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Travel time, delay and reliability of ferry transportation across a waterway

Debabrota Das[1*], Anuj Kishor Budhkar[2]

[1]*Indian Institute of Technology Kanpur*
[2]*Indian Institute of Engineering Science and Technology, Shibpur*

Abstract

This paper studies the journey time, delay, system reliability, vessel and passenger arrival patterns and their interdependence in six waterway transport (ferry) routes across a river. Deviations from average and buffer time indices (indicating reliability) are calculated for waiting delay, ferry journey and total travel time of passengers. Although the ferry journey is fairly reliable (6-19% deviations), large unreliability persists in waiting time (56-95% deviation). Intuitively, it decreases in locations with higher frequencies and passenger flow. Further, consistency in maintaining fixed frequency results in passengers remembering the schedule and arriving just in time, as observed statistically. A 50% hypothetical increase of frequency with fixed departures decreases the waiting delay by 29-59% and increases the reliability by 30-96%.

The outcome of this paper can invigorate transportation operations over short waterway routes, as the result provides implications from the passengers' and operators' perspectives.

Keywords: Inland waterways, Travel time reliability, Waiting delay, Ferry transportation, Hooghly River.

1. Introduction

Civilizations established worldwide across the rivers, often use water transport throughout human history in order to transport goods and people across them. Although the journey path is smaller as compared to transit distances over land, the mode change is inevitable, causing delays in waiting and thereby increasing the overall journey time. Several factors may affect the water transport across a river, such as wind speed, navigable width, bend radius, river current (Roeleven et al., 1995), tidal conditions (Muñuzuri et al., 2018), the width and length of the river, accessibility and connectivity of the transfer points with other places, climate (Weng et al., 2020), etc. However, any mode must be profitable, well-opted as well as convenient and reliable. It is also required that a minimum amount of waiting time is spent in transit, as well as the travel time is reliable enough. The same applies to water transport across rivers, where transfers to and from land points are common. There have been studies conducted for land transit points.

[*] Corresponding author: Debabrota Das (das.debabrota16@gmail.com)

However, although analogous, studies for ferries as a mode of transport have not been conducted significantly, in terms of reliability and transit delays.

Worldwide, the major rivers such as the Huang He, Ganges system, Rhine, Danube, Volta, Ob, Congo, Mekong, Amazon, and Nile constitute the inland waterways and a large amount of trade, as well as passenger movements, take place across the rivers at several locations.

The National Waterway-1 or the NW-1 (Refer to Figure 1) is a 1620 km long channel of The Ganga-Bhagirathi-Hooghly river system between Prayagraj and Haldia (Inland Waterways Authority of India, 2021), passing through the state of Uttar Pradesh, Bihar, Jharkhand and West Bengal of India, making it the longest operable waterway in India (“National Waterway 1”, 2021). The stretch between Haldia–Tribeni (196 km) is tidal and the Least Available Depth (LAD) of more than 3.0 m is maintained naturally (Inland Waterways Authority of India, 2021). Hooghly is one of the distributaries of the river Ganga flowing from North to South through the southern part of West Bengal state of India including Kolkata up to the Bay of Bengal. The River Hooghly is a part of the National Waterway-1 of India and is very important for its basin’s agricultural, industrial and cultural growth. The river has an average current speed of 1.5 to 6 knots during spring tides (*Hugli (Hooghly) River (NE India)*, 2012) and many sharp bends thus it is considered a difficult navigational channel for the movement of ships and ferries. As there are only 12 major bridges across the river Hooghly (Bandyopadhyay, 2020), water transport is very important to cross the river. It is usually done by small vessels, commonly termed a ferry, a boat that transports passengers and sometimes also vehicles. This waterway passes through an area with a population of over 50 million people (Population Census 2011, India), across its 260 km length. Therefore the ferry routes act as public transit mode with a large volume of regular users availing its services.

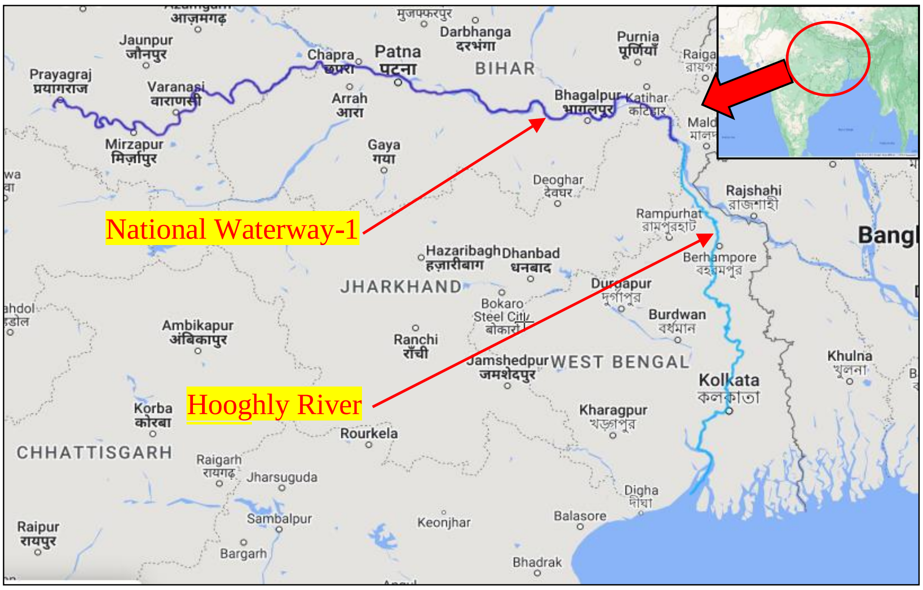

Figure 1: National Waterway-1 and Hooghly River, India.
Source: Google Map.

