Exploring the Influence of Freight Policies on Cargo Transportation System with Multi-agent-based Modeling

Lei FENG*, Wu XU and Si SONG

No. 3 Shangyuan Village, Haidian District, Beijing, China

*Corresponding author

Keywords: Demand response, Multi-agent modeling and simulation, Freight adjustment policies.

Abstract. With the rapid increase of energy consumption in the cargo transportation system, the problems of energy and environmental should be seriously considered. The freight transport structure should be developed in a more energy-saving and reasonable direction by adjusting freight to achieve the purpose of reducing energy consumption. Considering freight adjustment system itself characteristics, this paper introduced a multi-agent-based model that is constructed individually from government agent, transportation company agent, and cargo owner agent based on demand response. The experiment through the Netlogo proves that freight has played a positive role in regulating the energy consumption of the cargo transportation system and put forward energy saving advices and policies.

Introduction

The problem of rapid increase of energy consumption is the hot topic in the current global. Energy consumption of cargo transportation system is much larger than that of passenger transportation systems, occupying a major part of physical transportation. Relevant studies show that potential of the freight transport that in 2020 can reach over 70% of the whole transportation is significance.

According to requirements of "optimize the transportation structure and build an energy-saving integrated system", <People's Republic of China Energy Conservation Law> is set by the government in order to ensure sustainable social development and national energy security [1]. Guiding effective freight policies implemented by transportation companies is the leading factor in reasonable division of various cargo transportation types. In addition, supply and demand of cargo transportation system can be truly reflected and regulating the role of the freight transport market in healthy development can be played by the freight. Therefore, rationalizing the freight system is not only an important guarantee for the rationalization of the transportation structure, but also a powerful support for reducing the energy consumption of the cargo transportation system.

It is urgent to find the way of achieving the general goal of reducing the energy consumption by adjusting the freight and guiding cargo owner to choose a low energy consumption type of transportation. This paper builds a simulation of energy consumption system, using a method based on multi-agent modelling and simulation to put forward a new idea in the policies evaluation and decision support for energy-saving and emission-reduction.

The Freight Adjustment System of Cargo Transportation

Multi-agent Model of Freight Adjustment System

The paper builds a multi-agent system after having some insight in the real transport market structure which is highly complex, including the following agents:

First of all, as the subject of administrative, it is important for the government agent to achieve the total goal of reducing energy consumption by laying down freight policies and implementing policies to transport company agents. Secondly, transportation company agent serves as a connecting link between the preceding and the following; it not only supports freight policies, but also determines the most appropriate freight of different types of transportation according to the
change of the transportation market and the needs of cargo owner. Besides, cargo owner agent play an important role in freight adjustment system and respond to different transportation types mainly considering benefits based on the basic idea of user equilibrium theory. Finally, a timely monitor should be designed to control the system, meanwhile feeding back the change of indicators. The freight adjustment system of cargo transportation is shown in the figure 1 [2].

The Building of Freight Demand Response Model

The freight demand elasticity is flexible and refers to an effect reaction that is to represent changes in demand with changes in freight. The model of the choice of multiple transportation types is built based on freight demand elasticity. It not only considers the freight, but also comprehensively reflects other factors, including GDP, population, transportation alternatives and competitiveness. Consider these and put last year's turnover of freight traffic into this model:

\[
\ln(Q_{it}) = a_i + b_i \ln(P_{it}) + r_i \ln(Q_{it-1})
\]  

(1)

\[Q_{it} \]: i type of turnover of freight traffic during t period; \[P_{it} \]: i type of freight during t period; \[Q_{it-1} \]: i type of turnover of freight traffic during \(t - 1\) period; \[b_i \]: i type of the freight demand elasticity; \[r_i \]: i type of inertia elastic value during \(t - 1\) period; \[a_i \]: estimate coefficient.

Under the influence of freight policies, transportation companies adjust the freight of different transportation types according to the behavior of demand response, aiming to minimize the energy consumption. The analysis method can be represented as the economic response load model under the condition of the logarithmic function relation in formula 1, the profit of the cargo owner is shown below:

\[
B_i = B_{0i} + P_{0i}Q_iE_i \times \left[ \exp \left( \frac{Q_i - Q_{0i}}{E_iQ_{0i}} \right) - 1 \right]
\]  

(2)

According to the demand freight response and its related revenue function, we can get:

\[
\frac{\partial B_i}{\partial Q_i} = P_{0i} \times \exp \left[ \frac{Q_i - Q_{0i}}{E_iQ_{0i}} \right]
\]  

(3)

Cargo owners are encouraged to choose some type of transportation, thereby affecting turnover of freight traffic and energy consumption by changing freight.
\[ Q_i = Q_{i0} \left[ 1 + E_i \ln \frac{P_i}{P_{i0}} \right] \]  

(4)

\( B_i \): type of profit of the cargo owner; \( E_i \): Elastic coefficient.

The formula 4 represents the demand freight function of the logarithmic relationship, the freight elasticity of the four types of transportation (railway, waterway, highway and airway) and the demand response of the owner to the different types of transportation after the freight adjustment policies is implemented.

Objective of system can be expressed as follows:

\[
\min N = \sum_{i=0}^{4} Q_{i0} \left[ 1 + E_i \ln \frac{P_i}{P_{i0}} \right] \times S_i
\]  

(5)

\( S \): type of the cargo transportation energy intensity.

**Simulation Experiment Based on ABMS of the Freight Adjustment System**

**Parameter Setting of Simulation Experiment**

There are many kinds of Multi-Agent development tools, one of which is Netlogo. Netlogo is a software that can be used to simulate natural and social phenomena in programmable modeling environment [3]. In this paper, Netlogo is used to simulate the demand response of cargo owners to freight and the change of energy consumption caused by different transport structures. The simulation interface that based on the Netlogo platform contains three parts: command area, control area and output area. For simulation, the freight turnover, the structure ratio, the initial year (2016 as the base year) price, the elasticity coefficient, the energy consumption intensity of different types of transportation and so on need to be edited into the system in the form of logo language [3].

**Analysis of Simulation Experiment**

The energy consumption is the result of the coordinated development of various transportation types. Because the energy consumption intensity of Railway and waterway is low, but of the highway and airway is relatively high. In the wake of freight changes of different transportation types, there are some fluctuations in energy consumption. Based on the above, we set the following four simulation scenarios to explore the impact of freight adjustment on the energy consumption.

![Simulation Interface](image)

Figure 2. The simulation interface of various indicators under the condition of the increase of railway freight.
From figure 2-5, it is obvious that the price adjustment policy changes the transport structure. As the price of railway and waterway increases, highway and airway will share more turnover of freight traffic, resulting in a continuous increase in energy consumption. On the contrary, highway and airway belong to the high energy consumption types of transportation, and the effect is remarkable in reducing energy consumption. Through calculation analysis shows that a correct understanding of the low energy consumption types of transportation play an important role in the construction and development of national economy [4].
Conclusion

The ways to reduce cargo transport energy consumption are as follows:

(1) Adjusting and optimizing the structure of cargo transportation system requires more attention and more recognition, build energy-efficient cargo transportation system.

(2) Guiding the transportation market to choose more energy-efficient types by real fright signals.

(3) Developing the lower energy consumption and efficient transportation types such as railway and waterway by giving subsidies and welfare.

(4) High energy consumption transportation types such as highway and airway should convert negative externalities into actual costs, realizing internalization of costs by means of taxation, such as fuel tax and carbon tax [5].

Acknowledgement

This research was supported by the National Natural Science Foundation of China (No. 61503022) & (No. 71501011).

References


