Study on the possibility of inland waterway transport on the Ishikari river

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Abstract

Most Japanese rivers have steep gradients and experience large seasonal flow variations. Due to these topographical characteristics, Japanese rivers are not typically used for inland waterway transport. However, the gentle gradient found throughout the middle and lower reaches of Hokkaido's Ishikari River, Japan's third longest river and second largest in terms of basin area, gives the Ishikari River potential as an avenue for inland transport. Large cities dot the Ishikari River basin, but despite this, logistics based on inland waterway transport have not developed in Hokkaido. Instead, these basin cities generally rely on trucks to move goods to and from nearby ports, a fact that is behind the mounting pressure for reduced transportation costs. This study examines the possibility of using the Ishikari River for inland waterway transport by looking at the economics involved and the river's physical suitability.

1 Introduction

Most Japanese rivers tend to have steep gradients and experience large variations in seasonal flow. These disadvantages are why most Japanese rivers are not used for inland transport. The Ishikari River in Hokkaido (Figure 1), however, offers an unusually gentle gradient throughout its middle and lower reaches (Figure 2), giving it potential as a waterway for inland transport. In fact, the Ishikari River, which is Japan's third longest river (268km) and second largest in basin area (14,330km^2), has a history of supporting inland transport. Starting in the latter half of the 1800s, it carried the survey teams that mapped out inland development plans for Hokkaido, and was also used to transport the settlers that

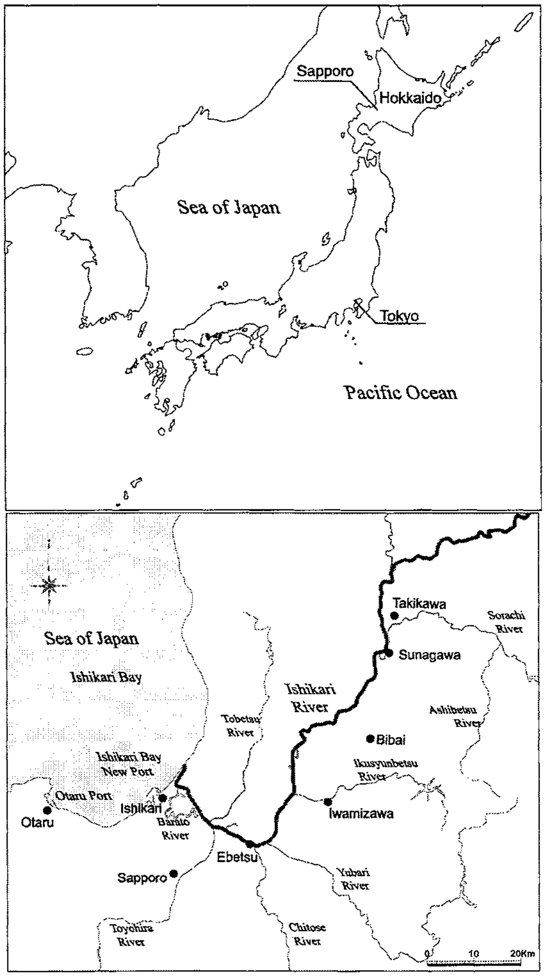

Figure 1: Location of Ishikari River.

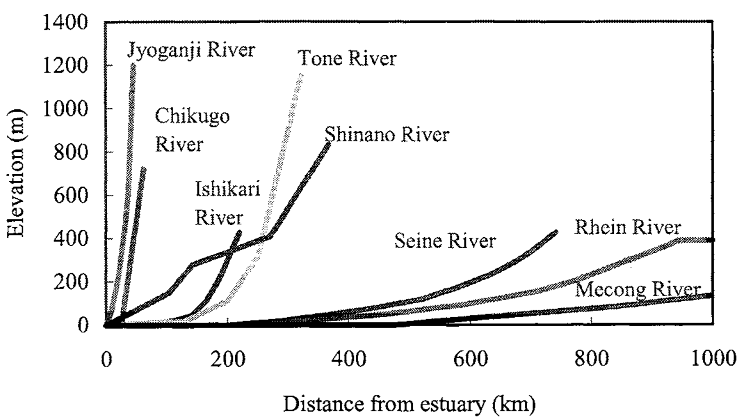

Figure 2: Gradients of domestic and international rivers.

