# Statistical properties and measures of countries liner shipping networks

**Daria Ulybina**

Math 442 Mathematics of Social Networks, Georgetown University, Washington, D.C.

## Abstract

The purpose of this paper to examine how shipping networks have evolved between 2006 and 2020; and to investigate the relationship between country network characteristics and its community structure. This study uses network analysis incorporating transportation research and social network approaches. In this study, network nodes (vertices) are the countries of ports-of-calls of liner shipping services, while network links (edges) are connections realized by liner shipping schedules. The network characteristics of ports are evaluated by distance metrics and centrality indices which can measure the relatively different importance of a node within a network: degree, closeness, betweenness, and eigenvector centralities. The study also examines the relationship between network characteristics and its community structures identified using Louvain algorithm.

## Introduction

Container shipping features a complex combination of end-to-end services, sequential, often bundled services, forming an extensive shipping network. On one hand, each port's position in the overall network is linked to the network design determined by service frequency, operator's availability, vessel capacity, fleet age and efficiency. On the other hand, ports role in the overall network can be analyzed from a position of global trade and demand for container boxes, freight rates, strength of political and cultural ties with trading partners, forming a higher-level, more aggregated network on a bilateral country-to-country levels.

## Dataset

The original data used in this paper is a modified version of the databank available from online scraping of liner shipping schedules. Specifically, it is structured in a bilateral manner where each row (record) represents a connection between Port 1 and Port 2 (nodes) at time t (quarterly frequency) with a variety of additional attributes summarizing the existing "connection" (edge). Example of those attributes include information about vessels characteristics (size or age), operators and services statistics, routes utilization and overall capacities operated on each route.

## Methodology

### Countries network construction

For this specific analysis I constructed a network of country connections whose edge weight is determined by the total deployed capacity between its ports (measured as sum of its twenty-foot equivalent units (TEU). The construction of a country network from ports bilateral connections resulted in the formation of self-loops. To clarify, the summation of shipping capacity over all ports for each country has led to the formation of two types of connection – internal connections with edges between ports that belongs to the same country; and external connections that consist of edges between ports associated with other countries. Globally and across years, there about 15 percent of all country capacity is deployed locally and this average percentage is characterized by remarkable stability across 14 years that were examined. My analysis excluded the value of self-loops from computations solemnly focusing on external connections between countries shipping lanes.

## Main findings and discussion

1. Remarkable stability and robustness of node-level central actors and their strategical positions across 14 years: China, Singapore, Korea, Malaysia, USA, UK, Hong Kong, Belgium, Spain, Netherlands
2. Louvain community detection algorithm identified clusters of countries broadly adherent to existing economic and geographical classifications: Western Hemisphere, Asia and Pacific, Europe and Middle-East (Fig 2.)
3. While diameter and centralities measure leadership remains stable across the years, other network measures exhibit systematic growths or declines unseen in port-to-port networks of liner shipping. The systemic growth of average shortest path lengths and decline in clustering coefficients can be explainer from theoretical SNA science perspective (decrease in the total number of edges) and linked to major structural changes in maritime transportation industry manifesting itself the formation of global shipping alliances.

## Visualizations

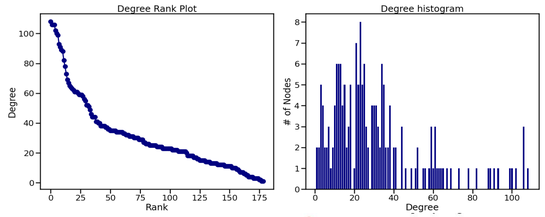


Figure 1. Degree rank plot and histogram of unscaled country-to-country liner shipping network displaying bimodality of degree distribution as well as properties if a small–world network. A) Degree rank plot. B) Degree histogram.

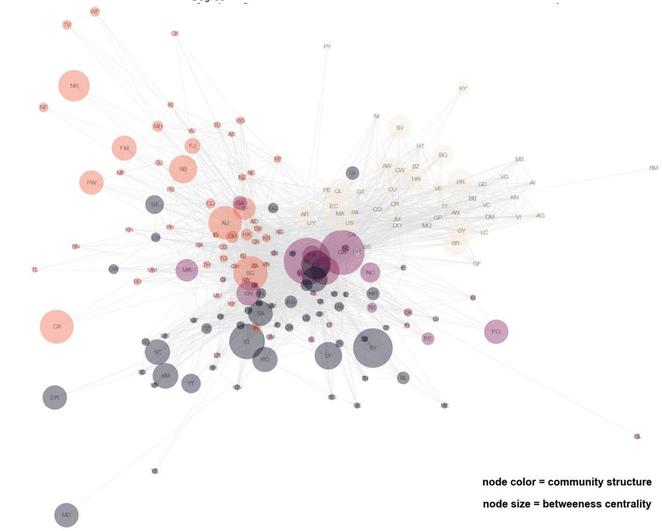


Figure 2. Betweenness centrality and Louvain community partitioning of countries in 2018 network .

## Conclusions

**Looking at liner shipping structure from the dynamic network perspective brings interesting and novel results. Beyond the traditional shipping network studies confining the nodes of shipping network to ports, my approach constructed the network with regards to countries as its nodes and connections between them as its edges, weighted by total trade capacity flowing between them. A comparative study of topological properties and key actors confirmed some existing research in the area as well as provided a novel perspective on long term statistical properties of network's distance-based measures.**

## References

1. Wills P, Meyer FG (2020) Metrics for graph comparison: A practitioner's guide. PLoS ONE 15(2): e0228728. https://doi.org/10.1371/journal.pone.0228728
2. Zhou M, Wu G, Xu HL (2016) Structure and formation of top networks in international trade, 2001–2010. Soc Networks 44:9–21
3. Wasserman S, Faust K (1994) Social network analysis: methods and applications. Cambridge University Press, New York
4. Notteboom T (2006a) The Time Factor in Liner Shipping Services, Maritime Economics and Logistics, 8, 19–39
5. Clark X, Dollar D, Micco A (2004) Port efficiency, maritime transport costs and bilateral trade. J Dev Econ 75(2):417–450
6. J. Saramäki, M. Kivelä, J.-P. Onnela, K. Kaski, and J. Kertész (2007) Generalizations of the clustering coefficient to weighted complex networks. Physical Review E, 75 027105 http://jponnela.com/web_documents/a9.pdf
7. Angeloudis P, Bichou K, Bell M, Fisk D (2006) Security and reliability of the liner container shipping network: Analysis of robustness using a complex network framework, presented to IAME 2006 conference, Melbourne