Revitalization of Urban Waterfronts through WaTOD: A Case of Jhelum River in Srinagar

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Abstract

Cities with rivers are increasingly looking at expanding their public transportation network by turning towards water transit as an alternative to land-based transportation. This approach aims to supplement the existing transportation network, thereby reducing traffic congestion and mitigating pollution.

Urban areas have been the epicentre of growth and a destination for employment opportunities. Therefore, they are in a constant flux due to migration from peripheral areas in search of jobs and better living conditions which eventually leads to urban sprawl. According to the Census 2011 projections, cities are expected to accommodate 41% of India's population by 2030, which is up from 31% in 2011. There are numerous benefits of urbanization, such as economies of scale and access to education, but there are also negative externalities, such as environmental degradation and reduction in the quality of life.

Srinagar has seen a rapid surge of urbanization, with increasing population and limited geographical features. The city is expanding horizontally at a very fast pace, resulting in the rise of private vehicle ownership, traffic congestions, road accidents, air pollution, haphazard growth, and a decline in the use of public transportation (Government of Jammu and Kashmir, 2020).The Urban Sprawl has shown major impacts on waterbodies and wetlands, the haphazard growth has

resulted in encroachment over water bodies and has fragmented them from the wetlands which has made the city more susceptible to floods (Srinagar Development Authority, 2015).

The Water Transit-Oriented Development (WaTOD) model aims to prepare a development plan by directing the importance of water bodies as an element of transit-based growth. The outcome is a water-centric city which will develop its urban land-use near water transit terminals to boost inland water transportation in conjunction with roadways and railways to make a sustainable urban transportation systems. This also involves redevelopment of the waterfront district for high-density business, residential, and tourism purposes along with Water Transit Terminals and proposed parks and green spaces that will encourage movement along the river. The development model will focus on building a relationship between livelihoods and water bodies to create a sense of attachment by converting water into an asset rather than a barrier.

Keywords: Urban Sprawl, Central Business District (CBD), Urbanization, Srinagar

Introduction

Though rivers, canals, backwaters, and creeks make up India's vast network of inland waterways but as compared to other developed countries India has underused its waterways for transportation services (Lambert, 2010). The failure to recognise the potential impact of inland water transportation system on national economies continues to be a key issue (EBP U.S., 2021). Inland waterways in industrialised nations, such as the United States, the European Union, and China, have been modernised, according to the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), and a substantial commercial Inland Water Transport (IWT) sector has emerged (Amos et al., 2009).

In India, inland waterways account for less than 1% of overall transportation, compared to 8.7% in China and 7% in the European Union (Government of Assam, 2016). When compared to neighbouring countries, IWT moves around 35% of freight in Bangladesh (UNESCAP, 2021). Rival routes of transportation, such as rail and road, are less established than river ports. In Thailand, inland water transport is second to roads in terms of freight moved, accounting for around 20 million tonnes (Pomlaktong et al., 2011). In and around Bangkok, passenger travel is considerable, with several kinds of services, including express services.

Inland waterways provide a more ecological and cost-effective alternative to road and rail cargo transportation (Tournaye et al., 2010). According to a report by the World Bank, as cited by Mukhopadhyay, 2017, the cost of transporting one tonne of freight across one kilometre is Rs 1.41 for railways with a capacity of 85 tonnes, and Rs 2.28 for roadways with a capacity of 24 tonnes, whereas IWT costs Rs 1.19 per tonne with a capacity of 105 tonnes (Mukhopadhyay, 2017). In the coming decades, inland waterways are expected to become a more ecologically friendly option than roads and railways in terms of energy efficiency, noise pollution, and emissions as traffic congestion and emissions from land-based transit grows.

Inland water transportation was a significant mode of cargo and passenger movement in India in the early twentieth century, but the influence of railways and road modernization led to its neglect (Hayter & Sharp, 1983). IWT now carries less than 0.5 per cent of India's freight traffic, compared to 66 per cent for roads and 27 per cent for railways (Hejib & Pade, 2018).

This research concentrates on identifying the various potentials of inland water transportation in the country as well as analysing the existing water transportation models in India and overseas. The study will look into the laws, policies, and initiatives that have been put in place by government agencies to find what else can be viable. It will also examine the institutional frameworks of important entities in India that are responsible for inland water transportation and point out the fundamental problems that are causing inland water transportation to be underutilised.

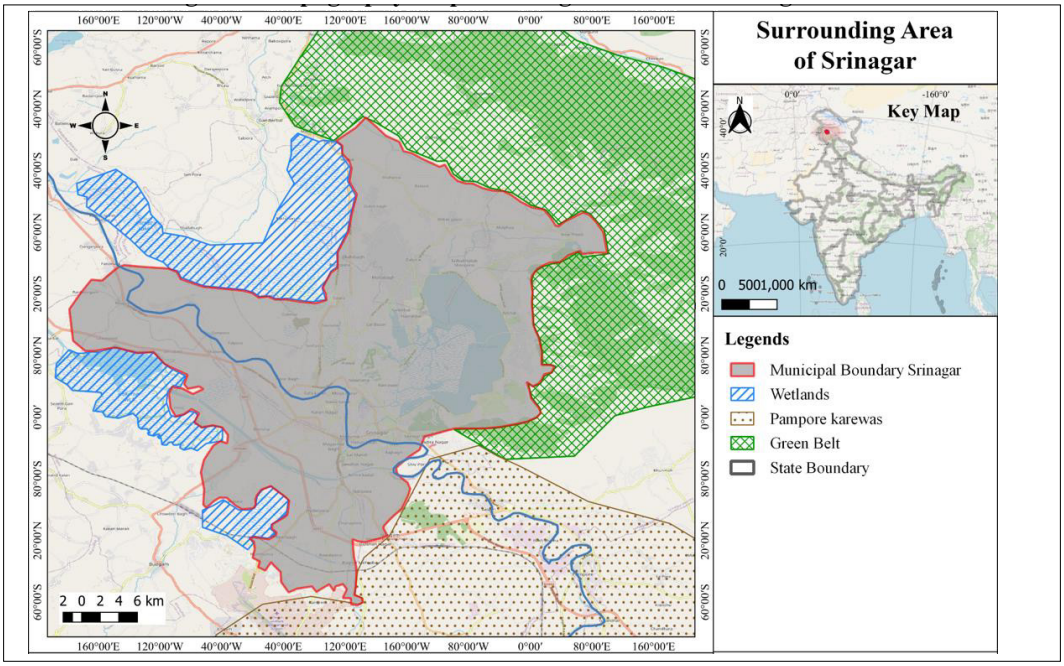
Rationale of the Study

Srinagar is the summer capital of the union territory of Jammu and Kashmir (J&K). It is located at an altitude of around 1586 meters above mean sea level on the banks of the Jhelum River. According to the Census 2011, the state's urban population expanded by 36.42% between 2001 and 2011, outpacing the national average of 31.1%. Kashmir region sums up about 63% (2.2 million) of J&K's urban population out of which Srinagar individually accounts for 55% (Srinagar Development Authority, 2015). The current development appears to be more focused on road corridors. The city is expanding along the major roads, hesitantly approaching clogged flood basins (Mohd & Hassan, 2019; Shah et al. 2023). In Srinagar city, the land-use conversion of natural wetlands to other uses is being done on a vast scale into residential, commercial, and agricultural activities (Dar et al., 2020).

The wetland coverage dropped from 5.21% in 1971 to 2.6% in 2014 (Kuchay et al., 2014). As a result, wetlands have fragmented from the water bodies, thus increasing the city's vulnerability to floods. The city's northern and eastern wards are connected by a green belt making any construction illegal, Pampore karewas on the South, and the wetlands on the West (shown below in Figure 1). Therefore, vertical expansion is the way forward, but it must be done correctly by taking into account the soil's bearing capacity and providing strong planned foundations for the soil (Primary Survey: 10th – 23rd February 2022).

Srinagar city has faced uncontrollable migration from the peripheral areas, and traffic is at an all-time high. According to the Comprehensive Mobility Plan (CMP) for Srinagar, roadways with a Right of Way (ROW) of less than 20 metres dominate the road network, and 91% of the entire road network has travel speeds of up to 20 km/h (Government of Jammu and Kashmir, 2020). This shows congestion in the city, which requires interventions related to road widening, which involves significant financial commitment, effort, and a huge amount of land acquisition, making it a tough proposition. The state Government is also making efforts towards rejuvenating the water transit system of the city to release the pressure on land transport.

Figure 1: Topography Map of Srinagar and Surrounding Areas



Source: Srinagar Master Plan 2035

Water Transit Oriented Development (WaTOD)

Water Transit Oriented Development (WaTOD) is a hybrid version of Transit-oriented Development (TOD), where the usual approach is more concentrated on Mass Rapid Transit System (MRTS) i.e. railways, and Bus Rapid Transit System (BRTS) i.e. buses. The WaTOD model focuses on integrated water transport and land use development. This includes development along water transit terminals and corridors, and building high-density, mixed land use such as business/neighbourhood centres. To promote water transportation and discourage private vehicle ownership, node-based development (i.e., Commercial, residential, etc.) or corridor development can be prospective approaches. WaTOD is based around one-fourth of a mile of the water transit stations to promote water transport and by making the water body the most important element of growth (Thompson et al., 2006).