A ferry crossing is usually an intermediate link in a journey, that is, the origin or destination of the ferry may rarely reflect the origin/destination of the travellers.

Therefore, a significant part of a traveller's journey is lost in transiting from land to water transport and vice versa during boarding and alighting from the ferry. It is important to observe and characterise the delay, as the passengers wait at the transit locations. Such a study is not conducted hitherto to the authors' best knowledge. According to Huo et al. (2018), in road transport, delay at a stop is affected by stop characteristics (location, place, connectivity), vehicle characteristics (size, capacity, furniture), traffic conditions (arrival rate, stop capacity etc.), and the passenger volume. The size of belongings with the passengers may increase the loading and unloading time and thus affect the delay (Chen, 1999). Since the principles of travel time remain similar for various modes of transport, these results are expected to hold for ferry transport too, after a pronounced study.

Travel time reliability is the consistency or dependability in travel times, as measured from day to day or across different times of the day (Federal Highway Administration report, 2006). Pu (2011) discussed different travel time reliability measures such as 95th percentile travel time, standard deviation, percent variation, buffer time index (BTI), planning time index, travel time index, etc. which asserts the Federal Highway Administration (FHWA) report (2006). Carrion & Levinson (2012) reviewed the value of travel time reliability of road transportation using centrality-dispersion (or mean-variance) and scheduling models and a meta-analysis was performed using several previously published studies but the result was inconclusive. The studies of Chen et al. (2003) show that people value both travel time and its predictability which is a good way to evaluate the benefits of a service.

Being analogous to a roadway public transit system, the concept of travel time reliability can be conspicuously applied to ferry transportation. The parameters mentioned in FHWA Report (2006) can provide an insight into how reliable travelling and waiting for a ferry is as a viable mode of transportation. For this purpose, the trend of passengers' and vessels' arrival and departure times at stations need to be recorded. The reliability of the waiting time and delay can also be calculated in the terms of Buffer Time Index (BTI) in a similar manner conducted by Nyaki et al. (2020) for bus operations.

Therefore the objective of this paper is to study the passenger delay and reliability of existing ferry routes, to evaluate the effect of ferry arrival patterns and frequencies on passenger delays and route reliability, and provide insights to optimise operation cost and passenger delays. This study is conducted by collecting the passenger and ferry arrival and departure rate at six different locations across the river Hooghly in India, as described in the subsequent section.

2. Methodology

Videos of passenger and ferry movement at different locations were captured and based on the arrival timing of passengers and ferries, the delays and reliability parameters have been extracted and analysed, as described hereunder.

2.1 Data Collection.

Passenger and ferry arrival and departure data have been collected from six locations at either station across river Hooghly in West Bengal, India as described in Table 1. Video data were captured using a camera to provide a clear view of passengers boarding, alighting and ferries arriving, as shown in an illustration in figure 2(b) (the still from the video is for Location 5 of Table 1). Although passenger movement from the opposite station could not be captured, ferry arrival and departure at the opposite station are recorded. It has been ensured during location selection, and data collection, that external factors such as pandemic, weather (rain, storm, etc.), tidal current, etc. had not affected the collected data. All the sites are located in West Bengal state of India, and the words in parentheses indicate the names of the districts.

Table 1: Details of the Locations of Data Collection.

Location	*Name*		*Total time of collected data (h:m)*	*No. of ferries observed*	*Average flow(pass/h)*	
	Station1	*Station2*			*Station1 →Station2*	*Station2 →Station1*
1	Naihati (North 24 Parganas)	Mechhuabajar (Hooghly)	5:50	66	440	417
2	Shyamnagar (North 24 Parganas)	Telenipara (Hooghly)	4:50	17	280	327
3	Serampore (Hooghly)	Barrackpore (North 24 Parganas)	2:10	8	226	252
4	Howrah (Howrah)	Shipping Ghat (Kolkata)	4:40	33	355	253
5	Metiabruj (Kolkata)	Najirgunj (Howrah)	1:20	9	1431	794
6	Budge Budge (South 24 Parganas)	Bauria (Howrah)	1:20	5	70	50

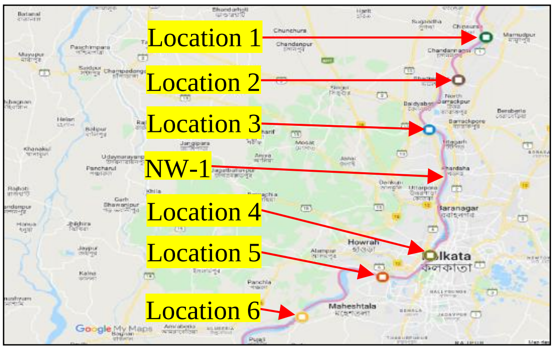

Figure 2(a): Locations of data collection along the NW-1.
Source: Google maps.

