Urban Mobility India
2024

Research Symposium

Last mile connectivity for Water metro, Kochi

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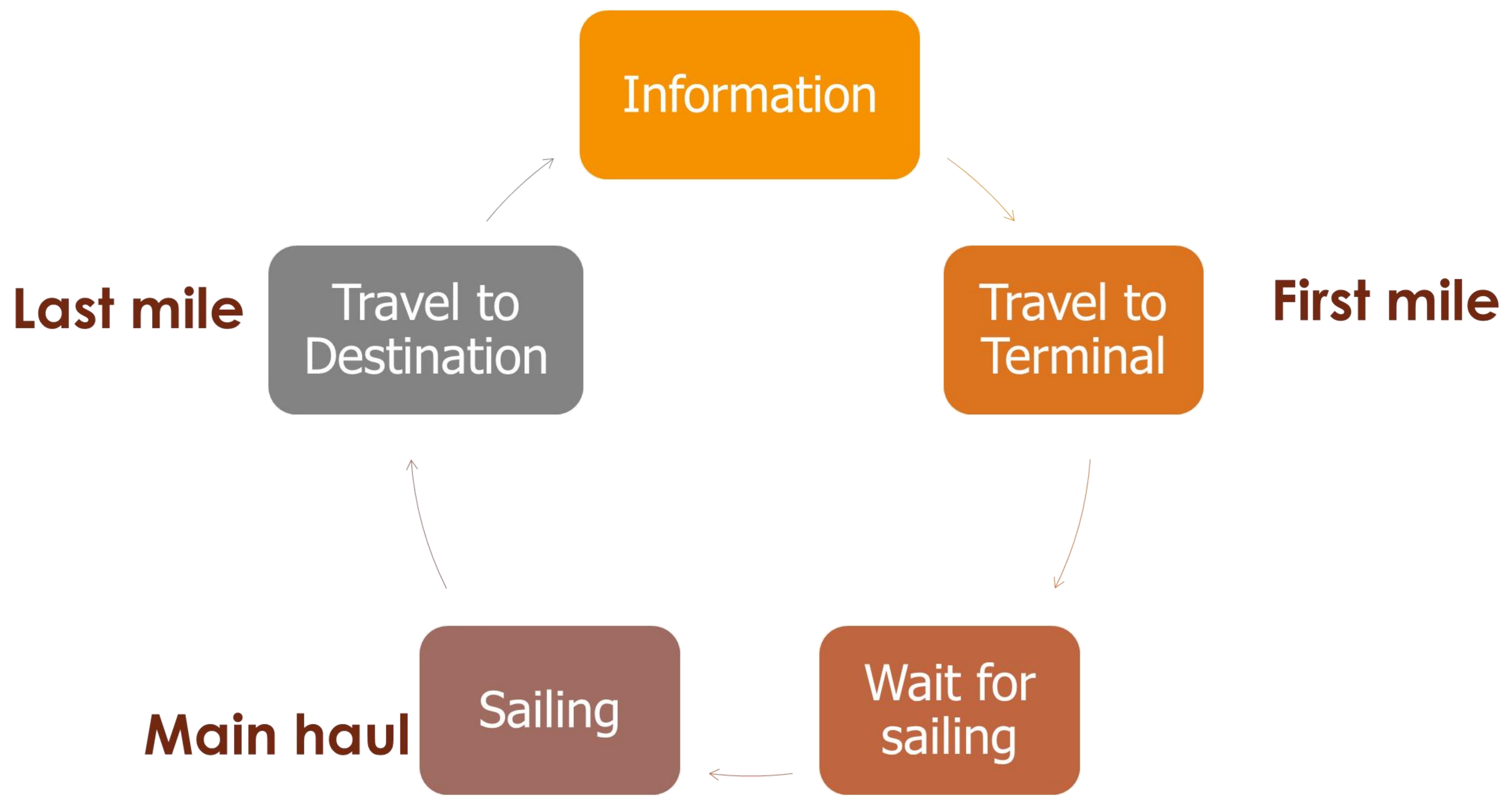
BACKGROUND

- 54% of the world's population live in urban areas, predicted to increase to 60% by the year of 2030 and up to 70% by 2050 (Kristian & Milos, 2021)
- Public transportation is the upcoming solution to reduce congestion and emissions for sustainable development
- Inland Water Transportation system such as ferries, water taxis, etc. is a reliable, economical and sustainable public transport for urban mobility especially in coastal cities

Advantages of IWT

Less fuel consumption
Environment friendly mode
Less land requirement
Less pollution
Lower cost of operation

Travel chain of IWT passenger



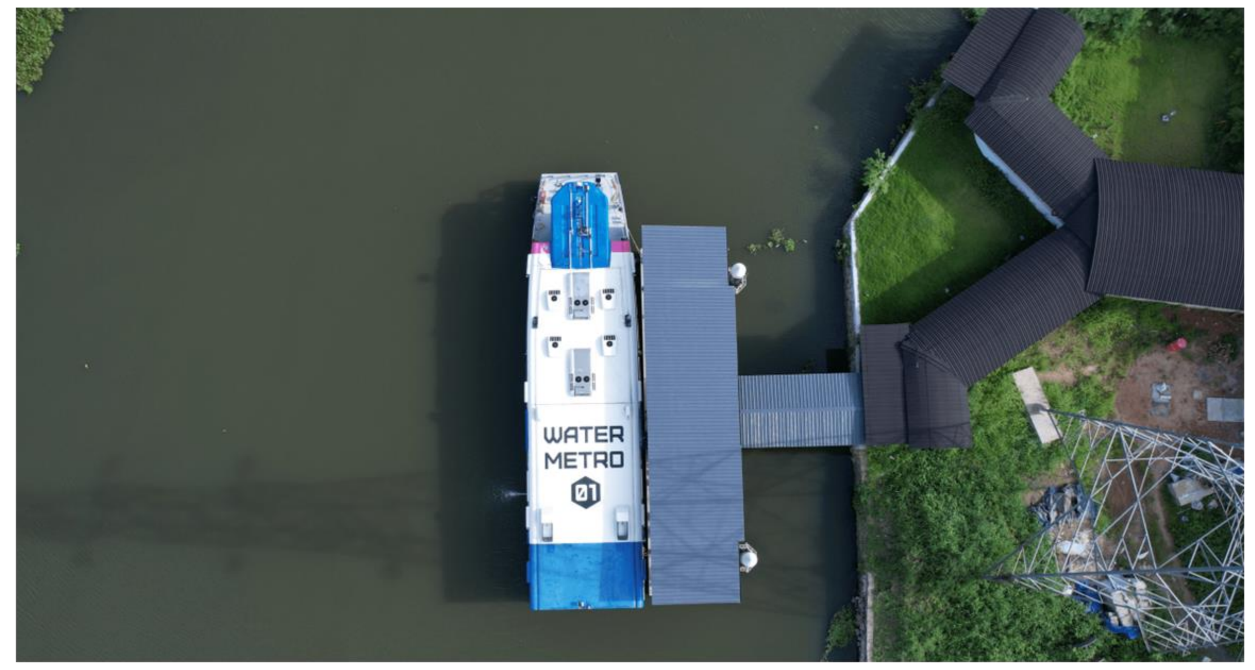
Source: Ercoli, S., Ratti, A. and Piardi, S. (2014) 'Water-based Public Transport Accessibility. A Case Study in the Internal Waters of Northern Italy,' Archivio Istituzionale Della Ricerca - Politecnico Di Milano, pp. 4996–5006.

Water metro project, Kochi

- For revival of ferry system in Kochi
- Electric ferries: 50 and 100 passenger capacity
- Partial operation began in April 2023
- 4 operational stations and 2 routes in 2023

16 routes	76 km route
18 Major hubs	38 stations

Source: Detailed Project Report 2015, Water metro Kochi, Kochi Metro Rail Ltd.



OBJECTIVES

- To appreciate concept of last mile connectivity in context to various transport systems
- To review methods and approaches to assess and plan last mile for transit systems
- To analyse existing last mile pattern of commuters at case water metro stations and assess its determinants
- To model travel behaviour for potential shift from competitive modes through mode choice model
- To develop planning strategies for improving last mile connectivity and water metro ridership

INLAND WATER TRANSPORTATION CONCEPT

CHARACTERISTICS

Planning and Design factors

- Route
- Ridership Estimation
- Scheduling and Fleet
- **Transit Network Integration**
- Terminal Design
- **Accessibility**
- Public perception and comfort
- Operating cost
- Vessel Design
- Environmental Considerations

- Reliable, economical and environment friendly mode
- Slower mode than roadways
- Usually less frequency than metro and bus service

Source: Tanko, M., Burke, M. I., & Cheemakurthy, H. (2018). Water Transit and Ferry-Oriented Development in Sweden: Comparisons with System Trends in Australia. Transportation Research Record, 2672(8), 890-900.

