ATLANTIS PRESS

Advances in Engineering Research, volume 170

7th International Conference on Energy and Environmental Protection (ICEEP 2018)

Study on Adaptability of the Freight Supply and Demand Structure in Urban Agglomeration Based on the Entropy Theory

Zhu Liu

Inner Mongolia Traffic Design and Research Institute Co.,Ltd.,Hohhot 010010,Inner Mongolia ,China

email:739875282@qq.com

Keywords: urban agglomeration; freight transportation; supply-demand equilibrium; information entropy theory; adaptability appraisal model

Abstract. According to adaptability of the freight supply and demand structure in urban agglomeration, this paper studies the mechanism of freight transportation's supply and demand in urban agglomeration, putting forward and demonstrating the adaptability theory of freight structure in urban agglomeration. Firstly, this paper analyzes the main factors affecting the freight demand structure and freight supply structure of urban agglomeration and according to the entropy theory, the information entropy models of the freight supply structure and demand structure in urban agglomeration are established. Secondly, the author compares the freight demand structure entropy and the supply structure entropy of urban agglomeration in order to establish an adaptability appraisal model of the freight supply and demand structure in urban agglomeration. Finally, this paper verifies the rationality and practicability of the model by analysis of examples.

Introduction

With the development of modern information and urban economy, the phenomenon of urban clustering is becoming more and more obvious, and urban agglomeration has increasingly become the forerunner of social and economic development in the region as well as the crucial tendency of the future urban development. Freight transportation, as an important component and supporting part of urban agglomeration's transportation and economic development, is attracting more and more attention. The adaptability of freight supply and demand structure means that it will form the different demand structures of freight transport in different stages of social and economic development. Thus, it requires that the supply structure and demand structure with a certain proportion relations to get satisfaction of all kinds of the freight transport modes' demands, so that the freight supply and demand structure can reach the equilibrium state. However, at present, Chinese urban agglomeration freight market is still generally influenced by the limited effective demand with the unreasonable supply structure and obviously imbalanced conditions of the supply and demand in traffic structure. Various freights methods cannot be coordinated in a reasonable proportion and people just pursue the maximization of the self-interests, as a result, a serious of problems have appeared, such as the coexistence of freight structural shortage and local capacity surplus, and the coexistence of backward infrastructure and low utilization ratio of some advanced infrastructure etc.

The domestic and foreign related researches are less based on the problem of freight supply and demand structure in urban agglomeration. Literature [1] applies the information entropy theory by taking the adaptability of regional freight supply and demand structure as the research object, and

establishes the information entropy evaluation model of freight supply and demand structure by analyzing the influencing factors of regional freight demand structure and regional freight supply structure. At last it comes up with the adaptability evaluation method. Literature [2] studies the relationship between transportation and social and economic development in structure, and analyzes the balanced problem between the demand structure and supply structure from the freight and passenger transport. Literature [3] predicts the freight volume based on the combination forecasting model of IOWA operator and its improved model. And it introduces the methods of regional freight forecast and selections of models from both qualitative and quantitative aspects, and comes up with the combination forecasting model based on the IOWA operator. Literature [4] puts forward the information entropy of traffic structure and applies the method that combined the principal component analysis and grey correlation method. It also clearly defines the dynamic factors that affect the transport structure and changes in order to provide optimization for transportation structure. Literature [5] analyzes the causality between Chinese industrial structure and transportation structure quantitatively by testing the causality of the industrial structure and the entropy of transportation structure. Literature [6] analyzes the classification, characteristics and supply-demand equilibrium of urban freight demand and supply based on the "Core - periphery" theory in spatial economics and elastic theory. Literature [7] designs the framework of traffic net based on the PESTEL model and recessive economic gravity model to analyze the traffic demands of every city in Sichuan. Literature [9] designs the interregional freight transport demand gravity model using transportation planning study and gravity model of trade theory for references, and then gives its solution of freight transport demand forecasting model and attack model with least square method. Lastly, this paper establishes the elastic model between them and analyzes their relationship.

In conclusion, most studies at home and abroad only focus on the single urban or a certain region, and rarely take urban agglomeration as the research object to analyze its equilibrium of freight supply and demand. This paper mainly takes the urban agglomeration as a whole unit and divides research category of its freight supply and demand structure into three parts. Then this paper applies information entropy theory to establish an entropy model for freight demand and supply in urban agglomerations by analyzing the influencing factors of freight demand and supply in urban agglomeration. Lastly, the adaptability of their entropy models is analyzed and it intuitively analyzes the disequilibrium problems of freight supply and demand structure in urban agglomeration. Eventually, the adaptive conditions based on the equilibrium of freight supply and demand in urban agglomeration are obtained in order to provide theoretical basis of realizing the equilibrium structure of freight supply and demand structure in urban agglomeration.