came later. However, as railway and road networks developed, its use as a logistics pipeline declined. More recently, however, rivers have been gaining renewed attention for their potential in reducing inland transportation costs, addressing global environmental issues and reducing CO_2 emissions through a modal shift, providing waterfront amenities, and stimulating education. Consequently, transportation options involving inland waterways are being looked at much closer.

This study is a basic exploration of the practicality of using the Ishikari River as a transport corridor. On the economic side, it focuses on transportation costs and looks into what cost savings could be achieved by shifting logistics currently carried by truck inland from Ishikari Bay New Port to the river. On the feasibility side, it analyzes possible navigation routes based on the river's physical characteristics.

2 Cost reductions through inland waterway transport

2.1 Present situation of logistics in Hokkaido

The Ishikari River basin encompasses 13 municipalities with a population of 2.09 million, which is 37% of Hokkaido's total population. It is an important nucleus within Hokkaido, and assets and logistics movements centered on the area represent a significant percentage of the prefecture's total.

Here and elsewhere, Hokkaido's inland industries suffer a large handicap due to transportation costs. Surrounded by ocean, Hokkaido cannot help but rely on its ports, and access to those ports has traditionally depended on road transport. Consequently, regions lose competitiveness in proportion to their distance from a port. If we direct our attention to the fact that a number of cities have developed in the Ishikari River basin, it seems reasonable that using the river for inland transport might offer a way to eliminate this bottleneck.

Several benefits are promised from the development of this waterway: a) reduced transportation costs, b) reduced discharge of transportation-related CO_2 emissions, c) reduced transportation-related energy usage, d) less road congestion, e) increased tourism and added regional development, and f) a boost for educational and cultural activities.

This study looks at the first of these benefits, reduced transportation costs. Logistics by municipality (Table 1) and by goods type (Table 2) for cargo shipped to and from the 13 basin municipalities are offered as an index of current logistics activity within the Ishikari River basin. These tables are derived from a 1993 survey of land-based cargo shipments. One notable point is that coal and wood chips shown moving through Tomakomai Port are scheduled to shift to Ishikari Bay New Port in response to improvements made at Ishikari Bay New Port. When this happens, support for inland transport on the Ishikari River, with Ishikari Bay New Port being the transit point for destinations outside Hokkaido, may gain momentum.

Table 1. Monthly cargo transported to and from basin municipalities (October 1993).

Municipality	Outbound (tons)	Inbound (tons)
Ishikari City	37,713 (7.7%)	2,624 (8.1%)
Sapporo City	314,849 (64.5%)	18,184 (56.2%)
Ebetsu City	6,536 (1.3%)	28 (0.1%)
Tobetsu Town	91,324 (18.7%)	8,516 (26.3%)
Shinshinotsu Village	667 (0.1%)	185 (0.6%)
Kita Village	907 (0.2%)	-
Tsukigata Town	1,469 (0.3%)	115 (0.4%)
Bibai City	4,402 (0.9%)	480 (1.5%)
Urausu Town	1,099 (0.2%)	180 (0.6%)
Naie Town	2,690 (0.6%)	272 (0.8%)
Sunagawa City	14,163 (2.9%)	358 (1.1%)
Shintotsugawa Town	1,545 (0.3%)	70 (0.2%)
Takikawa City	10,703 (2.2%)	1,536 (4.7%)
Total	488,057 (100.0%)	32,383 (100.0%)

Table 2. Monthly cargo transported to and from basin municipalities by cargo type (October 1993).

