Mathematics Analysis of the Chinese Ship-container-transportation Networks Properties

Di CUI

Research Associate, China Waterborne Transport Research Institute, Safety and Emergency Research Division, No.8 Xitucheng Road, Haidian District, Beijing, 100088, China

Keywords: Mathematics analysis, The networks properties, Chinese ship-transport networks.

Abstract. The logistics hub degree properties of Chinese ship-container-transportation networks is studied by the networks complexity theory and method analysis in this paper. Furthermore, the container of Chinese ship-container-transportation networks logistics hub degree is combined by actual shipping conditions. Especially, the degrees, weights characteristics and modular properties are mainly studied for Chinese ship-container-transportation networks. This research on logistics hub degree and weight characteristics can improve daily economic benefits. With 30 per cent of Chinese trade container carried by sea and with 85 percent of world trade carried by sea, the most important hub nodes of Chinese ship-container-transportation networks. Here, we use information about the itineraries of 22357 ships during the year 2016 to construct a network of links between seaports. The network has several features that set it apart from other transportation networks are shown. Container ships follow regularly repeating paths whereas bulk dry carriers and oil tankers move less predictably between seaports. The Chinese Ship-container-transportation Network possesses a heavy-tailed distribution for the connectivity of seaports and for the container loads transportation on the links weights. The data analyzed in this paper improve understanding current global trade by the container ship. We also study the trade flow degree and weight of Chinese ship-container -transport networks (CSCTN) based on the weighted network representation, and demonstrate the weight distribution can be described by power-law or exponential function depending on the assumed definition of network topology. Other features related to Chinese ship-container-transport networks (CSCTN) are also investigated.

Introduction

Ocean shipping has been among the most open and advanced sectors in China logistics. Recently, China’s exports are expected to increase with container destined for international economic markets. Container seaports like Tianjin, Shanghai and Shen Zhen are predicted to join the ranks of the top 3 biggest container ports of the world in terms of throughput. Container trade volumes are predicted to rise above 130.8 million TEUs by 2016. China recently invested Financial resources in inland water transportation, with the goal of developing an international standard container network with inter-modal capabilities. The largest three Chinese container carriers company– COSCO, China Shipping Group and Sinotrans – will benefit from WTO entry. Some of them are already ranked among the top carriers in the world. In general, ocean and inland water transport is not suitable for moving high-value finished goods and time-sensitive freight. Because of its low cost and low pilferage and damage rates, shipping and inland barges can be a good solution for bulk commodities transportation. However, this mode is severely underutilized for lack of required infrastructure.

In this paper, we present an investigation of the Chinese ship-container-transport networks (CSCTN). Recently, Cavana (1994) provided a brief review of the costal shipping industry in New Zealand and an overview of international cabotage laws. Later, Cavana (2004) discussed a qualitative analysis of reintroducing maritime cabotage legislation onto New Zealand’s coasts. Mak, Sheehy, and Toriki (2010) discussed the application of Passenger Vessel Services Act (PVSA) of 1886 to the US cruise ship industry. Here, we consider the Chinese ship-container-transport networks (CSCTN),
which comprises 37 sea ports and 25 river ports in different locations. We have gathered the ship
schedule information from the Internet.24 The nodes of the network are the ports and the edges are
the lines connecting them along the route. The results presented below are based on a large number of
passenger liners, which only carries passengers; cargo transport is not considered in our analysis.

The rest of this paper is organized as follows. Section 2 gives the notation and problem description.
Section 3 proposes complex properties, simulation and results of the Chinese
ship-container-transport networks (CSCTN). Furthermore, the numerical experiments based on the
Chinese ship-container-transport networks (CSCTN) are carried out. Finally, the conclusion is given
in Section 4.

Notation and Problem Description

We assume the Chinese ship-container-transport networks (CSCTN) considered in this paper are built,
owned and operated by citizens of country A. We will implement different scenarios by
considering different A. The set of seaports, which can be further classified into two disjoint subsets:
the set of hub ports denoted by $PC$ and the set of feeder ports $PF$. The maritime cabotage legislations in
liner H& S shipping network design can be simply described by introducing an indicator $\alpha_{ij}$ for each
pair of port $i$ and port $j$ ($i,j \in P$). If ships of country A are allowed to directly transport containers from
port $i$ to port $j$; $\alpha_{ij}$ is equal to 1; otherwise $\alpha_{ij}$ is 0 of Chinese ship-container-transport networks
(CSCTN)

The directed network of the entire cargo fleet is noticeably asymmetric, with 59% of all linked
pairs of seaports being connected only in one direction. Still, the vast majority of seaports (135 out of
97) belongs to one single strongly connected component, i.e. for any two seaports in this component
there are routes in both directions, though possibly visiting different intermediate ports. The routes
are intriguingly short: only few steps in the network are needed to get from one port to another. The
shortest path length between two ports is the minimum number of nonstop connections one must take
to travel between origin and destination.

