The polarization of global container flows by interoceanic canals: geographic coverage and network vulnerability

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Abstract

It is widely acknowledged that the two major interoceanic canals of Suez and Panama play a central role in global shipping flows. However, this role has rarely been measured with precision both in terms of the geographic coverage and network topological properties of canal-dependent flows. Based on vessel movement data for containerships, this research clarifies the weight and share of canal-dependent flows globally and at the level of world regions, routes, and ports. It also estimates and maps the effects of removing canal-dependent flows from the network by means of graph-theoretical methods. While main results converge in showing a decreasing importance of canal shipping in the context of growing south-south trade exchanges, certain areas remain more dependent than others, such as Asia, Europe, and North America.

Keywords: container shipping; maritime transport, networks, ports, vulnerability

1. Introduction

The main goal of the two interoceanic canals has been to avoid a deviation from the main trading routes connecting the principal economic centers of the world economy, namely Europe, Asia, and North America. It is estimated that Suez and Panama canals together concentrate about 15% of world seaborne trade, thus giving them high strategic importance. Thus, those two canals are considered being critical infrastructures raising issues of transport security (Salter, 2007), notably since many studies have investigated the economic potential of alternative routes due to congestion, cost, time, and piracy problems around the transoceanic canals (Verny and Grigentin, 2009; Fu et al., 2010; Liu and Kronbak, 2010; Notteboom, 2012).

However, rare studies have gone deeper into the measurement and implications of such vulnerability for canals, ports, and shipping networks. For instance, Berle et al. (2011) as well as Angeloudis et al. (2007) provide a rich discussion on the failure modes in the maritime transportation system but without providing empirical evidence about the precise role of canals. Throughout the research field of network vulnerability and critical infrastructures, more likely are studies of the worldwide energy supply including some maritime elements (Rodrigue, 2004; Zavitsas and Bell, 2011), the Internet network (Grubesic et al., 2008), the airline transport network (Derudder et al., 2007), and road networks (Jenelius et al., 2008). One first attempt to measure the centrality of interoceanic canals in the global maritime network was performed by Kaluza et al. (2010) as well as Ducruet and Notteboom (2012a) in their analysis of worldwide maritime container flows, thus implicitly claiming the overall vulnerability of the network. Other works on maritime networks have eluded vulnerability issues except the one of Guerrero et al. (2008) on supply chain disruption and vessel rerouting and the one of Ducruet et al. (2010) on hub dependence as a measure of vulnerability for ports. Instead, other works on liner shipping networks focus on the overall topological structure of flows (Deng et al., 2009; Hu and Zhu, 2009), the interdependence with airline networks (Parshani et al., 2010), or the geographic coverage of ocean carriers such as Maersk (Frémont, 2007).

The main goal of this chapter is to offer novel empirical evidence about the respective and combined influences of interoceanic canals in global maritime flows. It takes its inspiration from a wide array of methods and applications in network analysis in general. Its ambition is to measure and map the vulnerability of the global maritime network in relation to interoceanic canals at various geographic levels, from individual nodes to global sea routes. The case of container flows is explored through exploiting a global database of vessel movements in 1996 and 2006. After introducing the data and overall methodology, one first section describes the geographic coverage of the canals' influence on global vessel circulations and an estimation of their traffic weight in total container flows. The second section further discusses the topological importance of the canals and its evolution with regard to optimal network configurations and flow structures. A discussion about the local and global implications of the results is provided in the last section to conclude the chapter and identify further research pathways.

2. Data and methodology

Daily vessel movements are reported by Lloyd's List on a regular basis. Extracting all movements of fully cellular container vessels in 1996 and 2006 allowed to build a port-to-port matrix including both Suez and Panama canals as well as all ports connected by those vessel calls. The resulting network is weighted by the sum of vessel capacities in TEUs (Twenty-Foot Equivalent Units) passing through links and nodes during one year of movements, while it is kept undirected for simplicity. The analysis distinguishes between two dimensions of the network: the adjacency matrix of chains and the adjacency matrix of complete graphs. In the matrix of chains, ports are considered connected when a vessels performs a direct call between them during its circulation. In that configuration, the matrix is only made of adjacent calls between ports. In the matrix of complete graphs, all ports connected by one same vessel are considered connected with each other. It thus corresponds to the matrix of chains plus all indirect calls between ports. Those two dimensions exhibit rather distinct topological properties in terms of network density and size (Ducruet and Notteboom, 2012a).

One first method has been to identify the trajectory of vessels passing through each and/or both canals defined by their full voyage within each year of observation. The analysis of freight circulations through trajectories rather than segments provides better results as it catches the overall patterns of moving objects (Guo et al., 2010). Such an approach allows for considering the geographic coverage of canal-dependent shipping and its weight regarding world shipping in general. The share of canal-dependent traffic can be calculated at every port, range, and continent. The method can be applied to total traffic but also to intra and interregional traffic. Two drawbacks of the data and methodology should be underlined, however. First, in some cases vessel movement data does not fully inform about the true origin and destination of containers. Because many containers are transshipped at intermediate hub ports, it is impossible to track each of them being embarked from one vessel to the other. Vessel movement data is thus not trade data. Yet, all flows not passing through intermediate hub ports still overlap to a large extent trading routes, while transit flows better reflect upon logistics systems and carrier decisions in designing their networks. Great care must be inferred in interpreting the geographic coverage of canal-dependent traffics since a significant share is transiting through hub ports at certain regions. Second, the same vessel and its capacity in TEUs are counted as many times as the number of its calls during the period considered. Depending on the case, this might overestimate the traffic intensity of some links at the expense of others, such as in the case of multiple calls within certain port ranges. The true number of containers handled at each port is also not known from the data, as some port calls may only relate with bunkering, but this is impossible to verify.