Best Practices

Mukilteo, USA
Ferry-rail integration

New York, USA
Integrated Fare

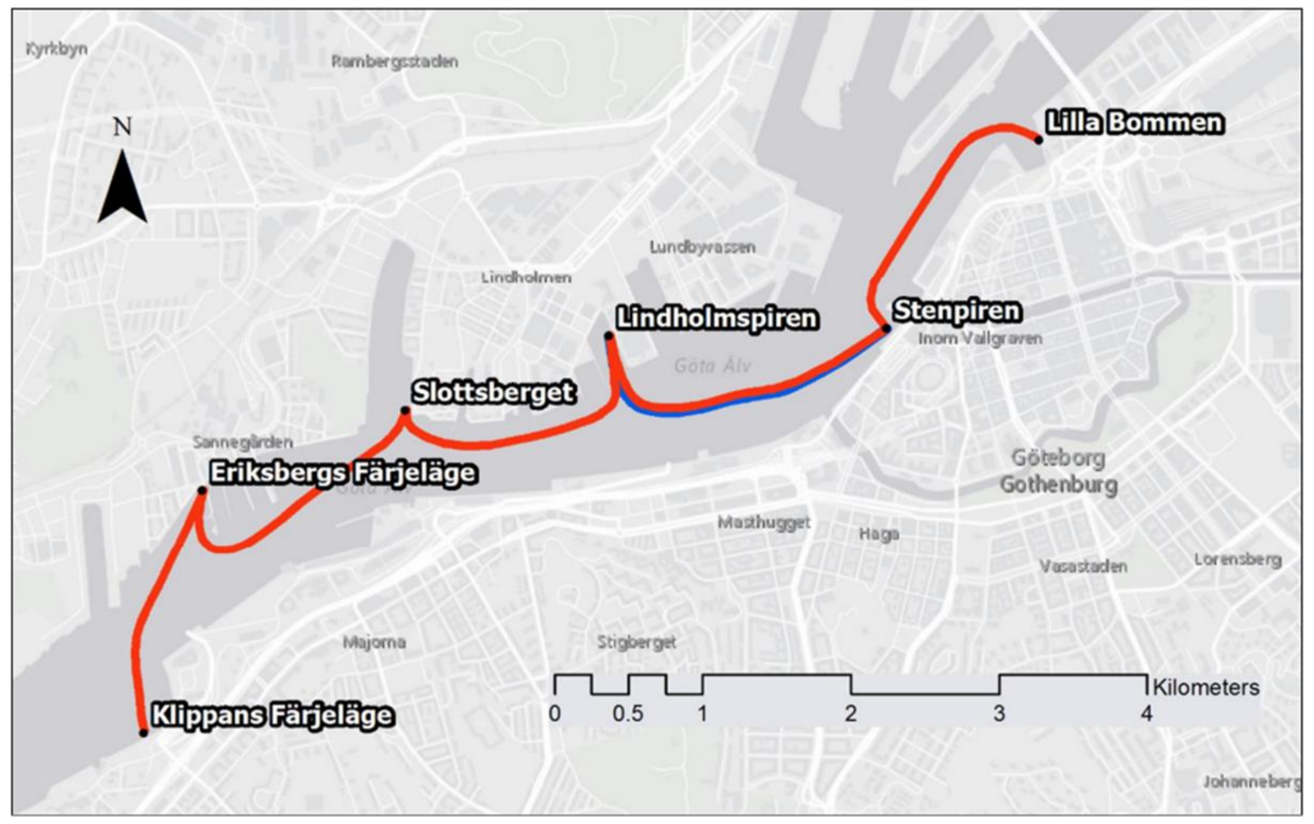
San Juan, Puerto Rico
Integration with PT