Cargo	Outbound (tons)	Inbound (tons)
Rice and grains	12,405 (2.5%)	4,222 (13.0%)
Marine products	1,569 (0.3%)	22 (0.1%)
Other agricultural products	1,676 (0.3%)	173 (0.5%)
Raw lumber	11,796 (2.4%)	0 (0.0%)
Other forestry products	57,628 (11.8%)	5 (0.0%)
Coal	2,397 (0.5%)	0 (0.0%)
Gravel, sand, and stone	53,150 (10.9%)	0 (0.0%)
Crude oil	0 (0.0%)	0 (0.0%)
Other mineral products	6,722 (1.4%)	13,558 (41.9%)
Metals	37,659 (7.7%)	3,864 (11.9%)
Machinery	2,252 (0.5%)	943 (2.9%)
Petroleum	175,153 (35.9%)	2,000 (6.2%)
Cement	86,554 (17.7%)	0 (0.0%)
Other chemical industrial products	12,896 (2.6%)	627 (1.9%)
Paper and pulp	3,549 (0.7%)	3,504 (10.8%)
Other light industrial products	9,210 (1.9%)	713 (2.2%)
Miscellaneous industrial products	9,550 (2.0%)	130 (0.4%)
Specialty products	3,891 (0.8%)	2,622 (8.1%)
Total	488,057 (100.0%)	32,383 (100.0%)

2.2 Reduced transportation costs

Conceptualizing waterway transport between any transit port and the interior invokes two possible scenarios: 1) cargo being shipped directly between riverside logistics hubs and plants and facilities; or 2) cargo going through riverside logistics hubs and being trucked to its final destination. Table 3 compares some of the key factors these two scenarios would involve in the case of Ishikari Bay New Port.

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Table 3. Modes of inland transport.

	Direct transport by waterway	Transport requiring transshipment by truck
Number of transshipments	Once at Ishikari Bay New Port. Applies to both waterway and overland modes. Requires efficient cargo handling at Ishikari Bay New Port and cost-efficient transport to riverside plants.	Waterway transport requires one additional transshipment (double handling).
Inland conveyance	In general, waterway transport requires more time than trucking. An onsite stockyard at serviced plants would allow the supply cycle to be adjusted to allow for the shipping time. A barge could also be used as a stockyard. Winter road conditions may make waterway transport a more reliable option.	In general, waterway transport requires more time than trucking. Winter road conditions may make waterway transport a more reliable option.
Transportation costs	Bulk transport by waterway tends to gain cost efficiency with distance.	Bulk transport by waterway tends to gain cost efficiency with distance, and long distances make it possible to absorb cargo-handling costs associated with transshipments.

Table 4. Cost comparison assumptions.

		Ebetsu	Sunagawa	Takikawa
Cargo		Wood chips	Coal	Rice & grain (containerized)
Specific gravity		0.35	1.2	-
Tonnage		500 ton (1000m^3)	300 ton (300m^3)	300 ton (5-ton container x 60)
Conveyance	Barge	2 (1,000 ton)	2 (300 ton)	2 (300 ton)
	Truck	50 (10 ton)	30 (10 ton)	30 (10 ton)
Distance (km)	Barge	32.56	82.80	91.25
	Truck	40.00	73.50	77.70
Time (hour/barge) (hour/truck)	Barge	18 hours (3.93)	48 hours (13.92)	48 hours (16.94)
	Truck	4 hours (1.00)	4 hours (1.84)	4 hours (1.94)

This section compares the economics of traditional truck transport with that of hypothetical river-based transport between Ishikari Bay New Port and the cities of Ebetsu, Sunagawa, and Takikawa. Cargo-handling costs are included in the transportation cost calculations. Cargo with the most potential for conversion from land-based transport to water transport (see list of current logistics movements) include wood chips, coal, and grains such as rice. Basic assumptions used for the trial calculations, such as cargo types and basic transportation parameters, are shown in Table 4.

For this study, it was assumed that wood chips would be bound for Ebetsu, coal for Sunagawa, and rice and other containerized grains for Takikawa. All

Table 5. Calculation of transportation costs.