Secondly, we measure the vulnerability of the network through two complementary approaches. On the one hand, average eccentricity and average transitivity are calculated on the level of the entire network before and after removing canals and canal-related circulations. Such measures indicate how much do canals influence the overall farness and connectedness of the network. We distinguished between links having more than 50% of their traffic being canal-related and all the links carrying canal-related traffics. This allows for comparing differences in link removal since some inter-port links carry both canal-related and other traffics. Eccentricity is a common measure of geodesic distance in graph theory and can be labeled Koenig number, Shimbel distance, and closeness centrality in the literature (Ducruet and Rodrigue, 2012). It corresponds for each node to the number of links needed to reach the most distant node in the network. Averaging all local measures provides one single measure at network level ranging from 0 (nodes are distant to each other) to 1 (nodes are close to each other). Average eccentricity has been used in network vulnerability studies to measure the global impact of node or link removal (Shimbel, 1953; Gleyze, 2005). Transitivity is a measure of connectedness proposed by social network analysis (Wasserman and Faust, 1994) and labeled clustering coefficient in the literature on complex networks. It corresponds to the probability that the adjacent neighbors of a given node are also connected to each other: the number of existing triangles (or triplets) is divided by the number of possible triangles (or triplets), thus ranging from 0 (no triangles) to 1 (all triangles). Low values often correspond to nodes having dominant functions while its adjacent neighbors are poorly connected (cf. hub-and-spoke pattern) while high values depict tightly connected and more homogenous patterns. With reference to studies of cascading failures in networks, we also compare the effects of canal removal on the centrality of individual ports (Albert et al., 2004; Gorman et al., 2004; Wang and Rong, 2009).

On the other hand, the optimal or maximum capacity route is extracted from the original network using the minimum spanning tree algorithm proposed by Kruskal (1956). The latter method belongs to a family of studies on the search for the optimal or shortest path on the level of the entire network (see also Roy, 1959; Warshall, 1962; Floyd, 1962; Johnson, 1977) and/or for a given node or link in the network (Bellman, 1958; Dijkstra, 1959; Ford and Fulkerson, 1962). The Kruskal algorithm is chosen for its simplicity and due to the fact that it remains a widely accepted reference in graph theory. We apply the algorithm to the inverse of traffic weight (TEUs) by link in order to extract the maximal weight spanning tree, i.e. the optimal route connecting all ports and carrying the maximum traffic volume. Based on this simplification of the network, we measure for each node its Strähler stream order (i.e. level of ramification) to reveal the branching property of ports and canals in the optimal route, as well as their degree centrality (i.e. number of adjacent neighbors). The Strähler index is well adapted to tree-like networks and has been used extensively in the case of river networks (see Haggett and Chorley, 1969; Taaffe and Gauthier, 1973).

3. Geographic coverage of canal-dependent flows

On a world level, the share of canal-dependent flows in total container flows was calculated on the basis of direct and indirect vessel calls between ports (Table 1). Results first confirm the high share of canal-dependent flows at both years (i.e. over 40%) which stands much higher than available estimations for all commodity traffics. However, this combined share has noticeably dropped between 1996 and 2006 from 44.2% to 40.7%. This reduction stems from several factors such as the emergence of alternative routes (e.g. Cape of Good Hope) as a response to vessel size limitations and passage costs. The combined share of the two canals is slightly lower than the sum of their individual importance since some vessels have used both canals during their line-bundling and round-the-world services (Ducruet and Notteboom, 2012b). This confirms that true round-the-world services occupy a very limited portion of global container flows (i.e. 6.8% in 1996 and 3.4% in 2006) since most liner services occur through pendulum routes between two main poles (Frémont, 2007). Yet, the combined share of the two canals in total interregional traffics has remained stable around 64%. The drop is thus mostly explained by a reduction of canal's weight in intraregional flows. The main explanation relates with the reinforced concentration of flows within certain regions around intermediate hub ports ensuring either (or both) interlining and hub-feeder functions (Rodrigue and Notteboom, 2010). This means that vessels using the canals have tended to limit the number of calls within regions, notably large vessels selecting a few dominant hub ports along the route. Another result is the higher share of Suez compared with Panama in all aspects, since the Europe-Asia route accounts for the majority of world container flows (27.7 million TEUs in 2007), followed by the Asia-USA route (20.3 million TEUs) and the Europe-USA route (7.2 million TEUs) (*Containerisation International*). The relative drop is felt relatively equally at the two canals except for interregional traffics where the share of Panama Canal has decreased more than for Suez Canal. This also is in accordance with the higher technical limitations of the Panama Canal in terms of vessel size, but it is not compensated by an increase of its intraregional function.