Gothenburg, Sweden
Land Development along route

Brisbane, Australia
Ferry Oriented Development

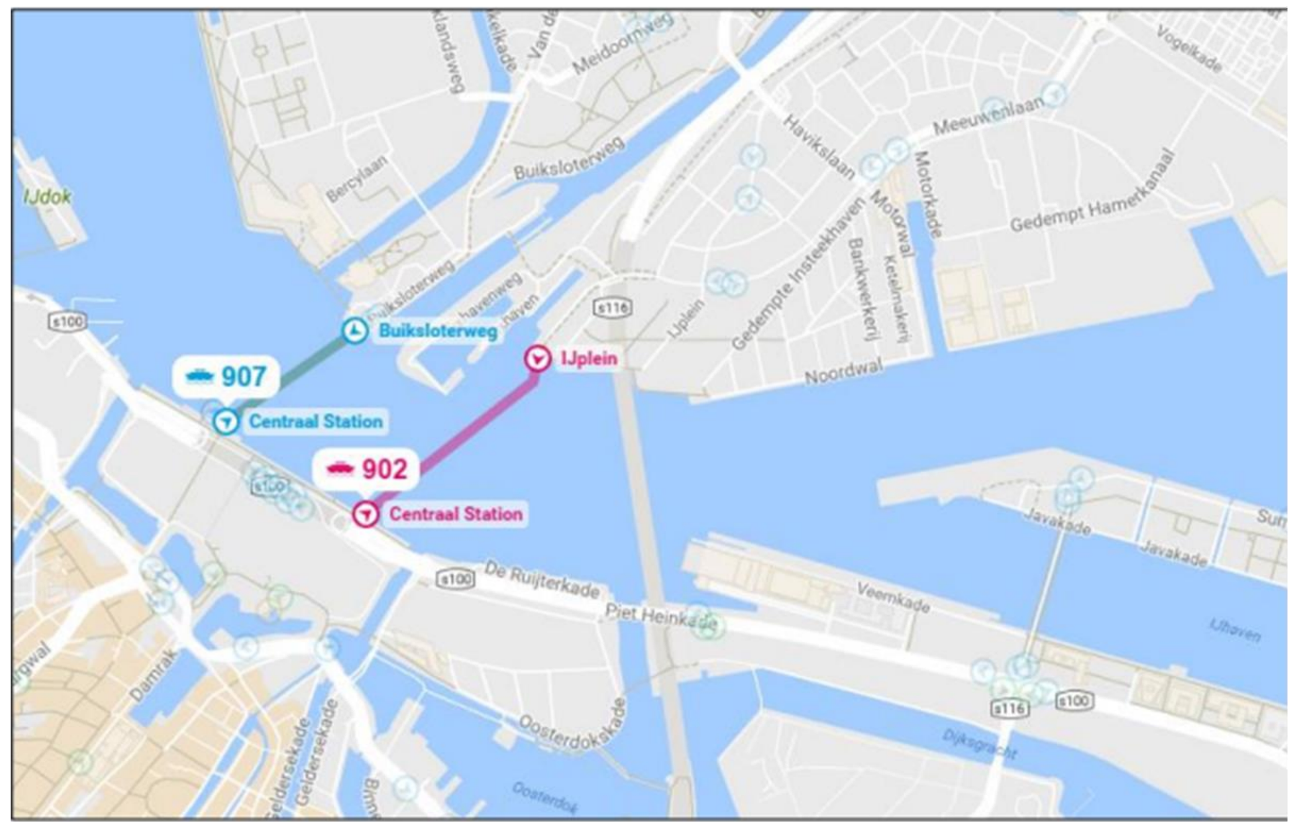
Route Type

Route Type A: Linear Ferry Systems



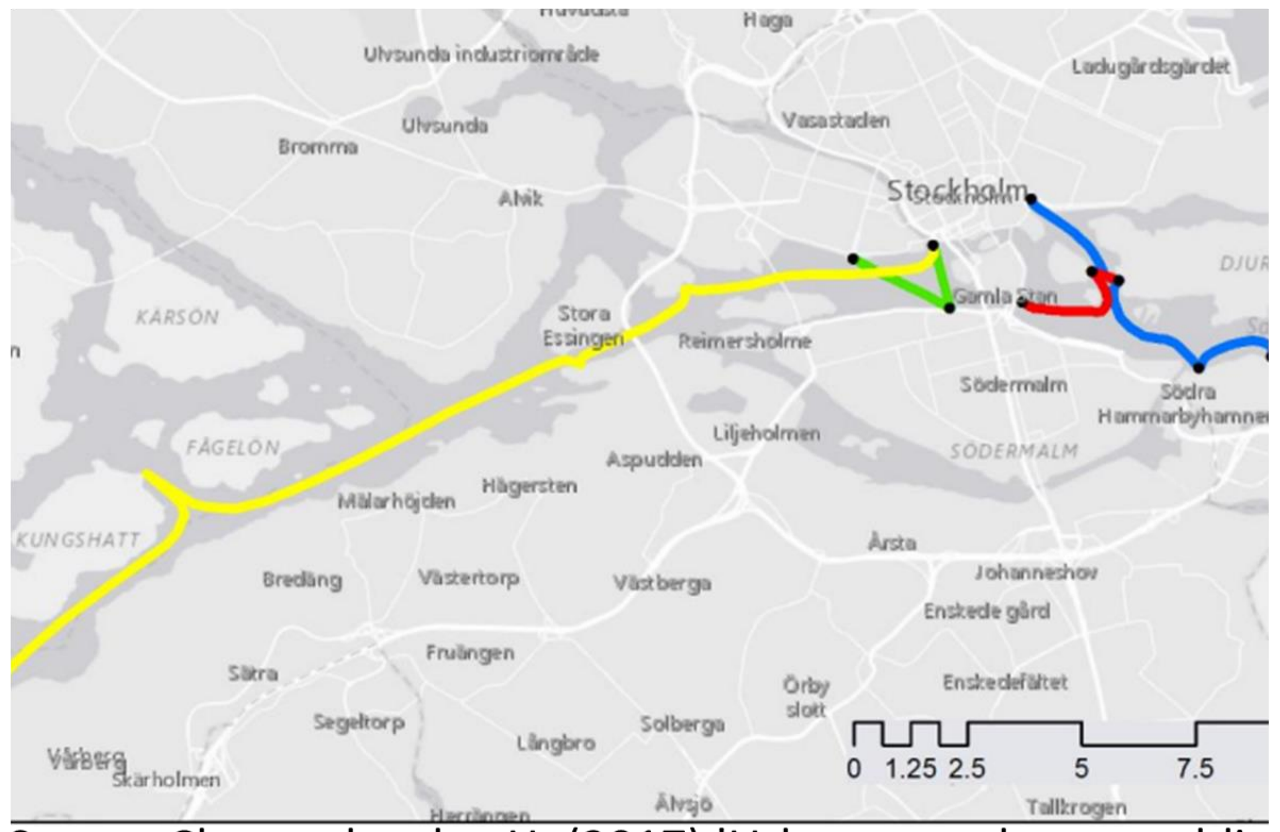
- Connects areas with a long route traversing along a water body
- High passenger capture capacity
- High journey time
- Facilitates TOD
- Examples- Älvsnabben service, Gothenburg; Brisbane; Hamburg

Route Type B: Short routes for crossing



- Short routes for crossing water body
- Low travel time
- Vessel designed to cater low turnaround time and high capacity
- High frequency service
- Examples- Copehagen, Amsterdam, Hong Kong, Venice

Route Type C: Links suburban area with inner city



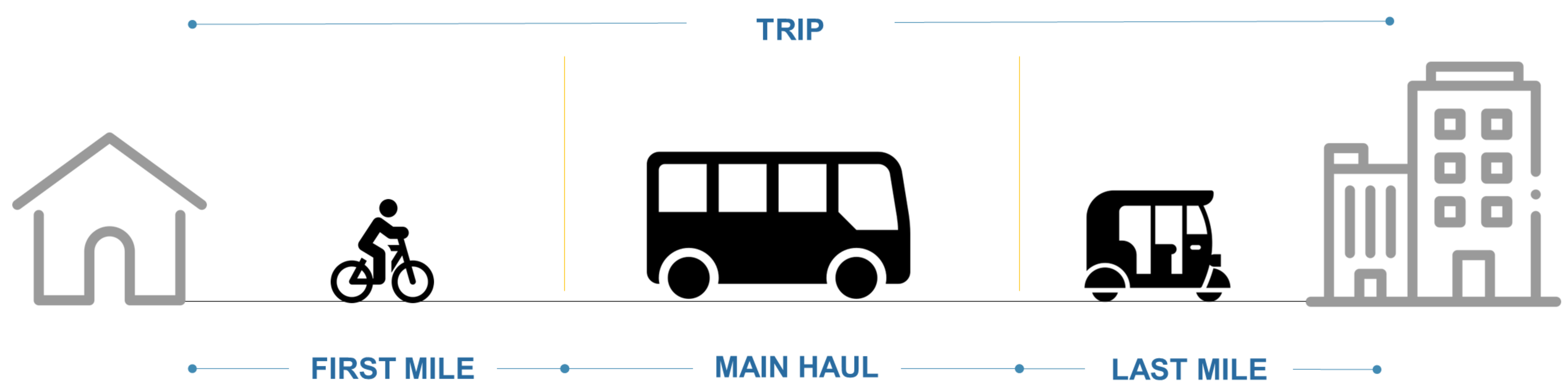
- Connect suburban areas with core city
- Long routes with low frequency
- Focus on passenger comfort and amenities
- Examples- Stockholm, Auckland

Source:Cheemakurthy, H. (2017) 'Urban waterborne public transport systems: An overview of existing operations in world cities,' KTH [Preprint]. http://kth.diva-portal.org/smash/record.jsf?pid=diva2:1168873.

LAST MILE CONNECTIVITY (LMC)

CONCEPT

- It is a set of links that connect main public transport service with end user. *(Silvio, et al., 2020)*
- It works like an extension of public transport services, expanding their reach from station or stop to doorstep.



LMC characteristics for different modes

Characteristics	Comparison
Catchment area	Metro have higher catchment area than bus due to larger distance between stations Metro station > Bus stop
Mode used	Rail travellers likely to choose Motorised transport than bus and metro commuters
Trip length	Longer trip distance for metro than bus Metro station > Bus stop
Travel time	Metro commuters willing to spend more time on LMC than bus Metro station > Bus stop
Interconnectivity Ratio	Between 0.2 to 0.5 for public transport trips

Source: Rahman, et al., 2022, The first-and-last-mile of public transportation: A study of access and egress travel characteristics of Dhaka's suburban commuters, Elsevier