Figure 2(b): Photograph of location 5

2.2 Data Extraction.

The following parameters are extracted manually from the collected video data at each section-

- Time of arrival and departure of each ferry at both the stations of either bank,
- Minute-wise arrival of passengers to the station at one of the banks.

The minute-wise passenger arrival at each location is presented graphically in figure 3. It can be concluded that in general there is no prominent 'peak hour' in the period of data collection. Therefore, the entire dataset of a particular location is used as one entity for any further analysis. The average flow of passengers is presented in Table 1. Furthermore, it is observed that ferries maintain frequencies intermittently, and the capacity of ferries is more than the passenger demand at several locations.

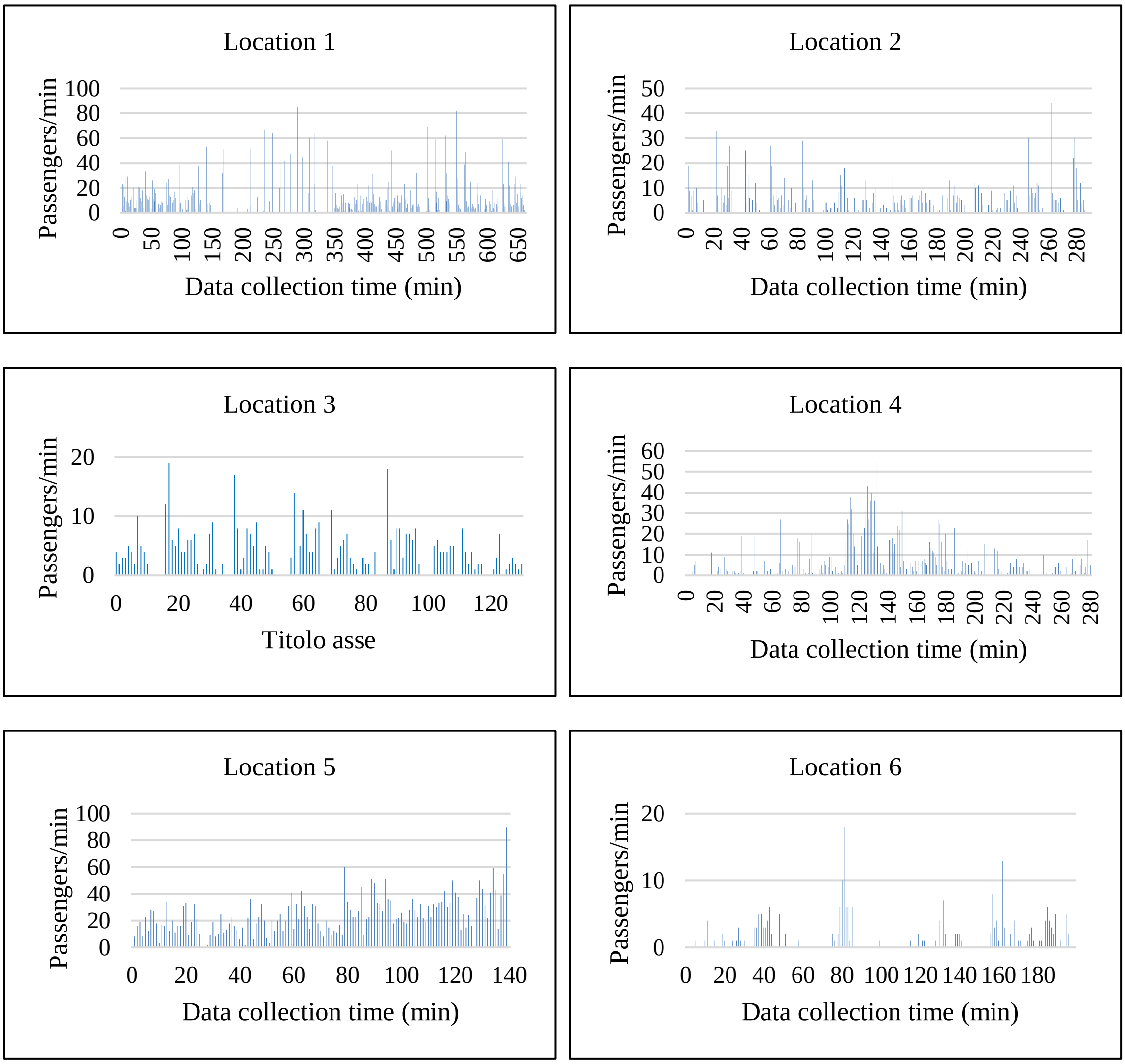

Figure 3: Passenger arrival rate during data collection in each location.

