Research on Logistics Network Infrastructure Based on HCA and DEA-PCA Approach

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***Abstract*—Logistics Network Infrastructure (LNI) is an important area of Logistics Infrastructure Capability (LIC). The connotation of LNI is analyzed in this paper. Compared with the extensive research on LNI in developed world, empirical work is still rare in China. In this paper the theory of LNI is firstly overviewed. Then a new evaluation index system for LNI evaluation is set up which contains factors that reflect economic development level, transportation accessibility and turnover volume of freight traffic. Thirdly, an empirical study is carried out by using Hierarchical Cluster Analysis (HCA), Data Envelopment Analysis (DEA) and Principal Component Analysis (PCA) approach to classify LNI into 4 clusters for 25 cities in Yangtze River Delta Region of China. Fourthly, according to the characteristics of the 4 clusters, suggestions are proposed for improving their LNI. Finally, after comparing different LNI of 25 cities in Yangtze River Delta Region of China, this paper focuses on that different LNI including Hub, Central Distribution Center & Cross Docking Center, Regional Distribution Center or Distribution Center should be build reasonably in order to meet the customer's requirement in the 4 different cluster cities.**

***Index Terms*—logistics network infrastructure, performance, hierarchical cluster analysis, data envelopment analysis, principal component analysis**

I. INTRODUCTION

Modern logistics in China possess the great development opportunity with the accession into the WTO [1]. Shanghai, Hong Kong and Guangzhou, some of the major gates to the outside world in China, plan to build themselves into major international logistics center in 5 to 10 years [2]. Therefor the research of Logistics Network Infrastructure (LNI) has recently become a hot topic in the logistics area.

Logistics Network Infrastructure (LNI) including Logistics Hub, Central Distribution Center, Cross Docking Center, Regional Distribution Center and Distribution Center is an important area of Logistics Network Infrastructure (LNI) [3]. Mentzer and Konrad reviewed urban logistics performance measurement practices from an efficiency and effectiveness perspective [4]. Much more attention is paid to freight transport on an interurban level, due to the evolution of supply chain analysis, but this attention is basically devoted to cost factors, which are to be minimized in order to improve the efficiency of the urban logistics system. However, LNI should be re-engineered in order to improve the effectiveness of the urban logistics system [5]. From 1952 to 2003, the large-scale city has increased from 9 to 49. Therefore, we need to construct different LNI according to each city's LIC.

This paper is organized into 5 sections. In section 1, a brief description of logistics for metropolitan cities in Yangtze River Delta Region of China is introduced. After comparing and analyzing different evaluation system of LNI and overview of LNI theory, a new LNI evaluation system is proposed in section 2, which is composed of market supply and demand, economic development and transportation accessibility. In section 3, LNI is classified into 4 clusters for 25 cities in Yangtze River Delta Region of China using Hierarchical Cluster Analysis (HCA) and DEA-PCA approach. In section 4, this paper focuses on that different Logistics Network Infrastructure (LNI) including Hub, Central Distribution Center & Cross Docking Center, Regional Distribution Center or Distribution Center should be build reasonably in order to meet the customer's requirement in the 4 different cluster cities. At the final section conclusions of the study is summarized, further research for this study is suggested.

II. EVALUATION SYSTEM OF LOGISTICS NETWORK INFRASTRUCTURE

Lu and Yang indentified the key logistics capabilities indicator for international distribution center operators, based on five key logistics capabilities including customer response, innovation, economic scale, flexible operation and logistics knowledge [6]. Zhang researched the theory of the location planning for logistics park and set up a new index system for logistics park performance evaluation [7].

The evaluation and determination of logistics system efficiency has been done through traditional financial analysis where the financial statements on Total Retail Sales of Consumer Goods (TRSCG) and Volume of Transaction at Large Commodity Markets (VTLCM) are examined.

However, these financial measures fail to represent other operational and quality-related measures of performance, which are critically important for the management of a business, especially in attempting to target areas for improvement. In the proposed model, as shown in Fig. 1, not only are financial measures and capability measures included, but also availability measures are examined.