To make water transportation successful, it needs to compete with or complement the alternative modes of transportation (Pratas et al. 2023). Ferry transportation is a cost-effective means of transit compared to other modes, with ferries alleviating more congestion per cost incurred on other modes. Ferries are similar to buses in that they are low-cost, quick-to-implement means of transportation and do not increase traffic congestion (Tanko et al., 2018).

According to research conducted by the San Francisco Bay Area Water Transit Authority, predicting ferry ridership has been a difficult task because it is not only dependent on the trip time and cost (Water Emergency Transportation Authority (WETA), 2012), but pleasure, aesthetics, comfort, and reliability also play an important role in selecting a ferry as a model (Pantouvakis, 2007). Initially, the ferry's inability to make multiple stops due to the long docking times was a hindrance in the development of water transit. This disadvantage resulted in the ferry's lack of ability to connect multiple TODs, due to which the prospective rider base should grow. With the evolution of marine technology, water taxis are being produced which are much quicker and can carry 100-120 passengers at a time with a top speed of 40-50 kms/h like the one implemented in Brisbane, Australia (Tanko et al., 2018), thus, making the ferry cost and time effective. The long docking times can also be substantially reduced by implementing Automatic Intelligent Docking Systems (AIDC).

The pros of the above-mentioned scenarios highlight water transport with the potential of taking a load of urban transport in conjunction with roadways and integrating multiple TODs/nodes. Water transport is a cost and time-effective alternative and at the same time provides access to other factors as well, such as reliability, access to open spaces, aesthetics, environment-friendly, etc (Rangaraj & Raghuram, 2007). Developing a TOD on a waterfront provides a lot of new challenges that need to be dealt with for the successful implementation of water transport which will play an important role in developing patronage over time. Some challenges that can be faced in developing a WaTOD model are listed below. These challenges have been carefully identified and curated from the literature review.

- The existing land use regulations for development along the waterbody.
- Content with storm hazards such as floods.
- High wind pressure near the shore will affect the high-rise buildings.
- Residential and commercial establishments should be located within half-kilometre of a transit stop.

To make urban water transportation and ferry-oriented development effective, major emphasis should be on terminal architecture and offering added facilities like shelter and business settings, compared to the traditional TOD practices (Thompson et al., 2006). Ferry services, when combined with waterfront restoration projects, have the potential to be a catalyst for economic revival in American cities. According to research, ferry passengers are often leisure users who are less concerned with time and are more prone to remain at ports and utilize supporting land uses (Thompson et al., 2006). These traits imply that effective WaTOD may benefit from the construction of spaces where individuals are more likely to spend time. These should be created in collaboration with the current transportation network and incorporate not just integrated ticketing but also standard signage and navigation to and from other forms of transportation.

A case study of Brisbane's waterway network discovered that the average monthly ferry ridership increased by 40% from 2003 to 2006 (Zuniga et al., 2013). This increase was an outcome of multimodal ticketing and a shift in the nature of development of waterfronts towards residential, commercial, and retail uses from industrial and warehouses (Sipe & Burke, 2011). As a result,

integrating water and land transportation should be the primary focus.

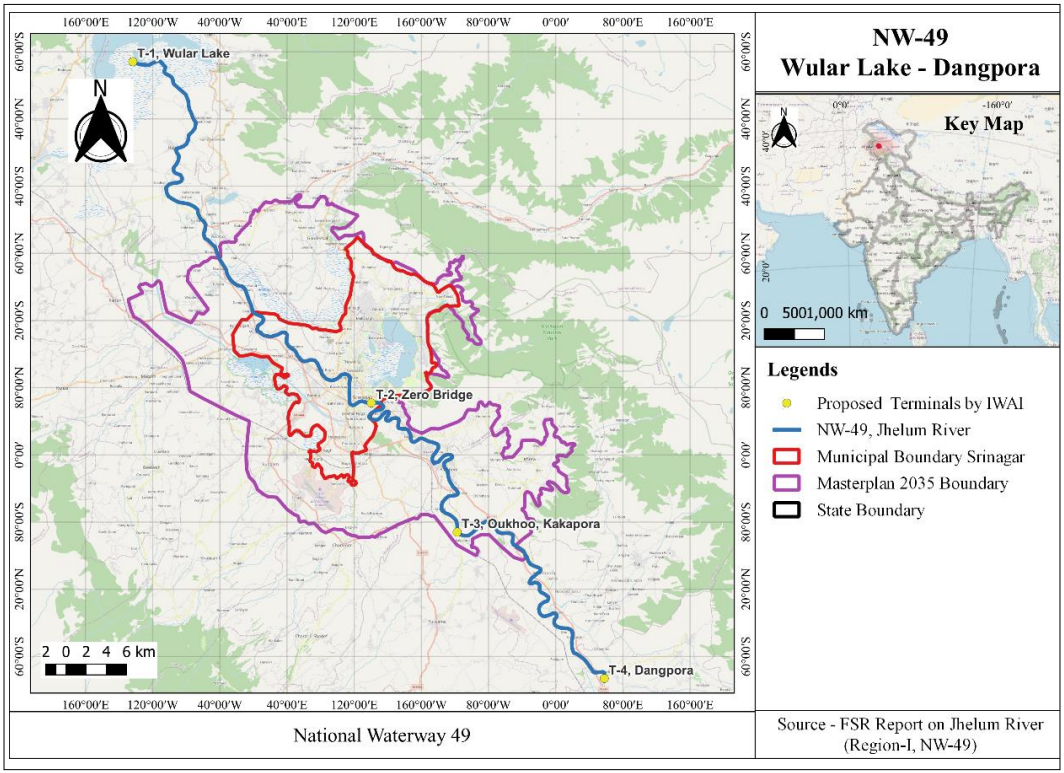
Transportation in Srinagar

Water Transport

National Waterway- 49

The National Waterway-49, located in Kashmir, travels through four districts and spans over 110 kilometres (Figure 2) (IWAI, 2017). According to the IWAI, NW-49 is technically considered feasible for the development of shipping and navigation by the Inland Waterway Authority of India (IWAI) with minimal dredging (IWAI, 2017). The river is navigable throughout the year with agricultural land existing on both its banks along the stretch. IWAI identified four potential terminals on NW-49, which are depicted on the map in Figure 2; one of them, Terminal 2, i.e. the Zero Bridge, is located in Srinagar city. In addition, the river flows from South-east to North-west.

Figure 2: National Waterway – 49



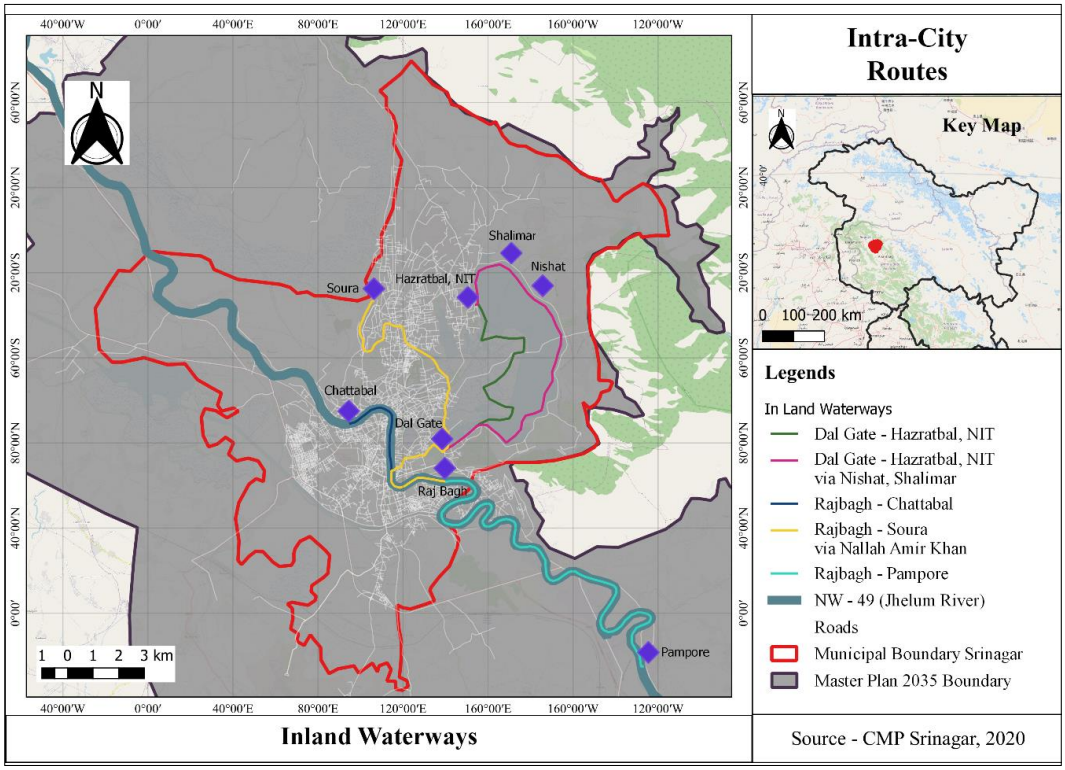
Source: FSR Jhelum River by the Inland Waterway Authority of India (IWAI)

Once known as the "Venice of the East," the river has lost its identity in the pages of history. Srinagar had a deep history of Inland water transportation with boats being the popular means of transport until the canals were closed in 1970 to make room for roadways (IWAI, 2017).