When passengers enter the station zone, they may need to wait if the ferry has not yet arrived at the station. This waiting time is out-of-vehicle delay (OVD). After the ferry arrives, the passengers board it and have to wait till the ferry leaves the station he/she boards it and again he/she has to wait for the ferry to start and leave the station, while other passengers are to access it. This waiting time is expressed as in-vehicle delay (IVD). The average OVD, IVD and the total delay, i.e., the sum of IVD and OVD for each minute are calculated and tabulated for each location. The total journey time of each of the ferries is also extracted from the collected videos, once the ferry reaches the other station. A sample data extraction table for the first 10-minute data collected from location 5 is shown in table 2. Average delay expressed in seconds and average flows of passengers in passengers/h are calculated as per equations 1 and 2 respectively.

$$\text{Average delay, } \overline{\mathrm{D}} = \frac{\sum_{i=0}^{n} p_i \times D_i}{\mathrm{P}} \quad (1)$$

$$\text{Average flow} = \frac{P}{\left(\frac{n+1}{60}\right)} \quad (2)$$

Where, p_i= number of persons entering the jetty in i^{th} minute; D_i=delay of the passengers entering the jetty at i^{th} minute; P=total number of passengers entering the jetty; n=number of minutes.

Table 2: A sample data extraction table for the first 10-minute data collected from location 5.

Minute	*Persons*	*With luggage*	*With bicycle*	*With motorcycle*	*No. of passengers*	*OVD (s)*	*IVD (s)*	*Total Delay (s)*	*Weighted delay (pass.s)*	*Comment*
0	19	0	0	0	19	161	448	609	11571	
1	7	0	1	0	8	101	448	549	4392	
2	12	2	2	0	16	41	448	489	7824	
3	13	6	0	0	19	5	393	398	7562	Ferry Arrived at 03:10
4	6	1	1	0	8	0	368	368	2944	
5	20	3	0	0	23	0	308	308	7084	
6	12	0	0	0	12	0	248	248	2976	
7	22	4	2	0	28	0	188	188	5264	
8	19	8	0	0	27	0	128	128	3456	
9	13	5	0	0	18	0	68	68	1224	
10	…	…	…	…	…	…	19	…	…	Ferry Departed at 10:38
				Total	178				54297	

3. Analysis and Results

In this section, the existing reliability parameters of the ferries and their journey time and the waiting delay of the passengers are calculated. The effects of the frequency on the reliability parameters of the ferry, as well as the passengers and the inter-dependability of the passengers' arrival pattern and the frequencies of the ferries are also discussed.

3.1 Calculation of existing reliability parameters.

For reliability analysis, it is assumed that the passengers are arriving at a uniform rate within respective one-minute intervals. The waiting times are assumed to be similar on both stations on the opposite bank. The total travel time of a passenger is from the moment he/she arrives at the ferry station, till he/she disembarks from the ferry at the other end. It consists of (i) Waiting delay and (ii) Journey time of the ferry. Waiting delay has two components- (a) time loss due to passengers not arriving on time, and (b) time loss due to the ferry not maintaining its frequency and departing later or earlier than its schedule. The journey time of the ferry is from the moment it leaves one station to the instance when it reaches the other station, whereas waiting delay for passengers arriving within a particular minute is calculated as a single entity, that is, the time difference between the mid of the respective minute, and instance when the ferry leaves the station. The average values, standard deviations and buffer time indices for waiting delay, journey time of ferry and total travel time are presented for each section along with the frequency information in Table 3. Formulae (3-7) assist a calculator to arrive at the mentioned values in Table 3. Planning time Index (PTI)-based reliability study (which requires free flow travel time), is not conducted since the free flow speed of ferries cannot be ascertained from collected data. Several factors such as tides, the direction of movement, movement of other ferries, etc. may affect the free flow speed, which is out of the scope of this paper.

$$\text{Average journey time of the ferry}, \bar{T} = \frac{\sum_{i=1}^{N} T_i}{N} \tag{3}$$

$$\text{Buffer time index for journey time of ferry (BTI)} = \frac{T_{95} - \bar{T}}{\bar{T}} \times 100 \tag{4}$$

$$\text{Standard deviation of waiting delay} = \sqrt{\frac{\sum_{i=1}^{P} p_i (D_i - \bar{D})^2}{P-1}} \tag{5}$$

$$\text{Buffer time index for delay} = \frac{D_{95} - \bar{D}}{\bar{D}} \times 100 \tag{6}$$

$$\text{Total journey time of the passengers of } i^{\text{th}} \text{ minute and boarding } j^{\text{th}} \text{ ferry}, t_i = D_i + \bar{T}_j \tag{7}$$

Where, T_i= Journey time of i^{th} ferry; N= number of ferries; T_{95}= 95th percentile journey time; $\bar{T}$=average journey; D_{95}=95th percentile delay.

Table 3: Different reliability parameters of frequency and journey time of ferries and waiting delay and total travel time of passengers.