The comprehensive evaluation on Logistics Network Infrastructure (LNI) needs a synthetic evaluation system

doi:10.4304/jcp.5.4.533-540

that takes factors as much as possible into consideration to release the objective evaluation for different impacts of different factors on selection of the logistics facility location, i.e. the planning of Logistics Network Infrastructure. In general, we select 13 factors which are grouped and stated as shown in Tab. I.

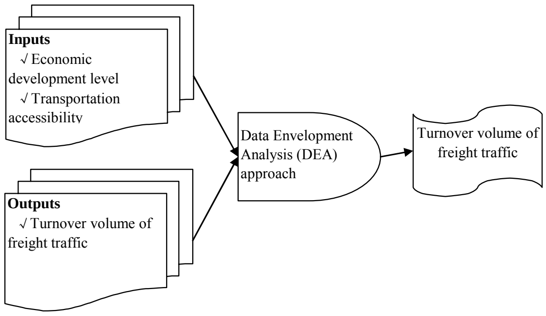


Figure 1. A conceptual model of evaluating LNI

III. Illustration of Classfication of LNI

A. Sample Cities Selection and Data Statistics

Due to imperfect evaluation index system for logistics static in China, and the statistical indicators are inadequate in Urban Statistical Yearbook of China, it is impossible for the sample we selected to contain all the influence indicators, i.e. to take factors from the available statistical data into consideration to covering influence indicators that we discussed as much as possible.

According to the difference inherent attributes of different city and distribution channel, 25 major cities in Yangtze River Delta Region in China are selected, which include:

(1) Shanghai city;

(2) Zhejiang province covering Hangzhou, Ningbo, Wenzhou, Jiaxing, Huzhou, Shaoxing, Jinhua, Qyzhou, Zhoushan, Taozhu, Lishui and Xuzhou;

(3) Jiangshu province covering Nanjing, Changzhou, Suzhou, Nantong, Lianyungang, Huai'an, Yancheng, Yangzhou, Zhenjiang, Taizhou, Xiuqian and Wuxi.

Based on National Bureau of Statistics of People's Republic of China (2007), China Statistical Yearbook (2007), China City Statistical Yearbook (2007) and China Statistical Yearbook for Regional Economy (2007), 13 indicators of the evaluation index system is analyzed above as statistical variables, we have the data showed in Table II.

TABLE I.
Evaluation Index System for LNI

	First-grade factor	Second-grade factor	Indicator (unitage)	Abbreviation
Inputs	Economic development level	Overall Economy Level	I_1-Gross Domestic Product (GDP) (100 million yuan)	GDP
		Total Investment	I_2- Total Investment in Fixed Assets in the region (100 million yuan)	TIFA
		Disposable Income	I_3- Disposable Income of Urban Households (yuan/person)	DIUH
		Consumption Expenditure	I_4- Consumption Expenditure of Urban Households (yuan/person)	CEUH
		Industry Developing Level	I_5- Number of State-owned and State-holding Enterprises (unit)	NSSE
		Gross Industrial Output Value	I_6- Gross Industrial Output Value (100 million yuan)	GIOV
		Total Retail Sales	I_7- Total Retail Sales of Consumer Goods (100 million yuan)	TRSCG
		Foreign Direct Investment	I_8- Foreign Direct Investment (10,000 USD)	FDI
	Transportation accessibility	Accessibility of Trucks	I_9- Possession of Civil Motor Vehicles (unit)	PCMV
		Accessibility of Highway	I_{10}- Highway Density (km/1000km^2)	HWD
Outputs	Turnover volume of freight traffic	Capability of Railway	O_1- Railway Turnover Volume of Freight Traffic (100 million Ton-kilometers)	RTVFT
		Capability of Roads	O_2- Highway Turnover Volume of Freight Traffic (100 million Ton-kilometers)	HTVFT
		Capability of Waterway	O_3- Waterway Turnover Volume of Freight Traffic (100 million Ton-kilometers)	WTVFT

Source: Stanley E.Fawcett (1997) [8]; David J. Closs, Thomas J. Goldsby and Steven R. Clinton (1997) [9]; Edward A. Morash, Cornelia L.M. Droge, Shawnee K. vichery (1996) [10]; Daniel F.Lynch, Scott B.Keller, John Ozment (2000) [11], arranged by the author.