[Insert Table 1 about here]

Another approach is to measure the weight of canal-dependent flows by geographic entity at the world region level and port level. Among world regions (Figure 1), the largest economic poles of the world are the most dependent upon the canals, but this dependence varies according to the level of flows (intra or interregional) and to the canal considered. At both years, North America is the most canal-dependent region and this has increased from 55% to 58% during the period for all flows. It is followed by Europe but its canal-dependence has slightly dropped from 51% to 49%. Asia and Latin America exhibit similar dependence levels and their respective share has also dropped from 42% to 36%. While Africa's dependence remains stable at the lowest level (20%), Oceania has witnessed the highest increase from 17% in 1996 to 29% in 2006. A complementary picture is obtained when distinguishing between interregional and intraregional flows. In fact, Europe and Asia are the most canal-dependent regions since about 75% of their external traffic relies on the canals, and this share has remained stable between 1996 and 2006. Their overall drop in canal-dependence thus better reflects the decrease of intraregional canal-related flows for the aforementioned reasons (i.e. growth of transshipment at intermediate hub ports, such as in the Mediterranean and South East Asian ranges). In comparison, North America's canal-dependence is lower externally and higher internally (inter-coastal flows), but both shares have increased significantly reaching 59% of interregional flows and 54% of intraregional flows in 2006. The growing dependence upon canals (here Panama) might be explained by congestion issues at West Coast ports making land bridge connections less beneficial to shippers than canal shipping (Hall, 2004). Latin America has a lower canal-dependence than North America but both interregional (-3%) and intraregional (-8%) canal-dependence have lowered, which indicates a diversification of its connections.

The distribution of canal-dependent flows among major shipping routes underlines, unsurprisingly, the chief role of Suez Canal for Europe-Asia traffics (95%), the rest being shipped via the Cape route. It is the largest and most canal-dependent traffic segment. The Europe-Oceania route also mostly passes through Suez, although one-third of those traffics use Panama Canal instead.

[Insert Figure 1 about here]

The analysis at port level allows for a clearer observation of traffic impacts (Figure 2). The combined traffic of the two canals is distributed along the circumterrestrial route linking the three main economic poles. A noticeable number of ports appears to be highly vulnerable in the pattern of flows since a dominant share of their traffic is explained by the canals. The distribution of vulnerability rests upon a subtle combination of distance and scale: on the one hand proximity to the canals foster related traffics, and on the other, larger hubs and gateways, often despite distance to the canals, generate high volumes and shares of canal-related traffic. In general, Asian ports appear to be less dependent on canals than their European and North American counterparts, probably due to higher levels of intra-regional traffics. The vulnerability is thus much localized in certain areas: the U.S. Northeastern seaboard (Panama traffic) and a number of West European ports (Suez traffic) such as Southampton and Gioia Tauro at both years. The Panama Canal that is often seen as a key node for Asia-North America trades has in fact a relatively low importance for Asian ports. The share of Suez traffics at Asian ports has notably decreased for Singapore and a number of Northeast Asian ports. Thus, there is a combination of liner service reconfiguration and trade reorientation in the changing geographic coverage of canal traffics. The appendix 1 provides a list of the top 30 ports based on canal-dependent traffics for a more detailed view.

[Insert Figure 2 about here]

4. Topological impacts of interoceanic canals

4.1 Canal removal and cascading failures

Average eccentricity and transitivity were calculated at both years on the level of the entire network before and after removing partly and fully each or both canal's related circulations, while also comparing effects for the two dimensions, chains and complete graphs (Table 3). In the matrix of chains, results in 1996 confirm the crucial role of canals in bringing world ports closer, as eccentricity decreases after removals compared with the original value (0.765). The combined effects of the two canals is not clearly visible since it is equal to Suez deletion impacts (for largest flows) and inferior than Suez deletion impacts (for all flows). The largest difference in eccentricity is observed for the Suez Canal (0.674) whereas removing Panama Canal's links and flows does not much influence the network's structure. This confirms previous results where the geographic coverage of Panama Canal's flows remained much narrower than the one of the Suez Canal. In 2006, the original eccentricity is significantly lower than in 1996 (0.644), which in itself indicates a dramatic increase in the size and geographic coverage of the liner shipping network (Ducruet and Notteboom, 2012a), thus making ports relatively more distant from each other than previously. One notable difference with 1996 is that removing canal-related circulations, either individually or in combination, increase the eccentricity thus making ports closer to each other. This counterintuitive result can be explained by crucial trends occurring along the period. In 1996, remote regions remain poorly connected so that the role of the canals is central and few bypasses do exist. The progression of South-South flows within the southern hemisphere, namely between Latin America, Africa, and Asia-Pacific as well as the relatively stagnant share of the canals in total flows (from 50 to 56%) have resulted in a less sparse network. Removing canal-related circulations thus reveal the strength of those new transversal linkages among world economies. This is why the Suez Canal has the highest impact on making ports closer: Asia and Europe are closer outside the Suez canal when considering the expanding links between Asia, Africa, and Latin America, the two latter being still well connected with Europe. The role of canals in an era of growing South-South trades appears more as a bottleneck than a facilitator of exchanges.

In the matrix of complete graphs, the impact of canal removal is similar to the latter dimension. Transitivity increases as more canal-dependent circulations are removed, while the impact is stronger for Suez Canal and combined canals. Like in the case of chains, impacts are bigger in 2006 than in 1996 due to the increasing centralization of the network around hub ports. Eccentricity always increases along with canal removal, due to the fact that complete graphs allow for the existence of many alternative paths outside the canal nodes. Thus, removing canal-dependent circulations brings ports closer to each other rather than dismantling the network's structure.