Locations		1	2	3	4	5	6
frequency (s)	Average (s)	618	1115	1050	584	939	2443
	Standard Deviation (s)	122	225	210	184	108	1299
Journey Time of Ferries	Average (s)	455	404	415	480	303	465
	Standard Deviation (s)	84	78	34	30	48	66
	BTI (%)	53.2	28.7	8.8	9.5	26.2	13.7
Waiting Delay of Passengers	Average (s)	374	280	460	207	462	1233
	Standard Deviation (s)	214	267	257	150	285	1050
	BTI (%)	441	254	223	344	153	474

	Average (s)	733	856	877	686	779	1672
Total Travel Time of Passengers	Standard Deviation (s)	162	286	259	152	295	1048
	BTI (%)	30.8	66.3	48.0	43.7	67.6	121.8

A ferry may be delayed either during its journey (once it departs) or due to a later than expected departure from the origin station. From table 3, it is observed that:

- In the case of journey time of ferry, the standard deviation is comparatively less (19 to 6% of the average), implying that the route-related constraints are low. This is intuitive since ferry traffic was not affecting the journey of a particular ferry. The traffic was too less (three to four vessels at a given maximum).
- The high value of the Buffer time index for waiting delay is anticipated since delay can vary from zero (passenger enters just when ferry departs) to maximum (passenger enters just after the ferry departs). A higher buffer time index indicates that a higher number of passengers face less delay (than the 95th percentile) perhaps because they remember the ferry departure timings. Section 3.2 describes this in detail.
- Section 6 has an unreliable frequency, (standard deviation >50% of average values) therefore even though the BTI of ferry journey is very less, there is a large value of overall BTI. The reason is chiefly due to lack of maintenance of frequency. In sections where the frequency is maintained (standard deviation is less) such as sections 5 or 2, the SD of overall time is lesser. Maintaining the frequency thus has a significant effect on the journey time of cross-river ferry transport.

The reliability and the inter-dependability studies between the passengers' arrival rate and the frequencies have been discussed in the following subsections.

3.2 Effect of frequency on the delay.

An experiment was conducted considering the same passenger arrival rate as observed from the field, but ferries are departing at different frequencies than the existing average frequency. However, the frequencies are kept fixed (i.e. there is no standard deviation as was observed in the field). Maximum theoretical delay, average delay, 95th percentile delay, its standard deviation, BTI of delay, average capacity and standard deviation are also calculated based on their sample size and the number of passengers in the corresponding minute. The maximum delay is calculated assuming a passenger arrives just when the previous ferry departs therefore he/she has to wait for the duration equal to frequency. These calculations are conducted considering ferries departing at fixed frequency but different epochs, and the values are averaged out to consider variation in passenger arrival rate. The detailed calculation for location 5 is illustrated with the existing average frequency of ferry in the 2nd column of Table 4. The maximum theoretical delay (D_{max}), experienced by a passenger under each fixed frequency remains constant: $D_{max} = 60(n-1) + 30$; where, n = fixed frequency of the ferry in minutes. The plot of maximum theoretical delay, average delay, 95th percentile delay, the standard deviation of delays, BTI of delay, average capacity and the standard deviations of capacity for fixed as well as existing frequency for all locations are provided in Figure 4.

Table 4: Different parameters of delay and capacity of fixed frequency in location 5.

Particulars	*Existing average arrival frequency (min:sec)*	*Fixed Frequency (min)*			
	15:39	*5*	*8*	*10*	*15*
Maximum theoretical delay (s)	1115	270	450	570	870
Average delay (s)	462	148	234	290	425
95th percentile delay (s)	1168	270	450	570	870
Standard deviation of delays (s)	285	83.6	135.5	170	256.1
Buffer time index of delay (%)	153	82.7	92.6	97	105
Average capacity (pass/ferry)	582	119	193	239	336
Standard deviation of capacity	138	1.3	3.6	4.6	15.4

