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China-Japan Port Networks Suitable for Short Sea Shipping

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Abstract: During the last few decades, China and Japan have become mutually dependent economically. Most significantly, trade volume by container transportation between two countries has increased considerably. However, in situations of short distance, container transportation entails the important shortcomings of costly investment for land and infrastructure at ports as well as time-consuming complex cargo-handling operations. The distances of China and Japan routes are much shorter than those transoceanic sea routes used for container transportation, e.g., between Europe and Asia. In Europe, short sea shipping by RORO (roll-on/roll-off) or ferries is well networked among countries because of their proximity. Therefore, it is difficult for container transportation to avoid the effects of cost and inefficiencies described above. Accordingly, short sea shipping should be introduced properly between China and Japan because the distances separating the countries are similar to those of existing European short sea shipping networks. This paper presents an exploration of the possibility of introducing better short sea shipping networks between China and Japan. First, data related to short sea shipping in Europe were surveyed. The data include short sea shipping operators and regions with local ports, but also include regional populations, regional GDPs (Gross Domestic Product), number of regional tourists, and total regional freight tonnage. From analyzing the characteristics of short sea shipping networks, two major groups of the short sea shipping networks were found: one-to-one port networks and one-to-more port networks. Finally, geographical conditions of port locations between China and Japan were examined to ascertain whether any future port combinations can be suitable for expanding short sea shipping networks. Results show that port combinations among Okinawa in Japan, Taiwan, and southeastern China conformed to the one-to-more port networks. A short sea shipping network already exists between Okinawa and Taiwan. This paper reports the means of future expansion of the network to China.

Key words: Port networks, short sea shipping, regional transportation, distance range, tourism, cargo handling, container, logistics.

1. Introduction

Along with development of global production networks, marine transportation has also tended to become more globalized, as described by Notteboom [1]. Container transportation remains the main mode of marine transportation of goods. However, along with construction of port networks, short sea shipping is increasingly used for shorter distance between countries.

For short sea shipping, the main ship tonnage is 1,000~10,000, with drafts ranging from around 2.5 m to 8.8 m. Principally, transfers of wet and dry bulk cargoes (grain, tertilizers, steel, coal, salt, stone, scrap and minerals, etc.) are done, in addition to those of containers and passengers [2].

Short sea shipping in Europe accounts for approximately 40% of all freight moved there. Cargo chiefly passes through the central region of Europe on rivers but not on oceans. Over the past several decades, the term of short sea shipping has broadened to include point-to-point cargo movements on inland waterways and inland to ocean ports for transhipment over oceans [3].

At the same time, short sea shipping has developed to some degree in the US. From the perspective of alleviating congestion, decreasing air pollution, and overall cost savings to the shipper and a government, short sea shipping is far more efficient and cost-effective than road transport. Moreover, it is

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much less prone to theft and damage.

China and Japan have become mutually dependent economically as the trade volume by container transportation between the countries has increased prodigiously. Nevertheless, container transportation networking for shorter distances has not occurred because of the necessary costly investments for land and infrastructure in ports and time-consuming complex cargo-handling operations. The distances separating China from Japan are short compared to those of transoceanic sea routes used for container transportation among the US, Europe, and Asia. Consequently, Ducruet [4] presented the view that potential network port cities can be evaluated by consideration of micro-scale (local environments) and macro-scale (regional patterns) factors. The present study chooses analyses of the port networks from macro-scale perspective and introduces better short sea shipping networks between China and Japan.

2. Assumption and Methodology

2.1 Assumption of Heterogeneous Port Networks for Short Sea Shipping

Global port networks linking economically developed regions that are mutually distant are generally connected by container shipping because of substantial cargo demand by trade between the regions. However, some economically developing regions might exist in proximity to those economically developed regions. Local port networks by RORO (roll-on/roll-off) or ferry shipping might be well adapted to such regional transportation because of the shorter distances with less or unstable cargo demand, as shown in the upper part of Fig. 1. Each port network is homogeneous depending on the shipping patterns, e.g., container, RORO, or ferry. If a shipping line calls for all the ports in the upper part of Fig. 1, then three port networks are needed, separately employing several ships on each network. That prospect presents risk to the shipping line.

However, geographic or economic niche markets of port networks might be found by which a shipping line can benefit from cargo demand for both economically developed regions and economically developing regions on a certain port network. When developing a geographic region that is located efficiently between two economically developed regions in terms of time or cost, the shipping line might be able to combine a global port network with different local port networks on the certain port network, as shown in the lower part of Fig. 1. This network of heterogeneous ports has different homogeneous port networks. Therefore, it is far superior for the shipping line than the case shown in the upper part of Fig. 1.

2.2 Methodology for Evaluating Future Port Networks for Short Sea Shipping between China and Japan

Based on the assumption presented above, this paper presents an examination of a methodology proposed by the following processes as depicted in Fig. 2:

(1) Assume advantages of heterogeneous port networks compared to homogeneous port networks;

(2) Analyze present port networks of short sea shipping in Europe because it is the world's largest

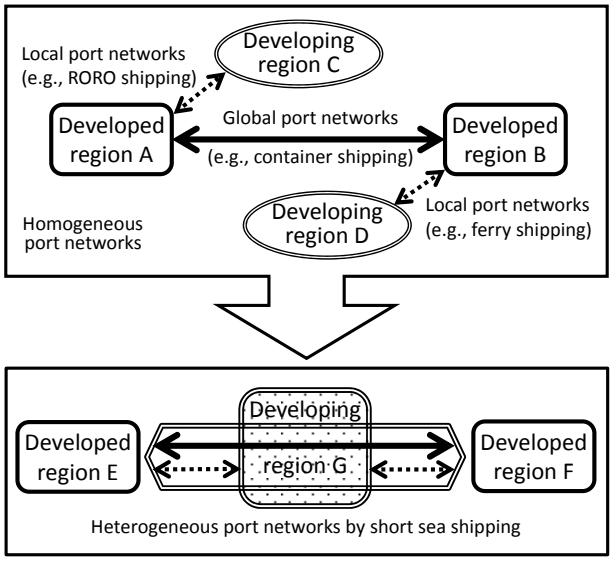

Fig. 1 Niche market of heterogeneous port networks for short sea shipping.

