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Examination of Truck and Rail Container Transportation in Japan's Food Logistics

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Abstract: The Japanese distribution industry is currently confronting difficulties that can be divided broadly into three categories. The first difficulty is an acute shortage of truck drivers (labor shortages). The second difficulty is the CO_2 emissions of trucks (environmental load). The third difficulty is a rapid increase in home-delivery services attributable to e-commerce market growth. In response to these difficulties, modal shift must occur from trunk cargo transportation that uses trucks to railroad or maritime container transportation. Therefore, this study analyzes the current conditions of the modal shift of Japan's food distribution (agricultural products, processed foods, etc.) from truck transportation to rail container transportation. The analysis verifies the modal shift effectiveness by calculating the three factors of truck transportation and rail container transportation, including distance, time required, and fares of each route section.

Keywords: Food Logistics, Modal Shift, Rail Container Transportation, Truck Transportation

1. Introduction

The current Japanese distribution industry is facing difficulties that can be divided broadly into three categories. The first difficulty is the shortage of truck drivers (labor shortages) (Tsuchiya & Kurokawa, 2022). The number of young truck drivers is on a declining trend because of long working hours and low wages. The second is an environmental difficulty caused by the CO_2 emissions of trucks (Shirai, Furihata, & Ono, 2016; Siskos & Moysoglou, 2019; Velázquez-Martínez, Fransoo, Blanco, & Valenzuela-Ocaña, 2016). Reduction of environmental loads in the logistics industry is strongly demanded because of global trends of reducing greenhouse gas emissions as a measure against global warming. Trucks cause the heaviest environmental loading among all modes of transportation for domestic distribution, including tracks, rail containers, and vessel containers (Sohoni, Thomas, & Rao, 2017; Wang, Nozick, Xu, & Gearhart, 2018). The third difficulty concerns the rapid increase in home-delivery services because of e-commerce market growth (Sheth, 2020).

In response to these difficulties, the use of a modal shift to convert truck cargo transportation from trucks to rail containers or vessel containers is important (Sohoni, Thomas & Rao, 2017; Wang, Nozick, Xu, & Gearhart, 2018). The only business entity which operates nationwide networks of rail container transportation in Japan is the Japan Freight Railway Company (Japan Freight Railway Company, 2024). Rail container transportation is characterized by low-cost and efficient (large-quantity) transportation with a high on-time performance rate (stability) for the longest route section, which is achieved by combining container cargo and truck transportation. Additionally, it supports the daily life of many people as an environmentally friendly mode of transportation (environmental friendliness).

This study analyzes the current conditions of the modal shift of Japan's food distribution (agricultural products, processed foods, etc.) from truck transportation to rail container transportation. The analyses used for this study verify the modal shift effectiveness by calculating the three factors of truck transportation and rail container transportation, including distance, time required, and fares of each route section.

2. Three-factor Calculation Analysis

The three-factor calculation analysis is intended to elucidate the current status of factors required for the two modes of transportation, i.e., trucks and rail containers. The factors required are distance, time needed, and fares in transportation sections. Having defined these three concepts as three factors, we then derive the three factors of each mode of transportation

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using three-factor calculation. Information related to the three factors of truck transportation and rail container transportation for urban route sections is not publicly available. Therefore, these three factors must be derived and compared with the three factors calculated for route sections set in advance. The traffic volume between cities must also be identified to conduct analyses particularly addressing intercity routes, which are expected to have significant effects on the optimization of logistics through the modal shift. Urban sections derived from this step correspond to the predetermined sections.

The regions used for the calculation are the routes between the 13 cities and Tokyo in eastern Japan presented below. Figure 1 depicts the locations of the regions.

Eastern Japan (13 cities)

• Hokkaido: Kitami, Asahikawa, Kushiro, Obihiro, Sapporo Muroran, Hakodate
• Tohoku: Aomori, Iwate, Akita, Miyagi, Yamagata, Fukushima

Figure 1. Locations of cities in the study (eastern Japan and Tokyo)

2.1 Three-factor Calculation of Truck Transportation and Rail Container Transportation

The following are the formulas used for calculating the three factors of truck transportation.