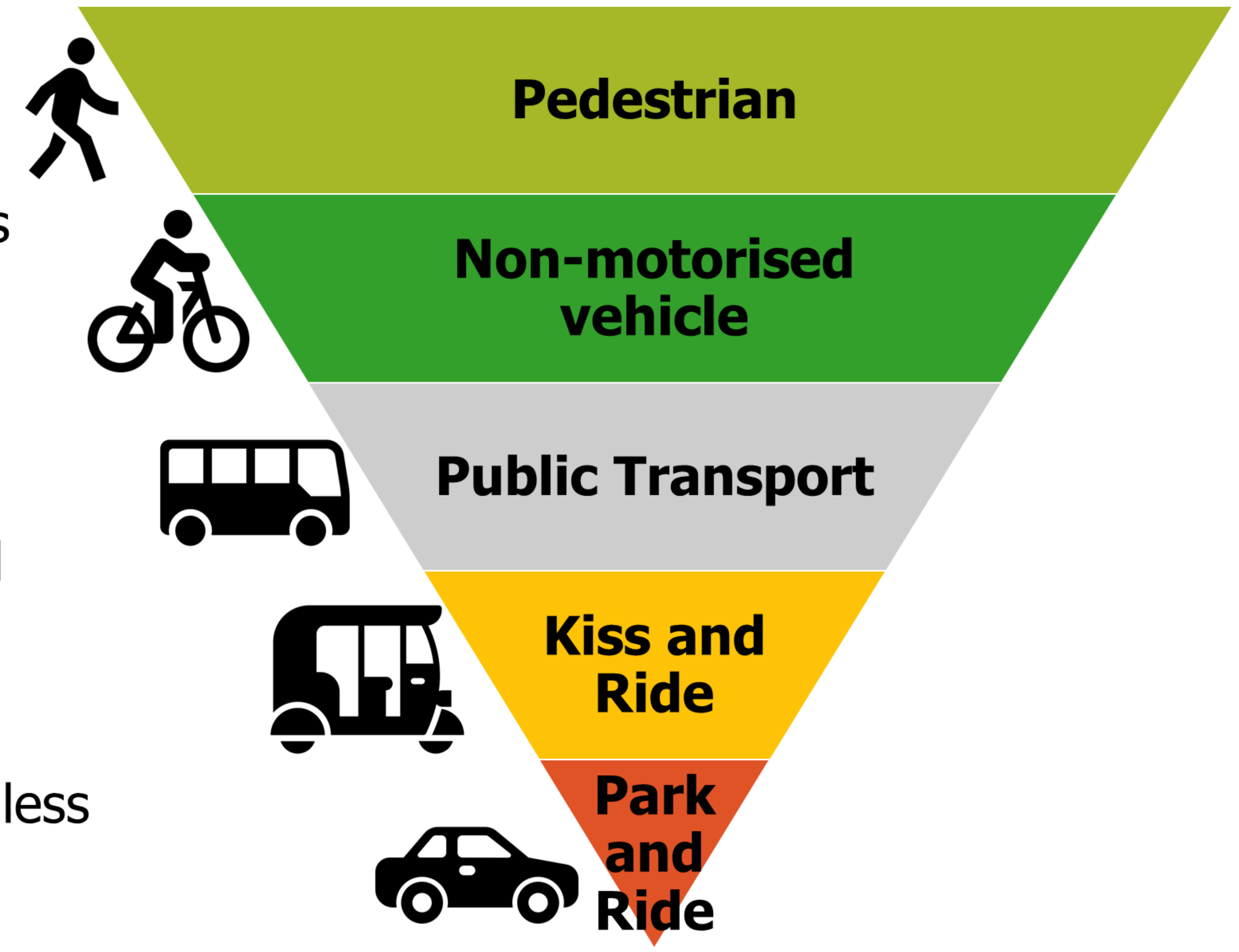
CHARACTERISTICS

Trip length Total distance travelled to reach transit stop	**Trip time** Total time taken to reach transit stop	**Trip cost** Total fare charged to reach transit stop
Mode used Type of mode used to reach transit stop (NMT/PT/car)	**User Characteristics** Age, gender, occupation, frequency	**Interconnectivity Ratio** Access + Dispersal time / Total trip time

PLANNING GUIDELINES

- Access modes to public transport stations to be planned on priority basis
- Green and NMT modes (Walking, cycling) to be promoted and facilitated
- Other PT modes to be interconnected for seamless transfer

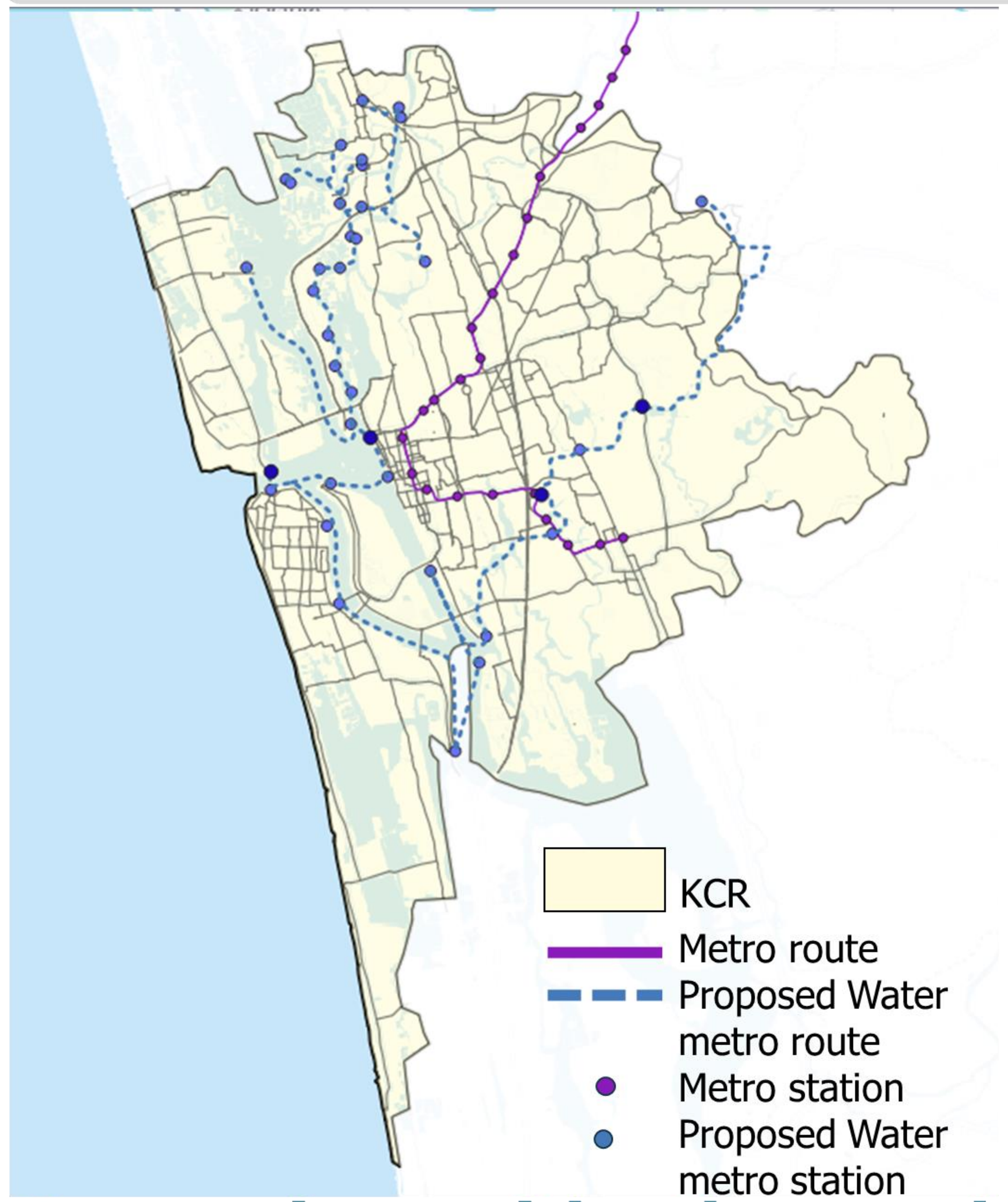
Hierarchy of priority to Access mode



Source: Levinson, H.S. *et al.* (2012) *Guidelines for providing access to public transportation stations, National Academies Press eBooks*. https://doi.org/10.17226/14614.

PROFILE OF KOCHI WATER METRO

INTRODUCTION



- **2 routes** operational since 2023 connecting 2 stations in each route
- Existing fleet: 13 (1 emergency)
- Average Daily ridership (till February 2024):
  - **3000** in weekdays
  - **8000** in weekends
- Competing PT modes: Bus, Ferry
- Complementing modes: Metro, Public Bicycle system