Entropy Model of Freight Demand Structure in Urban Agglomeration

Analysis of the influencing factors of freight demand structure in urban agglomeration

(1) The Industrial Structure of Urban Aggregation

The industrial structure is divided into three major industries. The primary industry is agriculture, and the second one is industry such as the power, metallurgy, manufacturing and construction industry etc. And the tertiary industry is service industry including catering, transportation industry, and wholesale retail etc. The origin of changes of transportation structure is industrial structure. The proportions of the three industrial structures are various while the changes of them will certainly cause the changes in freight types, flow and stream distribution, making the original transport form cannot adapt to transportation demand of the new cargo structure. As a result, it has changed the original freight demand structure and also influenced the adaptability of traffic supply and demand

structure in urban agglomeration.

(2) Production Distribution of Urban Agglomeration

A certain productivity layout needs different transportation modes to complete transportation of various raw materials and products. With the changes of productivity layout, freight that would have to depend on some transport to complete is presently less needed or replaced by other transport ways. So this is also the main influencing factors of freight demand structure that makes the original transport structure be broken, promotes the restructuring of transport and finally adapts to the new transport structure.

(3) Geographical Structure of Urban Agglomeration

The geographical structure is generally various in different urban agglomerations, such as the terrain differences and the differences between inland cities and coastal cities etc. Because of the differences of geographical environment, the transportation mode of cities in and out of urban agglomerations will also change, as well as the freight demand structure in urban agglomeration can also be affected by different geographical structure.

Construction of the entropy model of freight demand structure in urban agglomeration

The freight demand structure in urban agglomeration can be seen as a function which variables are influencing factors of freight demand structure. So the function expression of freight demand structure in urban agglomeration is defined as:

$$D(\vec{d}) = f(\vec{I}, \vec{L}, e) \tag{1}$$

Where d is a vector of the traffic demand structure of four transportation modes, I is a vector of industrial structure in urban aggregation, L is a vector of production distribution structure in urban agglomeration, and e is the other influencing factor of freight demand structure in urban agglomeration.

(1)The Entropy Model of Industrial Structure in Urban Agglomeration

According to the definition of entropy, this paper calculates the entropy of industrial structure by weights of different industrial structures in order to reflect industrial changes in urban agglomeration during the different stages of economic development. Entropy of industrial structure at time t is:

$$H_I(t) = -\sum_{i=1}^{3} P_{jt} \ln P_{jt} \tag{2}$$

Which specific gravity of industry j at time t is:

$$P_{jt} = I_{jt} / \sum_{j=1}^{3} I_{jt} \tag{3}$$

$$I_{jt} = \sum_{i=1}^{n} I_{ijt} \tag{4}$$

Where I_{jt} is the output value of industry j at time t in urban agglomeration (when j=1, 2, 3, they are the primary industry, the second industry and the tertiary industry), I_{ijt} is the output value of industry j at time s_{it} in urban agglomeration (when j=1, 2, 3, they are the primary industry, the second industry and the tertiary industry), and P_{jt} the weight of industry j at time t (when j=1, 2, 3, they are the primary industry, the second industry and the tertiary industry).

(2)The Entropy Model of Production Distribution Structure in Urban Agglomeration

This paper analyzes the four parts of production distribution structure including agriculture distribution, metallurgical industry distribution, power industry distribution and petroleum and

refining industry distribution.

The mapping (mapped to four traffic modes) of changes of productivity layout structure in urban agglomeration at time t is :

$$\vec{L}_{(t-1)}=[L_{1(t-1)},L_{2(t-1)},L_{3(t-1)},L_{4(t-1)}]\rightarrow\vec{d}_{(t-1)}=[d_{1(t-1)},d_{2(t-1)},d_{3(t-1)},d_{4(t-1)}]$$

$$\vec{L}_{(t)}=[L_{1(t)},L_{2(t)},L_{3(t)},L_{4(t)}]\rightarrow\vec{d}_{(t)}=[d_{1(t-1)}\pm e_1,d_{2(t-1)}\pm e_2,d_{3(t-1)}\pm e_3,d_{4(t-1)}\pm e_4]$$

$$\vec{L}_{(t-1)}=\sum_{i=1}^{n}L_{i(t-1)} \tag{5}$$

$$d_{(t-1)}=\sum_{i=1}^{n}d_{i(t-1)} \tag{6}$$

$$e_t=\sum_{i=1}^{n}e_{it} \tag{7}$$

The entropy of production distribution structure in urban agglomeration is :

$$H_L(t)=-\sum_{i=1}^{4}P_{it}\ln P_{it} \tag{8}$$

$$P_t^{'}=\frac{[d_{i(t-1)}\pm e_i]}{\sum_{i=1}^{4}[d_{i(t-1)}\pm e_i]} \tag{9}$$