[Insert Table 3 about here]

In terms of transitivity, one same trend is observed in 1996 and 2006 that is the increasing polarization of the network after removing canal-related circulations. A complementary result is provided in Figure 3 where we map the centrality of ports before and after canal removal. The whole network of direct links (left side) heavily depends on two central nodes (interoceanic canals) being the connectors between an Euromediterranean-Atlantic group and an Asia-Pacific group. Each group at both years is polarized by a few ports. Rotterdam and

Singapore are the most central ports of their belonged group, followed by Antwerp, Hamburg, Hong Kong, and Busan respectively. In 2006, Bremerhaven and Shanghai emerge as complementary hubs. The removal of all canal-related circulations, since it does not disconnect the global network, confers a very high centrality to other intermediate nodes. Those are South African ports in 1996 (Durban, Cape Town) and Brazilian ports in 2006 (Santos, Sepetiba). Removing canal-related circulations had the effect of increasing the centrality of established ports within their belonged group, notably Singapore and Rotterdam. In parallel, the multiplication of transshipment ports and hub-and-spoke strategies serving liner shipping operations contributed to this phenomenon. This also explains why the impact of canal removal has been much bigger in 2006 than in 1996 despite comparable transitivity levels in the original network. In addition, the combined removal had stronger impacts than individual removals.

[Insert Figure 3 about here]

4.2 Optimal routes and ramification

After extracting the optimal route from the original matrix, we map the centrality and ramification level of ports and canals using a Gem-Frick visualization algorithm (Figure 4). The design of the optimal route confirms the existence of two large subsystems or sub-trees each polarized by Rotterdam and Singapore, which have the largest number of adjacent neighbours (degree) and a high level of ramification (Strähler). In 1996, the Suez Canal has the highest ramification level as it stands, together with Djibouti, Reunion, and Aden at the source of the global tree. The gravity centre of the global maritime system is thus clearly around the Suez Canal but it has shifted to other locations in 2006. Singapore as well as a number of Latin American ports (i.e. Vitoria, Santos, Paranagua, Port of Spain, Kingston, etc.) took over Suez Canal at the source of the optimal route. This corroborates previous results since Asian traffics have increasingly penetrated the Atlantic through direct calls bypassing the Suez Canal, i.e. around the Cape of Good Hope. Many African ports have shifted under Asian influence due to the fast development of Asian Foreign Direct Investment (FDI) in Africa (Chaponnière, 2010). Asian terminal operators have also multiplied terminal concessions in many African ports such as in the Maghreb (Mohammed-Chérif and Ducruet, 2011) and West African ranges (Debrie, 2012) during that period. Emerging economies such as Brazil have generated increasing volumes of flows linking not only Asia but also traditional partners such as Europe and the U.S. (see also Guy, 2003), thus becoming a new gravity centre for global shipping. Notably, the interlining function of Algeciras that appeared clearly in 1996 for connecting East-West and North-South flows considerably reduced in 2006 since Durban in South Africa appears as a new relay hub between West Africa and Asia. Overall, we observe a significant shrink of Rotterdam's influence in the network as an effect of the aforementioned factors. The sub-network including New York, Houston, Casablanca, and a number of Atlantic European ports is in 2006 connected to Hong Kong via Itajai, a Brazilian port. Although the method has removed many links that connect ports in more complex ways, the resulting pattern is by no means revelatory of profound changes in network configurations.

[Insert Figure 4 about here]

The same method applied to the matrix of complete graphs provides complementary results although many indirect and long-distance links between ports would not have existed without canals, such as Rotterdam-Tokyo. Due to the existence of many alternatives in this dimension of the network, canals appear to have a relatively minor role at both years on the optimal route. Interesting configurations and evolutions are, nevertheless, observable. In 1996, European ports are clearly dominant in terms of both centrality and ramification levels, together with Asian ports that appear more to the fringe of the figure. In 2006, it is the opposite: Asian ports dominate the optimal route while European (and other) ports are relegated to the semi-periphery.

Conclusion

The application of several network analytical methods to the global matrix of inter-port vessel movements provides many clues about the changing role of canals and ports in liner shipping flows. As such, it informs us better about the way shipping networks both reflect and shape the world economy and its components (Ullman, 1949; Vigarié, 1968). As a complement to studies of network vulnerability, this research provides several evidences about the distribution of canal-related flows and their wider significance for ports and shipping. After providing a novel estimation of the importance of canal traffic in global container flows, the research revealed the uneven geographic coverage of the canal's influence at different levels of analysis. While canal traffic concentrates at the vicinity of those major infrastructures, it reveals the higher vulnerability of the "old Atlantic world" compared with emerging countries such as in the Asia-Pacific and South Atlantic regions. Canal's role in global shipping has thus shrunk during the period under study (1996-2006) as an effect of growing South-South trades and Asia's expansion across the Cape of Good Hope. Former structures, such as Rotterdam's prominence as the main hub of Europe-Atlantic networks, are thus currently losing grounds, since Latin American ports play a new role in network interlining. Yet, there is a permanency of a bipolarization of the world organized by Singapore and Rotterdam, which remain the main pivotal nodes. Drastic changes are better felt for smaller ports such as Algeciras which interlining function has declined. Further research shall test the continuity of such trends by applying these methods to other commodity types (e.g. bulks, general cargo) and to more recent data, as a means taking into account, too, the likely impacts of the 2008 financial global crisis on network configurations. Untangling the respective influence of carrier decisions and territorial factors will remain a difficult challenge to tackle.