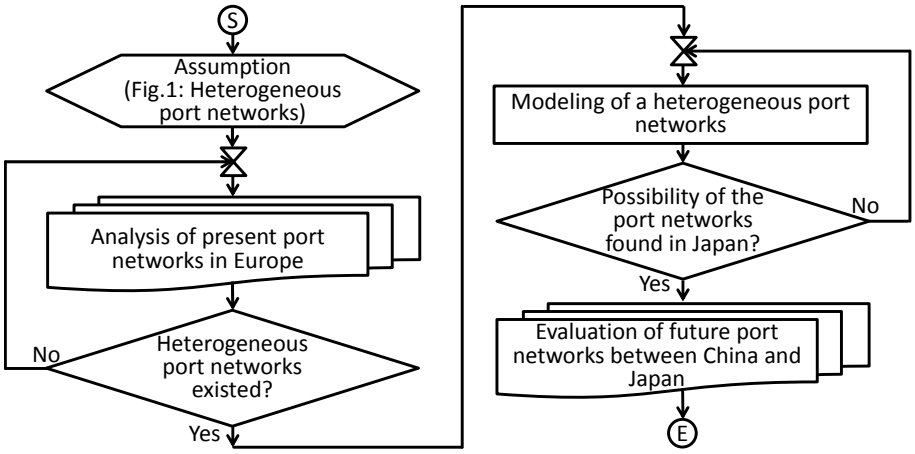

Fig. 2 Methodology for evaluating short sea shipping port networks suitable for expansion between China and Japan.

short sea shipping markets;

(3) Whether or not a heterogeneous port networks exist in Europe as assumed by (1);

(4) Model a heterogeneous port network that is applicable for short sea shipping between China and Japan;

(5) Find suitable port networks of short sea shipping between China and Japan, as modeled by (4);

(6) Evaluate possible future port networks of short sea shipping between China and Japan.

3. Data Collection of European Short Sea Shipping

3.1. Well-Developed Networks of Short Sea Shipping in Europe

Most European countries are well networked for short sea shipping because of their close mutual proximity. The salient benefits of short sea shipping in Europe portrayed in the figure are explainable by comparison with container transportation for transoceanic shipping routes. Ships used for short sea shipping are typically RORO or ferries [5]. Therefore, ports need less infrastructure for cargo handling equipment such as cranes. It is also an important benefit of RORO and ferries that cargoes on board are mobile, such as cars, trucks, and trailers. Therefore, the turnaround times of both the ships and the cargoes in ports are shorter than those for container transportation, for which containers must be stacked at container terminals in ports for days to weeks to match the timing of delivery or picking up of the containers by their shippers. Moreover, less space is needed in ports for short sea shipping because the wheeled cargoes can leave the ports soon after being discharged from the ships. In contrast, container terminals need more space in ports to accommodate a substantial number of containers, thereby meeting the timing needs of the shippers [6].

For China and Japan, Table 1 presents some short sea shipping routes in the Mediterranean by distance for illustration. Fig. 3 shows short sea shipping networks among countries according to data in Table 1. Short sea shipping is better at producing a network among neighboring regions at close distances when local ports are available for each. However, ports are not well equipped with infrastructure such as container terminals. The distances of China and Japan approximate those in the Mediterranean, as portrayed in Fig. 3. Therefore, suitable characteristics of short sea shipping in Europe can be found for possible new port networks for short sea shipping between China and Japan.

3.2 Major Short Sea Shipping Operators in Europe

Table 2 presents major operators of short sea shipping in Europe including all the networks presented

Table 1 Examples of short sea shipping routes in the Mediterranean (listed by distance).

No.	Region	Port	Region	Port	Distance (km)
1	Andalucia, Spain	Algeciras	Ciudad Autonoma de Ceuta (ES), Spain	Ceuta	25.56
2	Andalucia, Spain	Algeciras	Tangier-Tetouan	Tangier Med	35.74
3	Campania, Italy	Napoli	Campania, Italy	Casamicciola	60.00
4	Corsica, France	Calvi	Provence-Alpes-Cote d'Azur, France	Nice	140.75
5	Corsica, France	Bastia	Toscana, Italy	Livorno	143.57
6	Corsica, France	Bastia	Toscana, Italy	Piombino	154.18
7	Andalucia, Spain	Almeria	Oriental, Morocco	Nador	203.35
8	Andalucia, Spain	Almeria	Tlemcen, Algeria	Ghazaouet	238.35
9	Cataluna, Spain	Barcelona	IIIes Balears, Spain	Ibiza	243.35
10	Corsica, France	Bastia	Provence-Alpes-Cote d'Azur, France	Nice	250.02
11	Andalucia, Spain	Almeria	Ciudad Autonoma de Melilla (ES), Spain	Melilla	251.87
12	Cataluna, Spain	Barcelona	IIIes Balears, Spain	Formentera	295.02
13	Corsica, France	Bastia	Liguria, Italy	Savona	295.39
14	Corsica, France	Ajaccio	Provence-Alpes-Cote d'Azur, France	Toulon	309.14
15	Cataluna, Spain	Barcelona	Languedoc-Roussillon, France	Sete	319.56
16	Corsica, France	Ajaccio	Provence-Alpes-Cote d'Azur, France	Nice	335.68
17	Andalucia, Spain	Almeria	Oran, Algeria	Oran	350.03
18	Toscana, Italy	Livorno	Sardegna, Italy	Golfo Aranci	362.64
19	Corsica, France	Bastia	Provence-Alpes-Cote d'Azur, France	Toulon	387.07

Source: RO-RO & Ferry Atlas Europe 2014/15 [7].

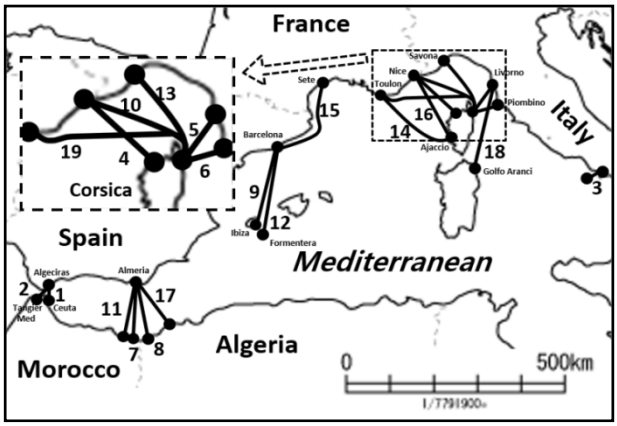

Fig. 3 Networks of short sea shipping route in Mediterranean.

