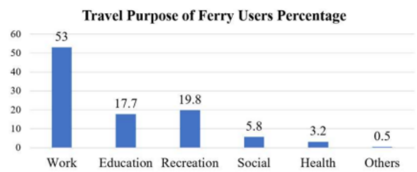


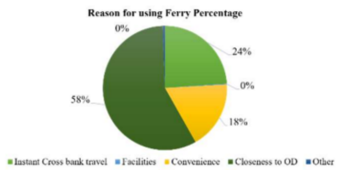
Figure 26 UHI map KMA

The study of Urban Heat Island (UHI) and bathymetry plays a crucial role in identifying alternative routes for optimizing CO2 emissions. Understanding the UHI effect provides insights into localized temperature variations within urban areas, which can influence the efficiency and environmental impact of transportation routes. Additionally, bathymetry studies offer valuable information about water depth and topography, enabling the identification of optimal water routes for inland water transport (IWT) that minimize CO2 emissions. By integrating findings from these studies, planners can strategically plan alternative transportation routes that mitigate the carbon footprint associated with transportation activities. This approach facilitates the development of more environmentally sustainable transport networks, contributing to reduced emissions and improved air quality in urban areas

Survey data analysis

- The survey was conducted from 21st March 2024 to 27th March 2024 with a total head count of 50 passenger responses within 34 routes where each route having a head count of 2-3 passengers each.
- The key intent is to establish the user profile, analyze the trip characteristics and to study the IWT working system.
- The age group of 24-35 is the highest representation in the ferry passenger survey so the 18-50 age group make up 90% of the survey samples. And 10% of the survey sample constitutes of >18 and 60+ age groups safety and security is a critical issue or challenge faced in transportation.
- 55% of the sample are employed and 20% of overall are students which indicates time urgent user group and 15 % are daily business workers (hawkers/ raw material) which concludes the importance of the reliability of the IWT system.





- The income group with 1-5lakh annum constitute 52% of total passengers and 35% of those below 1 lakh which indicates that the users of the IWT system largely consist of captive riders i.e the commuters with limited alternate mode choices because of the unavailability of other mode and limited able to pay.

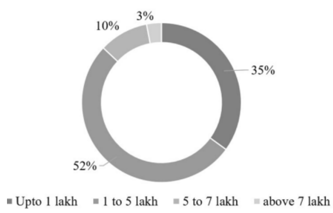


Figure 27 Income survey

Table 3 Ferry distribution of users

Distribution of users using the ferry for various purposes with respect to trip frequency in percentage				
Times	**Work**	**Education**	**Recreation**	**Social**
Daily	67.6	65.7	18.7	38.2
4 times a week	3	3.8	2.3	2.9
3 times a week	4.8	8.8	5.4	7.4
occasional	24.6	21.7	73.6	51.5
Total	100	100	100	100

- Survey shows that 67.6% of working class people commute daily and 24.6% working people takes IWT occasionally. But about 65.7% people takes IWT for educational purpose and 51.5% people takes IWT for Social occasionally. So we can conclude that 2/3rd of the people takes IWT occasionally for the purpose of Recreation and Social.

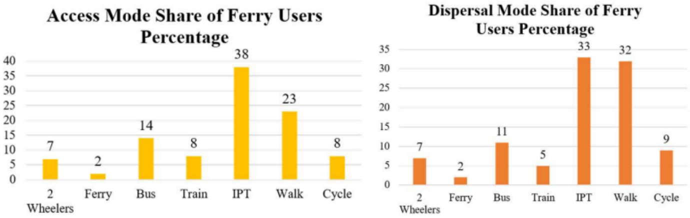


Figure 28 Access and Dispersal Mode

- The distribution of users by access and dispersal mode shows that NMT modes (walk and cycle) are very important access and dispersal modes catering 31% of access trips and 41% dispersal trips.
- Similarly in the category of IPT is observed to perform a key role by catering 38% of access trips and 33% of dispersal trips.
- The Bus also plays an import role for the access and dispersal mode about 14 and 11 % respectively.
- Access and dispersal distance is a key indicator of the hinterland of the system. For non motorized transport it is observed that the average walk distance from ghat is 0.6 to 0.7 km. Similarly, the average travel distance to/from ghats for cycle users is 2.2 to 3.1 km