Where $\vec{L}_{(t-1)}$ is a vector of the productivity distribution structure in urban agglomeration at time t-1, $\vec{d}_{(t-1)}$ is a vector of the productivity distribution in urban agglomeration which is corresponding to various traffic modes of demand structure at time t-1, $d_{i(t-1)}$ is the traffic volume of the productivity distribution structure of city i in urban agglomeration which is corresponding to traffic modes at time t-1, $d_{g(t-1)}$ is the traffic volume of the productivity distribution structure which is corresponding to traffic modes at time t-1, e_t is the change of demand degree of the corresponding traffic mode caused by the change of productivity distribution structure in urban agglomeration at time t-1, and e_{it} is the change of demand degree of the corresponding traffic mode (which involved highway, railway, aviation and water transportation) caused by the change of productivity distribution structure in city i at time t.

According to the above calculation about the entropy of influencing factors of freight demand in urban agglomeration, we can get the entropy model of freight demand structure in urban agglomeration:

$$H_d(t,d)=aH_{I(t)}+bH_{L(t)}+e_{(t)} \tag{10}$$

Where a and b are undetermined coefficients.

Construction of the entropy model of freight supply structure in urban agglomeration

Analysis of the major influencing factors of freight supply structure in urban agglomeration

(1) The impact of fixed assets structure on freight supply structure

The fixed assets constitute the material base of the production capacity of each mode of freight, which reflect the production capacity. Under the vested structure, the structure of fixed assets mainly depends on the investment structure and affects the freight supply structure.

(2) The impact of fixed assets structure on technical economy structure

Because of the differences of various freight transport modes among the technical characteristics (such as the delivery speed and transmission capacity etc.), economic characteristics (such as the transportation cost and occupation of funds etc.) and adaptability of geographical environment, every kind of transportation mode has their own comparative advantage and application range, influencing the constitutions of freight structure.

Entropy model of freight supply structure in urban agglomeration

In order to be realistic, this paper establish an entropy model of freight supply structure in urban agglomeration by practical traffic volume of four freight transport mode and then get the vector of freight supply structure in urban agglomeration with w_1, w_2, w_3, to show the freight weight coefficient of single city in urban agglomeration, between city and city in urban agglomeration and between the urban agglomeration and the outside of the urban agglomeration.

$$\vec{S} = (S_1, S_2, S_3, S_4) \tag{11}$$

$$S_i = w_1 \sum_{i=j=1}^{m} s(i,j) + w_2 \sum_{i=1}^{m}\sum_{j=1}^{n} s(i,j) + w_3 \sum_{i=1}^{m}\sum_{j=1}^{n} s(i,j) \tag{12}$$

Where S_i is traffic volume of the freight transport mode i in urban agglomeration (when i=1,2,3,4, they are highway, railway, aviation and water transportation), and $S_i(i, j)$ is the traffic volume of the freight transport mode i between city s_i and city s_j in urban agglomeration (when i=1,2,3,4, they are highway, railway, aviation and water transportation). As a result, we can get the entropy model of freight supply structure in urban agglomeration:

$$H_s(t,s) = -\sum_{i=1}^{4} Y_i \ln Y_i \tag{13}$$

The specific gravity of freight transport mode is:

$$Y_i = s_i \Big/ \sum_{i=1}^{4} s_i \tag{14}$$

Decision of adaptability of freight supply and demand structure in urban agglomeration

For judging the adaptability degree of freight supply or demand structure in urban agglomeration, we should compare the freight supply structure and freight demand structure. The freight demand structure and freight supply structure are both the functions of time, so we establish an adaptability appraisal model of the freight supply and demand structure in urban agglomeration at time t:

$$G(t) = \left| 1 - \frac{H_d(t,d)}{H_s(t,s)} \right| \tag{15}$$

The ratio of the entropy of freight supply structure to the entropy of freight demand structure is

more closer to 1, their approximate degree is more greater and the adaptability of freight supply and demand structure is more stronger. Through this function, when $H_d(t,d) = H_s(t,s)$, $G(t)$ get the minimal structure 0, the adaptability of freight supply and demand structure in urban agglomeration is the strongest.