• Distance of truck transportation TD

$$TD = da + db + dc + dd \quad (1)$$

da: Distance of truck transportation on highways of the Hokkaido route sections
db: Distance of truck transportation on highways of the Honshu route sections
dc: Distance of truck transportation from shippers to interchanges (goods collection distance)
dd: Distance of truck transportation from interchanges to shippers (delivery distance)

• Time necessary for truck transportation TT

$$TT = ta + tb + tc + td \quad (2)$$

ta: Duration of truck transportation on highways of the Hokkaido route sections
tb: Duration of truck transportation on highways of the Honshu route sections
tc: Duration of truck transportation from shippers to interchanges (goods collection time)
td: Duration of truck transportation from interchanges to shippers (delivery distance)

• Fares for truck transportation TF

$$TF = fa + fb + fc + fd \tag{3}$$

fa: Fares for truck transportation in Hokkaido route sections
fb: Fares for truck transportation in Honshu route sections
fc: Highway tolls for Hokkaido route sections and Tsugaru Kaikyo Ferry fares
fd: Highway tolls for Honshu route sections

The following are formulas used for calculation of the three factors of rail container transportation.

• Distance of rail container transportation RD

$$RD = de + df + dg \tag{4}$$

de: Distance of rail container transportation between cities
df: Distance of truck transportation from shippers to goods stations (goods collection distance)
dg: Distance of truck transportation from goods stations to shippers (delivery distance)

• Time required for rail container transportation RT

$$RT = te + tf + tg \tag{5}$$

te: Duration of rail container transportation between cities
tf: Duration of truck transportation from shippers to goods stations (time required for goods collection)
tg: Duration of truck transportation from goods stations to shippers (time required for delivery)

• Fares for rail container transportation RF

$$RF = fe + ff + fg + fh \tag{6}$$

fe: Fares for rail container transportation between cities
ff: Fares for truck transportation from shippers to goods stations (fares for goods collection)
fg: Fares for truck transportation from goods stations to shippers (delivery charges)
fh: Additional charges for rail container transportation through the Seikan Tunnel connecting Honshu and Hokkaido

Table 1. Results of three-factor calculation of truck transportation from cities in eastern Japan to Tokyo (data from 2021)

Table 1 (a) Distance

Departure		Arrival	Distance (km)	Breakdown (km)			
Area	City			Distance on highways of Hokkaido (*da*)	Distance on highways of Honshu (*db*)	Distance of goods collection (*dc*)	Distance of delivery (*dd*)
Hokkaido	Kitami	Tokyo	1,351	581	731	20	20
	Asahikawa		1,233	463	731	20	20
	Kushiro		1,324	554	731	20	20
	Obihiro		1,210	440	731	20	20
	Sapporo		1,089	319	731	20	20
	Muroran		968	198	731	20	20
	Hakodate		788	18	731	20	20
Tohoku	Aomori		713	0	673	20	20
	Iwate		594	0	554	20	20
	Akita		657	0	617	20	20
	Miyagi		414	0	374	20	20
	Yamagata		426	0	386	20	20
	Fukushima		300	0	260	20	20

Table 1 (b) Time necessary

Departure		Arrival	Time necessary (hour)	Breakdown (hour)			
Area	City			Duration on highways of Hokkaido (*ta*)	Duration on highways of Honshu (*tb*)	Duration of goods collection (*tc*)	Duration of delivery (*td*)
Hokkaido	Kitami	Tokyo	19.25	8.50	8.25	1.25	1.25
	Asahikawa		17.5	6.75	8.25	1.25	1.25
	Kushiro		18.75	8.00	8.25	1.25	1.25
	Obihiro		17.25	6.50	8.25	1.25	1.25
	Sapporo		15.75	5.00	8.25	1.25	1.25
	Muroran		14.00	3.25	8.25	1.25	1.25
	Hakodate		11.75	1.00	8.25	1.25	1.25
Tohoku	Aomori		10.00	0.00	7.50	1.25	1.25
	Iwate		8.50	0.00	6.00	1.25	1.25
	Akita		9.75	0.00	7.25	1.25	1.25
	Miyagi		7.00	0.00	4.50	1.25	1.25
	Yamagata		7.25	0.00	4.75	1.25	1.25
	Fukushima		5.75	0.00	3.25	1.25	1.25

