Evaluating Impacts of the COVID-19 Pandemic on China’s Container Ports Based on AIS Big Data

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Abstract. To quantitatively analyse the impacts of the COVID-19 pandemic on China’s container ports, the berthing ships are mainly investigated by the big data of Automatic Identification System (AIS). First, the methods of AIS data acquisition, cleaning and statistical analysis are introduced. Then the sample ports of Shanghai, Ningbo-Zhoushan and Tianjin are selected, and the monthly ratios of key indicators such as the number of berthing ships and berthing time are calculated by AIS analysis system. Finally, the numerical results show that although the COVID-19 epidemic does not significantly affect the number of container ships arriving at China’s ports, it has a significant impact on the average berthing time of container ships.

Keywords: COVID-19; Container ports; Berthing time; AIS big data.

1. Introduction

The COVID-19 pandemic has swept the world in 2020. It has caused a huge impact on the world economy and triggered the worst recession since the great depression in 1929. According to statistics released by Johns Hopkins University, as of May 21, 2020, there were more than 4.968 million confirmed COVID-19 cases and more than 326,000 deaths worldwide. The most affected countries, such as China, the United States and Italy, have to take measures, such as the isolation, lockdowns, and widespread closures, to slow the spread of the COVID-19 pandemic. Consequently, the global consumer demand has been blocked and the economy has suffered a sharp decline. According to the latest world economic outlook released by the International Monetary Fund (IMF) in April 2020, the global economy will show negative growth in 2020, with GDP growth estimated at -3.0% and trade growth down to -11.0% (IMF, 2020).

Port industry is a typical export-oriented and globalized industry. The busyness of port production is traditionally viewed as an important barometer of world economy. Affected by the COVID-19 pandemic, the global commodity demands have been greatly suppressed, and the global supply chain severely damaged. The sharply declined of global trade has resulted in a significant decrease in the demand for cargo transportation at China’s ports. According to statistics, in the first four months of 2020, the container throughput of China’s coastal ports amounts to only 67.6 million Twenty-feet Equivalent Unit (TEU), with a negative growth rate of -7.4%.

The cargo throughput is regarded as a key indicator reflecting the global port production. It is also an important leading indicator for the global economic and trade. However, the data of port cargo throughput is acquired by the traditional statistical methods, which needs a series of fixed statistical procedures such as data collection, reporting, verification and release. Generally, the data of port cargo
throughput is released monthly. In the event of the COVID-19 pandemic outbreak, a more timely and comprehensive evaluation method of global port production is of great importance to the whole world.

Recently, many researchers have started to pay attention to study the impacts of the COVID-19 pandemic on port production in China (Clarkson Research, 2020; Zhang et al., 2020; Liu et al., 2020). However, the existing research are all based on the traditional statistics. The timeliness of the data is greatly limited. The Automatic Identification System (AIS) can provide real-time dynamic information of global ships. It has the advantages of full sample, objectivity and real-time (Zhu et al., 2020). To acquire more timely and accurate data of global port production, the AIS big data statistical analysis model is proposed to evaluate the docking status of berth calling ships around the world. Based on it, a more timely, objective and comprehensive statistical tool is provided to evaluate the impact of the COVID-19 pandemic on global port production.

2. AIS Analysis Model

2.1. Characteristics of AIS Big Data

AIS is a kind of marine navigation aid equipment widely used in the global shipping. It transmits signal by the very high frequency (VHF). The onboard AIS equipment can automatically and regularly broadcast the dynamic and static ship information. The dynamic information includes the accurate ship position, course, navigation speed, turning speed, the encounter distance to nearest ship, etc. The static information is comprised of ship name, call sign, ship type, ship length, ship width, etc. Within the range of 20 nautical miles covered by VHF, the onboard and shore-based AIS equipment can automatically receive the message data broadcast by other ships. Therefore, the message communication among ships can be realized, and the ship's maritime navigation status can be identified and monitored in real time through the shore-based and satellite-based equipment.