According to literature [2], we can divide the adaptability of freight supply and demand structure in urban agglomeration into following grades as the table 1 shows:

Table 1 the grades of the adaptability of freight supply and demand structure

types	Adapted types	G(t)
Adaptive types	High quality adaptation	$0.9 < G(t) \leq 1$
	Good adaptation	$0.8 < G(t) \leq 0.9$
	Basic adaptation	$0.7 < G(t) \leq 0.8$
Inadaptable types	Basic inadaptation	$0.6 < G(t) \leq 0.7$
	inadaptation	$0.4 < G(t) \leq 0.6$
	Fairly inadaptation	$0 < G(t) \leq 0.4$

Analysis of examples

Supposing that there are three central cities which are A, B and C and three freight transport modes: highway, railway and aviation in an inland urban agglomeration, their specific gravity of three major industries are 0.49, 0.47, 0.04 respectively, and the specific gravity of traffic volume caused by the metallurgy, commercial and trade, agriculture and power are 0.17, 0.25, 0.46, 0.12 respectively. And we supposed that the influencing degree of industrial structure and productivity distribution on the freight demand structure in urban agglomeration are same, which is a=b=0.5. And we can get the entropy of its demand structure is $H_d(t,d) = 1.05$. The specific gravity of these three freight supply are 0.48, 0.46, 0.06 respectively and the entropy of freight supply structure in urban agglomeration is $H_s(t) = 0.88$. Finally we can get $G(t) = 0.19$, so we can know that the entropy of freight supply structure in urban agglomeration is fairly inadaptation.

So according to the development status of urban agglomeration, we should adjust the supply ratio of various freight transport modes timely to reach the adaptability of freight supply and demand structure. For getting this state, we should focus on adjusting the supply ratio of various freight transport modes, and cannot continually increase or reduce the supply of some freight transport modes. Also we should take advantage of various freight transport modes to form the maximum efficiency of the freight supply system. Then every city in urban agglomeration should strengthen contacts, speed the cooperation up, realize the information sharing and promote the relative adaptability of freight supply and demand structure with the development of urban agglomeration.

Conclusion

(1) This paper takes the urban agglomeration as the research object, and get the adapt degree of the freight supply and demand structure urban agglomeration by applying information entropy theory to study the adaptability of freight supply and demand structure in urban agglomeration quantitatively.

(2) The research shows that the industrial structure and production distribution structure in urban agglomeration are the major factors influencing the freight demand structure in urban agglomeration. Then, the urban agglomeration's geographical position also has influences on the demand of every traffic mode.

(3) This paper has the great application value on analysis of the adaptability of freight supply and demand structure in urban agglomeration. And it also can provide theoretical basis for optimization of urban freight supply and demand structure.

References

[1] Adaptability between Supply Structure and Demand Structure of Regional Freightage Based on Information Entropy Theory[J]. TANG Jianqiao. Journal of Highway and Transportation Research and Development, 2013

[2] Study on the Structure Equilibrium of Transportation Supply and Demand[D]. Yuan Jing. Chang'an University, Xi'an, 2007

[3] Study on Forecasting method of Regional Freight Transportation Demand[D]. Sun Fenghua. Chang'an University, Xi'an, 2011

[4] Evolution of Regional Transport Structure Information Entropy and Its Dynamic Analysis[J]. YU Shi-jun. Journal of Transportation Systems Engineering and Information Technology, 2011

[5] Entropy Theory based Study on Relationship between Transportation and Industry Systems[J]. WU Feng, SHI Qi-zhou. Journal of Transportation Systems Engineering and Information Technology, 2006

[6] The Economic Analysis of demand and supply of Urban freight transport[D]. Li Hong juan. Chang'an University, Xi'an, 2010

[7] A Study on Transportation System Planning for Urban Agglomerations[D]. Liu Zhijie. Chang'an University, Xi'an, 2011

[8] Study on Information Entropy's Basic Properties[J]. Tian Zhenqing, Zhou Yue. Journal of Inner Mongolia Normal University, 2002

[9] Research on Mechanism of Demand and Supply in the Freight Transport Market[D]. Feng Yu. Dalian Maritime University, Dalian, 2006

[10] Study on Optimization of Regional Transportation Structure[D]. TANG Jianqiao. Southwest Jiaotong University, Chengdu, 2007