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Table 1: Importance of canal-dependent flows in global container flows (% TEUs)

	Panama Canal		Suez Canal		Panama & Suez	
	1996	2006	1996	2006	1996	2006
Total traffic	17.0	13.3	34.0	30.8	44.2	40.7
Intraregional traffic	10.7	8.0	24.6	21.8	31.8	27.8
Interregional traffic	26.8	23.1	48.8	47.6	63.7	64.4

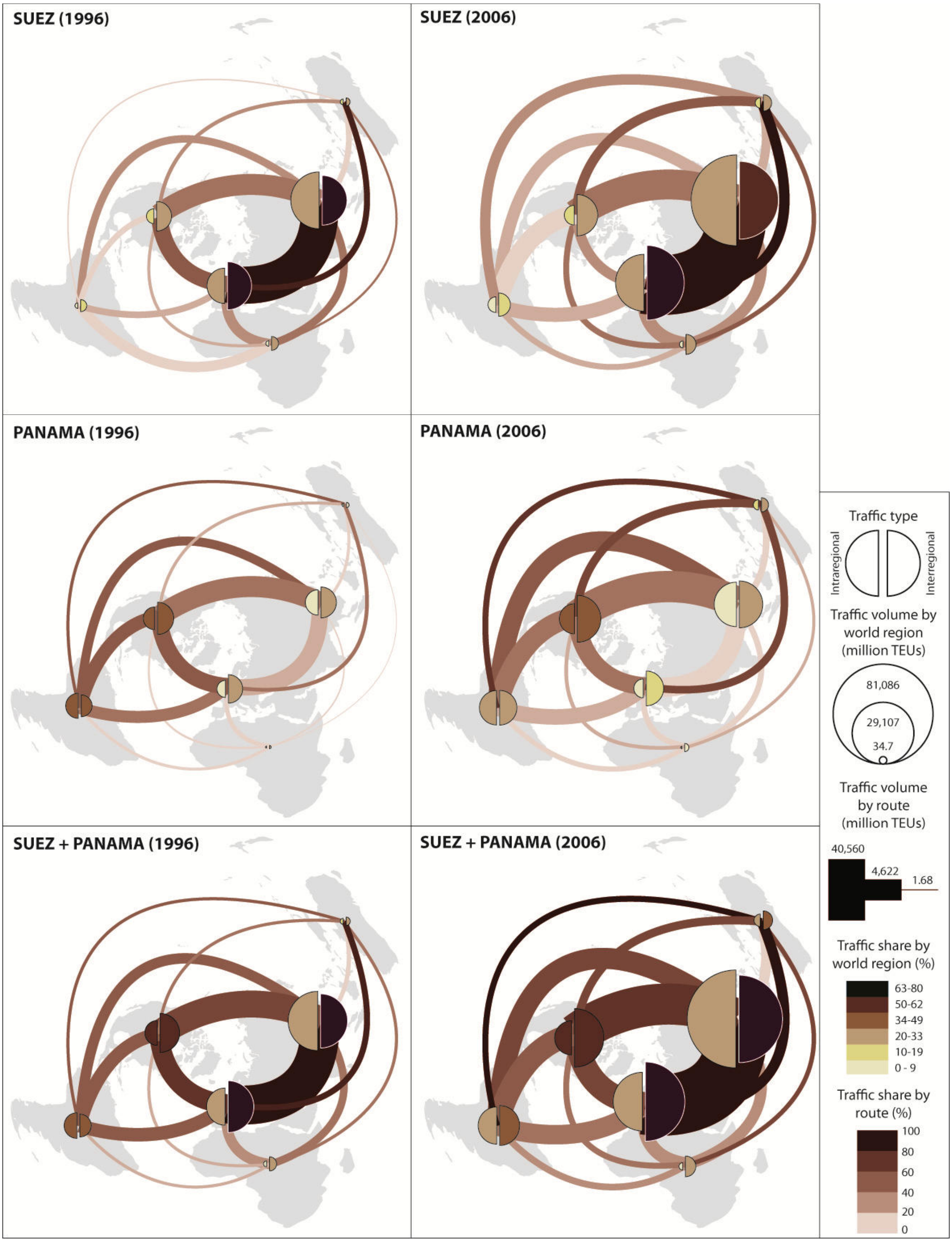
Source: own calculation based on Lloyd's List

Table 2: Topological effects of removing interoceanic canals in 1996 and 2006

		Matrix of chains				Matrix of complete graphs			
		Eccentricity		Transitivity		Eccentricity		Transitivity	
		1996	2006	1996	2006	1996	2006	1996	2006
Original network		0.765	0.644	0.527	0.517	0.623	0.628	0.747	0.737
Without links > 50% canal-related traffic	Panama	0.762	0.666	0.489	0.492	0.728	0.629	0.723	0.714
	Suez	0.698	0.742	0.444	0.476	0.730	0.635	0.683	0.684
	Both	0.698	0.739	0.417	0.436	0.734	0.723	0.465	0.453
Without all canal-related links	Panama	0.749	0.707	0.451	0.394	0.733	0.762	0.638	0.598
	Suez	0.674	0.731	0.399	0.413	0.726	0.762	0.571	0.550
	Both	0.688	0.720	0.349	0.267	0.767	0.803	0.375	0.345