According to the installation carriers of AIS equipment, it can be divided into onboard AIS, shore-based AIS, auxiliary navigation AIS, airborne AIS and satellite-based AIS. The onboard AIS can be divided into three categories: Class A, class B and receiver. Class A onboard equipment can transmit the class A AIS message and receive the class A and class B AIS message. Class B onboard equipment can transmit the class B AIS message and receive the class A and class B AIS message. The maximum receiving distance of shore-based AIS equipment is usually within 50 nautical miles offshore. The satellite-based AIS uses one or more low orbit (orbit height 600-1000km) small satellites to form a small satellite constellation or small satellite formation to receive AIS signals from ships and transmit them to the ground station for analysis and processing, and then realize the dynamic monitoring of ships in a wide range or even in global sea area (Wang et al., 2016).

| No. | Ship dynamic conditions | Normal reporting time interval (Second) |
|-----|-------------------------|----------------------------------------|
| 1   | The ship is anchored or moored and moves at a speed below 3 knots / hour. | 180 |
| 2   | The ship is anchored or berthed and the speed is higher than 3 nautical miles, or the speed is 0-14 nautical miles / hour. | 10 |
| 3   | The speed is 14-23 nautical miles / hour. | 6 |
| 4   | The speed is between 14-23 knots and the course is changed, or the speed is greater than 23 knots. | 2 |

Table 1. Time interval of AIS information report (Equipment of Class A).

The quantity and coverage of onboard AIS equipment is an important prerequisite to ensure the quality of AIS data. According to the SOLAS Convention of the International Maritime Organization (IMO), ships with a gross tonnage of more than 300 on international routes and ships with a gross tonnage of more than 500 on domestic routes must be equipped with AIS equipment. Normally, the AIS data will be released once every 2-180 seconds (Table 1). The AIS data contains the basic static and dynamic
position information of the ships, and the position information corresponds to the time. Therefore, the AIS data has the advantages of mass, space-time and high frequency.

2.2. AIS Analysis System
AIS data contains a lot of repetitive and redundant information. For example, due to the high transmission frequency of the onboard AIS equipment, two AIS messages can be used to describe the track of an anchor ship, and the system will receive several AIS messages, most of which will be duplicated and redundant (Zhao, 2018). To effectively collect AIS data, an AIS big data analysis system is established to collect AIS data as shown as follows.

Step1. When the serial port receives one character, the system will enter the interrupt program. The microprocessor reads and saves the character in the interrupt handler. Next, continues reading the remaining characters until all characters of a message are retrieved.

Step2. After receiving a message, the data processing module will check and calculate it. In AIS analysis system, the cyclic redundancy code (CRC) is used to compare and judge messages, and then the calculated results are compared with the check field values. If the two are not equal, it indicates that the message is received incorrectly, and the message is discarded. Then the data processing module receives the next message. Otherwise, it indicates that the reception is correct, and the next processing is carried out.

Step3. After processing a message, continue to read AIS message from the serial port module, if there is any unprocessed data, continue to process. Otherwise, the module is in the waiting state.

It should be noted that the determination of port boundary is a very important issue for analysing ship berthing time. It can be obtained through the port master plan, or modelled by analysing the historical track of ships' berthing. After Delimiting the boundary of a port, the berthing situation of ships can be statistically analysed by the above AIS analysis system. In the AIS analysis system, the berths and anchorages have different geographical coordinates. Therefore, the berthing and anchoring of a ship can be easily identified.

3. Container Port Production under the COVID-19 Epidemic
To evaluate the impacts of the COVID-19 epidemic on China’s port operation and production more objectively, the AIS big data analysis system is used to analyze the berthing situation of ships. Shanghai port, Ningbo-Zhoushan port and Tianjin port are selected as typical samples. The time range of data statistics is from January 1 to April 31, 2020.