Intra-city Water Transport

River Jhelum has served as the city's historical spine and offers great potential for inland water transportation. The country's road-based transportation infrastructure must be supplemented with water transit. It will also serve as a key tourist attraction for visitors interested in the city's history and beauty. The famous Mughal Gardens, Dal Lake, Hazratbal, National Institute of Technology (NIT), Soura, Chhattabal, and other locations can all be reached via the IWT.

Figure 3: Proposed Intra City Water Routes in Srinagar



Source: Comprehensive Mobility Plan (CMP) for Srinagar, 2020

In the Comprehensive Mobility Plan (CMP) for Srinagar for 2035, five intra-city waterways networks have been proposed which cover a stretch of 60-km with 60 water buses which will be in action by the year 2044(Government of Jammu and Kashmir, 2020). During the period of December and January, the Dal Lake freezes, but the trails are formed to allow smooth passage of the boats, and the Jhelum River is navigable all through the year.

Table 1: Proposed Intra City Water Transportation Routes in Srinagar

Sl. No.	Proposed Inland Water Transport Routes	Length (km)	Phase
1	Dal Gate to Hazratbal/NIT	10	Phase I
2	Dal Gate to Hazratbal via Nishat and Shalimar Baghs	13	Phase I
3	Raj Bagh to Chhatabal (along River Jhelum)	7	Phase II
4	Raj Bagh to Soura via Nallah Amir Khan and Khushalsar	10	Phase II
5	Raj Bagh to Pampore	20	Phase III
Total		60	

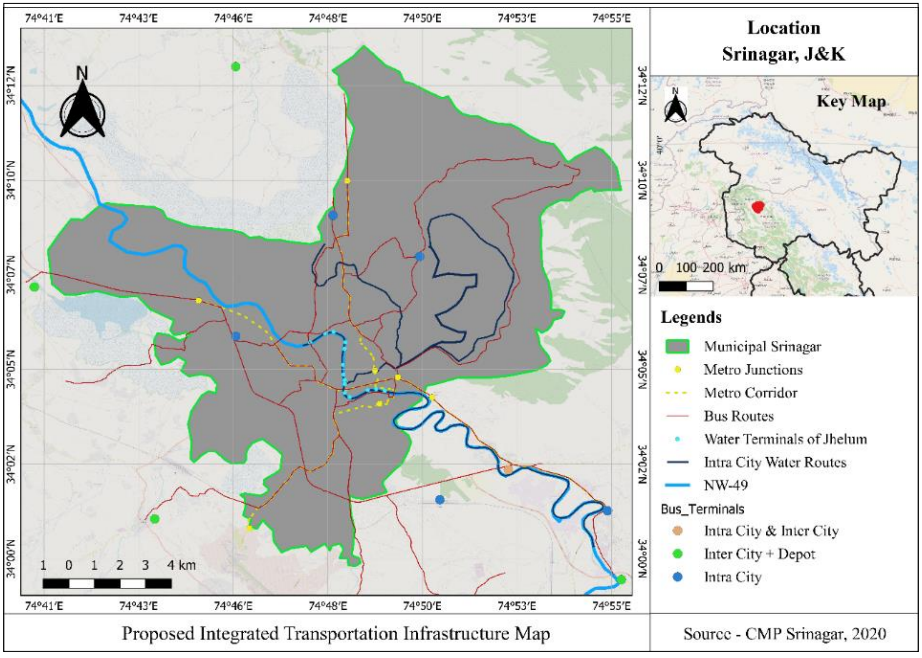
Note: This table shows the proposed intra-city water transportation plan for Srinagar, along with its phasing, as outlined in the Srinagar Comprehensive Mobility Plan 2020.

Source: Comprehensive Mobility Plan (CMP) for Srinagar, 2020

Transport Infrastructure

The proposed Transport Infrastructure for the city was designed in 2020 as part of Srinagar's Comprehensive Mobility Plan 2035 (Figure 4). The water transit stretch of River Jhelum has been chosen for further research since it flows through the city and traverses it in two parts. In addition to water transportation, bus and metro infrastructures are also proposed to serve the city's population (Government of Jammu and Kashmir, 2020).

Figure 4: Proposed Integrated Transportation Infrastructure of Srinagar



Source: Comprehensive Mobility Plan (CMP) for Srinagar, 2020

Methodology

Following is the objective-wise methodology: the initial stage of the research involved a literature review that helped in developing a comprehensive understanding of the concept which included definitions, causes, impacts, and indicators. This review then informed the identification of key parameters for evaluating each terminal to scale down the study area. The second stage involves analysing the built fabric with a focus on existing densities, land uses, and transportation infrastructures utilising the parameters identified in the previous stage. To complement this data analysis, a primary survey is conducted to gather insights directly from stakeholders, such as residents and businesses within the study area. Finally, the research delved into the critical analysis of the three key dimensions (3Ds) of a TOD model i.e. Density, Diversity, and Design.

Therefore, an attempt has been made to implement the WaTOD model in a real-world scenario. The proposals also comprise city-level connectivity-based strategies to implement the multi-modal Integration. The area for residential units for different income mixes was drawn from the Transit Oriented Development Guide for Smart Cities published by National Institute of Urban Affairs (NIUA) to provide affordable housing.

Figure 5: Methodology of this Study

Aim: Regeneration of the Waterfront Districts through Water Transit-Oriented Development.		
Objectives of research	**Scope of Work**	**Tools and Techniques**
To establish a scenario of existing land use patterns and transport along the river.	Demarcating the influence area	Mapping existing land use using google earth imagery & QGIS
	Assessing the population and built form trends in the study area	Demand - Supply gap analysis
To evaluate the TOD framework with existing Land Use Regulations along the water body.	Assessment of land use regulations for development.	Opportunity and Problem Analysis for connectivity
	Identifying the land potential for TOD	Land and Demographic opportunity Analysis
	Identifying the deficit between demand and supply of existing infrastructure.	
To formulate a comprehensive WaTOD plan.	Detailed TOD implementation Strategies	Density, Diversity & Design
	Multimodal Integration	City-level connectivity strategies

Source: Prepared by the Author

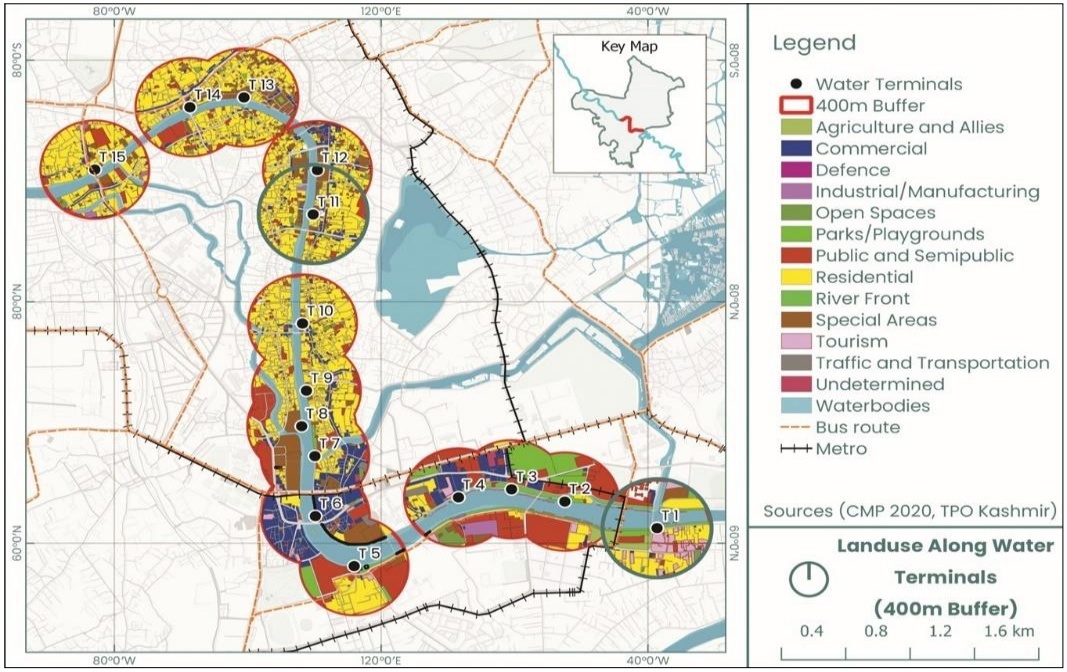
Analysis

Terminal-Wise Land Use Assessment

The water transit route of River Jhelum runs from Southeast to Northwest and comprises a total of 16 terminals. To better understand the characteristics of each terminal, a detailed land-use evaluation was conducted.

The Srinagar city is split into two sections: the old city and the new city. The new city is from Terminal 1 to 5, and the old city is from Terminal 6 to downstream. The characteristics of the two sides of the city vary considerably based on a variety of factors that will be examined further.