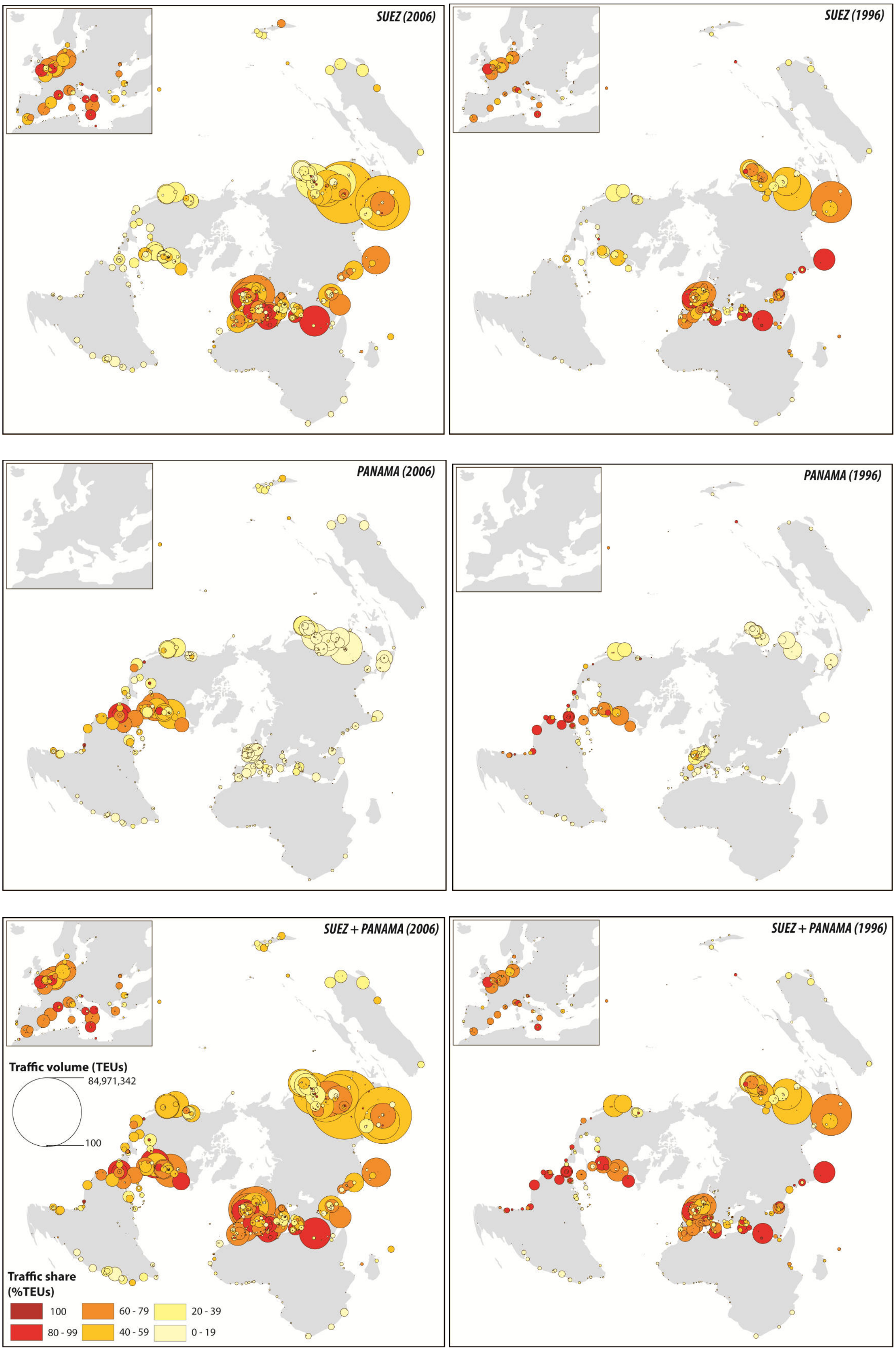
Source: own calculation based on Lloyd's List data and TULIP software