Table 1 (c) Fares

Departure		Arrival	Fares per truck (14.2 tons) (JPY)	Fares per ton (JPY)	Breakdown (JPY)			
Area	City				Fares in Hokkaido per truck (*fa*)	Fares in Honshu per truck (*fb*)	Highway tolls and ferry fares for Hokkaido per truck (*fc*)	Highway tolls for Honshu per truck (*fd*)
Hokkaido	Kitami	Tokyo	557,310	39,247	187,550	260,150	84,180	25,430
	Asahikawa		518,880	36,541	149,050	260,150	84,250	25,430
	Kushiro		544,660	38,356	174,900	260,150	84,180	25,430
	Obihiro		506,320	35,656	138,600	260,150	82,140	25,430
	Sapporo		471,570	33,209	107,800	260,150	78,190	25,430
	Muroran		436,610	30,747	76,450	260,150	74,580	25,430
	Hakodate		382,930	26,967	29,150	260,150	68,200	25,430
Tohoku	Aomori		269,230	18,960	0	245,300	0	23,930
	Iwate		220,980	15,562	0	200,750	0	20,230
	Akita		252,680	17,794	0	230,450	0	22,230
	Miyagi		162,030	11,411	0	147,400	0	14,630
	Yamagata		168,120	11,839	0	153,450	0	14,670
	Fukushima		123,280	8,682	0	112,200	0	11,080

Goods collection distances and delivery distances are specified as 20 km based on the average calculated from the survey report of the Ministry of Land, Infrastructure Transport and Tourism (MLIT-2021). The time necessary for goods collection and delivery is specified as 1.25 hr (1 hr 15 min) by calculating the time required for a typical automobile to travel 20 km. Fares for Hokkaido routes, Honshu routes, goods collection, and delivery were calculated from the "standard fares" in the distance-based fares specified by the MLIT. Truck transportation uses trucks with the maximum load of 14,200 kg. Rail container transportation uses 12-foot containers.

Table 1 presents the results of the three-factor calculation for the truck transportation from cities in eastern Japan to Tokyo (data from 2021). Table 2 presents results of the three-factor calculation of the rail container transportation (data from 2021).

Table 2. Results of three-factor calculation of rail container transportation from cities in eastern Japan to Tokyo (data from 2021)

Table 2 (a) Distance

Departure		Arrival	Distance (km)	Breakdown (km)		
Area	City			Distance of rail (*de*)	Distance of goods collection (*df*)	Distance of delivery (*dg*)
Hokkaido	Kitami	Tokyo	1,581	1,541	20	20
	Asahikawa		1,403	1,363	20	20
	Kushiro		1,545	1,505	20	20
	Obihiro		1,419	1,379	20	20
	Sapporo		1,287	1,247	20	20
	Muroran		1,167	1,127	20	20
	Hakodate		981	941	20	20
Tohoku	Aomori		729	689	20	20
	Iwate		613	573	20	20
	Akita		680	640	20	20
	Miyagi		390	350	20	20
	Yamagata		501	461	20	20
	Fukushima		310	270	20	20

Table 2 (b) Time necessary

Departure		Arrival	Time necessary (hour)	Breakdown (hour)		
Area	City			Duration of rail (*te*)	Duration of goods collection (*tf*)	Duration of delivery (*tg*)
Hokkaido	Kitami	Tokyo	88.5	86	1.25	1.25
	Asahikawa		88.5	86	1.25	1.25
	Kushiro		88.5	86	1.25	1.25
	Obihiro		88.5	86	1.25	1.25
	Sapporo		40.5	38	1.25	1.25
	Muroran		83.5	81	1.25	1.25
	Hakodate		40.5	38	1.25	1.25
Tohoku	Aomori		35.5	33	1.25	1.25
	Iwate		35.5	33	1.25	1.25
	Akita		40.5	38	1.25	1.25
	Miyagi		35.5	33	1.25	1.25
	Yamagata		35.5	33	1.25	1.25
	Fukushima		16.5	14	1.25	1.25

Table 2 (c) Fares

Departure		Arrival	Fares per 12-foot containers (5 tons) (JPY)	Fares per ton (JPY)	Breakdown (JPY)			
Area	City				Fares for rail per 12-foot containers (5 tons) (*fe*)	Fares for goods collection per 12-foot containers (5 tons) (*ff*)	Fares for delivery per 12-foot containers (5 tons) (*fg*)	Seikan Tunnel additional fares per 12-foot containers (5 tons) (*fh*)
Hokkaido	Kitami	Tokyo	95,240	19,048	84,500	5,020	5,020	700
	Asahikawa		86,240	17,248	75,500	5,020	5,020	700
	Kushiro		95,240	19,048	84,500	5,020	5,020	700
	Obihiro		86,240	17,248	75,500	5,020	5,020	700
	Sapporo		81,240	16,248	70,500	5,020	5,020	700
	Muroran		76,740	15,348	66,000	5,020	5,020	700
	Hakodate		65,740	13,148	55,000	5,020	5,020	700
Tohoku	Aomori		53,040	10,608	43,000	5,020	5,020	0
	Iwate		48,540	9,708	38,500	5,020	5,020	0
	Akita		50,540	10,108	40,500	5,020	5,020	0
	Miyagi		36,040	7,208	26,000	5,020	5,020	0
	Yamagata		42,040	8,408	32,000	5,020	5,020	0
	Fukushima		32,540	6,508	22,500	5,020	5,020	0

2.2 Calculation of Cargo Data for Truck Transportation and Rail Container Transportation

Data of cargo from cities in eastern Japan to Tokyo were calculated based on intercity traffic volume obtained from the Regional Cargo Movements Survey of MLIT, (data from 2021).