Figure 6: Land-Use Map of the Terminals of Jhelum Water Transit stretch in Srinagar



Note: This map highlights the 15 intra-city water terminals along the Jhelum River and their areas of influence within a 400-meter radius.

Source: Town Planning Organisation, Kashmir (2015), Comprehensive Mobility Plan for Srinagar, 2035

Terminal 1: Zero Bridge

The Zero Bridge terminal has the potential to be the major IWT hub of the city, catering to both intra-city and the terminals of National Waterway-49. Residential and commercial (tourism) are the most common land uses in the region. This zone is predominantly inhabited by a transient population as it houses Srinagar's major educational training centres, paying guests (PG), and hostels. Additionally, it is a well-known place among travellers. The majority of the structures here are villas with large gardens.

Terminal 2: Peerzu

Peerzu has gained popularity among locals for its diverse range of cafeterias and dedicated spaces for relaxation, coupled with extensive and well-structured open environments.

Terminal 3: Regal Chowk

Terminal No. 3, commonly referred as Regal Chowk, is characterized by land uses primarily centred around commercial activities, owing to its proximity to the Central Business District (CBD). The area exhibits a mixed-use pattern, with ground floors predominantly dedicated to commercial enterprises while the upper floors accommodate office spaces.

Terminal 4: Lal Ded Hospital
This is primarily characterized by the presence of a commercial zone that surrounds the hospital premises. Additionally, the area accommodates a significant number of office establishments, contributing to the mixed-use nature of the zone.

Terminal 5: Amira Kadal
This terminal is in the Lal Chowk area, which serves as the Central Business District (CBD) of Srinagar city. 'Kadal' is a Kashmiri word, meaning a bridge. This zone is predominantly characterized by an abundance of commercial settlements and exhibits mixed-use configurations. The ground floors are primarily allocated for commercial purposes, while the upper floors are used either as warehouses or office spaces. Noteworthy features of the area include parallel roads to the River Jhelum with a Right of Way (ROW) measuring 10-meters, and the widest ROW spanning 16-metres.

Terminal 6: Basant Bagh
According to the Srinagar City Master Plan 2035, this terminal is designated as an unplanned residential zone (Srinagar Development Authority, 2015). The area is predominantly residential which is characterized by haphazard and organic development, with structures reaching up to G+3.

Terminal 7: Divisional Commissioner's Office
The terminal is primarily characterized by public and semi-public zones. This is home to the Divisional Commissioner's office which is situated in the historic Seher-e-Garhi Palace that was originally constructed by the Dogra rulers. The palace, with its significant historical importance, was the summer residence for the Dogra rulers. Its strategic location near the river acted as a major transportation route.

Terminals 8 & 9: Ganpathyaar and Old Habba Kadal
Extending downstream from Terminal No. 7 is the old city that is primarily characterized by residential land use and organic development.

Terminals 10, 11, & 12: Old Fateh Kadal, Khanqah-e-Maula, and Maharaj Gunj
The area is dominated by residential and commercial buildings and is home to two historical markets of the city: Zaina Kadal Market which is renowned for brass utensils, and Maharaj Gunj Market that is famous for spices. Maharaj Gunj was the old Central Business District (CBD) of Srinagar city, situated on the bank of River Jhelum. The characteristics of the area include narrow streets, a dense circulation network, and high population density. This zone features vernacular architecture which includes historic and religious structures. The widest Right of Way (ROW) observed was 6-meters, while the minimum ROW was 1-meter. The old city of Srinagar was least affected by the 2014 floods, as it sits at a higher elevation.

Terminals 13, 14, 15, & 16: Bul Bul Lankar, Nawa Kadal, Safa Kadal, and Chattabal Weir
According to the master plan, the principal land uses in this region are unplanned residential and mixed-use. This area of the city is a mix of old and recent developments that showcase vernacular as well as modern structures.

Figure 7: Built Form around Water Terminals of Srinagar City

Terminal 1 Zero Bridge **Major Land uses:** Residential, Hostels & Hotels	 G+2	 G+1	 G+2
Terminal 2 Peerzu (Island) **Major Land uses:** Parks, Restaurant/ Cafes.		 G	 G+1 (Mixed use)
Terminal 3 Regal Chowk **Major Land uses:** Commercial, Public-Semi Public	 G+3	 G+5	 G+3
Terminal 4 LD Hospital **Major Land uses:** Commercial, Residential, Public-Semi Public	 G+3	 G+4	 G+1
Terminal 5 Amira Kadal **Major Land uses:** Commercial, Public-Semi Public	 G+3	 G+2	 G+2
Terminal 6 Basant Bagh **Major Land uses:** Residential	 G+3	 G+2	 G+3

Terminal 7 Div. Comm. Office **Major Land uses:** Public-Semi Public, Tourism	 G+1	 G+1	 G+1
Terminal 8 Ganpathyaar **Major Land uses:** Residential	 G+3	 G+3	 G+2
Terminal 9 Old Habba Kadal **Major Land uses:** Residential		 G+2	 G+2
Terminal 10 Old Fateh Kadal **Major Land uses:** Commercial, Residential, Heritage	 G+1	 G+2	 G+2
Terminal 11 Khanqah-e-Maula **Major Land uses:** Religious Tourism, Mixed Use	 Maula	 G+3	 G+2
Terminal 12 Maharaj Gunj **Major Land uses:** Residential, Mixed use, Heritage	 Jamia Masjid	 G+2	 G+2

Terminal 13 Bul Bul Lankar **Major Land uses:** Religious, Tourism, Residential	 Masjid	 G+2	 G+1
Terminal 14 Nawa Kadal **Major Land uses:** Religious Tourism, Mixed Use	 G+3	 G+3	 G+2
Terminal 15 Safa Kadal **Major Land uses:** Residential, Mixed Use	 G+2	 G+2	 G+3
Terminal 16 Chattabal Weir **Major Land uses:** Residential, Mixed Use	 G+3	 G+2	 G+2

Note: This table shows the built environment within the 400-meter influence zones of the water terminals.
Source: Primary Survey, 10th – 23rd February, 2022

Following a terminal-wise built form analysis, the study area was narrowed down to two terminals, corresponding to the factors outlined in Table 2. These terminals showcase opposite characteristics when compared. Terminal 1, known as Zero Bridge, symbolizes the new city, while Terminal 11, Khanqah-e-Maula, represents the old city. These two terminals were selected to illustrate the contrasting sides of a potential WaTOD Model, based on their differing characters, and to answer the question: How can WaTOD function in these two scenarios?

The old city is densely populated, has a small Right of Way (ROW), and is dominated by built forms with historic character. In contrast, the new city terminal, Zero Bridge, exhibits entirely different

characteristics such as a sparse road network, minor congestion issues, large plot sizes, and so on. Given these distinctive features, both terminals will require an entirely different approach for the WaTOD. These varied models aim to conserve the existing fabric of the place while simultaneously providing easy access to the water body.

Table 2: Parameters for Site Selection

Parameters	New City (T-1: Zero Bridge)	Old City (T-11: Khanqah-e-maula)
Plot Size	Max (200 sqm) Min (100 sqm)	Max (70 sqm) Min (40 sqm)
Road Network Density	1.5%	4.2%
Min. ROW	3-m	1-m
Max. ROW	16-m	6-m
Parallel road to Jhelum	Yes	No
Congestion No (Reason: Enough ROW)		Yes (Reason: Encroachment, Roadside Parking)

Note: This table shows the analysis of the existing built environment around the water terminals, along with the parameters used for selecting the study area.

Source: Prepared by the Author

Density Projections

The population projections in the Srinagar Master Plan-2035 encompassed the entire Srinagar Municipal Corporation area, including the outgrowths. However, our research focuses on two 400-meter buffer zones around the selected water terminals, namely Zero Bridge (Terminal-1) and Khanqah-e-Maula (Terminal-11). Consequently, the population projections were recalculated to approximate the demand gap analysis for the horizon years 2022, 2025, and 2030. These population forecasts were derived by applying the compound interest formula, incorporating the growth rate provided by the Master Plan for 2035 (Table 3).

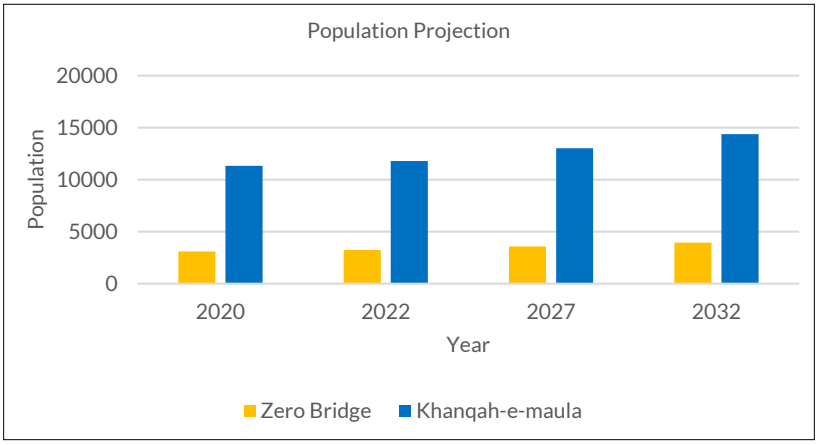
A few assumptions were made in the Srinagar Master Plan-2035, considering rapid transportation, flux in economic activities, and external inputs. Firstly, it was assumed that as of 2020, the population growth in the Srinagar Metropolitan Region had maintained relative stability, persisting at the current rate of 1.8%. Secondly, looking ahead to the period between 2020 and 2030, there is an anticipated increase in population for both urban and suburban areas, with an expected rise of growth rate to 2.0%. However, in the subsequent years from 2030 onward, the growth rate for the local region is projected to decline, settling at 1.8% for the remainder of the plan period up to 2035 (Srinagar Development Authority, 2015).