		Ebetsu	Sunagawa	Takikawa
Capacity per trip		500 tons	300 tons	300 tons
Physical units of transportation costs	Barge (¥/hour/vessel)	17,307	6,768	6,768
	Truck (¥/vehicle)	25,575	37,730	37,730
Cargo-handling cost	Barge (¥/time)	456,000	456,000	524,800
	Truck (¥/time)	228,000	228,000	262,600
Transport cost	Barge (¥)	1,079,052	1,105,728	1,174,528
	Truck (¥)	1,506,750	1,359,900	1,394,500
Cost differential (¥)		(427,698)	(254,172)	(219,972)
Cost differential (%)		28.4%	18.7%	15.8%

land-based transport calculations assume the use of 10-ton trucks, while waterway calculations are based on 1,000-ton pusher barges servicing Ebetsu and 300-ton barges being used to access Sunagawa and Takikawa. To develop physical units to calculate transportation costs, an hourly charter fee, based on compiled, existing data, was determined for waterway transport, while the distance-based fare schedule issued by the Hokkaido Land Transportation Bureau was used for land-based transport. It was assumed that one self-propelled and one pushed barge would be used in each case for water transport. Transit times are one-way and average upstream and downstream transits. They reflect river current velocities at time of drought and a vessel speed of 5 knots. Trucks are estimated to average 40 km/h.

In estimating total transportation costs, logistics hubs are assumed to be fully developed facilities with efficient cargo-handling equipment. Calculations also assume the following:

1) Cargo-handling costs consist of labor, miscellaneous expenses, and equipment rental. Cargo-handling would take place twice in the case of waterway transport and once for overland trucking. Power shovels and other equivalent equipment would be used for the wood chips and coal, whereas the rice and grain would be handled with truck cranes and related equipment.
2) Transportation costs are limited to actual costs of moving and handling cargo.
3) For the purposes of this study, only transportation costs between Ishikari Bay New Port and the destination logistics hubs are considered. Costs for trucking to a final destination are not taken into account.

The results of these calculations appear in Table 5. Based on the aforementioned preconditions, they show approximately 15-30% in savings for water-based transport.

3 Route considerations

3.1 Existing examples of inland waterway transport in Japan

In the latter half of 1990s, use of domestic rivers for inland transport began gaining increased attention in Japan. The impetus comes from the environmental benefits rivers offer and the advantages they would offer for emergency transport if an earthquake was to strike a major city. In fact, the Ara River (Tokyo) and

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Yodo River (Osaka) are already in use. However, due to insufficient channel widths and restrictive navigational clearances under bridges and other existing structures, the majority of Japanese rivers have not yet been used for inland waterway transport. Ishikari River, on the other hand, maintains an abundant flow throughout the year and many of the structures that cross the river are relatively large. In other words, compared with other domestic rivers, Ishikari River comes with fewer physical restrictions to navigation.

In this section, we will set forth assumptions regarding specific routes that would be utilized for transport on the Ishikari River. We will also examine the suitability of different vessel types, the river's flow, and restrictions imposed by existing structures that span the river. These factors will then be used to calculate the effective annual working days available for each proposed route. Finally we will examine how river conditions would affect the general practicality of waterway transport and discuss some issues that would have to be resolved.

3.2 Route assumptions

Cargo transport on the Ishikari River would connect Ishikari Bay New Port, a transit point linking Hokkaido with points outside the prefecture, with the municipalities of the Ishikari River basin. Two routing options present themselves in the vicinity of the estuary (Figure 3).