B. Hierarchical Cluster Analysis of LNI

Hierarchical cluster analysis is a statistical method for finding relatively homogeneous clusters of cases based on measured characteristics. The aim is to maximize between-group variance and to minimize within-group variance. It starts with each case in a separate cluster and then combines the clusters sequentially, reducing the number of clusters at each step until only one cluster is left. In this paper, we apply the Hierarchical cluster method in Statistical Package for Social Sciences to analysis the 25 major cities. The final result is showed in Fig. 2.

According to Fig. 2, Shanghai is in one cluster district with rescaled distance cluster combine between 3 and 24, i.e. Shanghai has the first cluster with high logistics capacity, and the rest cities are in the other cluster. For rescaled distance cluster combine between 2 and 3, these 25 cities can be classified into 3 clusters, Shanghai as the first cluster, Suzhou as the second cluster, and the 23 rest cities as the third cluster.

From Fig. 2, we found that Shanghai and Suzhou topped the list in terms of LNI, but the rest 23 cities' clusters are not clear. So the following PCA and DEA analysis of LNI are necessary.

C. Principal Component Analysis of LNI

Since most of the indicators suffer from simultaneity and multi-colinearity, PCA is best suited for removing such difficulties because it maximizes the variance rather than minimizing the least square distance where any other technique (such as regression analysis) fails to do so.

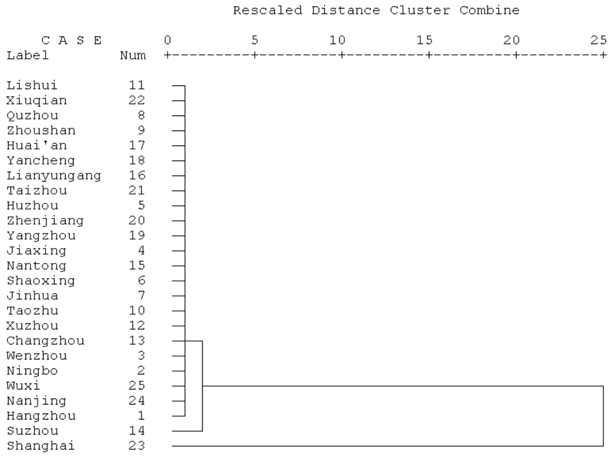


Figure 2. Hierarchical cluster analysis of 25 major cities in Yangtze River Delta Region of China

In this paper, we apply the “Factor Analysis” method in Statistical Package for Social Sciences (SPSS) to analysis the 25 major cities in Yangtze River Delta Region in China. The results shown in Tab. III suggest a two-factor solution. The eigenvalues clearly show that only two common factors are present by using the criterion of “eigenvalue greater than 1” and it is further confirmed by the fact that the break point occurs at the three eigenvalue of the scree plot (see Fig. 3). This being the case, the two-factor solution would appear to be acceptable. Tab. IV shows the two Component loadings. From the Table we see that GDP, TIFA, TRSCG, PCMV and GIOV carried more weight than DIUH, CEUH and HWD in case of ranking LIC of cities. We also find that the first component explains 74.845%, and the second component explains 14.546% of the total variation in the data. Since both the eigenvalue of the first component and the second component (in case of ten variables) are greater than 1, in the present case the two components are used to calculate component score for each city to determine the ranking of selected cities. The two Principal Components (PC) explain about 89.391% of the variations in the level of LIC. The variables like GDP, TIFA, TRSCG, PCMV and GIOV played a major role in classifying the cities in terms of LIC compared with the variables such as DIUH, CEUH and HWD.

In order to calculate the the ranking of the selected cities, the principal components can be expressed as follows:

PC_1=0.3151*I_1 + 0.3123* I_2 + 0.1866*I_3 + 0.1859*I_4 + 0.2908*I_5 + 0.3090*I_6 + 0.3164*I_7 + 0.2943*I_8 + 0.3097*I_9 + 0.1523*I_{10} + 0.2757*O_{11} + 0.3023*O_{12} + 0.2840*O_{13}

PC_2=-0.0538*I_1-0.0560*I_2 + 0.5665*I_3 + 0.5701*I_4 + 0.2131*I_5-0.0364*I_6-0.0611*I_7-0.0887*I_8-0.0909*I_9-0.4843*I_{10}-0.1949*O_{11}-0.0022*O_{12}-0.0938*O_{13}