Table 3: Population Growth Rate of Srinagar City

Year	Growth %
2015-2020	1.8%
2020-2030	2%
2030-2035	1.8%

Source: Srinagar Master Plan-2035

Figure 8: Population Projection for the Two Terminals of Srinagar City



Note: This table shows the projected population for the influence zones of the two water terminals selected for the study area (Zero Bridge terminal and Khanqah-e-maula terminal), based on the growth rate mentioned in the Srinagar Master-plan 2035.

Source: Author

The Srinagar Municipal Corporation provided the population-wise density of each ward. Once the density of wards within the buffer zones was determined, an estimated projection for the density of each buffer zone was made using the vector intersection tool in GIS. This allowed us to obtain individual densities for each buffer zone. Thus, the buffer zone density of the Zero Bridge terminal was 52.75 PPH (Persons Per Hectare), while for the Khanqah-e-Maula terminal, it was 192.10 PPH. A significant variation was observed in the densities of these two terminals which is attributable to Khanqah-e-Maula being the old CBD of Srinagar City. Similarly, significant contrasts were also noted in the city's physical characteristics due to their density distribution.

Floor Area Ratio (FAR)

The digitization of building footprints in the Buffer zones was carried out, along with their existing heights that were obtained from the primary survey. Subsequently, this information was processed to determine the existing and projected Floor Area Ratio (FAR) for the Buffer zones.

Table 4: Developable Land in the Buffer Zones, Srinagar City

S.no.	Category	Developable Land (Ha)	
		Zero Bridge	Khanqah-e-maula
1	Built-up Area	0.42	0.64
2	Area of Buffer	0.50	0.50
3	Area of Waterbody	0.10	0.05
4	Available land for Development	0.41	0.45

Note: These calculations determine the available developable land within the 400-meter influence zones of the water terminals, accounting for water body buffer zones and other exclusions.

Source: Author

Income Mix

Primary surveys were done to determine the population mix of the Buffer zones of the two terminals. The results are shown in Table 5.

Table 5: Projected Residential Demand in the Buffer Zones for Different Income Groups in Srinagar

Buffer Zones	Parameters	EWS	LIG	MIG	HIG
Zero Bridge	Percentage	15%	23%	45%	17%
	Population	1775.21	2721.99	5325.64	2011.91
	Dwelling Units	355.04	544.40	1065.13	402.38
	Unit size (sqm)	27.8	46.4	83.6	165
	Built-up area (sqm)	9870.18	25260.09	89044.66	66392.95
Khanqah	Percentage	15%	50%	25%	10%
	Population	492.35	1641.15	820.58	328.23
	Dwelling Units	98.47	328.23	164.12	65.65
	Unit size (sqm)	27.8	46.4	83.6	165
	Built-up area (sqm)	2737.44	15229.88	13720.02	10831.6

Source: Author

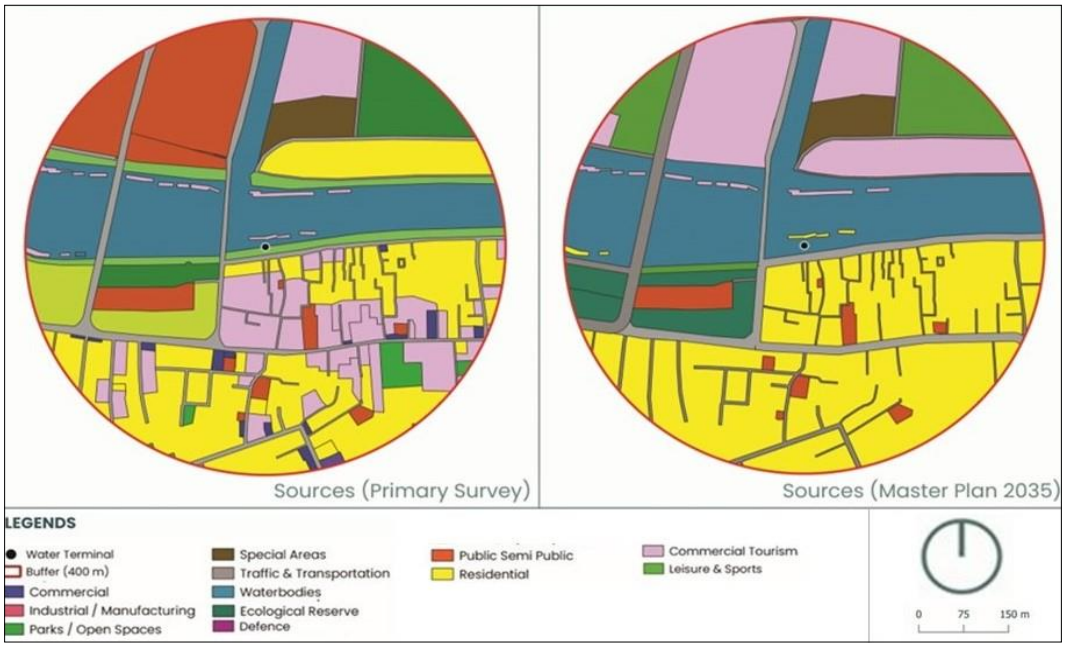
As per recommendations, the above calculations will be used to distribute the total built-up area required for land uses other than residential.

Land Use of Water Terminals in the Buffer Zones

Terminal 2: Zero Bridge Terminal

The residential and commercial areas of the Zero Bridge Terminal underwent significant modifications. The residential zone has been expanded while the commercial area has been decreased in the proposed land use. More commercial space will be needed to sustain the growing residential, therefore mixed land use is required to satisfy local demand.

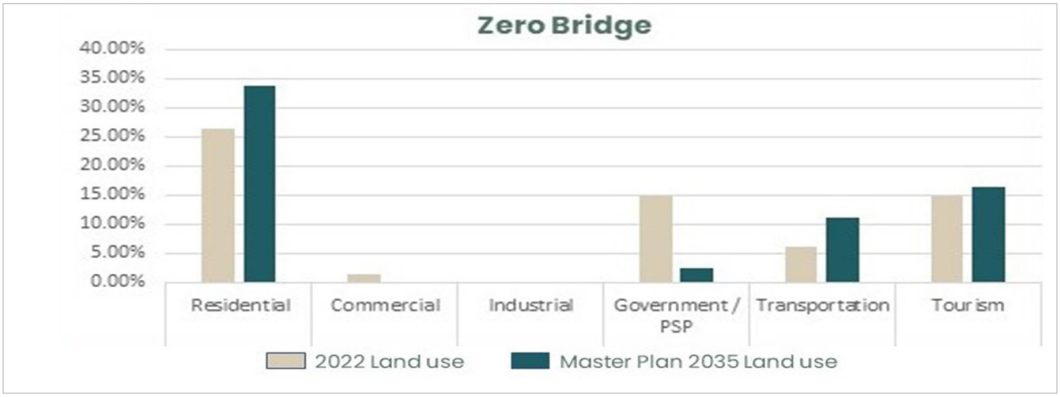
Figure 9: Land Use Map for Zero Bridge Terminal, Srinagar



Note: The 2022 scenario is collected from primary survey, whereas the 2035 scenario is taken from the Srinagar Master-plan 2035.

Source: Primary Survey (10th – 23rd February 2022), Srinagar Masterplan 2035.

Figure 10: Land Use Variation for Zero Bridge Terminal Buffer Zone, Srinagar



Source: Author

Terminal 11: Khanqah-e-Maula

This terminal has not undergone any significant changes, however, 12% of the total land area has been transformed from the special areas to adaptive reuse for the tourism sector. After considering the demand and the current situation to improve accessibility and safeguard the

historic area from transportation-related damage, the terminal has been relocated from its original site to one that is close to the bridge.