Source: Table 1.

in Fig. 3. Numbers of regions and their local ports and combinations among the ports are sufficiently varied to show characteristics that are suitable for short sea shipping between China and Japan.

The prominent characteristics presented in Table 2 are that substantial capacity of passengers as well as cars and trucks are secured by the operators. Therefore, sufficient demand exists for short sea shipping in Europe not only for pure logistics but also for passenger transportation, i.e., higher potential might exist for short sea shipping for tourism.

3.3 Fundamental Activities in Regions Related to Short Sea Shipping

In all, 56 regions have 86 local ports networked by the operators presented in Table 2, as shown in Table 3. Because it is natural to regard fundamental activities in regions as a driving force for short sea shipping, information related to the regional economy must be analyzed. For this study, population (inhabitants), GDP (Gross Domestic Product) and the number of tourists per inhabitant in each region together with total freight tonnage on routes of short sea shipping connected to each local port were collected for Europe in publicly available statistics. The dataset is presented in Table 3, in which the number of tourists per inhabitant was calculated by dividing the number of tourists by the population.

Table 2 Major RORO and ferry operators in Europe.

No.	Operators	No. vessels	Total gross tonnage (2014~2015)	Total No. passengers (2014~2015)	Total No. cars (2014~2015)	Total No. trucks (2014~2015)
1	Stena Line	24	749,998	23,801	6,470	151
2	P & O Ferries	16	496,495	16,448	7,288	484
3	DFDS Seaways	11	296,394	12,726	3,935	230
4	Color Line	6	246,770	10,004	2,644	0
5	Grandi Navi Veloci	6	245,429	11,893	1,744	0
6	Brittany Ferries	9	238,256	14,737	4,617	65
7	Corsica Sardinia Ferries	11	222,837	18,435	5,770	0
8	Trasmediterranea	14	214,7111	12,330	3,269	0
9	Irish Ferries	5	149,250	6,300	5,385	0
10	SNAV	6	134,776	7,482	2,392	236
11	Nel Lines	10	70,179	10,601	2,519	0
12	LD Lines	2	54,318	492	195	0
13	Condor Ferries	4	11,264	2,523	625	0

Source: Refs. [8-10].

Table 3 Fundamental activities in regions related to short sea shipping in Europe.

No.	Region	Port	Freight tonnage (thousand tonnes)	Population (inhabitants)	GDP (Euro)	No. tourists
1	Zuid-Holland, Netherlands	Rotterdam	404,829	3,552,407	32,000	2,079,393
2	Zuid-Holland, Netherlands	Hoek of Holland	404,829	3,552,407	32,000	2,079,393
3	Andalucia, Spain	Algeciras	119,589	8,377,810	18,300	9,584,247
4	Andalucia, Spain	Almeria	119,589	8,377,810	18,300	9,584,247
5	Andalucia, Spain	Cadiz	119,589	8,377,810	18,300	9,584,247
6	Noord-Holland, Netherlands	Amsterdam	93,453	2,709,822	36,600	3,014,630
7	East Yorkshire and Northern Lincolnshire, UK	Hull	82,990	919,611	20,100	1,143,000
8	Provence-Alpes-Cote d'Azur, France	Nice	81,595	4,927,578	26,000	11,004,030
9	Provence-Alpes-Cote d'Azur, France	Toulon	81,595	4,927,578	26,000	11,004,030
10	Sicilia, Italy	Palermo	79,053	4,999,854	16,300	2,548,463
11	Haute-Normandie, France	Le Havre	76,984	1,844,097	24,000	1,938,264
12	Haute-Normandie, France	Dieppe	76,984	1,844,097	24,000	1,938,264
13	Liguria, Italy	Genoa	69,359	1,567,339	26,700	2,215,890
14	Liguria, Italy	Savona	69,359	1,567,339	26,700	2,215,890
15	Comunidad Velenciana, Spain	Valencia	68,559	5,009,650	21,200	5,536,438
16	Cataluna, Spain	Barcelona	67,908	7,514,991	28,400	8,346,741
17	Nord-Pas-de-Calais, France	Calais	54,238	4,048,230	22,100	3,087,397
18	Nord-Pas-de-Calais, France	Dunkerque	54,238	4,048,230	22,100	3,087,397
19	Sardegna, Italy	Golfo Aranci	52,133	1,637,846	19,300	1,247,003
20	West Wales and The Valleys, UK	Fishguard	49,420	1,936,283	16,100	5,113,000
21	West Wales and The Valleys, UK	Holyhead	49,420	1,936,283	16,100	5,113,000
22	West Wales and The Valleys, UK	Pembroke	49,420	1,936,283	16,100	5,113,000
23	Västsverige, Sweden	Gothenburg	48,955	1,892,328	29,600	4,030,458
24	Västsverige, Sweden	Strömstad	48,955	1,892,328	29,600	4,030,458
25	Västsverige, Sweden	Varberg	48,955	1,892,328	29,600	4,030,458

(Table 3 continued)

