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Research the Safety Specialties for the Container Shipping Logistics Networks of China

Di Cui

Safety and Emergency Research Division, Waterborne Transportation Institute, Beijing 100000, China

Abstracts: Structural properties of the ship container logistics network of China (SCLNC) are studied in the light of recent investigations of complex networks. SCLNC is composed of a set of routes and ports located along the sea or river. Network properties including the degree distribution, degree correlations, clustering, shortest path length, centrality and betweenness are studied in different definition of network topology. It is found that geographical constraint plays an important role in the network topology of SCLNC. We also study the traffic flow of SCLNC 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 SCLNC are also investigated.

Key words: Logistics networks; ship container logistics networks; the safety characters.

1. Introduction

The ship container logistics network of China transportation systems is of great importance to the development of a country and are important indicators of its economic growth. They form the backbone of the tourism industry, and support movement of goods and people across the country, thereby driving the national economy.

During the past few years, complex network analysis has been used to study transportation systems. In this paper, we study the statistical properties of the of the ship container logistics network of China (SCLNC) in which the nodes are ports and the links are passenger liners connecting the seaports.

Several spatial networks in which the nodes occupy a precise position in two or three dimensional Euclidean space and edges are real physical connections have received much attention from the complex network point of view. Typical examples include neural networks, information/communication networks, electric power grids, and transportation systems ranging from river, waterway logistics, street, bus, railway, subway, ant networks of galleries, etc. Most of the work in the literature has focused on the characterization of the topological properties of spatial networks, including the small-world behavior and scale-free structure.

In this paper, we present an investigation of the ship container logistics network of China (SCLNC). Previous analysis on ship-transport network can trace back to the work of Pitts in the last century. Pitts studied the medieval Russian river network, in an effort to assess the centrality of the urban places on the graphs, and showed that Moscow was most central and accessible with aggregate least effort. Pitts's work had received much attention by historians and geographers concerning the growth of Moscow. Here, we consider the ship container logistics network of China, which comprises 42 sea-ports and 120 river ports in different locations. We have gathered the ship schedule information from the Internet. 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,

Corresponding author: Di Cui, researcher, research fields: logistics, transportation.

which only carries passengers; cargo transport is not considered in our analysis. Compared with other types of transport networks, the ship container logistics network of China has a more complex structure due to the following features. The topological structure is constrained by geographical embedding. Since the ports are distributed along the sea or river and the ship can only travel along the river, this imposes a strong constraint to the structure of SCLNC. In addition, the existence of branching rivers also makes its topological structure significant.

The following analysis of the evolution of the ship container logistics network of China uncovered a number of features, suggesting that despite of small fluctuations in some structural properties, the network has undergone a strong rewiring dynamics in the considered period. What in principle might appear as a slowdown of the aviation sector, in fact is a reorganization of the structure according to changing demand. One of the consequences has been an increase in the centrality of SCLNC, which may affect the performance of the network.

2. The Concepts of Topological Structure Logistics Networks

There are directed, weighted links with slightly fluctuating frequency. Quite similar to the waterway logistics networks, there may be many direct ship schedules connecting two neighboring seaports A and B every day. Therefore, asymmetric matrices are used to characterize properties in-degrees, out degrees, etc., which are sensitive to the direction.

Some ship schedules travel through more than two seaports. Therefore, there are two topological representations for SCLNC, the so-called space L and space P. Based on the concepts of spaces L and P, we will show that scaling laws may govern intrinsic features of the physical quantities. This gives analogues feature to the railway network or bus-transport network.

Sen et al. have introduced a new topology describing the public transport networks—the idea of the space P in which two arbitrary stations or ports in this paper are connected by a link when there is at least one vehicle ship that stops at both the stations seaports. Generally, we can present the public transport network in two different topological representations.

The first topological representation is the space L, which consists of nodes being ports, and a link between two nodes exists if they are consecutive stops on the ship route. The node degree k in this topology is just the number of different ship routes one can take from a given port. The distance in such a space is measured by the total number of stops passed on the shortest path between two nodes. The second representation is the space P, in which an edge is formed between two nodes given that there is a ship schedule traveling between them. Consequently, the node degree k in this topology is the total number of nodes reachable using a single ship route and the distance can be interpreted as a number of transfers plus one has to take to get from one port to another. It is obvious that in the space P, the distances are numbers of transfers plus one needed during the travel and distances are much shorter than in the space L.

3. Networks Simulation

The structure of SCLNC can be symbolized by an asymmetrical weight matrix W whose element Wij is the number of passenger liners traveling from port i to port j. In this perspective, we can use two different matrices WL and WP to denote the traffic flow of SCLNC in the spaces L and P, respectively.

We should note that the element Wij includes the contribution from the direct ship transportation between i and j without middle stops. As a matter of fact, the direct ship between two ports gives the same contribution to the weights in the space L and space P. Based on the directed representation of spaces L and P, we define a set of quantities to characterize the properties of SCLNC.

For this purpose, following Refs. [1, 2], we introduce cost function dynamics, given as

$$C_{ij}(t+1)=\begin{cases} C_{ij}(0)\dfrac{Ce_{ij}}{x_{ij}(t)} & if\ x_{ij}(t)>Ce_{ij} \\ C_{ij}(0) & otherwise \end{cases} \quad (1)$$

where $C_{ij}(0)$ is the initial "practical capacity" of link (i, j).