•Route 1: Ishikari Bay New Port - Sea of Japan - river estuary - Ishikari River
•Route 2: Ishikari Bay New Port - Ishikari Drainage Channel - Barato River - Ishikari River

3.3 Vessel assumptions

Since this study is focused on the transport of goods, the hull size, draft, and maximum carrying capacity of various cargo transport vessels were investigated. It was assumed that pusher barges would be most effective, and from there the selection was further narrowed to barges with carrying capacities of 300 and 1,000 tons. Japan does not have any clear guidelines for vessels that navigate rivers, but technical standards and commentaries for port and harbor facilities in Japan suggest that channel widths must be at least equal to the length of transiting vessels. So we assume that the channel must maintain a width approximately equal to vessel length where current exists and twice vessel width through sections with no current. In addition, a depth equal to the vessel's full-load draft plus 10% is assumed to be required throughout the channel and anchorages. Based on these rules of thumb, barges in the 300-ton class require channel widths of 20-45m and a water depth of 2.0m, while barges in the 1,000-ton class require channel widths of 30-55m and a water depth of 3.0m. The maximum height for the pusher is assumed to be 3.5m above the water surface.

3.4 Natural impediments

Potential impediments to inland waterway transport, both on the river and on the open sea, were investigated.

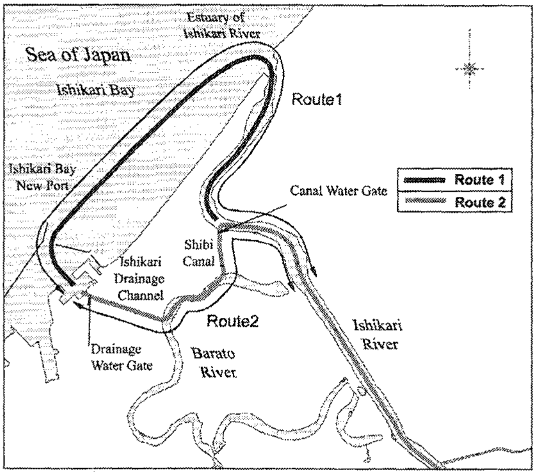

Figure 3: Possible routes

1) River impediments: Using historical flow data for Ishikari River, both ordinary and droughty water levels were calculated at various points along the river. Based on the aforementioned channel requirements, it was found that the river possessed both the channel width and water depth required for a 1,000-ton class barge to travel 34.5km upstream from the estuary when the river is at droughty water levels, and that navigable waters were assured up to 41.5km upstream for a 300-ton class barge. This indicates that river navigation is practical under existing conditions. In the upper reaches, above 41.5km, some points do not meet the channel width requirement. However, it is conceivable that with modest river improvements, a 300-ton barge could navigate up to 94.0km upstream.

2) Open sea impediments: In using Route 1, a vessel would have to navigate the open sea between Ishikari Bay New Port and the Ishikari River estuary. Consequently, it would be subject to ocean waves when the sea turned rough. Barges are typically vulnerable to high waves, and the breakpoint for safe navigation would be a wave height of 1m. Seas off the coast of Ishikari Bay New Port exceed 1m approximately 40% of the year, and during winter months they exceed this limit 70% of the time. Navigation would thus be curtailed during those periods.

3.5 Restrictions due to bridges and other structures

The clearance and span of bridges and other structures constructed along Ishikari River, Barato River, and the Ishikari Drainage Channel are shown in Tables 6 and 7. Route 1 does not offer any particular clearance or span problems for the first 41.5km after the estuary, meaning that our assumed vessel could safely navigate under present conditions. Along Route 2, however, some bridges spanning the Ishikari Drainage Channel do not meet clearance requirements during high water. Under existing conditions, therefore, navigation would not be

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practical. However, a review of current land use around the drainage channel

Table 6. Clearance and span of bridges crossing the Ishikari River.

River	Type	KP	Route	Girder elevation (EL m)	High water level (EL m)	Clearance (m)	Span (m)
Ishikari River	Road bridge	5.46	1	8.07	0.27	7.69	50
	Road bridge	14.50	1 & 2	8.23	0.38	7.70	86
	Rail bridge	15.00	1 & 2	10.22	0.39	9.68	58
	Road bridge	23.46	1 & 2	10.19	1.77	8.22	48
	Road bridge	26.56	1 & 2	10.66	2.26	8.18	66
	Road bridge	44.49	1 & 2	15.44	5.85	8.46	56

Table 7. Clearance and span of bridges crossing the Ishikari Drainage Channel and Barato River.