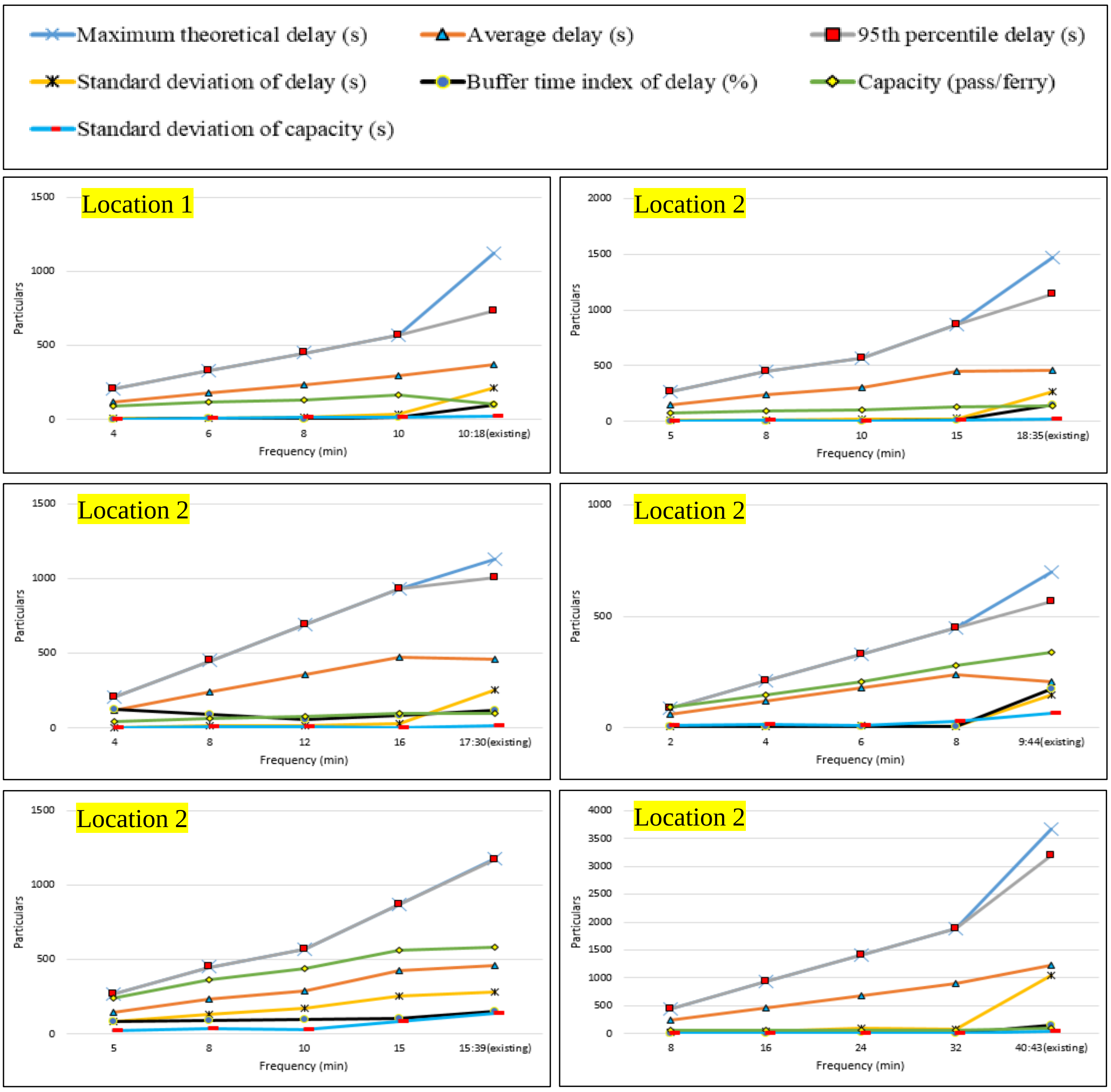

Figure 4: Plot of different particulars with varying and existing frequency.
A common legend for all locations is provided at the top of the figure.

From the plot, it is observed that maximum theoretical delay, average delay, 95th percentile delay and average capacity, standard deviations of delay and capacity decrease with frequency. For existing frequency, the capacity of the ferry is higher than varying frequency which indicates that smaller ferries with higher frequency are more reliable. One can also observe the drop in 95th percentile delay from the existing frequency with deviation to almost the same frequency but at fixed intervals.

3.2.1 Inference for the travellers.

Travellers have to wait less time in the ferry station if the frequencies of the ferries are high and fixed for a particular location. The improved standard deviations and buffer time indices of the delays increase the reliability of their journey. The variations of the waiting delay and BTI of the waiting delays with percentage improvements of existing fixed existing frequencies that have been calculated separately for every location for the uniformity are tabulated in table 5.

Table 5: Reduction in BTI and waiting delay with the improvement of frequency.

Location	*Percentage reduction in waiting delay*			*Percentage reduction in BTI*		
	*25%**	*50%*	*75%*	*25%*	*50%*	*75%*
1	44	59	39	95	93	94
2	70	38	9	96	96	93
3	72	43	16	17	30	43
4	65	29	-5	97	96	97
5	75	50	27	49	39	36
6	76	52	31	98	96	97

* The '%' indicates percentage values of the existing average frequency.

From table 5, it is observed that the waiting delays, as well as the BTI of the waiting delays, are reducing than existing with the percentage reduction of the existing fixed frequencies in each location. It is to be noted that in the hypothetical analysis, the passenger frequency is independent of ferry arrivals, thereby explaining the anomaly in location 4, frequency of 75% of existing in Table 5. Overall, it can be observed that the reliability and dependence of the service to the passengers are increasing for higher and fixed frequencies.