PC=0.2551*I_1 + 0.2523*I_2 + 0.2484*I_3 + 0.2485*I_4 + 0.2781*I_5 + 0.2528*I_6 + 0.2550*I_7 + 0.2320*I_8 + 0.2445*I_9 + 0.0487*I_{10} + 0.1991*O_{11} + 0.2528*O_{12} + 0.2226*O_{13}

TABLE II.
SYNTHETIC SCORES OF 25 MAJOR CITIES IN YANGTZE RIVER DELTA REGION OF CHINA

City	Indicator												
	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10} [a]	O_{11}	O_{12}	O_{13}
Hangzhou	2,515	1,202	14,565	11,213	5,627	4,149	704	140,982	410,781	406	480	13,117	5,289
Ningbo	2,158	1,104	15,882	11,283	8,263	3,815	596	210,322	266,201	600	1,200	9,890	4,734
Wenzhou	1,403	507	17,727	14,212	5,401	1,886	588	20,916	233,877	464	50	8,277	2,399
Jiaxing	1,051	635	14,693	10,689	4,860	1,744	325	102,187	118,169	527	96	2,360	5,463
Huzhou	591	366	13,487	9,380	2,348	833	208	61,121	67,609	522	200	4,683	7,269
Shaoxing	1,314	629	15,642	10,608	3,876	2,514	335	82,344	132,867	513	999	8,132	1,176
Jinhua	978	518	13,910	9,879	3,288	1,138	362	42,983	175,351	632	333	10,649	236
Qyzhou	284	203	11,477	8,284	650	236	105	2,080	31,244	350	443	6,411	3
Zhoushan	172	128	13,747	9,835	450	222	88	2,251	15,604	655	0	1,439	3,991
Taozhu	1,174	479	16,113	12,130	3,825	1,353	303	30,296	171,175	438	0	5,362	3,487
Lishui	265	176	11,892	8,686	670	248	119	2,053	39,582	273	176	2,450	382
Xuzhou	1,096	445	9,840	6,669	959	952	274	30,399	115,916	868	1,535	5,225	662
Changzhou	1,101	589	12,868	9,878	3,161	2,013	324	53,563	128,735	811	361	4,334	952
Suzhou	3,450	1,555	14,451	9,783	5,044	7,308	625	464,810	355,096	760	168	6,942	1,892
Nantong	1,226	607	10,937	7,768	2,715	1,603	384	101,986	107,932	1,086	26	6,296	1,537
Lianyungang	416	246	8,872	6,218	552	288	141	22,773	50,150	644	1,247	3,328	251
Huai'an	501	276	8,209	5,704	885	451	156	9,215	53,108	569	53	1,953	1,699
Yancheng	871	375	9,362	6,566	1,795	889	256	14,210	62,282	512	15	3,027	4,145
Yangzhou	788	330	9,851	6,509	1,773	1,130	228	75,177	67,249	823	4	4,197	1,317
Zhenjiang	781	321	10,858	7,374	1,531	1,073	192	55,965	66,997	790	794	4,283	349
Taizhou	705	306	9,695	6,318	1,492	997	201	38,255	61,681	798	0	2,032	3,342
Xiuqian	336	197	6,378	4,403	516	148	88	1,394	35,841	715	15	1,561	350
Shanghai	7,450	3,085	16,683	12,631	12,316	12,885	2,455	654,100	2,028,500	1,231	6,814	31,554	30,148
Nanjing	1,910	1,202	11,602	8,350	2,165	3,285	711	151,208	247,036	1,243	987	9,741	6,206
Wuxi	2,350	1,114	13,588	9,518	4,543	4,575	579	194,828	234,541	866	186	6,174	1,070

Note: [a] computed by Total Length of Highways divide by area of the city.

Source: National Bureau of Statistics of People's Republic of China (2007); China Statistical Yearbook (2007); China City Statistical Yearbook (2007), arranged by the author.