No.	Region	Port	Freight tonnage (thousand tonnes)	Population (inhabitants)	GDP (Euro)	No. tourists
26	Attiki, Greece	Piraeus	47,332	3,961,122	26,900	1,141,018
27	Attiki, Greece	Lavrio	47,332	3,961,122	26,900	1,141,018
28	Hampshire and Isle of Wight, UK	Portsmouth	44,058	1,908,498	25,600	2,798,000
29	Lietuva, Lithuania	Klaipeda	41,033	3,003,641	16,900	1,090,318
30	Sydsverige, Sweden	Karlskrona	38,021	1,405,912	26,800	2,169,464
31	Sydsverige, Sweden	Trelleborg	38,021	1,405,912	26,800	2,169,464
32	Sydsverige, Sweden	Karlshamn	38.021	1,405,912	26,800	2,169,464
33	Pomorskie, Poland	Gdynia	37,452	2,283,500	15,600	1,511,595
34	Kent, UK	Dover	36,431	1,739,957	21,200	1,486,000
35	Schleswig-Holstein, Germany	Kiel	34,765	2,837,641	25,900	5,262,000
36	Merseyside, UK	Liverpool	32,924	1,508,892	20,200	1,245,000
37	Prov. West-Vlaanderen, Belgium	Zeebrugge	31,974	1,173,818	28,500	1,730,961
38	Toscana, Italy	Livorno	30,770	3,667,780	27,600	5,489,961
39	Toscana, Italy	Piombino	30,770	3,667,780	27,600	5,489,961
40	Pay s de la Loire, France	Saint Nazaire	29,219	3,630,780	24,100	5,464,222
41	Sy-ddanmark, Denmark	Esbjerg	24,705	1,201,342	27,800	1,151,795
42	Sor-Ostlandet, Norway	Larvik	24,604	949,963	27,500	2,658,344
43	Sor-Ostlandet, Norway	Sandefjord	24,604	949,963	27,500	2,658,344
44	Northern Ireland, UK	Belfast	23,226	1,818,935	19,700	2,073,000
45	Northern Ireland, UK	Larne	23,226	1,818,935	19,700	2,073,000
46	Mecklenburg-Vorpommern, Germany	Sassnitz	22,529	1,634,734	21,100	6,501,273
47	Mecklenburg-Vorpommern, Germany	Rostock	22,529	1,634,734	21,100	6,501,273
48	Principado de Asturias, Spain	Gijon	21,503	1,074,308	22,700	1,501,806
49	South Western Scotland, UK	Cairnryan	19,845	2,332,454	22,300	2,323,000
50	South Western Scotland, UK	Troon	19,845	2,332,454	22,300	2,323,000
51	Campania, Italy	Napoli	18,258	5,764,424	15,700	2,734,344
52	Campania, Italy	Casamicciola	18,258	5,764,424	15,700	2,734,344
53	Lazio, Italy	Civitavecchia	17,765	5,500,022	29,300	3,634,164
54	Agder og Rogaland, Norway	Kristiansand	17,606	728,934	36,500	1,925,614
55	Jadranska Hrvatska, Croatia	Split	14,839	1,410,551	14,700	1,005,235
56	Hovedstaden, Denmark	Copenhagen	12,770	1,714,589	38,300	1,196,177
57	Midtjylland, Denmark	Grenaa	12,682	1,266,682	28,200	717,686
58	Marche, Italy	Ancona	8,316	1,540,688	25,500	1,854,613
59	Nordjylland, Denmark	Frederikshavn	7,917	579,996	27,500	574,229
60	Nordjylland, Denmark	Hirtshals	7,917	579,996	27,500	574,229
61	Northumberland and Tyne and Wear, UK	Newcastle	6,950	1,422,375	20,800	2,032,000
62	IIIes Balears, Spain	Ibiza	6,871	1,100,715	25,300	1,362,008
63	IIIes Balears, Spain	Formentera	6,871	1,100,715	25,300	1,362,008
64	Oslo og Akershus, Norway	Oslo	5,641	1,169,539	47,400	2,685,092
65	Languedoc-Roussillon, France	Sete	5,042	2,699,498	20,900	6,540,839
66	Bretagne, France	Roscoff	4,939	3,239,659	22,400	5,298,813
67	Bretagne, France	St. Malo	4,939	3,239,659	22,400	5,298,813
68	Cantabria, Spain	Santander	4,803	592,383	23,500	1,268,303
69	Lancashire, UK	Heysham	4,035	1,463,495	19,600	2,107,000

(Table 3 continued)

No.	Region	Port	Freight tonnage (thousand tonnes)	Population (inhabitants)	GDP (Euro)	No. tourists
70	Essex, UK	Harwich	3,189	1,735,048	21,500	961,000
71	Basse-Normandie, France	Cherbourg	2,751	1,478,057	21,200	2,928,513
72	Basse-Normandie, France	Caen	2,751	1,478,057	21,200	2,928,513
73	Surrey, East and East Sussex, UK	Newhaven	2,696	2,755,118	26,800	3,066,000
74	Devon, UK	Plynouth	2,374	1,139,062	20,200	3,612,000
75	Ciudad Autonoma de Ceuta (ES), Spain	Ceuta	1,554	83,845	20,900	52,137
76	Corsica, France	Bastia	1,554	318,316	22,800	1,746,324
77	Corsica, France	Calvi	1,554	318,316	22,800	1,746,324
78	Corsica, France	Ajaccio	1,544	318,316	22,800	1,746,324
79	Notio Aigaio, Greece	Andros	1,216	343,283	22,300	538,635
80	Notio Aigaio, Greece	Milos	1,216	343,283	22,300	538,635
81	Notio Aigaio, Greece	Syros	1,216	343,283	22,300	538,635
82	Notio Aigaio, Greece	Naxos	1,216	343,283	22,300	538,635
83	Anatoliki Makedonia, Thraki, Greece	Kavala	856	622,159	14,200	313,581
84	Dorset and Somerset, UK	Weymouth	752	1,281,108	21,100	3,188,000
85	Dorset and Somerset, UK	Poole	752	1,281,108	21,100	3,188,000
86	Ciudad Autonoma de Melilla (ES), Spain	Melilla	604	81,792	19,000	36,718

Source: Refs. [10-14].

Table 4 One-to-one port networks in Europe.

No.	Region A	Port A	Region B	Port B
1	Northumberland and Tyne and Wear, UK	Newcastle	Noord-Holland, Netherlands	Amsterdam
2	Surrey, East and East Sussex, UK	Newhaven	Haute-Normandie, France	Dieppe
3	Sydsverige, Sweden	Karlskrona	Pomorskie, Poland	Gdynia
		Karlshamn	Lietuva, Lithuania	Klaipėda
4	Vastsverige, Sweden	Stromstad	Sor-Ostlandet, Norway	Sandefjord
		Varberg	Midtjylland, Denmark	Grenaa
5	Campania, Italy	Napoli	Campania, Italy	Casamicciola
6	Andalucia, Spain	Cadiz	Canary Islands	Arrecife
7	Jadranska Hrvatska, Croatia	Split	Marche, Italy	Ancona

Source: Refs. [8-14].

4. Analysis of Characteristics of European Short Sea Shipping

4.1 Combinations of Ports by Short Sea Shipping in Europe

Analyses based on port of call services provided by each operator presented in Table 2 revealed 7 combinations of one-to-one port networks and 36 combinations of one-to-more ports networks. Table 4 shows the one-to-one port network. Table 5 shows the one-to-more port network. Numbers of ports were combined to produce one-to-more port networks or 2~5 destinations, as presented in Table 5. Hereinafter, a port connected with more than one port is designated as a master port. A port connected with such a master port is designated as a subordinate port, as expressed in the headings of Table 5.

Table 5 One-to-more port networks in Europe.