3.1. Number of Container Ships Arriving at China's Ports

![Figure 1. Quantity comparison of container ships arriving at China's ports.](image)

The number of container ships arriving at China's ports is counted by the AIS analysis system. Affected by the COVID-19 epidemic, the number of container ships arriving at China’s ports slightly declined in recent four months. As shown in Figure 1, the number of container ships dropped most
severely in January 2020, down 7.7% compared with the same period last year. By April 2020, it has gradually recovered to the level of the same period last year. The monthly growth rate of container ships arriving at sample ports are calculated from January to April, 2020. As shown in Figure 2. The number of container ships arriving at Tianjin port and Shanghai port increased by 4.7% and 6.5% respectively, while Ningbo-Zhoushan port decreased by 3.3%. Therefore, the COVID-19 epidemic has greater impact on Ningbo-Zhoushan port, especially in February 2020, the number of arriving container ships sharply decreased by 14.4%.

![Figure 2. Monthly growth rate of container ships arriving at sample ports](image)

3.2. Berthing Time of Ships

It can be seen from the above discussion that the COVID-19 epidemic has slight impact on the number of container ships arriving at China’s ports. However, from the perspective of the port production, the berthing time of the container ships in China’s ports is obviously shortened. According to the statistical analysis of AIS analysis system, from January to April 2020, the average berthing time of container ships is obviously shortened in China's ports. In January 2020, the average berthing time in China’s ports for container ships is 16.6 hours, with 0.8 hours shorter than the same period in 2019. By April, the average berthing time decreased to 15.0 hours, with 2.3 hours shorter than the same period last year. The numerical results indicate the average number of containers loading and unloading per ship has been reduced in china’s ports.

From the perspective of sample ports, the berthing time of container ships in Ningbo-Zhoushan port has not changed much, but decreased significantly in Tianjin port and Shanghai port. Especially in April 2020, the average berthing time of container ships in Tianjin Port has been shortened to 18 hours, with 4.6 hours less than that in the same period of last year. The average berthing time in Shanghai port has been shortened to 11.8 hours, with 3.8 hours less than that in the same period last year.

| Port          | Tianjin port | Shanghai port | Ningbo-Zhoushan port | China's all ports |
|---------------|--------------|---------------|-----------------------|-------------------|
| Year          | 2019         | 2020          | 2019                  | 2020              | 2019            | 2020            |
| Jan.          | 27.4         | 22.0          | 14.5                  | 13.9              | 17.4            | 19.4            | 17.4            | 16.6 |
| Feb.          | 21.8         | 20.3          | 13.9                  | 13.8              | 17.0            | 17.4            | 16.8            | 15.6 |
| Mar.          | 23.6         | 19.6          | 14.1                  | 13.9              | 15.4            | 18.6            | 16.9            | 15.9 |
| Apr.          | 22.6         | 18.0          | 15.6                  | 11.8              | 18.9            | 18.5            | 17.3            | 15.0 |
4. Conclusion

Through the AIS data, the real-time position information of ships sailing in the world can be obtained, which has the typical characteristics of big data. In this paper, an AIS analysis system is proposed to collect, process and analyse the information of ships' berthing at global ports. Based on it, the number and time of berthing of ships in China’s ports is statistically analysed. The impacts of the COVID-19 epidemic on the production of China's container ports is evaluated quantitatively. The numerical results show that although the COVID-19 epidemic does not significantly affect the number of ships arriving at China’s ports, it has a significant impact on the average berthing time of ships arriving at the port. It indicates that the number of containers loaded and unloaded at the ports is indeed significantly reduced under the influence of the epidemic. To more comprehensively evaluate the impact of the COVID-19 epidemic on port production and operation, the proposed AIS analysis system can also be extended to the berth calling statistics of dry bulk cargo, liquid bulk cargo, roll on/roll off, cruise ship and other types of ships. In addition, according to the static and dynamic message data of AIS, such as the ship type, berthing time, draft change and so on, a port throughput estimation model can be proposed based on AIS big data. a more objective, high-frequency and precise statistical means of port cargo throughput can be established, and more timely and accurately evaluation model can be use to investigate the impacts of epidemic, tsunami, war and other emergencies on global port production.

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