Figure 29 Access road Issues identificastion

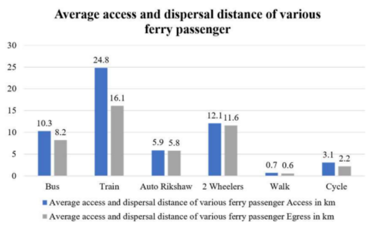


Figure 30 Average access and dispersal

- In case of public transport users the average access / dispersal distance has been observed to be 8 -10km for bus and ~6km for autorickshaw and 16-24 km for train. Which indicates that IWT with different public transit modal integration has a good impact on the range of passenger approach's to IWT.
- And train users likely to take IWT due to lack of bridge infra structure and hence IWT is an important part in daily movements.

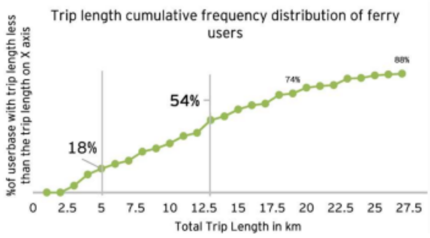


Figure 31 Trip Frequency

- As per the frequency distribution curve, the average 54% trip length is ~12.5km and this suggest that large fraction of users travel between TAZ that are not close to each other.
- The chats shows that the share of ferry's travel distance in total trip length where we can see that for 80% of users use ferry for less that 1/3rd of their total trip length.

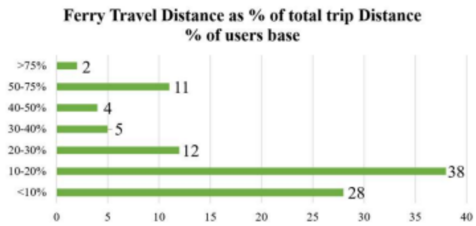


Figure 32 Travel Distance as % of total Distance % of users base

- It is evident that the long length trip chains are present in indicating that improving the ferry system can improve journey convenience, however, the system components like last mile and accessibility need to be improved to improve mobility positively and holistically.
- Diagram of the systematic representation of every trip dairy of ferry passenger where they start their journey from origin via a mode of transport like IPT, Bus, Walk or cycle etc to reach the ferry ghats then take the ferry to cross the river and then board another medium to reach their destination.

Figure 33 Trip Diary

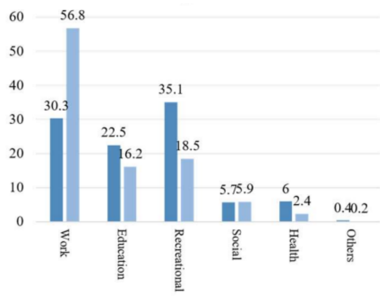


Figure 34 trip purpose distribution

The survey findings reveal significant insights into the demographics of ferry passengers and their perceptions of service quality. The data suggests that the maximum male population primarily consists of working passengers, while the highest number of female passengers is observed during recreational visits. This gender-based differentiation highlights the diverse purposes for which ferry services are utilized, indicating the importance of tailoring service offerings to meet the varied needs of different passenger groups. Additionally, approximately 50% of respondents expressed dissatisfaction with the current operating speed of ferries, indicating that the speed, which typically ranges between 6-8 knots, is perceived as too slow. This sentiment is critical as it impacts overall journey time and passenger satisfaction. Another noteworthy concern is the waiting time, which was reported to be significantly high by a substantial proportion of respondents. This waiting time not only affects the overall efficiency of the ferry service but also contributes to longer trip durations for passengers. Moreover, 12% of respondents highlighted the necessity for a greater number of vessels, suggesting that the existing fleet may not adequately meet the demand. Furthermore, there is a call for more comfortable vessel designs to enhance the overall passenger experience. The requirement for improvement in terminal facilities has been cited by 36% of responses, indicating a need for upgrades to enhance the comfort, safety, and convenience of passengers during embarkation and disembarkation. Addressing these concerns is crucial for optimizing the inland water transport (IWT) system and enhancing passenger satisfaction. By increasing operating speeds, reducing waiting times, expanding the fleet, and improving terminal facilities, ferry services can become more efficient, reliable, and passenger-friendly. These improvements will not only meet the current needs of passengers but also attract new users, thus contributing to the overall development and sustainability of the IWT network.