No.	Master			Subordinates					
	Region	Port	No. subordinate ports	Region	Port	Region	Port	Region	Port
1	Corsica, France	Bastia	5	Toscana, Italy	Piombino	Toscana, Italy	Livorno	Provence-Alpes-Cote d'Azur, France	Nice
				Liguria, Italy	Savona	Provence-Alpes-Cote d'Azur, France	Toulon		
2	Hampshire and Isle of Wight, UK	Portsmouth	4	Cantabria, Spain	Santander	Haute-Normandie, France	Le Havre	Basse-Normandie, France	Caen
				Basse-Normandie, France	Cherbourg				
3	Basse-Normandie, France	Cherbourg	4	Dorset and Somerset, UK	Poole	Southern and Eastern, Ireland			
				Southern and Eastern, Ireland	Dublin				
4	Cataluna, Spain	Barcelona	4	Liguria, Italy	Genoa	Languedoc-Roussillon, France	Sete	IIIes Balears, Spain	Ibiza
				IIIes Balears, Spain	Formentera				
5	Andalucia, Spain	Almeria	4	Oriental	Nador	Ciudad Autonoma de Melilla (ES), Spain	Melilla	Tlemcen Province	Ghazaouet
				Oran Province	Oran				
6	Northern Ireland, UK	Belfast	3	Lancashire, UK	Heysham	South Western Scotland, UK	Cairnryan	Merseyside, UK	Liverpool
7	Dorset and Somerset, UK	Poole	3	Basse-Normandie, France	Cherbourg	Bretagne, France	St Malo	Principado de Asturias, Spain	Gijon
8	Southern and Eastern, Ireland	Dublin	3	Merseyside, UK	Liverpool	West Wales and The Valleys, UK	Holyhead	Basse-Normandie, France	Cherbourg
9		Rosslare	3	West Wales and The Valleys, UK	Fishguard	Basse-Normandie, France	Cherbourg	West Wales and The Valleys, UK	Pembroke
10	Provence-Alpes-Cote d'Azur, France	Nice	3	Corsica, France	Calvi	Corsica, France	Ajaccio	Corsica, France	Bastia
11	Osloog Akershus, Norway	Oslo	3	Nordjylland, Denmark	Frederikshavn	Schleswig-Holstein, Germany	Kiel	Hovedstaden, Denmark	Copenhagen
12	Notio Aigaio, Greece	Syros	3	Notio Aigaio, Greece	Andros	Notio Aigaio, Greece	Milos	Notio Aigaio, Greece	Naxos
13	Kent, UK	Dover	2	Nord-Pas-de-Calais, France	Calais	Nord-Pas-de-Calais, France	Dunkerque		
14	Devon, UK	Plymouth	2	Bretagne, France	Roscoff	Cantabria, Spain	Santander		
15	Essex, UK	Harwich	2	Zuid-Holland, Netherlands	Hoek of Holland	Syddanmark, Denmark	Esbjerg		
16	Merseyside, UK	Liverpool	2	Southern and Eastern, Ireland	Dublin	Northern Ireland, UK	Belfast		

(Table 5 continued)

No.	Master			Subordinates					
	Region	Port	No. subordinate ports	Region	Port	Region	Port	Region	Port
17	East Yorkshire and Northern Lincolnshire, UK	Hull	2	Prov. West-Vlaanderen, Belgium	Zeebrugge	Zuid-Holland, Netherlands	Rotterdam		
18	Northern Ireland, UK	Larne	2	South Western Scotland, UK	Troon	South Western Scotland, UK	Cairnryan		
19	South Western Scotland, UK	Cairnryan	2	Northern Ireland, UK	Larne	Northern Ireland, UK	Belfast		
20	West Wales and The Valleys, UK	Holyhead	2	Southern and Eastern, Ireland	Dun Laoghaire	Southern and Eastern, Ireland	Dublin		
21	Bretagne, France	St Malo	2	Dorset and Somerset, UK	Poole	Dorset and Somerset, UK	Weymouth		
22	Corsica, France	Ajaccio	2	Prov. West-Vlaanderen, Belgium	Nice	Provence-Alpes-Cote d'Azur, France	Toulon		
23	Provence-Alpes-Cote d'Azur, France	Toulon	2	Corsica, France	Ajaccio	Corsica, France	Bastia		
24	Sydsverige, Sweden	Trelleborg	2	Mecklenburg-Vorpommern, Germany	Sassnitz	Mecklenburg-Vorpommern, Germany	Rostock		
25	Vastsverige, Sweden	Gothenburg	2	Schleswig-Holstein, Germany	Kiel	Nordjylland, Denmark	Fredrikshavn		
26	Nordjylland, Denmark	Hirtshals	2	Agderog Rogaland, Norway	Kristiansand	Sor-Ostlandet, Norway	Larvik		
27	Schleswig-Holstein, Germany	Kiel	2	Vastsverige, Sweden	Gothenburg	Osloog Akershus, Norway	Oslo		
28	Liguria, Italy	Genoa	2	Cataluna, Spain	Barcelona	Sicilia, Italy	Palermo		
29	Sicilia, Italy	Palermo	2	Liguria, Italy	Genoa	Lazio, Italy	Civitavecchia		
30	Toscana, Italy	Livorno	2	Corsica, France	Bastia	Sardegna, Italy	Golfo Aranci		
31	Attiki, Greece	Piraeus	2	Voreio Aigaio, Greece	Vathy	Voreio Aigaio, Greece	Mytilene		
32		Lavrio	2	Anatoliki Makedonia, Thraki, Greece	Kavala	Voreio Aigaio, Greece	Mesta		
33	Cantabria, Spain	Santander	2	Hampshire and Isle of Wight, UK	Portsmouth	Devon, UK	Plymouth		
34	Andalucia, Spain	Algeciras	2	Ciudad Autonoma deCeuta (ES), Spain	Ceuta	Tangier-Tetouan	Tangier Med		
35	IIIes Balears, Spain	Ibiza	2	Comunidad Valenciana, Spain	Valencia	Cataluna, Spain	Barcelona		
36	Principado de Asturias, Spain	Gijon	2	Dorset and Somerset, UK	Poole	Pays de la Loire, France	Saint Nazaire		

Source: Refs. [8-10].