Figure 11: Land Use Map for Khanqah-e-Maula Terminal, Srinagar

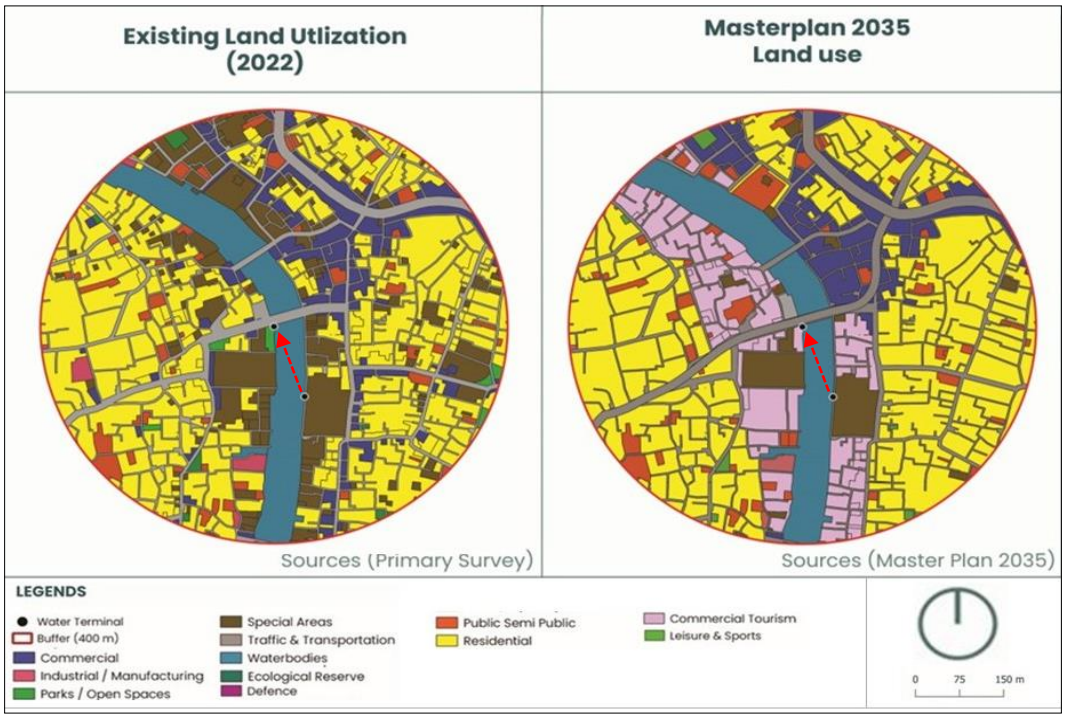
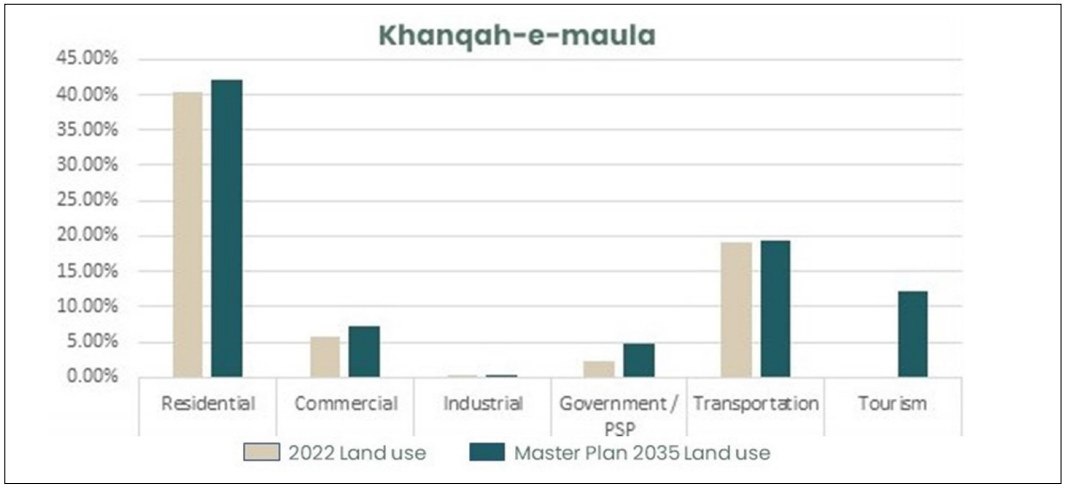


Figure 12: Land Use Variation for Khanqah-e-Maula Terminal Buffer Zone, Srinagar



Recommendations

Density

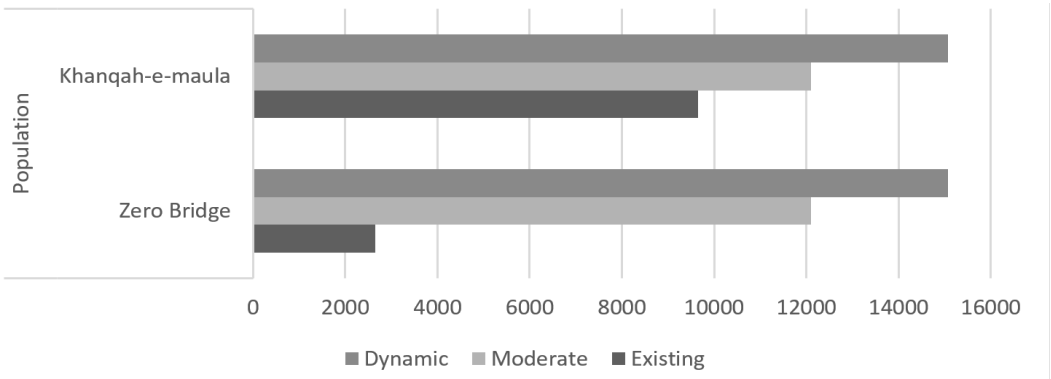
The existing and proposed densities of the buffer zones, as per the Master Plan, led to the development of three scenarios for the WaTOD model: Existing, Moderate, and Dynamic. The Existing Scenario represents the current density of the study area which provides insights into the present distribution of land use that is based on the current population dynamics. The Moderate Scenario incorporates the proposed density from the Master Plan, specifically considering the density that is outlined in the Master Plan-2035, which is 241 PPH. The third is the Dynamic Scenario which represents the WaTOD Model. In this scenario, an increase of 25% is assumed from the Moderate Scenario. The mentioned percentage was determined through a literature review of the existing Transit-Oriented Development (TOD) case studies that suggests an average increase of 25 per cent.

Table 6: Proposed Density Scenarios in Srinagar

Scenario	Density (PPH)	
	Zero Bridge	Khanqah-e-Maula
Existing	52.75	192.1
Moderate	241	241
Dynamic	300	300

Source: Srinagar Master Plan 2035

Figure 13: Population Projection of the Proposed Density Scenarios at the Two Terminals, Srinagar



Following the population density distribution, four scenarios were formulated for Floor Area Ratio (FAR) in the Buffer zones. This approach was adopted to allocate the total built-up area that will be required for land use other than residential. The scenarios for FAR distribution are summarized as:

- Scenario 1: The total area of the Buffer zone is considered as the plot area.
- Scenario 2: The area covered by water bodies has been subtracted from the total area to determine the available land for development, which is referred to as the plot area.
- Scenario 3: All-natural features, including water bodies, defence areas, ecological reserves, and

heritage sites have been excluded to define the remaining developable land as the plot area.

- Scenario 4: Only the area covered by major land uses, such as Residential, Public, Semi-public, Commercial, Industrial, and Tourism, were considered as the plot area.

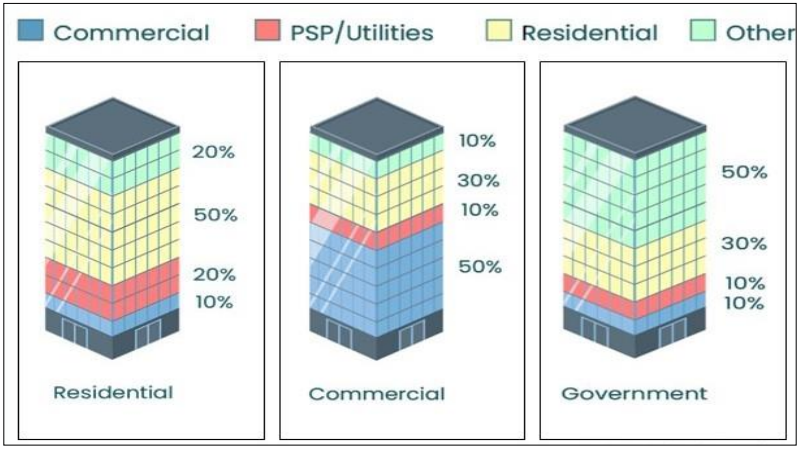
Table 7: FAR for the Buffer Zones as per the Assumed Scenarios in Srinagar

Land Use	Terminal	FAR			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Existing	Zero Bridge	0.8	1.0	1.0	1.4
	Khanqah-e-Maula	1.3	1.4	1.6	2.6
Proposed (Master Plan-2035)	Zero Bridge	0.8	1.1	1.2	1.6
	Khanqah-e-Maula	1.3	1.4	1.5	1.9

Diversity

The proposed FAR has been distributed by aligning with the recommendations that are outlined in the National Transit-Oriented Development (TOD) Policy 2021 (Government of India, 2021) (Figure 14) based on the land use distribution of the two terminals.