Comparison with other modes

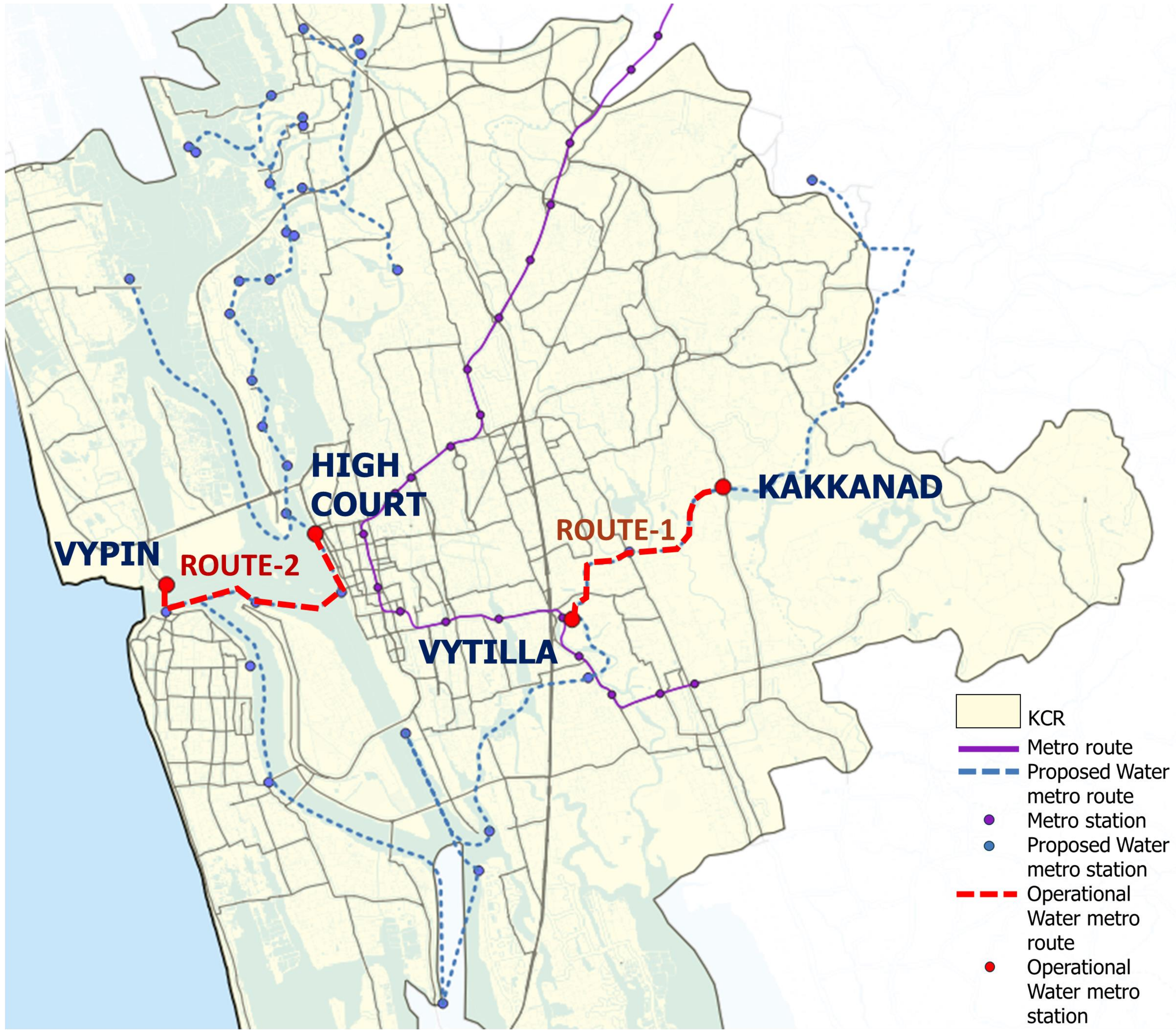
Route 1: Vytilla -- Kakkanad

Mode	Distance (km)	Time (min)	Cost (INR)	Waiting Time (min)
Water Metro	5	30	30	12
Bus	11	60	28	5
Private	6	15	40	-

Route 2: High court -- Vypin

Mode	Distance (km)	Time (min)	Cost (INR)	Waiting Time (min)
Water Metro	3.4	20	20	10
Bus	6	25	15	3
Private	6	15	40	-
Ferry	5.3	35	6	15

OPERATIONAL ROUTES



Station	Route	Station Type
Vytilla	1	Major station, Mobility hub, metro interchange
Kakkanad	1	Minor station, near IT sector hub
High court	2	Major station, near commercial and PSP area, metro interchange
Vypin	2	Minor station, dense residential island

COMPARITIVE ANALYSIS OF ROUTES

Route 1: Trip Characteristics

Parameter	Water Metro	Bus	Difference (Water metro-Bus)
ATL (km)	11	11	0
ATT (min)	53	62	-9
ATC (rs)	60	25	+35
Main haul Avg Distance (km)	5	10	-5
Main haul Avg Time (min)	30	42	-12
Main haul Avg Cost (rs)	26	21	+5
Waiting time (min)	3	1	+2

Parameter	Water Metro	Bus	Difference (Water metro-Bus)
Avg Access Distance (km)	4	0.7	+3
Avg Access Time (min)	15	10	+7
Avg Access Cost (rs)	16	4	+12
Dispersal Distance (km)	2	0.3	+1.7
Dispersal Time (min)	5	10	-2
Dispersal Cost (rs)	18	0	+18

- Average Trip Cost is significantly higher in Water metro than bus
- Higher cost of Access trip is major reason for higher total trip cost of water metro