4.2 Correlation of Freight Tonnage with Regional Economy

Short sea shipping is supported by economical activities in the short term. In the longer term, port networks of the short sea shipping might, however, be affected by political relations, historical background, military power, and other factors. Analyses therefore demand the use of a macro-scale approach by which variables are widely applicable to different economic areas and a micro-scale approach by which variables are specialized to regionally oriented matters. These analyses examine the former set of variables. Therefore, it is better to include universal variables that are applicable to both Europe and Asia. The authors selected population, GDP, and number of tourists as such universal variables, although other candidate variables can be considered.

Table 6 presents correlation coefficients of the freight tonnage of both the one-to-one and the one-to-more port networks with the population, GDP, and the number of tourists per inhabitant in the regions connected with the port networks, with the calculated R^2. The population was significant, but GDP was not significant for any port network. Each had few tourists per inhabitant. None was significant for one-to-more port networks.

Comparison of R^2 of the population as shown in Fig. 4 reveals that coefficients of one-to-more port networks were significant, as were those of one-to-one port networks. This result might be explained by Table 4: most networks appearing in the table have greater importance for connecting two countries as a corridor rather than for meeting demand for the regional economies of local ports. This reasoning matches the finding of a lack of significance of one-to-one port networks with both GDP per inhabitant and the number of tourists per inhabitant in regions connected by port networks. This rationale also matches the assumption shown in the lower part of Fig. 1 that one to more port networks might have heterogeneous networks driven by both the developed and the developing regions, which is caused the higher significance of the population than that of one to one port networks, as shown in Table 6 and Fig. 4. Because

Table 6 Correlation of short sea shipping with regional economy in Europe by R^2.

	One-to-more port networks	One-to-one port networks
Population (inhabitants)	0.6277	0.4181
GDP (per inhabitant)	0.0383	0.0022
No. tourists per inhabitant	0.1064	0.0570

Source: Refs. [8-14].

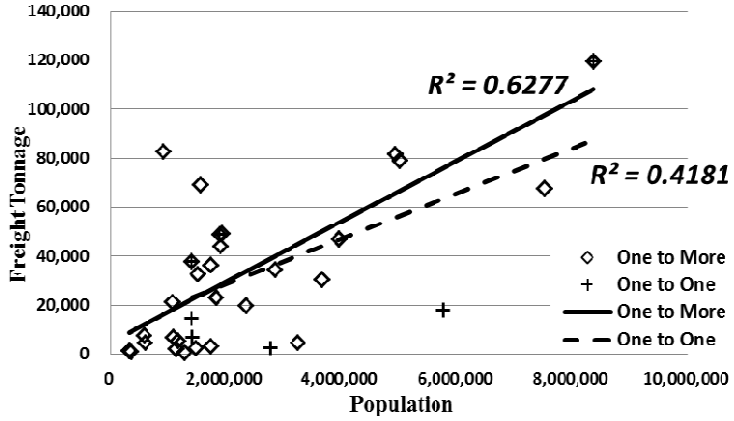

Fig. 4 Comparison of correlation (R^2) with freight tonnage to population between one-to-one and one-to-more port networks.

Source: Refs. [8-14].

China and Japan are already connected by container transportation, maintaining such national economic corridors for decades, it is difficult for short sea shipping to be newly introduced between the countries under conditions of one-to-one port networks.

4.3 Characteristics of Newly Introduced Short Sea Shipping between China and Japan

Characteristics of short sea shipping in Europe suitable for China and Japan are found in the one-to-more port networks. However, too many networks exist, as shown in Table 5. It is therefore reasonable to infer that limited characteristics might be applicable for introducing new short sea shipping between China and Japan. When reviewed in Table 6, the population should be regarded as a general characteristic needed for all the one-to-more port networks because of the higher value of R^2. The number of tourists per inhabitant might affect a few networks, but apparently not all, because of the lower value of R^2. To verify this assumption, master ports and subordinate ports were compared with the number of tourists per inhabitant as shown in Fig. 5.

Two groups are clearly evident in the figure: one has a greater number of networks ranging widely in the figure; the other has only a few networks concentrated at the master ports but lower at the subordinate ports. These are the networks connected to Corsica of the Mediterranean as master ports. This is unexpected: an isolated region with low population such as Corsica has master ports. Therefore, master ports and subordinate ports were compared with the population, as shown in Fig. 6, which emphasizes the position of Corsica as highlighted by arrowed lines.

Two groups are shown in the figure as one distributed lower for master ports, but wider for subordinate ports and as other positions, mostly higher for the master ports. Corsica belongs to the former, and the lowest among master ports because Corsica is surrounded by populated and economically developed regions such as France and Italy, as shown at the right in Fig. 3.

Corsica is located intermediate between France and Italy. In addition to its position, the island has attractive tourism resources, although it is less populated. This is an ideal condition for RORO or ferry operators who wish to benefit from both the demand of pure logistics between the two countries and tourists to the island using a route connecting countries of destination at both sides calling for a master port at the island on the middle of the route, as illustrated at right in Fig. 3. By this configuration, the operators can maintain higher or stable booking orders for ships on the route throughout the year. This is the typical heterogeneous port network, as shown in the lower part of Fig. 1.

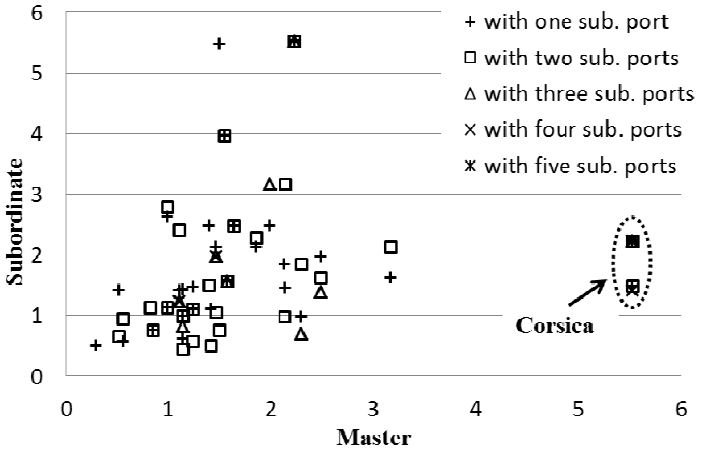

Fig. 5 Relation between master port and subordinate port on number of tourists per inhabitant.
Source: Refs. [8-14].