Figure 1: Canal-dependent traffic by route and region in 1996 and 2006



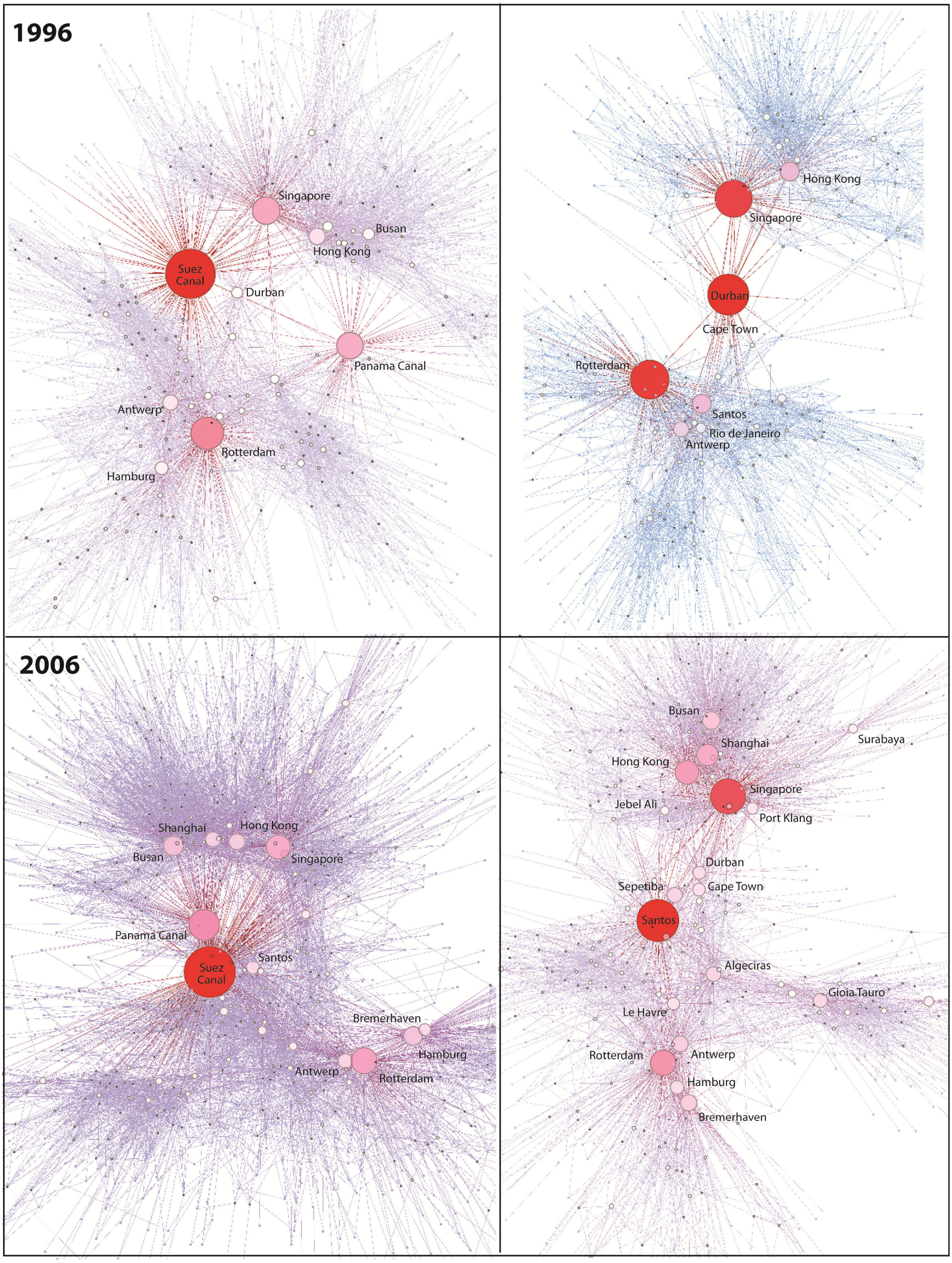
Source: own elaboration based on Lloyd's List data

Figure 2: Canal-dependent traffic at world ports in 1996 and 2006



Source: own elaboration based on Lloyd's List data

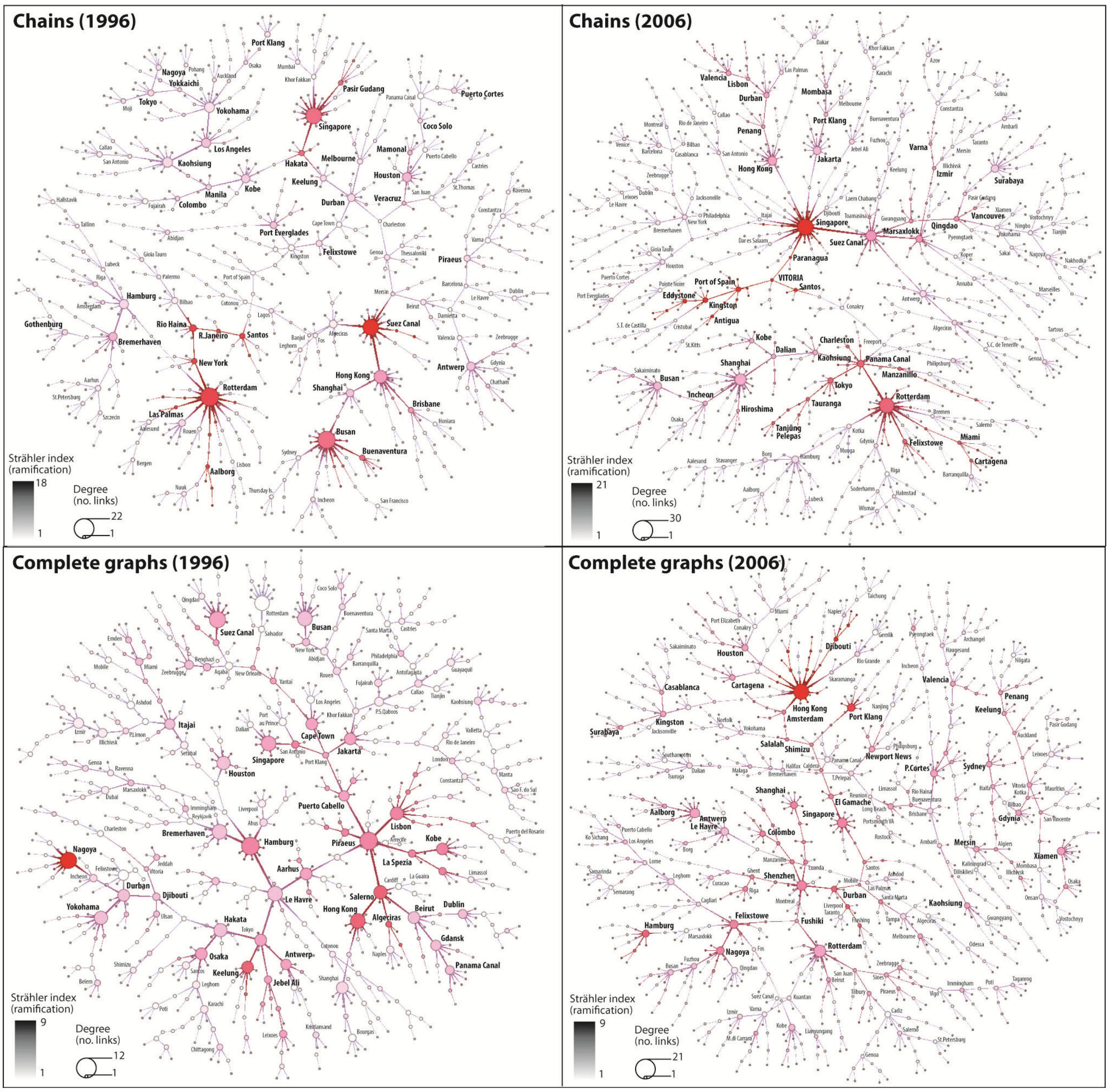
Figure 3: Visualization of canal centrality and impacts in 1996 and 2006