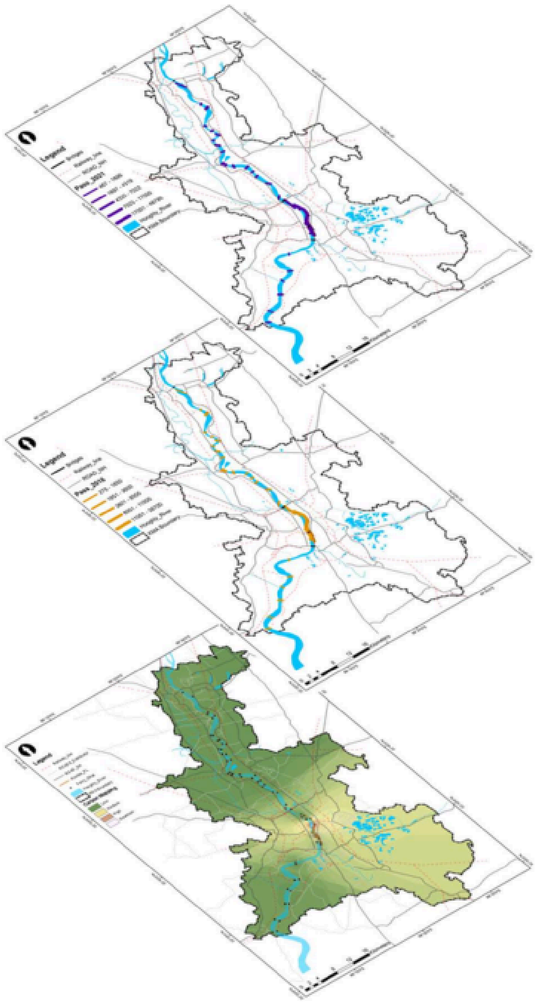


Figure 35 Weightage calculation overlay

Following the route optimization process in GIS, a weighted matrix analysis was conducted using three key parameters: the passenger flow data of 2018, 2021, and carbon emission levels. This comprehensive analysis enabled the generation of an optimization map on a scale of 5, facilitating the identification of new routes for the ferry ghats. By integrating data from different years and carbon emission levels, the weighted matrix analysis provided a holistic understanding of passenger demand and environmental impact, enabling the identification of the most efficient and sustainable routes. The scale of 5 used in the optimization map allowed for a nuanced assessment of the potential routes, considering factors such as passenger flow and carbon emission levels to determine the optimal configuration. Through this process, the GIS-based route optimization methodology effectively leveraged data-driven insights to propose new routes for the ferry ghats. By aligning with the overarching objectives of enhancing efficiency, reducing environmental impact, and improving passenger experience, the optimized routes are poised to contribute to the overall improvement and sustainability of the inland water transport system.

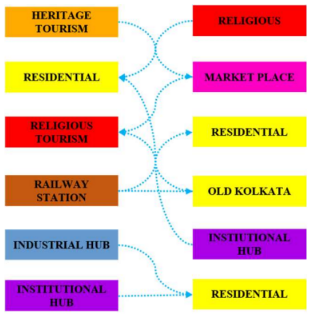


Table 4 Different proposed routes

Rt_No	Route Names	Pax 2018	Pax 2021	Length
1	Naihati to Chandannagar	16100	27370	5.5
2	Chandannagar - Athpur - Shyamnagar	12700	21590	3.6
3	Symngr-Garuli-Debi-Nawa-Maniram-Baba - Serampore	39950	67915	11.4
4	Rishra - Konngar- Uttarpra - Dakshineswar	21500	36550	8.1
5	Uluberia-pujali-budgbudge-bata-akra	14500	24650	15.9
6	Howrah-golbari-jaganath-belur-Dakshineswar	49375	83937.5	8.8