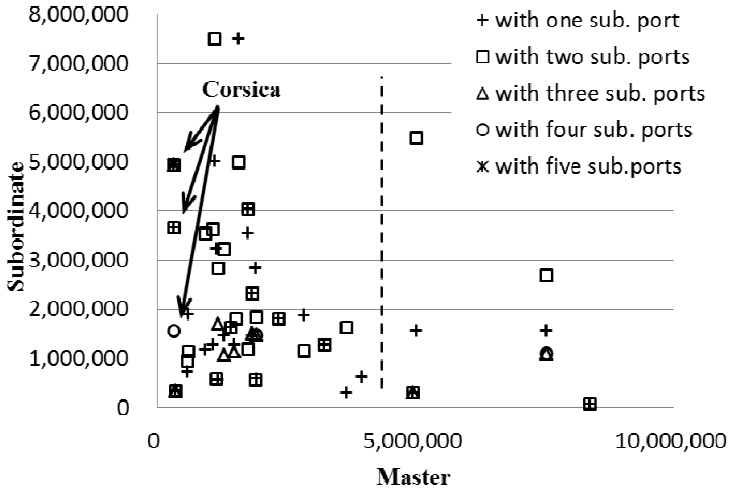

Fig. 6 Relation between master port and subordinate port on population.
Source: Refs. [8-14].

Fig. 7 Geographical proximities of Okinawa to China, Taiwan and Japan.
Source: All China Info [16].

5. Possible One-to-More Port Networks of Short Sea Shipping between China and Japan

5.1 Similarity between Okinawa in Japan and Corsica in the Mediterranean

Okinawa in Japan, located near the southwestern border of the country, can satisfy similar conditions to those of Corsica as presented below:

- Isolated island in the ocean;
- Surrounded by economically active countries nearby: China, Taiwan, and Japan;
- Valuable tourism resources exist on the island, which has various marine flora and fauna because of coral reefs near the island.

Fig. 7 presents the geographical proximities of Okinawa to the three countries.

5.2 Verification on Benefits of Okinawa for Master Ports

As the master port, Corsica is located intermediate between France and Italy (Fig. 3) with seven subordinate ports as shown in Table 5. To find the relation between Corsica with the capitals of the nearby countries, a comparison of the number of tourists per inhabitant, population and GDP between Corsica, Paris, and Rome is shown in Fig. 8. Results show that Corsica has numerous tourists per inhabitant but less population and GDP than either Paris or Rome.

To verify the advantage of Okinawa to have master ports on the one-to-more port networks of short sea shipping, the numbers of tourists per inhabitant, population and GDP were compared between Okinawa, Tokyo, and Taipei, as shown in Fig. 9.

It is readily apparent that Okinawa has great potential for tourism despite its lower population and GDP. For Okinawa, it has the same tendency as that of Corsica in terms of the number of tourists per inhabitant, the population and GDP comparing with the capitals. Therefore, Okinawa might benefit both from pure logistics among the three countries and from tourism from the three countries to the island, as the heterogeneous port network as shown in the lower

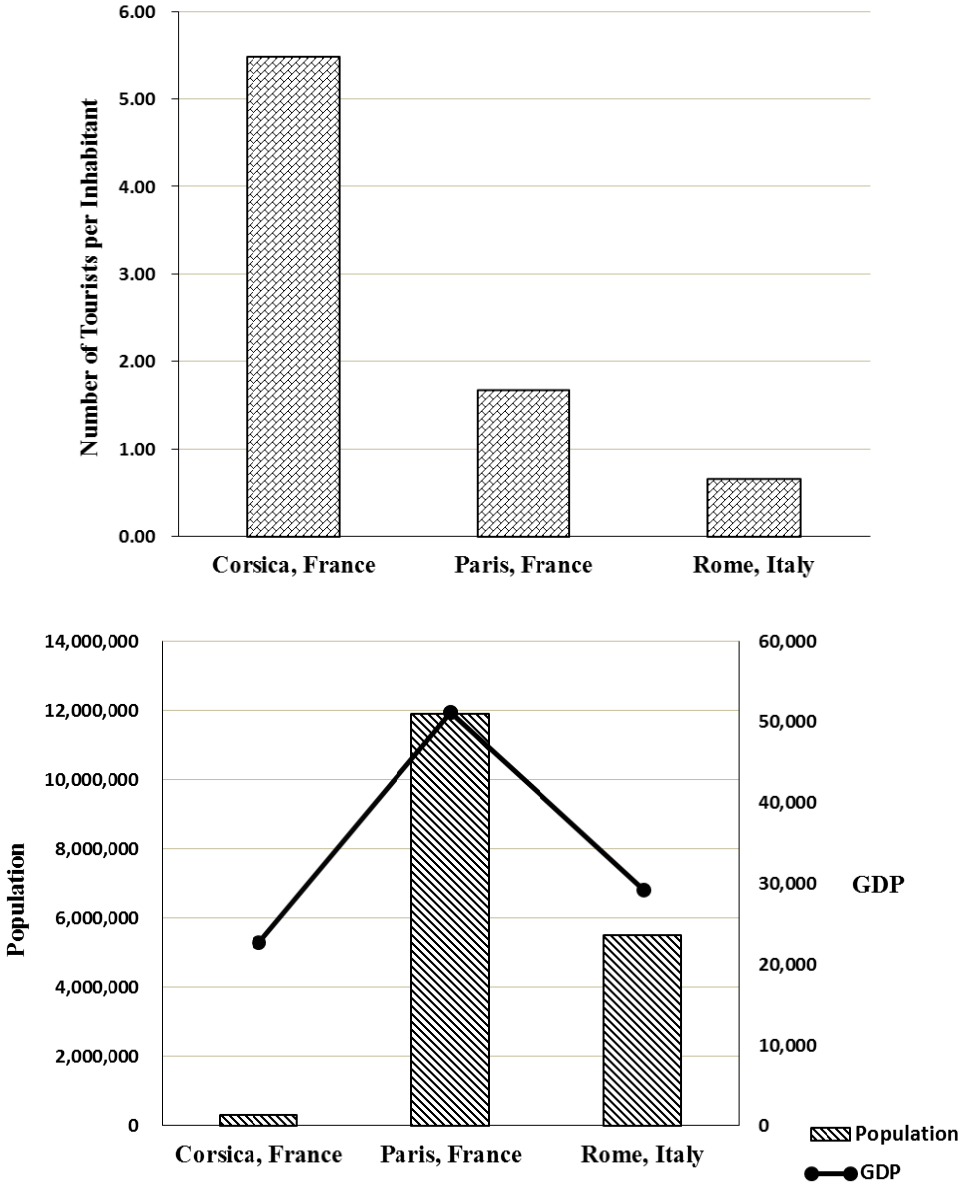

Fig. 8 Comparison of the number of tourists per inhabitant, population and GDP between Corsica, Paris, and Rome.
Source: Refs. [11-14].

part of Fig. 1.