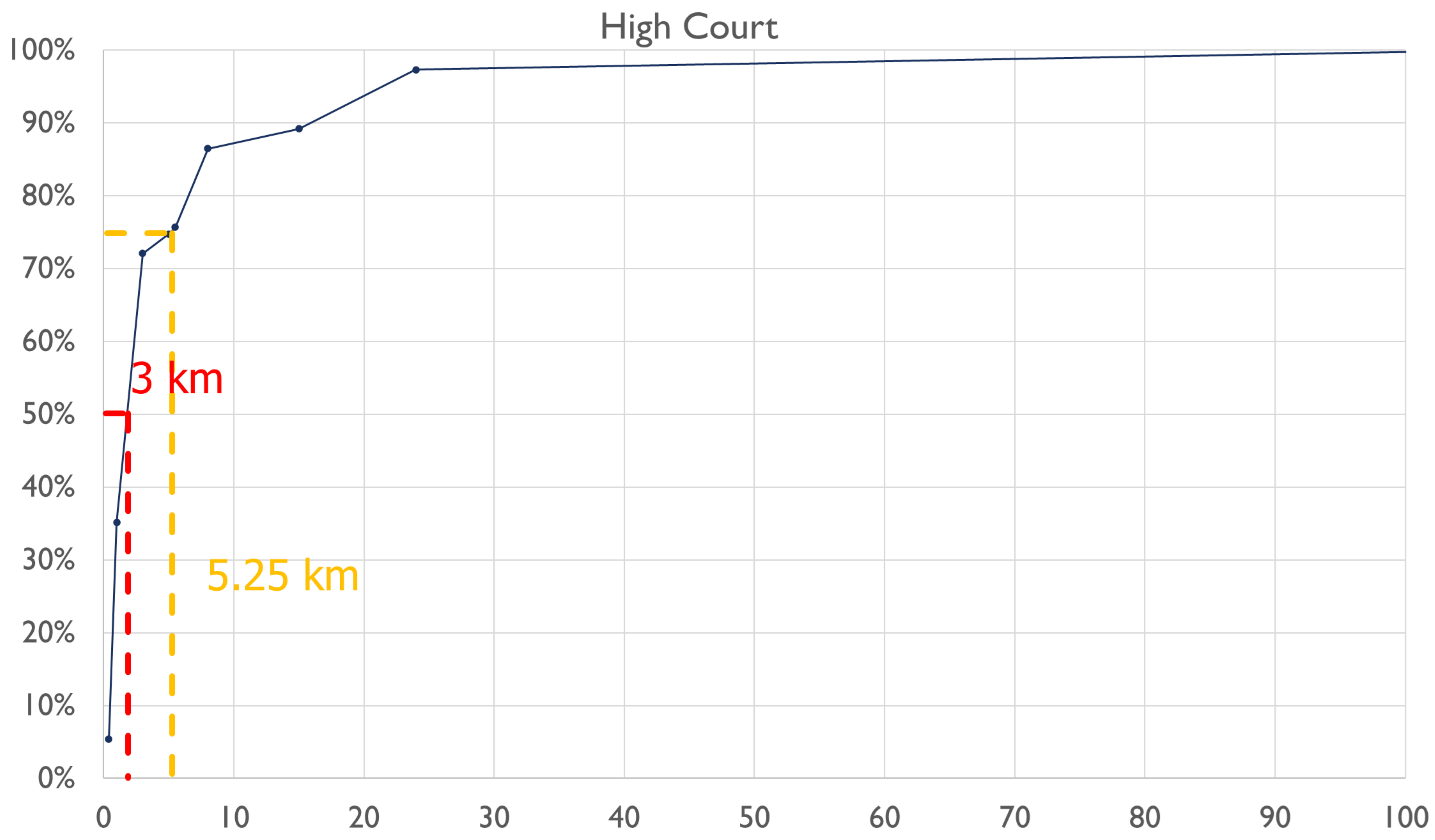
Route 2: Trip Characteristics

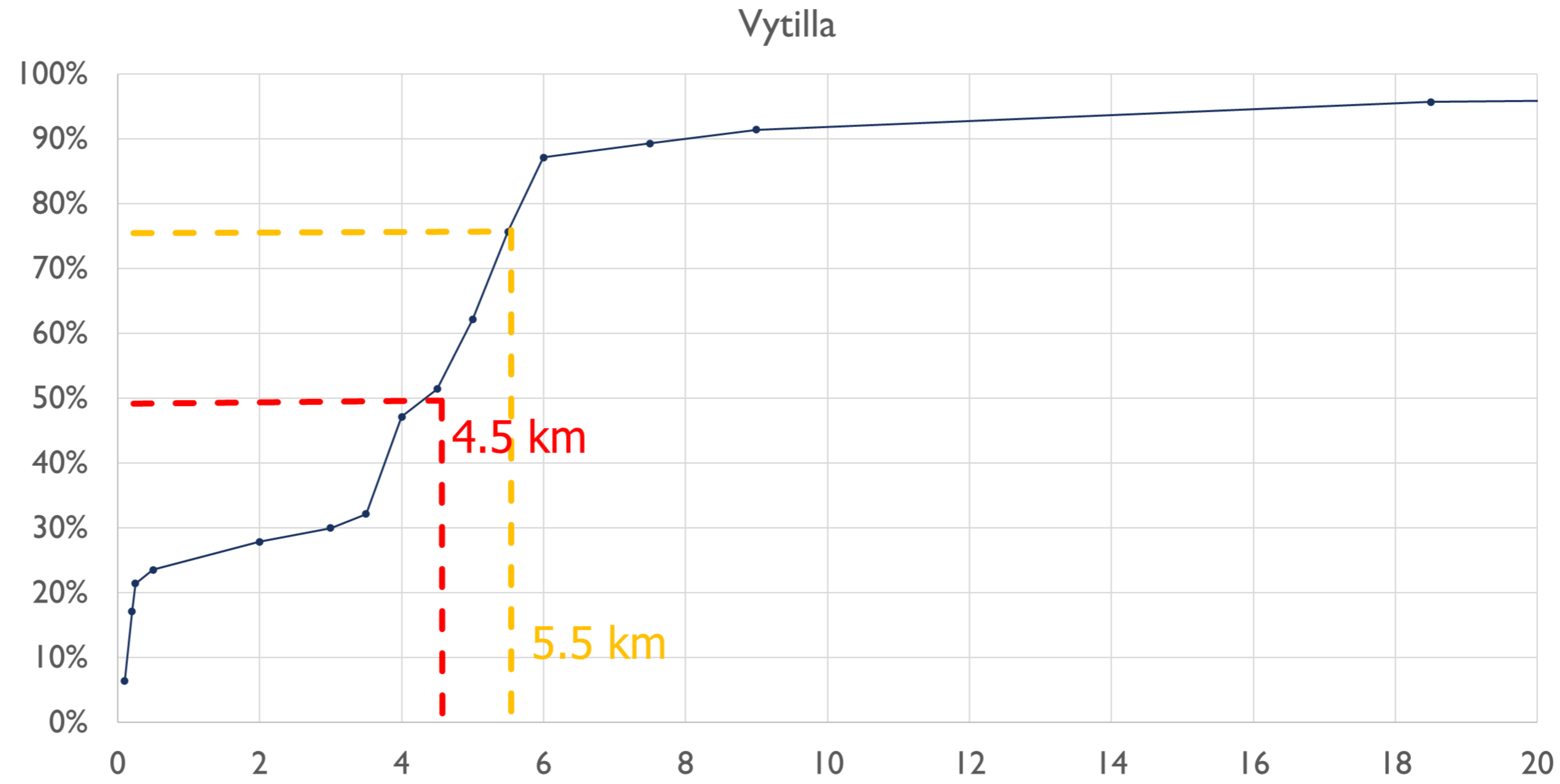
Parameter	Water Metro	Bus	Difference (Water metro-Bus)	Ferry	Difference (Water metro-Ferry)
ATL (km)	11	11	0	12	-1
ATT (min)	64	69	-5	74	+20
ATC (rs)	57	23	+34	13	+44
Main haul Avg Distance (km)	3.3	10	-7.7	5.3	-2
Main haul Avg Time (min)	20	56	-16	35	+3
Main haul Avg Cost (rs)	20	21	-1	6	+14
Waiting Time (min)	10	1	+9	20	-10

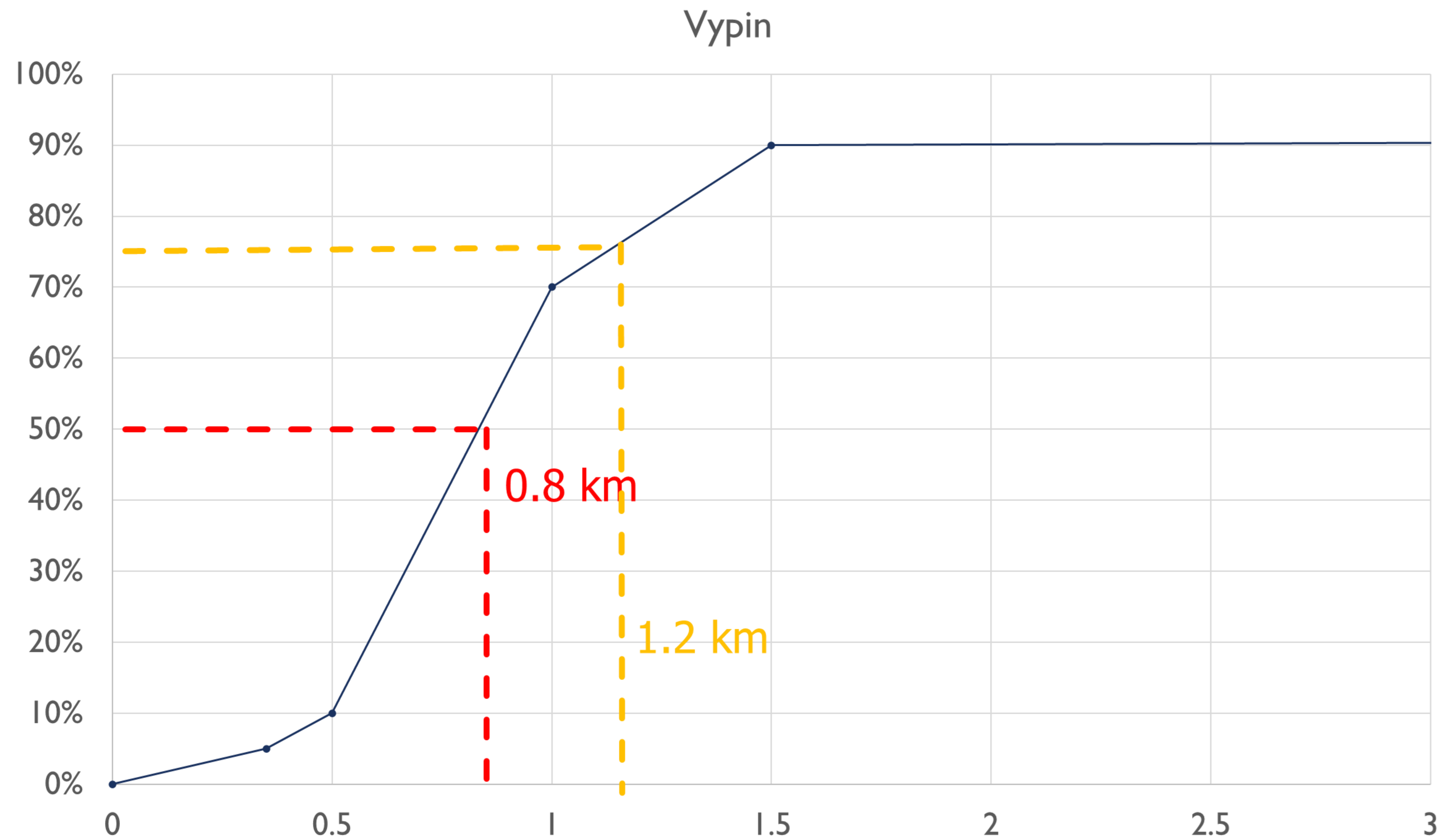
Parameter	Water Metro	Bus	Difference (Water metro-Bus)	Ferry	Difference (Water metro-Ferry)
Avg Access Distance (km)	5	0.4	+4.6	1.6	+3.4
Avg Access Time (min)	20	5	+15	10	+10
Avg Access Cost (rs)	14	0.2	+13.8	5	+9
Dispersal Distance (km)	2.7	0.6	+1.9	1.4	+1.3
Dispersal Time (min)	20	8	+12	10	+10
Dispersal Cost (rs)	23	1.8	+21	2	+21