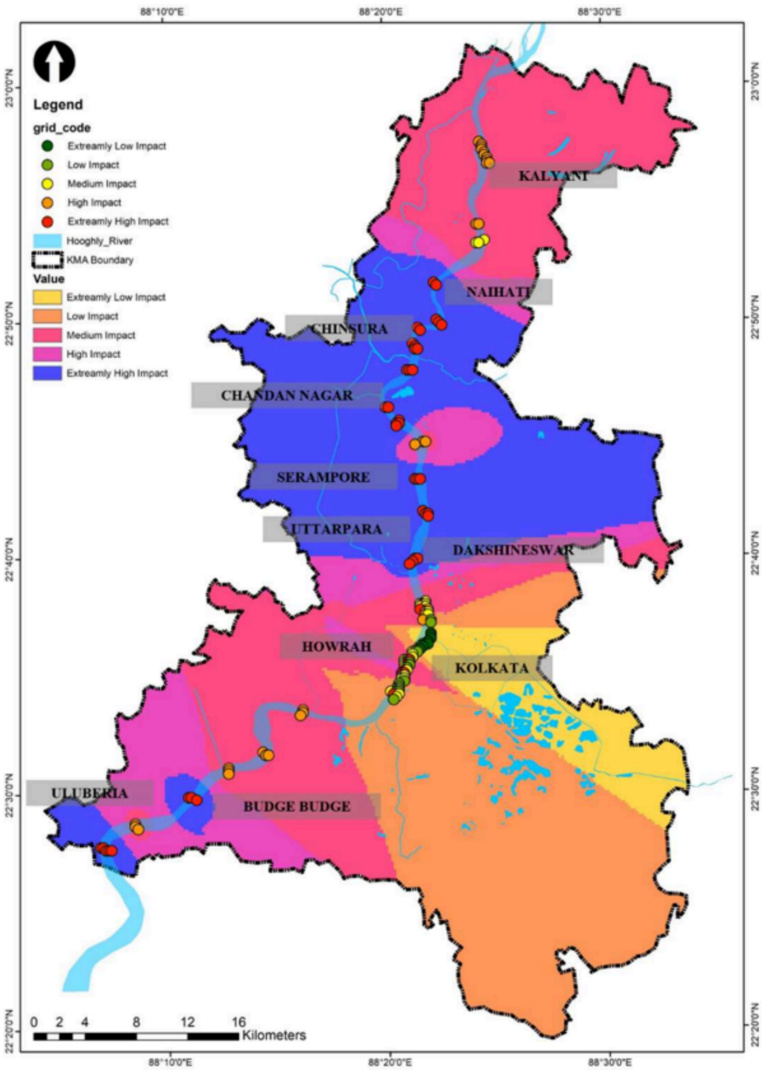


Figure 36 weightage matrix map

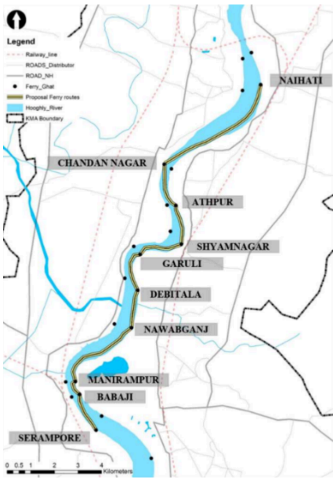


Figure 37 Propose route 1,2

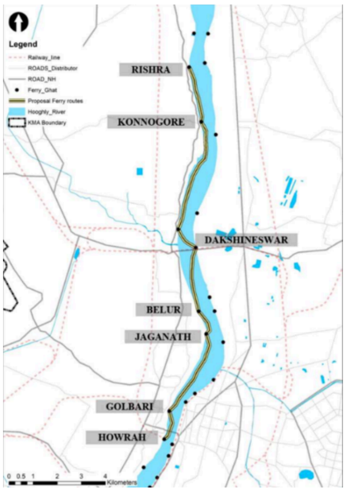


Figure 38 Proposed route 2,3

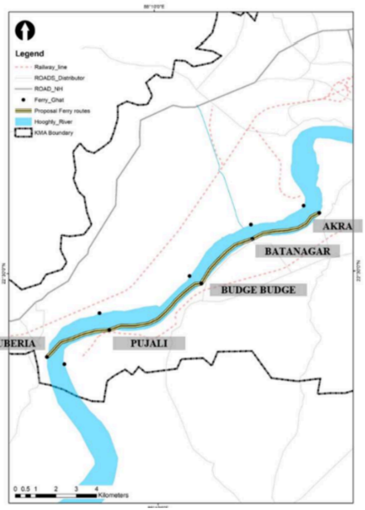


Figure 39 Proposed route 4,5

The proposed routes are derived from the optimization map where we can analyze the future need for the passenger in routs and conning the ferry ghats.

- Route 1 Connects the religious place with the tourism.
- Route 2 Connects the important marketplace of Shyamnagar to Heritage place
- Route 3 Connects the heritage cum residential place to the marketplace
- Route 4 Connects the residential area to a religious place
- Route 5 Connects the industrial and educational area to the last connecting railway station. • Route 6 Connects the Railway station to a Religious place

CONCLUSION

The Inland Water Transport (IWT) system in the Kolkata Metropolitan Area (KMA) has served as a vital transportation lifeline for ages, facilitating the convenient passage of passengers across the river. However, a significant drawback of the system is the limited interconnectivity, with most ferries or vessels only linked to one or two jetties, leaving a gap in the network across the 34 routes. This loss in interconnectivity has been identified as a crucial issue in the route mapping process. Without sufficient connectivity between multiple jetties, passengers face challenges in accessing their desired destinations efficiently. Furthermore, the use of High-Speed Diesel (HSD) vessels within the IWT system poses a significant environmental concern, as it leads to a substantial amount of carbon emissions and the release of effluents into the river, impacting both air and water quality. To address these challenges, the possible outcome of the problem statement is the implementation of route optimization for alternative connective routes and the adoption of carbon accounting to understand the carbon emission scenario of the IWT system. Exploring possible transport alternative