To measure the network sensitivity we consider three quantities, the efficiency of the network E, the degree of congestion of the network FC, and the number of overloaded edges in the network Num. Following Ref. [3], the efficiency of the network is defined as

$$E=\frac{2}{N(N-1)}\sum_{i>j}\frac{1}{\omega_{ij}} \quad (2)$$

where N is the size of the network. Following Refs. [4, 5], the degree of congestion of the network is expressed as

$$FC=\frac{2}{N(N-1)}\sum_{i>j}\frac{x_{ij}w_{ij}}{x_{ij}w_{ij}^0} \quad (3)$$

In the following, we will illustrate how the tolerance parameter α affects the three quantities in random and scale-free networks.

In our simulations, we consider random networks and scale-free networks. The network size is $N=1000$, and the average degree is $\langle k\rangle=6$. Random networks can be generated by the binomial model [5], where each pair of nodes is linked with probability $\frac{\langle k\rangle}{N}$. To generate scale-free networks, we use the standard Barabasi-Albert (BA) scale-free model [6]. For simplicity, for each link (i, j), $C_{ij}(0)=1$ and $w_{ij}^0=1$ within the link performance function are considered. In general, the demand function between r and s can be expressed as $q_{rs}=A_rB_sf(\omega_{rs})$, where A_r and B_s are known parameters associated with origin r and destination s, respectively, and $f(\omega_{rs})$ is a monotonically decreasing function of ω_{rs}. Here we consider a simple form, given as

$$q_{rs}=\frac{k_r\cdot k_s}{\omega_{rs}^{\ 2}} \quad (12)$$

where k_r and k_s is the degree of node r and s, respectively. All the resulting data are averaged over 30 realizations. In order to study the sensitivity of the network under attack, we focus on removing a single node with the largest degree in the network.

In Fig. 1, we perform the same simulations under the case of User Equilibrium with variable demand. As shown in Fig. 1, for the ship container logistics network of China, it is clear that, weight monotonously increases for the node degree.

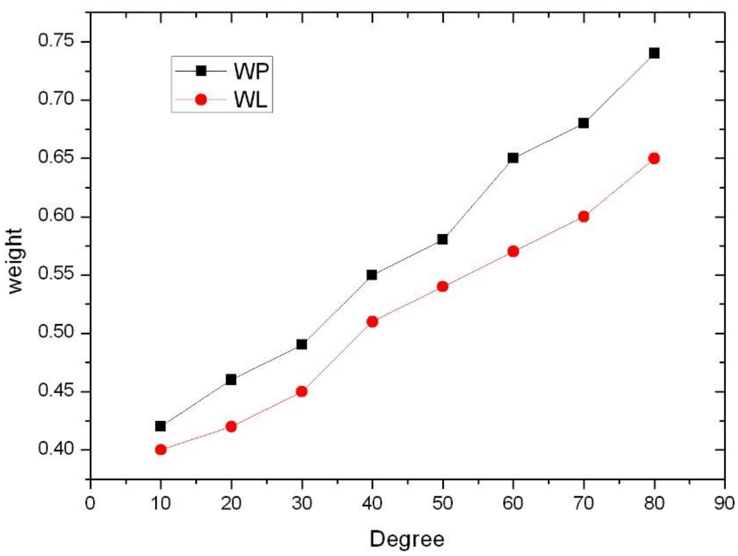

Fig. 1 The relationship between the degree and weight of WL and WP.

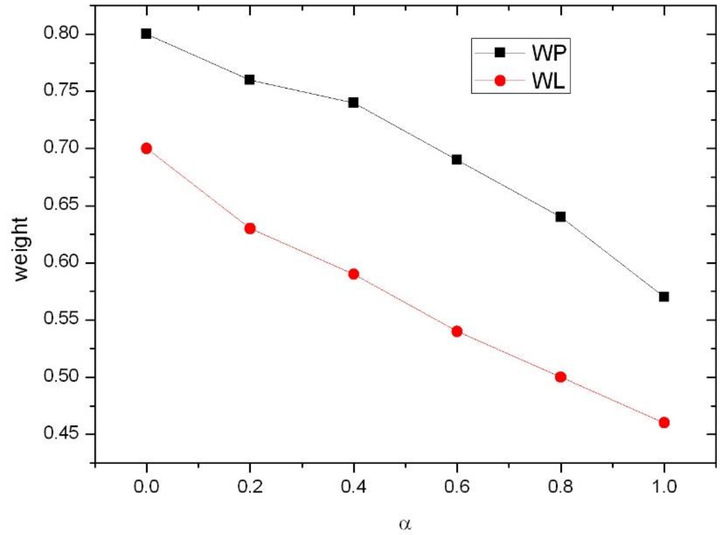

Fig. 2 The relationship between the tolerance parameter and weight of WL and WP.

In Fig. 2, we perform the same simulations under the case of User Equilibrium with variable demand. As shown in Fig. 2, for the ship container logistics network of China, it is clear that, weight monotonously decreases for the tolerance parameter.

5. Conclusion

We would like to point out that, since STNC is a weighted, directed, and dual-topology network. We conjecture that STNC has an intermediate topology between airport network and the railway network. One can propose an evolution model for the ship-transport network with a simple idea which can be realized through computer simulation. At the beginning of the ship-transport development, there are a few ships connecting only the geographical neighboring ports. In the subsequent evolution, more ship routes are established to connect river ports and sea ports according to the spatially preferential attachment. The new ships are established by optimizing an objective function involving both the geographical and topological ingredients. Such combined ingredients may endow STNC with the complex structure in both the network topology and traffic dynamics.

Under the case of User Equilibrium with fixed demand, the fragile property of scale-free networks and the robust feature of random networks to the initial attacks are recovered. While, under the case of User Equilibrium with variable demand, the discrepancy of the instability between random and scale-free networks is largely reduced. That is, traffic demand has a large effect on the instability or sensitivity of complex networks to the intentional attacks. These results should be useful in furthering studies in the important area of network security.

Acknowledgements

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