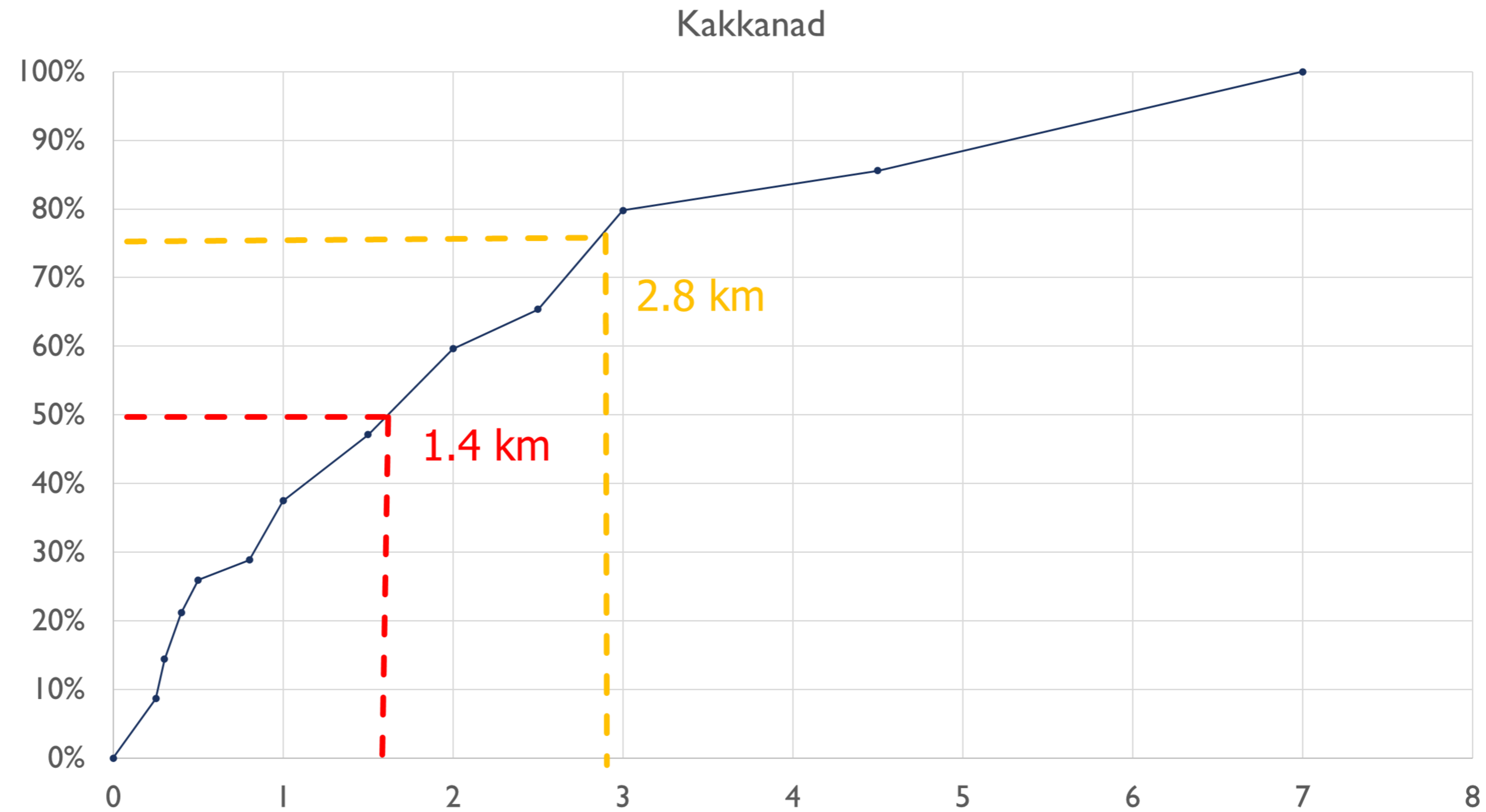
- Average Trip Cost is significantly higher in Water metro than bus and Ferry
- Average Travel time is higher for ferry due to slow speed and longer route

WORK ACCESS/DISPERSAL TRIP LENGTH FREQUENCY DISTRIBUTION









- Influence area of each station differs with respect to access/dispersal mode availability

MODEL CALIBRATION

- Model significance= <0.001
- Prediction Accuracy = 85.4%
- Hosmer and Lemeshow > 0.005
- -2 Log Likelihood > 200
- Nagelkerke R square = 0.485

Binary Logit Regression Output

Variables in the Equation

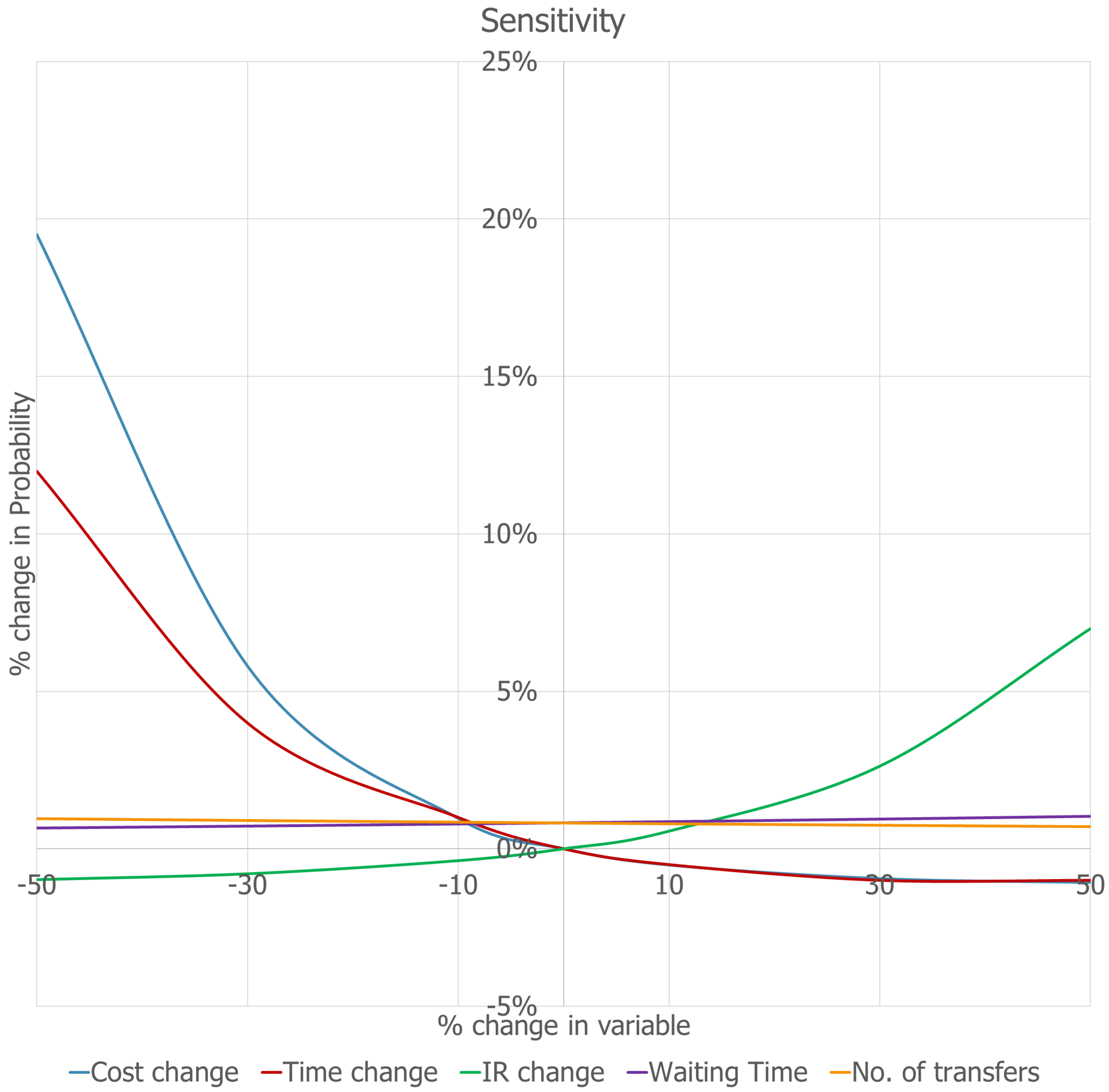
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Travel Time	-0.086	0.025	12.083	1	0.001	0.918
	TotalCost	-0.104	0.026	16.456	1	0.000	0.901
	Waiting time	0.045	0.039	1.303	1	0. 004	1.046
	No.oftransfers	-0.316	0.276	1.316	1	0.003	0.729
	Interconnectivity Ratio	9.311	2.268	16.848	1	0.000	11054.232
	Constant	2.066	1.789	1.333	1	0.248	7.890