The structure of CSCTN can be symbolized by an asymmetrical weight matrix $W$ whose weight
element $W_{ij}$ is the number of cargo transport liners traveling from seaport $i$ to seaport $j$. We should
note that the weight element $W_{ij}$ includes the contribution from the direct ship transportation
between the nodes $i$ and $j$ without middle stops.

The weights $W_{ij}$ denotes the travel time on the link $(i,j)$ when there is no cargo traffic flow, and
$W_{ij}$ assumed randomly in the range $(0,1]$ for each link in our simulations.

First, we employ $k$ to denote the degree of a given node $i$ for directed CSCTN to represent the
undirected degree of the CSCTN in the same network topology. The degree of seaport $i$ stand for
number of seaports. The CSCTN consists of nodes representing seaports and links between two nodes
exists if they are consecutive stops on the route. The node degree $k$ in this topology is just the number
of different ship routes one can take from a given seaport. An edge between two nodes means that
there is a ship schedule traveling between them. From which one can arrive at seaport $i$ and the
number of seaports that can be reached from seaport $i$, respectively. Using the weighted matrix, we
can write these quantities as follows:

$$k_i = \eta W_{ij}$$

$$S_i = \sum_{j \neq i} W_{ij}$$

Where $\eta$ is a unit step function, which takes 1 for $x>0$and 0 otherwise. Similarly, we can also
obtain the above equations. As the CSCTN network is a directed connected network with 97 nodes,
we report the size of the giant strongly component defined. We find that the strongly connected component, i.e., every pair of ports is connected in both directions, comprises 97 seaports. The sizes of the component are found to be 97. This indicates that the corresponding adjacency matrix for the network is almost symmetrical. Next, we consider the cargo traffic flow of the weighted CSCTN networks. We define the total cargo traffic flow coming into node i as the strength.

The large amount of cargo traffic flow in both spaces suggests that database is highly redundant in its topological structure; i.e., most connections between pairs of ports are represented by more than one ship. This makes the analysis of network topology reliable.

**Simulation and Results**

In our simulations, the network topologies considered here are lattice networks as the example of regular networks, random networks generated by Chinese ship-container-transport networks (CSCTN) model (The rewiring probability is 0.1 here). The average degree <k> of the four networks is <k> = 4 (i.e., m = 2), as it resembles typical crossroads. The size of the generated network varies from 60 to 100. All the resulting data is averaged more than 10 realizations.

A common measure for investigating the performance of Chinese ship container-transport networks (CSCTN) can be characterized. Numerically investigating the Chinese ship container-transport networks (CSCTN) traffic flows assignments over three ship types (container ships) topologies, it suggests that both the assignment strategy of Chinese ship container-transport networks (CSCTN) and the topology work significantly on container traffic flows (the node degree) distribution, as shown in Fig.1.

The Fig.1 shows the relationship of accumulative act-size (the degree number of seaports) and weights (the container trade flows) for CSCTN networks. In the Fig.1, the vertical axis represents the weights and the horizontal axis, a certain number node degrees of the act-size. The solid cycles denote the empirical data.

The Fig.2 shows the distribution of accumulative weights (the cargo traffic flows) for CSCTN in the year of 2010 to 2016. In the Fig.2, the vertical axis represents the weights, and the horizontal axis, a certain number of the years (from 2010 to 2016). The solid cycles denote the empirical data. The solid line the least-square fitting. Fig. 3 presents the relationships of strength and weights (the cargo traffic flows) for CSCTN networks for the container ship.

![Figure 1. The relationship of degrees and P(k) in the Chinese ship container-transport networks (CSCTN).](image-url)
Summary
In conclusion, we have analyzed the statistical properties of CSCTN networks. We explore scaling laws and correlations that may govern intrinsic features of such network. The topological properties, including the degree distribution, weight and strength are studied. Our results indicate that nodes with high memberships play a central role in these networks. Furthermore, our investigations revealed interesting differences between the two types of networks concerning the dependence of the centrality measures on the relative out-degree of module members (the ratio of out-degree versus number of all nearest neighbors within the modules)

Acknowledgments
This paper is the product of an effort undertaken by the projects of Chinese Safety Committee of seaport. The writer is grateful for the technical assistance provided by all committee members. This work is financially supported by the Chinese Safety Committee of seaport under Grant Nos.410X01 and Nos.41201.

Reference