routes between Ferry Ghats is crucial, especially given the demanding economic situation and energy demand requirements. The proposed six alternative routes offer a solution to enhance the efficiency of the transportation system while providing connectivity between areas with multiple land-use approachability. Shifting towards an Electric Vehicle (EV) mode of transportation presents a promising solution to reduce carbon emissions and improve travel time between jetty points. Comparing the carbon emission factors, an EV ferry is estimated to emit about 388 kg of CO_2 per day, significantly lower than conventional HSD vessels, which contribute approximately 9146 kg of CO_2 per day. This substantial reduction in carbon emissions underscores the environmental benefits of transitioning to EV ferries within the IWT system. Implementing route optimization and transitioning to EV modes of transportation represent proactive steps towards a more sustainable and efficient IWT system in the KMA area. By addressing the issues of limited interconnectivity and high carbon emissions, the IWT system can be transformed into a more environmentally friendly and passenger-centric mode of transportation, meeting the needs of both commuters and the environment. Moreover, the adoption of carbon accounting practices will provide valuable insights into the environmental impact of the IWT system, guiding future policy decisions and infrastructure investments to ensure long-term sustainability and resilience.

ACKNOWLEDGEMENT

The heading of the acknowledgement section and the reference section must not be numbered. Acknowledgements of people, grants, funds, etc. should be mentioned wherever applicable.

FUNDING STATEMENT

The heading of the funding statement section must not be numbered. Acknowledgements of people, grants, funds,

etc. should be mentioned wherever applicable.

DECLARATION OF CONFLICTING INTERESTS

The heading of the declaration of conflicting interests section must not be numbered.

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