Interpretation:

- All variables have sig. (Significance value) <0.005 meaning all these variables have significant impact on mode choice of ferry passengers

SENSITIVITY ANALYSIS

- **Ferry passengers are more cost-sensitive than travel time**



Probability of shifting from Ferry to Water metro =
2%

MODEL CALIBRATION

- Model significance= <0.001
- Prediction Accuracy = 74.7%
- Hosmer and Lemeshow Test > 0.005
- -2 Log Likelihood > 200
- Nagelkerke R square = 0.394

Binary Logit Regression Output

Variables in the Equation

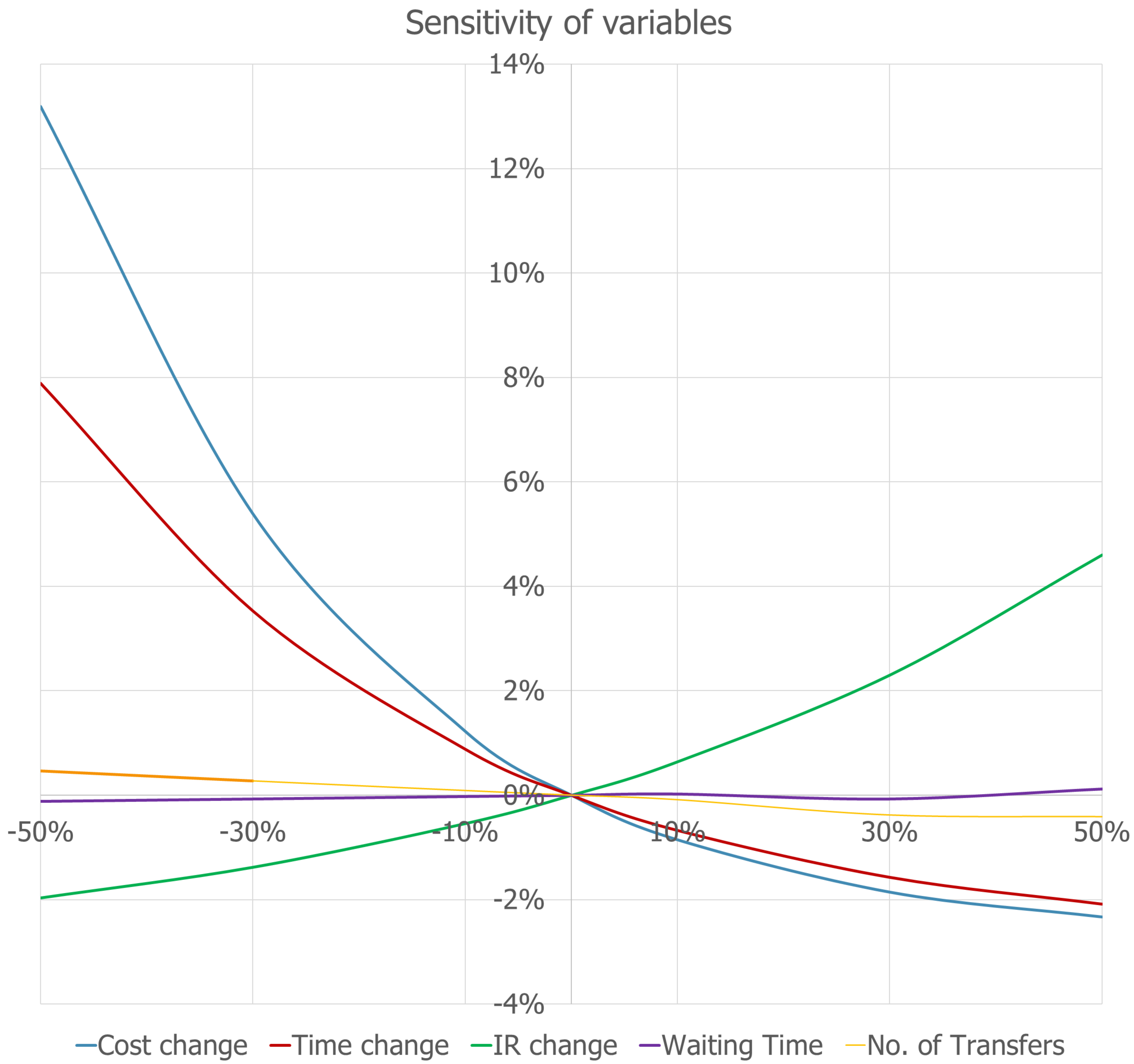
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Travel Time	-0.048	0.011	20.312	1	0.000	0.953
	Total Cost	-0.063	0.011	33.737	1	0.000	0.939
	No. of transfers	-0.346	0.128	7.347	1	0.007	0.707
	Interconnectivity Ratio	4.183	0.868	50.720	1	0.000	65.590
	Waiting time	0.007	0.048	13.129	1	0.000	1.007
	Constant	1.545	0.848	83.472	1	0.000	4.690

Interpretation:

- All variables have sig. (Significance value) <0.005 meaning all these variables have significant impact on mode choice of bus passengers

SENSITIVITY ANALYSIS

- **Bus passengers are more cost-sensitive than travel time**
- Desired mode shift from bus (as per DPR) = **8%**
- 8% mode shift achievable at total trip cost of **40 INR**



Probability of shifting from Bus to Water metro in existing condition = **3%**

CONCLUSION

- Water metro has a competitive advantage over buses in terms of distance and time.
- Buses have an advantage in terms of trip cost, a sensitive variable in the mode choice model.
- Average trip length for water metro is lower than buses and ferries, but the trip cost is higher.
- 86% of trips involve walking as the first/last mile or both, highlighting the need for pedestrian-friendly environments.
- Traveling behavior modeling shows trip cost, travel time, waiting time, number of transfers, and interconnectivity ratio impact mode choice.
- Commuters in the study area are highly sensitive to trip cost and travel time, with trip cost being more sensitive.

RECOMMENDATIONS

- Integrate Public Bicycle Sharing System with Kochi1 card for integrated fare collection in order to promote usage of PBS.
- Installing guidance and informational signage in the direction of water metro stations.
- enhance and promote the pedestrian experience by giving priority to the provision of pedestrian infrastructure within the vicinity of water metro stations.
- Discounted fares can also be provided for Kochi 1 card holders in order to encourage and provide incentive to people to use Kochi1 card.
- Route planning of buses to complement the water metro by acting as a last mile service can enhance public transport ridership.

Thank You

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	45.168	5	<.001
	Block	45.168	5	<.001
	Model	45.168	5	<.001

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	WM_TotalTime	11.394	1	<.001
		WM_TotalCost	13.502	1	<.001
		WM_No.oftransfers	2.675	1	.002
		IRatio	11.646	1	<.001
		Main haul wait time	.001	1	.005
	Overall Statistics		42.122	5	<.001

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	13.343	8	.101

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	218.904[a]	.250	.485

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Classification Table[a]

Observed			Predicted: Selected Cases[b] Choice 0	Selected Cases[b] Choice 1	Selected Cases[b] Percentage Correct	Unselected Cases[c] Choice 0	Unselected Cases[c] Choice 1	Unselected Cases[c] Percentage Correct
Step 1	Choice	0	621	26	95.9	32	5	85.7
		1	95	84	47.1	11	26	71.4
	Overall Percentage				85.4			78.6

a. The cut value is .500

MODE CHOICE MODEL VALIDATION (BUS TO WATER METRO)

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	WM_TotalTime	17.455	1	<.001
		WM_TotalCost	30.219	1	<.001
		WM_No.oftransfers	6.394	1	.001
		Main haul wait time	8.276	1	.004
		IRatio	49.191	1	<.001
	Overall Statistics		113.472	5	<.001

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	127.148	5	<.001
	Block	127.148	5	<.001
	Model	127.148	5	<.001

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	563.898[a]	.223	.394

a. Estimation terminated at iteration number 5 because paran than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	6.429	8	.599

Classification Table[a]

Observed			Predicted: Selected Cases[b] Choice 0	Selected Cases[b] Choice 1	Selected Cases[b] Percentage Correct	Unselected Cases[c] Choice 0	Unselected Cases[c] Choice 1	Unselected Cases[c] Percentage Correct
Step 1	Choice	0	255	95	71.9	23	21	52.0
		1	107	359	77.4	4	36	90.9
	Overall Percentage				74.7			70.2

a. The cut value is .500