Table 3 exhibits the following results obtained from calculation of cargo data for truck transportation (data from 2021).

(A) Annual cargo volume of truck transportation
(B) Number of trucks per year, considering the load factor (average load factor of trucks is set to 70%) for the annual cargo volume
(C) Number of trucks per day
(D) Number of trucks per business day

Table 4 exhibits the following results of the calculation of cargo data for rail container transportation (data from 2021).

(E) Annual cargo volume of rail container transportation
(F) Number of 12-foot containers (5 tons) per year, considering the load factor (average load factor of rail container transportation is set to 70%) for the annual cargo volume
(G) Number of 12-foot containers per day
(H) Number of 12-foot containers per business day

3. Analysis of Modal Shift

Table 5 and Figure 2 presents the shares of transportation from cities in eastern Japan to Tokyo (percentages of truck transportation, rail container transportation, and vessel container transportation) and relations between fares per ton of truck transportation and rail container transportation (data from 2021) based on the data in Tables 1–4.

Cargo transportation from cities in Hokkaido to Tokyo is characterized by rail container transportation comprising nearly all transportation from Kitami and a high percentage of rail container transportation from Asahikawa. The percentages of rail container transportation and truck transportation from Obihiro and Sapporo are comparable. The percentages of vessel container transportation from Kushiro, Muroran, and Hakodate are high. Regarding Tohoku, truck transportation is evidently dominant in cargo transportation. Therefore, rail container transportation is expected to have a strong effect on transportation in Hokkaido and Honshu.

Table 3. Results of calculating cargo data for truck transportation (data from 2021)

Departure Area	Departure City	Arrival	(A) Annual cargo volume of truck transportation (ton)	(B) Number of trucks per year considering the load factor for the annual cargo volume (Set the load factor to 70%)	(C) Number of trucks per day	(D) Number of trucks per business day
Hokkaido	Kitami	Tokyo	0	0	0	0
	Asahikawa		9,807	987	3	4
	Kushiro		13,369	1,345	4	6
	Obihiro		19,460	1,958	5	8
	Sapporo		113,774	11,446	31	47
	Muroran		3,538	356	1	1
	Hakodate		19,858	1,998	5	8
Tohoku	Aomori		461,520	46,431	127	190
	Iwate		369,636	37,187	102	152
	Akita		201,613	20,283	56	83
	Miyagi		908,868	91,435	251	375
	Yamagata		425,743	42,831	117	176
	Fukushima		1,103,416	111,008	304	455

Table 4. Results of calculating cargo data for rail container transportation (data from 2021)

Departure Area	Departure City	Arrival	(E) Annual cargo volume of rail container transportation (ton)	(F) Number of 12-foot containers per year considering the load factor for the annual cargo volume (Set the load factor to 70%)	(G) Number of 12-foot containers per day	(H) Number of 12-foot containers per business day
Hokkaido	Kitami	Tokyo	26,770	7,649	21	31
	Asahikawa		33,042	9,441	26	39
	Kushiro		3,412	975	3	4
	Obihiro		17,144	4,898	13	20
	Sapporo		123,045	35,156	96	144
	Muroran		13,136	3,753	10	15
	Hakodate		24,644	7,041	19	29
Tohoku	Aomori		43,261	12,360	34	51
	Iwate		28,287	8,082	22	33
	Akita		9,871	2,820	8	12
	Miyagi		160,824	45,950	126	188
	Yamagata		2,678	765	2	3
	Fukushima		4,203	1,201	3	5

This trend has the strongest relation with “fares” among the three factors, i.e., distance, time required, and fares. The fares of Kitami, in which the percentage of rail container transportation is high, rail container transportation can be reduced to approximately half of the truck transportation. Moreover, Kitami is a large production center of onions, which comprise a large part of transportation in the Kitami routes. Onions are heavy and fit for long-term preservation, which leads to demand for reduced transportation costs.

Although rail container transportation had been slowly on the rise until 2017, the increase in traffic volume has slowed since 2018. The volume has been slightly decreasing during the last five years.