Figure 14: Mix of Uses/Distribution of FAR in TOD, Srinagar



Source: National TOD Policy of India, 2021

Figure 15: Built-up Area for the Buffer Zone of Zero Bridge Terminal (Srinagar) as per the Density Scenarios

	FAR	TOTAL PROPOSED LAND USE	Built-up Distribution			
EXISTING	1.5	0.170	0.13	0.03	0.05	0.05
		0.083	0.04	0.06	0.01	0.01
		0.011	0.01	0.002	0.002	0.01
MODERATE	2.5	0.170	0.17	0.03	0.07	0.07
		0.083	0.05	0.08	0.02	0.02
		0.011	0.01	0.00	0.00	0.01
DYNAMIC	3	0.170	0.25	0.05	0.10	0.10
		0.083	0.07	0.12	0.02	0.02
		0.011	0.05	0.02	0.02	0.08

(All areas are in square kilometres)*

Source: Prepared by the Author

Figure 16: Built-up Area for the Buffer Zone of Khanqah-e-Maula Terminal (Srinagar) as per the Density Scenarios

	FAR	TOTAL PROPOSED LAND USE	Built-up Distribution			
EXISTING	1.5	0.21	0.16	0.03	0.06	0.06
		0.10	0.04	0.07	0.01	0.01
		0.02	0.01	0.004	0.004	0.02
MODERATE	2.5	0.21	0.21	0.04	0.08	0.08
		0.10	0.06	0.10	0.02	0.02
		0.02	0.01	0.005	0.005	0.02
DYNAMIC	3	0.21	0.32	0.06	0.13	0.13
		0.10	0.09	0.15	0.03	0.03
		0.02	0.02	0.01	0.01	0.04

(All areas are in square kilometres)*

Source: Prepared by the Author

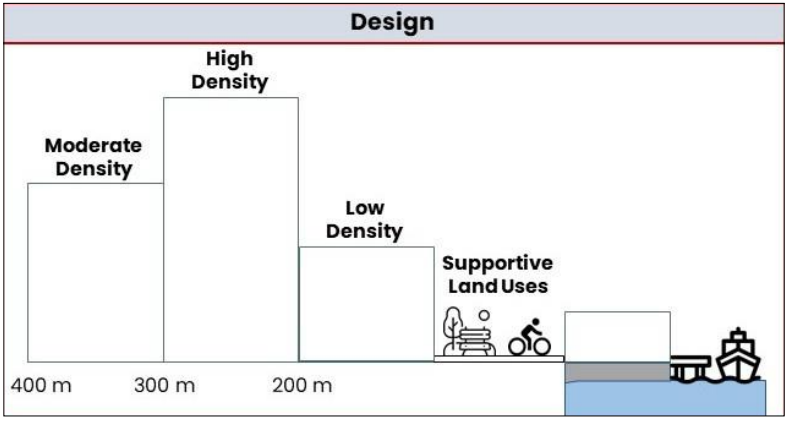
Design: River City Interaction

To ensure that TOD does not merely become high-density development only along transit areas, potentially leading to a higher concentration of private vehicles and congestion, Urban Local Bodies (ULBs) must make sure that the comprehensive implementation of the all-important aspects of TOD takes place as outlined in the earlier sections.

Cities should strive for transparency and clarity in TOD policies and procedures, thus providing economic incentives for all the stakeholders. This approach would facilitate multiple landowners to come together, build consensus, and save time in the implementation of TOD.

For long-term commitment of public agencies and the private sector in the implementation of TOD, cities should establish clear and equitable rules for sharing costs, benefits, and risks among stakeholders.

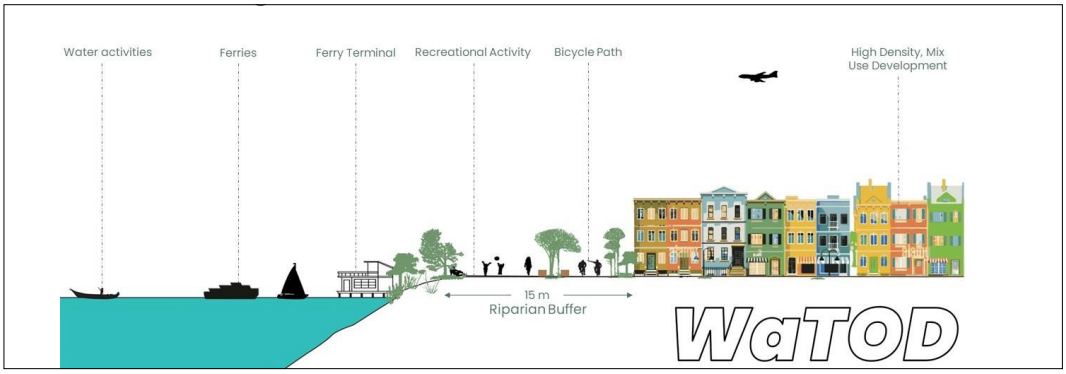
Figure 17: Density Diversification in WaTOD



Source: Prepared by the Author

Based on the literature review, supportive land uses are recommended to be located closest to the river to provide open spaces for social gatherings and communal activities. Following this buffer, densities are categorized into three levels: High, Moderate, and Low, with scaling by 200m to 400m, respectively. The proposal suggests placing Low density closer to the river due to potential water overflow, particularly during the rainy season. Moderate density is positioned farther from the river, aligning with the existing built fabric and zoning considerations. Finally, High density is strategically placed in the centre to optimize land use zoning.

Figure 18: Intersection of WaTOD Model with the River



Source: Prepared by the Author

People's movement along and adjacent to the river will help to promote water transport as a mode of choice. Therefore, it is essential to provide supportive land uses along the water corridor. The ferry terminals can be designed in an interesting way to attract people and serve as recreational spaces that are integrated with the open areas around the water body, including the buffer zone.

To enhance the riparian buffer along the riverbanks, a strategy for buffer zone management should be developed and implemented. These strips of vegetated land hold the potential to provide various environmental benefits. These include stabilizing the stream banks which lead to a reduction in erosion and sedimentation. Moreover, they contribute to the infiltration of stormwater runoff, maintain the base flow of streams, and offer organic matter that acts as a source of food and energy for the aquatic ecosystem. Additionally, these vegetated strips provide tree canopies that shades the streams and regulates temperature, further contributing to the overall ecological well-being of the area.

However, cities may also implement a three-zone riparian buffer, with more riparian flora along the riverside, small and medium shrubs in the middle zone, and a pathway with native trees in the landward portion that is based on the availability of land in the river zone.

Connectivity: Multi-Modal Integration

Since people have become more active than ever before they are regularly using transportation amenities. There is no way to establish an end-to-end transportation system. As a result, issues such as traffic congestion and pollution arise. Multi-modal integration is used to seamlessly connect the numerous transport modes and maximise the potential of mass transportation to clear congestion and establish a sustainable system, as well as ease people's mobility. The main principles are to reduce the number of interchanges and, if that is not possible, then make the transition as smooth as possible. For this reason, transportation services are separated into two types: mass transit and feeder services. The idea is to make it easier for people to use the mass transit system in a timely and comfortable manner.

The logical interpretation of transportation modalities involves several fundamental steps. Firstly, there is a need to increase accessibility and coverage to cater to a wider population. The second step is to focus on shortening the journeys and saving time for commuters. Additionally, efforts should be directed towards decreasing the number of interchanges in the transportation system, thereby simplifying the travel experience. Lastly, a crucial aspect is to design and implement a system that is viable for the long term, thus ensuring the sustainability and efficiency of the transportation infrastructure.

The success of the mode is determined by how well it is received by the general audience. The willingness to change modes will be determined by the length of time and frequency of service, trip distance, walk time and distance, level changes between services, ambience of the surroundings (rain, sun, etc.), convenience of transfer, and the overall trip cost. Walking is preferable for distances under 0.5 km, and NMT is recommended for distances between 0.5 and 1.5 km.

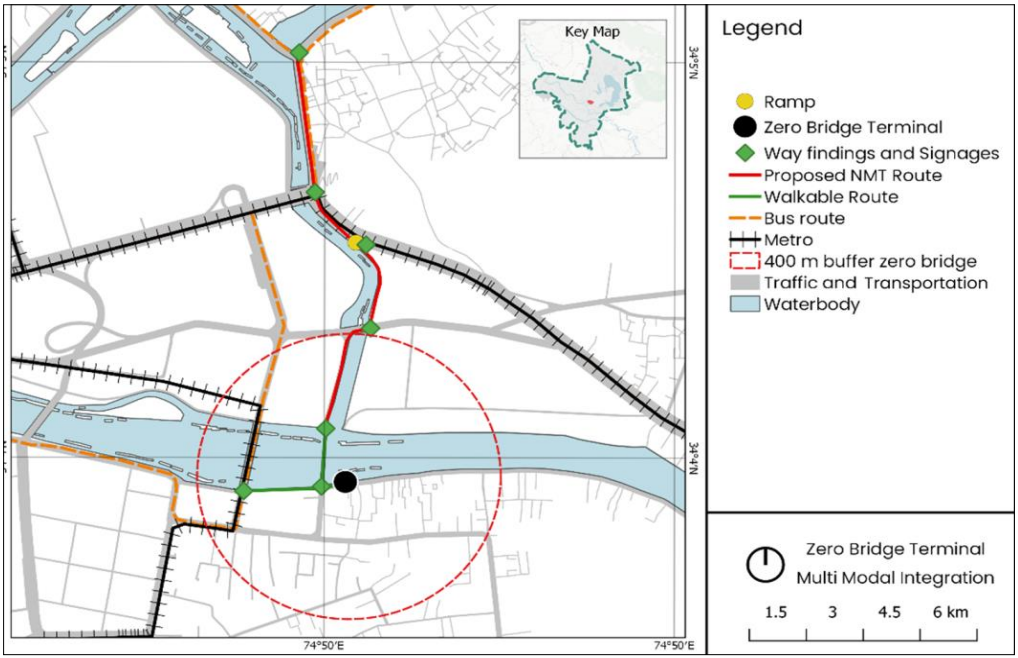
Three types of integration are necessary to generate beneficial responses:

- **Physical Integration:** Physical infrastructure is completely integrated with the pedestrian and NMT environment, as well as their connectivity to feeder services and ultimately, to the mass transport system. Providing parking and other common services at the stations where the interchange will take place has also been planned.
- **Information Integration:** By simply and uniformly providing information about the service, such as a timetable, route maps, and real-time information.
- **Fare Integration:** Commuters benefit from an integrated fare system which includes a common card and integrated tickets.