3.2.2 Inference for the operators

If ferry frequency has to be improved, more vessels are required in the fleet with less vessel capacity. This will incur an additional cost on the operator, but the fuel cost per trip will reduce due to lesser vessel capacity. For example, considering an average journey time of five minutes, in one direction, to achieve frequencies of 5, 8 and 10 minutes, an additional 3, 1 and 1 vessel(s) are required respectively in addition to the existing two vessels catering the existing frequency of location 5. The buffer time indices are improved by 46%, 39% and 37% with respect to the existing. But assuming proportionate variation in ferry operation cost and vessel capacity, the operation cost reduces by 65%, 43% and 29% respectively, if the number of passengers remains as it is observed. The operators must maintain a fixed frequency of the ferries to drastically improve the reliability as observed from the analysis. Due to the increase in reliability parameters, the derived demand of passengers may increase resulting in increased revenue for the operators.

The above experiment was conducted considering that the passengers are coming to the station at the same arrival rate as observed from the collected data, which may not be fixed and thus the ferry frequency may be revised and considered for change based on the passengers' arrival pattern or vice versa. So, the inter-dependability of the passengers' arrival pattern and the frequency of the ferries at all locations need to be studied in future research.

3.3 Effect of ferry frequency on passenger arrival pattern.

From the observed passenger as well as ferry arrival data, it is important to notice if ferry arrival or departure is causing any effect on the passengers, i.e., are the passengers remembering the ferry arrival and departure timings? If that is the case, the pattern of passenger arrival will depend on the ferry arrival rate. If more people are remembering the ferry arrival rate, it means that to minimise their delay, they would reach the ferry station just before the ferry departure time. Therefore, a few people are expected to miss their ferry (i.e., they arrived just after the ferry departed), which would increase the reliability of the passengers' journey. In other words, regular travellers on the ferry routes are accustomed to the ferry timings. It is important to check this hypothesis because it will have an impact on the trips of the ferry users on the other modes of transport as well. Furthermore, it may affect the reliability of this route significantly.

For this purpose, all the frequencies of ferries are normalised and the passenger arrival rate is observed in between the departure of all the ferries. The departure headways of each ferry of all locations are divided into a number of bins according to the square root choice of histogram selection (Qimacros, 2022). The number of passengers who arrived within the stipulated time is calculated using equation (8). For a particular location, the numbers of arriving passengers within the binned interval are averaged to get a glimpse of the average arrival pattern of the people.

If a bin consists of n number of minutes and $x_1,\ x_2, x_3, \dots, x_n$ number of passengers arrived at the ferry station in 1st, 2nd, 3rd, …, n^{th} minute of that bin respectively,

Total number of passengers in any bin b_i,

$$n_{b_i} = x_1 \times \frac{(60-t_1)}{60} + x_2 + x_3 + x_4 + \cdots + x_{n-1} + x_n \times \frac{t_n}{60} \qquad (8)$$

Where i is the serial number of the bin; t_1 is the starting time of the bin in the 1st minute and t_n is the ending time of the bin in the n^{th} minute.

The peoples' arrival rate is divided as per the ferry arrival time into 4 sections: 0-25%, 25-50%, 50-75% and 75-100% of the individual frequency of each ferry for each location. The number of people arriving for each of these fractions is observed for each ferry departure, and these numbers are compared statistically by the $\boldsymbol{t}$-test. The average number of passengers coming to ferry station 1 with the bin time of location 1 is represented in figure 5. Similarly, this graph can be plotted for other locations. For all the ferry arrival observations of a particular location, the $\boldsymbol{t}$-test is conducted between the initial 50% and the subsequent 50% of the departure of the ferry as well as 25% distributions (i.e., division into four fractions), with 5% significance level and assuming two-tailed distribution. The results are presented in table 6 for each location with the critical $\boldsymbol{t}$-value ($\boldsymbol{t_c}$) and the $\boldsymbol{t}$-statistic ($\boldsymbol{t}$) value for the significance level of 0.05.

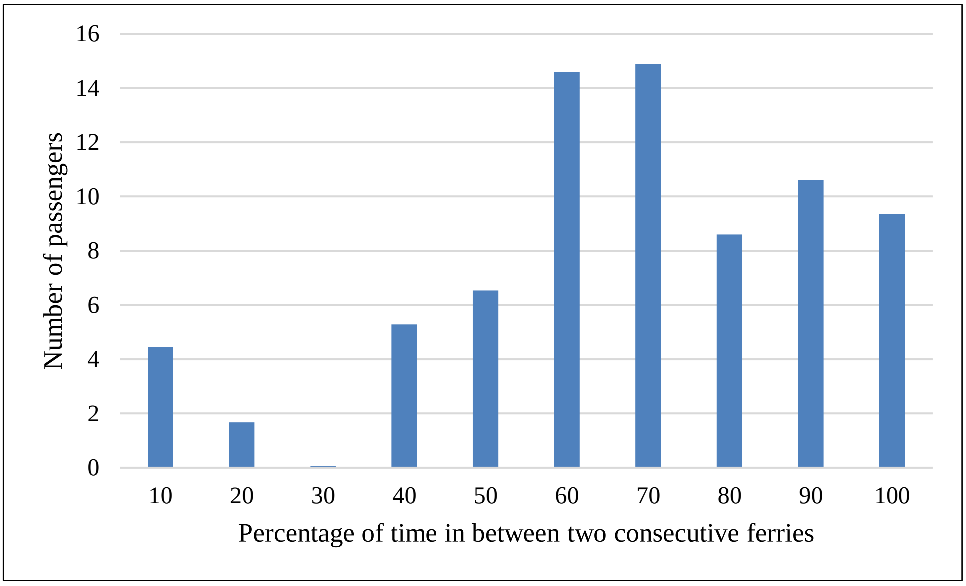

Figure 5: Passenger arrival pattern with the percentage of time between two consecutive ferries in location 1.