5.3 Possible Expansion of Short Sea Shipping from Okinawa to China

A domestic short sea shipping network has been operated by a Japanese operator for decades, connecting Okinawa with Tokyo and other economically developed regions throughout Japan. It was fortunate and good timing that the operator opened a new international short sea shipping route between Taiwan and Okinawa in June 2015: Ryukyu Kaiunkaisha [15]. This fact supports the results presented in the paper cited above. Furthermore, the new route of the operator is expected to be expanded southward to eastern coastal regions of China from Taiwan because of the results presented in this paper, as shown in Fig. 10.

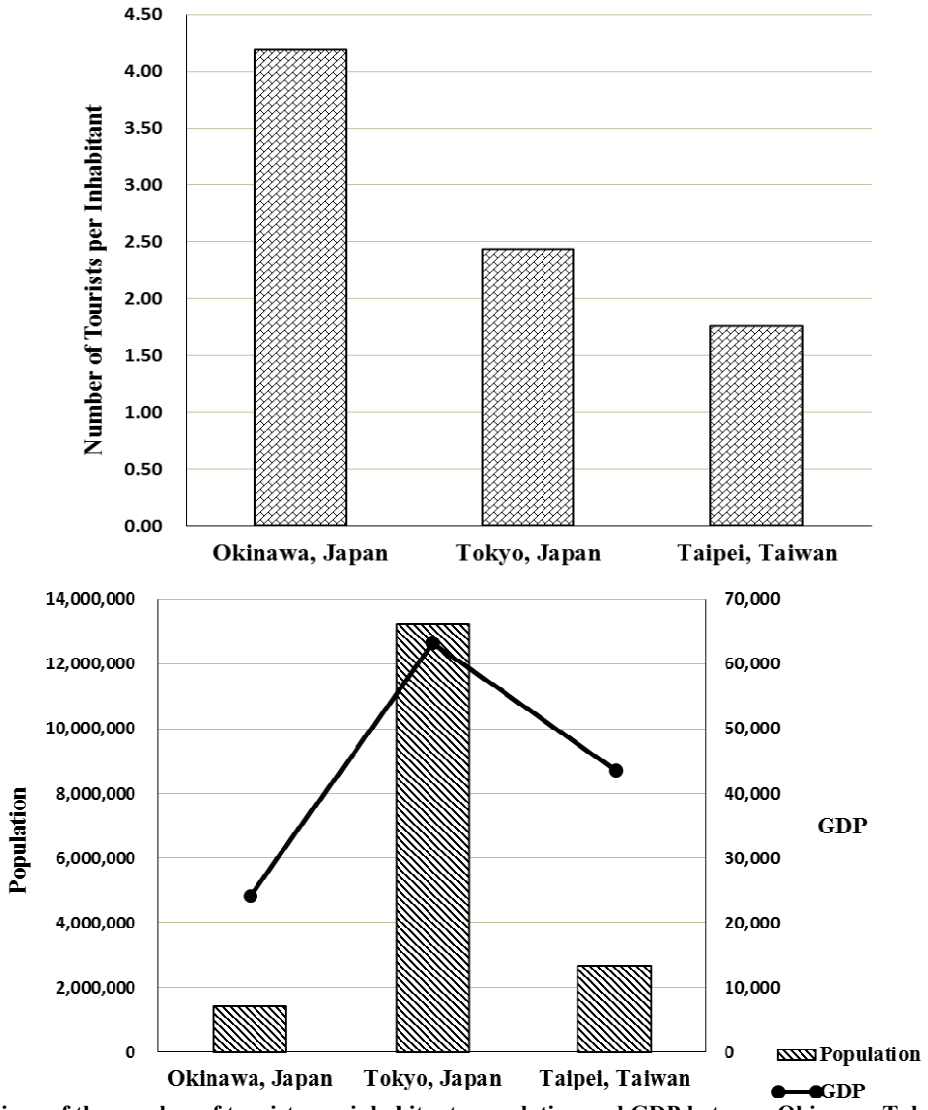

Fig. 9 Comparison of the number of tourists per inhabitant, population and GDP between Okinawa, Tokyo, and Taipei.
Source: Refs. [17-25].

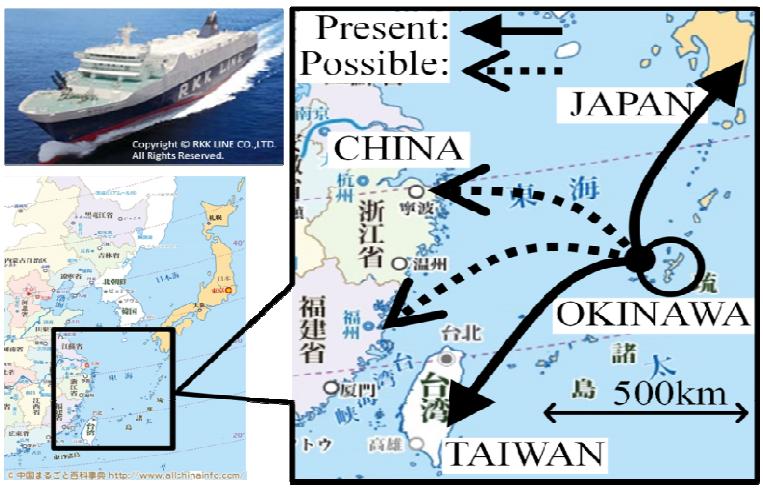

Fig. 10 Possible expansion of short sea shipping from Okinawa to China.
Source: Refs. [15, 16].

6. Conclusions

Results of this study demonstrate that Okinawa can expand short sea shipping networks to China as a master port on the networks because of its similarity to Corsica in the Mediterranean. Corsica has benefited greatly from short sea shipping for many decades. Because of new short sea shipping routes opened between Taiwan and Okinawa this year, the conclusions presented herein are expected to contribute to mutual understanding between China and Japan of the importance and benefits of short sea shipping in the near future.

This paper mainly presents a macro-scale view to explain an exploration of the possibility of short sea shipping networks between China and Japan. For further research, the authors expect to examine microscale issues for comparison with macro-scale aspects to elucidate aspects such as regional matters, environmental factors, trade patterns, historical background.

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