Terminal-1 (Zero Bridge) Buffer Zone

An intermodal system has been proposed at the Zero Bridge terminal, connecting it to the nearest mass transit station. Two mass transit points are accessible from this terminal. For the first point, commuters would need to walk along a 200-meter pathway through the park.

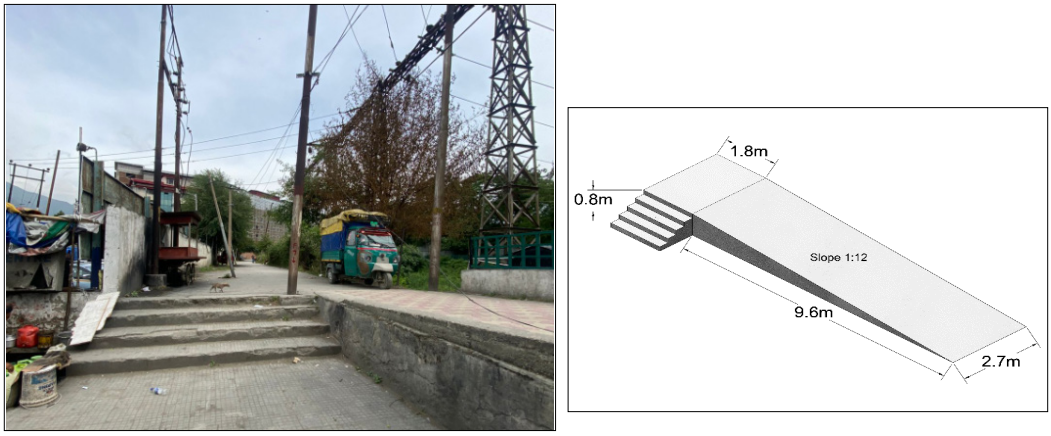
Figure 19: Multi-modal Integration of Zero Bridge Terminal



Source: Prepared by the Author

In the second scenario, commuters will have to walk across a pedestrian-only Zero Bridge for a distance of 200-meters, then board a Non-Motorized Transport (NMT) to reach Dal Lake, covering a stretch of 1-km. Along this route, stairs located near Krishna Dhaba, parallel to the footpath, are proposed to be converted into a ramp for the NMT (Figure 20).

Figure 20: Ramp Provided for Easy Accessibility of Non-Motorized Transport (NMT)

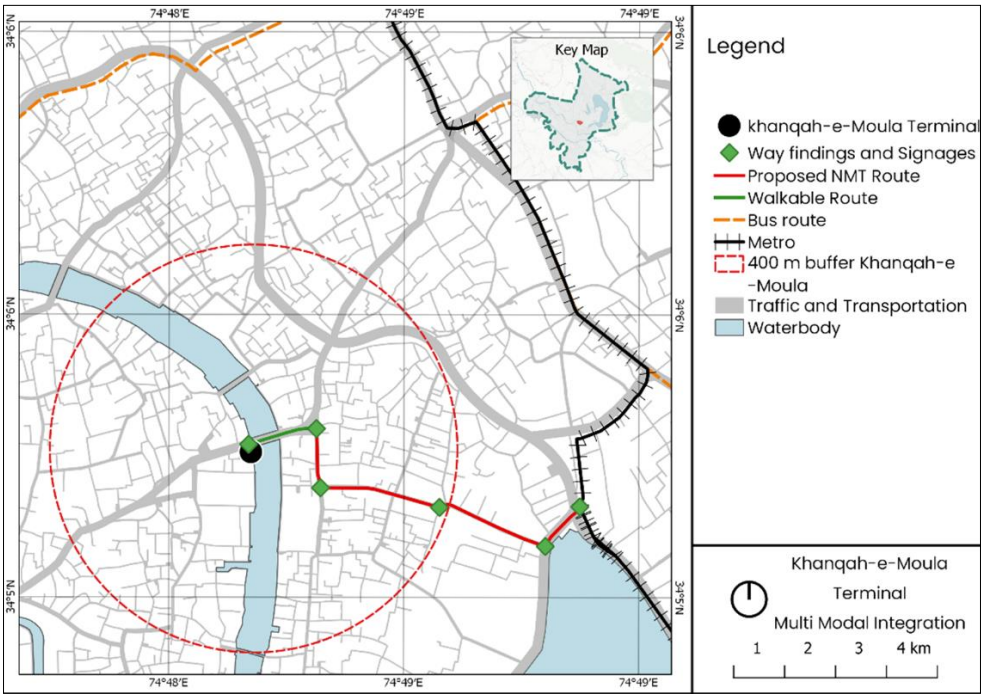


Source: Prepared by the Author

The dimensions of the ramp have been determined by following the guidelines of the Indian National Building Code 12.18.1. A width of 2.7 meters was available which will be fully utilized for the ramp. The height will measure 0.8 meters, and the slope ratio of 1:12, as per IRC 011 (2015), was implemented. Calculations based on this slope ratio yielded a ramp length of 9.6 meters. In addition, a perpendicular staircase has been proposed which will feature five steps with a riser of 0.15 meters and a tread of 0.3 meters.

Terminal-11 (Khanqah-e-Maula) Buffer Zone

Figure 21: Multi-modal Integration of Khanqah-e-Maula Terminal, Srinagar



Source: Prepared by the Author

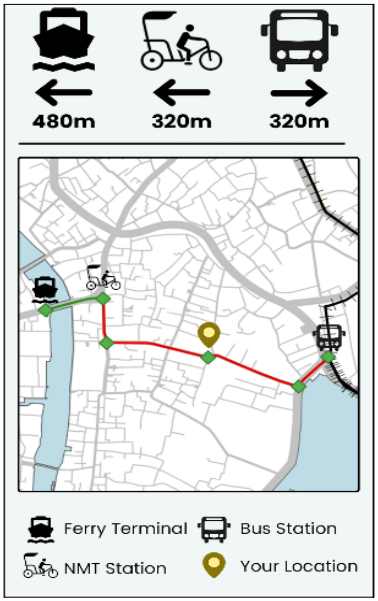
At the Khanqah-e-Maula terminal, an intermodal system has been proposed which will connect the terminal to the nearest mass transit station that is approximately 650-meters away. The chosen route spans a length of 800-meters. Commuters will need to walk approximately 150-meters via the New Zaina Kadal and then board the Non-Motorized Transport (NMT) to reach the station, making it a direct 650-meter stretch.

Wayfinding and Signages

To facilitate navigation and locate the terminals and key nodes easily, proposals for signages have been developed. The primary focus of these signages is to ensure clear and consistent information at the junctions for enhanced visibility. They will convey information about the terminal's location, distance, routes, and more. Six specific locations have been identified to install the signages

which will cover both the Zero Bridge and Khanqah-e-Maula terminals and the associated routes (Figures 19 and 21).

Figure 22: Signages for Ferry Terminals, Srinagar



Source: Prepared by the Author

Integrated Ticketing System

A proposed integrated fare card system for tickets aims to provide commuters with the convenience of using any service without the need to purchase new tickets or different cards. These cards will be obtainable at the ferry terminal, thus streamlining the usage of the entire transportation system and facilitating seamless switching between modes. Given the fixed route for the Non-Motorized Transport (NMT), pricing will be determined based on the distance travelled along that route. Customers will have the option to make direct payments to the NMT operator using the card at the point of use.

Conclusion

In general, there is a substantial demand for water transportation, but its viability in the current landscape that is dominated by land transport, raises significant questions. The observed congestion in Srinagar city presents a novel challenge in urban transport which demands an alternative mode of transportation. The old city of Srinagar is particularly affected by the rising demand and constrained transportation infrastructure since it is unable to expand due to land limitations. The closure of the old canal system, which was once the lifeline of a thriving water economy, further complicates the situation. Although there is potential for revival, its scope is limited, and it is primarily suited for long-distance travel along with cargo movement, tourism, and leisure activities.

However, Waterfront Transit-Oriented Development (WaTOD) emerges as a crucial factor in developing new cities. It not only contributes to the city's aesthetic appeal but also prompts the question of whether aligning development towards a river, rather than turning away from it, could lead to better river management.

Creating new roads may not be financially viable, thus Inland Water Transport (IWT) is a possible option. Yet, further research is necessary to ensure that these high-density developments are ecologically sensitive. Currently, there is a lack of comprehensive research on high-density riverfront development, and the existing models lack proper documentation which results in the availability of limited data to assess their effectiveness.

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Conflict of Interest

The authors declare no conflict of interest.

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