These results suggest that examining the characteristics and geographical conditions of transported goods and surveying intercity routes having potential benefits of cost, volume, and environmental factors can be expected to yield keys to accelerating modal shift to rail container transportation.

Table 5. Relations of transportation shares and fares for transportation from cities in eastern Japan to Tokyo (data from 2021)

	Percentages of truck transportation	Percentages of rail container transportation	Percentages of vessel container transportation	Fares for truck transportation per ton (JPY)	Fares for rail container transportation per ton (JPY)
Kitami	0.0%	91.3%	8.7%	39,247	19,048
Asahikawa	22.9%	77.1%	0.0%	36,541	17,248
Kushiro	10.6%	2.7%	86.8%	38,356	19,048
Obihiro	48.0%	42.3%	9.7%	35,656	17,248
Sapporo	48.0%	52.0%	0.0%	33,209	16,248
Muroran	0.3%	1.2%	98.5%	30,747	15,348
Hakodate	6.5%	8.1%	85.4%	26,967	13,148
Aomori	56.0%	5.3%	38.7%	18,960	10,608
Iwate	34.7%	2.7%	62.6%	15,562	9,708
Akita	95.3%	4.7%	0.0%	17,794	10,108
Miyagi	65.5%	11.6%	22.9%	11,411	7,208
Yamagata	99.4%	0.6%	0.0%	11,839	8,408
Fukushima	99.4%	0.4%	0.2%	8,682	6,508

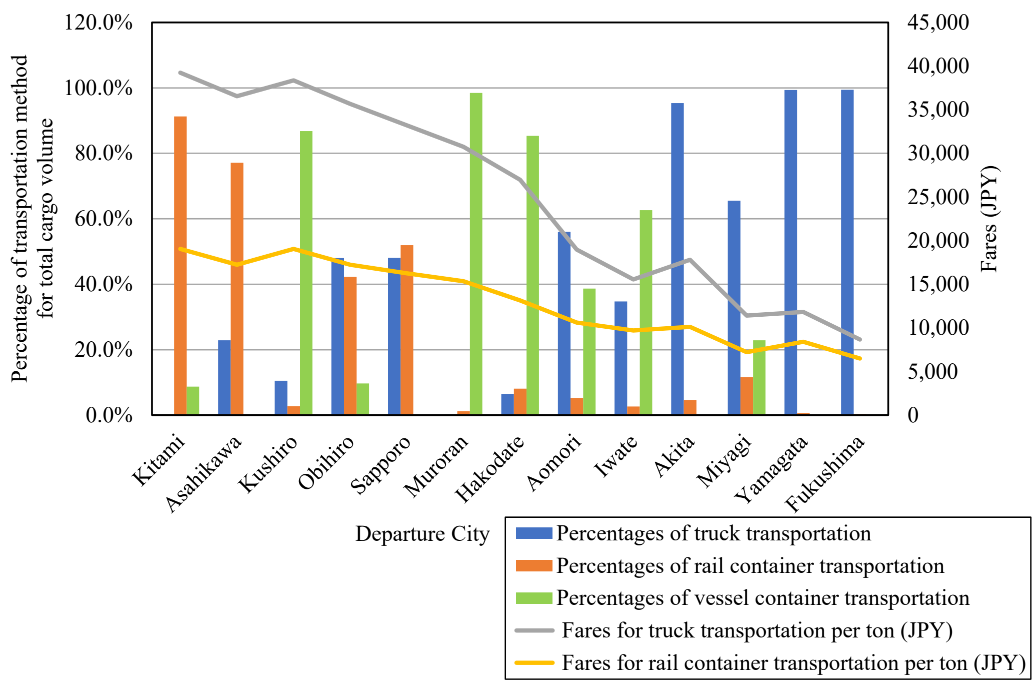

Figure 2. Relations of transportation shares and fares for transportation from cities in eastern Japan to Tokyo (data from 2021)

4. Conclusion

This study specifically examined difficulties associated with modal shift from truck transportation to rail container transportation in the distribution of food products (agricultural products, processed foods, etc.) in Japan. Modal shift to rail container transportation was found to be considerably challenging because of a gradual decrease in the share of rail container transportation. To accelerate modal shift, it is important to demonstrate its benefits for small and medium-sized truck transportation companies and for end consumers who will receive the transported products.

Issues left for future studies include analysis of three-factor calculation of vessel container transportation and routes between small and medium-sized cities and between eastern Japan and western Japan (direct transportation routes in Hokkaido and Kyushu without passing the Tokyo metropolitan area (route via the Sea of Japan)), from which it is purportedly more difficult to derive benefits from modal shift.

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