River	Type	KP	Route	H.W.L. (m)	Clearance (m)	Span (m)
Ishikari Drainage Channel	Pedestrian overpass	0.032	2	1.50	3.66	50
	Road bridge	0.040	2	1.50	1.50	50
	Water gate	0.083	2	1.50	2.80	25
	Road bridge	1.138	2	1.66	1.34	50
	Water pipe bridge	2.304	2	1.83	1.47	50
	Road bridge	2.345	2	1.83	1.47	50
Barato River	Road bridge	0.552	2	1.85	4.60	18.5
	Water gate	0.564	2	1.85	2.75	18.5

suggests that reworking the bridges would not impose any significant effect on the area.

A drainage water gate, canal bridge, and canal water gate along Route 2 also require attention as their spans are narrower than required. However, since the current is extremely slow in these areas, navigation would be possible as long as the channel width was at least equal to the hull width. Furthermore the drainage water gate, located where the drainage channel joins Ishikari Bay New Port, is always kept closed to prevent salt water from reaching the Barato River. It would therefore be necessary to overcome this obstacle in some way, such as through the construction of a lock gate. The canal water gate, on the other hand, is not a serious impediment. Located at the juncture of the Barato and Ishikari Rivers, it is only closed when the water level of Ishikari River rises. Data over the past five years indicates that, on average, it is only closed 12.6 days per year. Upstream limits to navigation are determined by a head works 55.4 km from the estuary. A lock or other such facility that could bypass this obstacle could extend navigability further upstream.

3.6 Estimated annual working rate

Assuming some improvements are made to existing structures, restrictions imposed on vessel navigation are likely to stem mainly from natural conditions.

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Table 8 shows estimated unavailabilities and annual working days for the two

Table 8. Annual availability of routes.

	Unit	Route 1	Route 2	Notes
Water level below droughty water level	Days	Approx. 10 days	Approx. 10 days	Based on a 355-day data sample
Rough water in open sea	Days	Approx. 150 days	-	Frequency wave height exceeds 1m
Canal water gate closed	Days	-	Approx. 13 days	Based on 5-year data sample
Annual unavailability for navigation (total)	Days	Approx. 160 days	Approx. 23 days	
Annual working rate	%	56%	94%	

routes. It assumes that some improvements would be made to bridges and that a lock would be installed in the drainage channel along Route 2. These figures take into consideration several factors that may impede navigation: water levels falling below droughty water levels, closing of the canal water gate due to high water in the Ishikari River, and rough waters in the open sea. The results indicate that Route 1's annual availability to navigation would be 56% and Route 2's would be 94%. Thus Route 2 appears more favorable. It should be noted, however, that flooding has the potential to hinder safe navigation over both routes and thus reduce their annual availability.

4 Conclusions

The following are the primary conclusions derived from this study.

1) A trial calculation estimated cost savings that might be realized if the inland logistics that connect Ishikari Bay New Port and cities in the Ishikari River basin were shifted from truck-based transport to a waterway corridor. It was estimated that costs could be reduced some 15-30% and that a modal shift to an inland waterway would thus offer some advantages.
2) Two possible routes connecting Ishikari Bay New Port to the Ishikari River were evaluated. Route 1 does not suffer any clearance or span limitations until 41.5km after the estuary, making it navigable as is. Route 2, however, encounters drainage channel bridges that do not meet clearance requirements at high water. In addition to upgrading those bridges, a lock would be required at the drainage water gate.
3) Annual route availability was estimated for the two routes. After considering natural conditions and allowing for some improvements to existing structures, Route 2 was found to be more advantageous.

References

[1] JSCE: Handbook of Civil Engineering, pp. 1799-1802, 1989
[2] H. Saeki: Dreaming of Inland Waterway Transport, Harbors, pp. 65-70 June 1999
[3] Coastal Service Journal: A collection of miscellaneous coastal data, 1995 Edition, pp. 29, 1994
[4] River Transport Research Society: River Transport Handbook, 2001