Table 6: Results of the t-tests of the 50% and quarters of the arrival rates.

Locations	*frequency (s)*	*0.5**			*Comparison of the quarters*											
					1-2#			*2-3*			*3-4*			*1-4*		
		t_c	t	p	t_c	t	p	t_c	t	p	t_c	t	p	t_c	t	p
1	618	1.98	5.81	<u>0.00</u>	2.00	0.64	0.53	2.02	4.12	<u>0.00</u>	2.03	2.08	<u>0.05</u>	2.00	5.35	<u>0.00</u>
2	1115	1.98	4.66	<u>0.00</u>	2.00	0.46	0.65	2.00	3.59	<u>0.00</u>	2.01	1.03	0.31	2.00	2.92	<u>0.01</u>
3	1050	2.02	0.38	0.71	2.07	2.62	<u>0.02</u>	2.07	0.18	0.86	2.06	1.86	0.07	2.06	2.52	<u>0.02</u>
4	584	1.98	1.95	0.05	2.02	1.34	0.19	2.03	2.04	<u>0.05</u>	2.01	0.66	0.52	2.00	0.32	0.75
5	939	1.98	0.92	0.36	2.00	0.75	0.46	2.00	0.93	0.35	2.01	0.23	0.82	2.02	0.29	0.77
6	2443	2.03	0.64	0.53	2.18	1.69	0.12	2.15	1.66	0.12	2.18	1.96	0.07	2.20	1.97	0.07

*comparison between initial and final 50% time of the departure of the ferry.
comparison between 1st and 2nd quarter time of the departure of the ferry.

In Table 6, the p-values which are less than 0.05 are underlined. In locations 1 and 2, the majority of p-values are less than 0.05, indicating a significant difference between passenger arrival rates between halves as well as quarters of the interval between two ferry departures. The passengers, therefore, remember the ferry timings (considering the low and moderate ferry frequencies and average passenger flow levels in Table 1). In location 3, despite low frequency, the passenger arrival rate is not prominently dependent on ferry timings, perhaps due to low passenger volume. The travellers are not regular travellers, explaining the anomaly. Despite this, a significant difference is observed in the first and fourth quarter. This statement can be further confirmed in location 6, which has the lowest arrival rate. Despite the lowest frequency, the section does not have passenger arrival dependent on ferry timing (as evident from the p-values). In locations 4 and 5, almost all the t-test results are statistically insignificant. Therefore, passengers do not remember the frequencies of the ferries, perhaps due to low and moderate frequency values. In a nutshell, passenger delay can be reduced if ferries are having moderate frequencies and the departure timings are fixed and communicated to the passengers.

4. Concluding Remarks

Reliability study of a cross-river ferry transport is important since navigable waterways which cannot be often bridged but remain historically important routes, need to be sustained to integrate with regional level travel patterns and planning. This paper reveals the trends of cross-river ferry movements, the ferries' and the passengers' arrival patterns across six locations in a river, and analyses passenger delays, journey times and their reliability with the change in frequencies. This novel study has the following implications for transportation planners:

- The ferries have an overall short journey time, however, considering passenger demand, the waiting time to board the ferry contributes significantly (to the range of 74% to 30%) of the overall travel time. This decreases their reliability and passengers may shift to alternative modes of transport if found viable.
- Waiting delay at the ferry stations due to its less frequency has a conspicuous effect on the travel time. It is observed that the BTI for waiting delay of the passengers varies from 153% to 474%, which is much greater than that of journey time of ferries, varying from 8.8% to 53.2%. However, if passengers arrive particularly close to ferry departures, this delay reduces significantly. For this purpose, the passengers shall remember the ferry schedules, and the ferries shall punctually maintain the schedules.
- It is observed that for sections with an average frequency from 600 to 1200 seconds and the passenger flow from 250 to 400 passengers/hour, the passenger arrival trend depends on the ferry schedule, or in other words, passengers remember the schedules. Yet the waiting delays are significant due to the lack of punctuality maintained by the ferry operators.
- In order to minimise the delay, therefore, an improved frequency of ferries (with cost reckoning to the operators) with punctuality in frequency is essential, along with passengers remembering the ferry frequencies.

The studies in this paper can be supplemented with detailed passenger management data at ferry boarding/alighting points, and the capacity of ferries. Furthermore, the effect of luggage and personal vehicles of the passengers on their boarding/alighting can be checked and a comprehensive analysis of passenger movements can be conducted. Input from the passengers (by means of the interview studies) can further enhance the study of inland waterway transport. This will boost more ferry-related studies and contribute to the field of waterway transportation.

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