N.B. left figures show the whole network; right figures show the network without canals and their related links

Source: own elaboration based on Lloyd's List data and TULIP software

Figure 4: Situation of ports and canals on the optimal traffic route in 1996 and 2006



Source: own elaboration based on Lloyd's List data and TULIP software

Appendix 1: Canal-dependent traffics at largest ports of the world in 1996 and 2006

1996				2006			
Port	P+S	PAN	SUEZ	Port	P+S	PAN	SUEZ
Singapore	57.9	6.8	57.4	Hong Kong	56.3	15.1	45.6
Hong Kong	52.5	11.9	47.4	Suez Canal	100.0	7.0	100.0
Suez Canal	100.0	9.9	100.0	Panama Canal	100.0	100.0	19.3
Panama Canal	100.0	100.0	31.0	Singapore	49.0	4.2	47.8
Kaohsiung	53.6	17.4	45.3	Shenzhen	72.0	21.2	56.3
Rotterdam	67.9	17.7	60.7	Busan	47.5	20.8	32.1
Los Angeles	54.3	41.9	31.5	Shanghai	53.5	18.8	40.8
Hamburg	75.7	17.6	71.8	Kaohsiung	49.8	14.5	37.7
Busan	53.7	20.1	45.4	Rotterdam	74.1	11.4	66.8
Le Havre	74.2	26.2	67.3	Ningbo	64.3	15.7	55.0
Colombo	87.1	18.9	87.1	Hamburg	76.4	6.9	73.6
Kobe	37.8	14.3	25.5	Port Klang	50.7	7.8	50.1
Tokyo	47.1	17.5	38.8	New York	76.8	58.9	28.8
Jeddah	98.3	4.3	98.3	Savannah	92.9	86.1	27.3
Felixstowe	65.9	20.6	56.6	Jeddah	89.8	5.7	89.5
New York	76.3	63.3	38.0	Manzanillo(PAN)	94.0	94.0	14.6
Yokohama	33.4	14.7	20.7	Tokyo	45.7	24.8	23.7
Nagoya	38.3	13.2	30.2	Colombo	67.1	9.3	66.6
Antwerp	63.3	25.8	54.9	Qingdao	57.6	15.1	46.0
Osaka	49.5	24.0	39.3	Xiamen	57.9	7.8	54.3
San Francisco	44.2	29.9	26.1	Oakland	51.9	28.6	26.8
Southampton	96.6	2.3	96.5	Yokohama	37.0	22.9	16.6
Port Klang	45.6	5.3	45.6	Felixstowe	68.4	6.8	65.7
Bremerhaven	57.1	32.1	40.6	Kobe	43.0	23.0	22.0
Manzanillo(PAN)	95.4	95.4	13.5	Jebel Ali	52.2	4.6	51.6
Keelung	26.9	10.3	21.9	Los Angeles	54.2	28.5	32.0
Savannah	92.8	89.3	28.3	Tanjung Pelepas	77.0	8.0	74.6
Charleston	64.4	46.7	35.3	Long Beach	53.2	27.1	30.8
Cristobal	95.1	95.1	61.9	Charleston	64.0	50.7	24.7
Shimizu	61.6	12.2	61.3	Bremerhaven	61.0	18.6	46.6
Barcelona	65.0	18.8	49.0	Nagoya	37.6	17.1	22.5
Buenaventura	90.4	88.4	3.1	Antwerp	59.2	14.1	47.4

Source: own elaboration based on Lloyd's List data

N.B. ports are ranked in decreasing order based on total canal-dependent traffic at each year