Based on the expressions mentioned above, we can calculate the ranking of the selected cities. Column 2 to 9 of Tab. V shows the ranking of the selected cities based on Principal Component (PC) scores as well as ranking based on GDP. From the Tab. V, We can classify LIC into 3 clusters among the selected cities in China. For the purpose of analysis conveniently, here we define the first cluster as the high LIC cities, the second cluster as the medium LIC cities, the third cluster as the low LIC cities. The high LIC cities including Shanghai, Ningbo, Hangzhou and Suzhou, the medium LIC cities including Wenzhou, Shaoxing, Taozhu, Jiaxing, Nanjing and Wuxi, the low LIC cities including Jinhua, Huzhou, Zhoushan, Qyzhou, Lishui, Changzhou, Nantong, Xuzhou, Zhenjiang, Yangzhou, Yancheng, Taizhou, Lianyungang, Huai'an and Xiuqian. From the Table V, we see that, Shanghai topped the list in terms of LIC followed by Ningbo, Hangzhou and Suzhou. For the rate of GDP and PC score are quite high, Shanghai is the front runner among the selected cities. Comparing the LIC of Zhejiang with Jiangshu province, we found that Zhejiang province has two high LIC cities including Ningbo and Hangzhou, but Jiangshu province has only one high LIC city which is Suzhou. We also found that Zhejiang province has four medium LIC cities including Wenzhou, Shaoxing, Taozhu and Jiaxing, but Jiangshu province has two medium LIC cities including Nanjing and Wuxi. So we can draw a conclusion that the LIC of Zhejiang province has competitive advantage compared with Jiangshu province.

D. Data Envelopment Analysis of LNI

We use standard DEA models to calculate the efficiencies of LNI. The DEA scores of 25 major cities in Yangtze River Delta Region of China are shown in column 10 and 11 of Tab. V.

We can define the PCA score as efficiency and DEA score as effectiveness of logistics infrastructure, the 25 cities major cities in Yangtze River Delta Region of China are scattered in Fig. 4. From Fig. 4, we can classify LNI into four clusters:

(1) Benchmark cluster: In this cluster, both PCA score and DEA score are high in the region (PC score >= 0.6 and DEA score >= 0.9), the logistics infrastructure are both efficient and effective, including Shanghai, Ningbo, Hangzhou, Wenzhou and Nanjing.

(2) Efficiency cluster: In this cluster, PCA score is high but DEA score is low in the region (PC score >= 0.6 and DEA score < 0.9), the logistics infrastructure are efficient but ineffective, including Suzhou and Wuxi.

(3) Effectiveness cluster: In this cluster, PCA score is low but DEA score is high in the region (PC score < 0.6 and DEA score >= 0.9), the logistics infrastructure are effective but inefficient, including Shaoxing, Taozhu, Jinhua, Huzhou ect..

(4) Weakness cluster: In this cluster, both PCA score and DEA score are low in the region (PC score < 0.6 and DEA score < 0.9), the logistics infrastructure are both ineffective and inefficient, including Jiaxing, Changzhou, Nantong, Zhenjiang ect..

The result of classification shows that there are four basic logistics infrastructure clusters (see Fig. 5), which is useful for application in China.

For the purpose of analysis conveniently, here we define the first cluster city as the Hub city; the second cluster as the CDC (Central Distribution Center & Cross Docking Center) city; the third cluster as RDC (Regional Distribution Center) city, and the fourth cluster as DC (Distribution Center)city. The following researches are based on the four classification.

TABLE III.
EIGENVALUES OF THE CORRELATION MATRIX (13 VARIABLES)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.730	74.845	74.845	9.730	74.845	74.845
2	1.891	14.546	89.391	1.891	14.546	89.391
3	0.584	4.492	93.883			
…	…	…	…			

Source: calculated by the author.

TABLE IV.
COMPONENT LOADINGS (EIGENVECTORS)

	Component	
	PC_1	PC_2
GDP	0.983	-0.074
TIFA	0.974	-0.077
DIUH	0.582	0.779
CEUH	0.580	0.784
NSSE	0.907	0.293
GIOV	0.964	-0.050
TRSCG	0.987	-0.084
FDI	0.918	-0.122
PCMV	0.966	-0.125
HWD	0.475	-0.666
RTVFT	0.860	-0.268
HTVFT	0.943	-0.003
WTVFT	0.886	-0.129

Source: calculated by the author

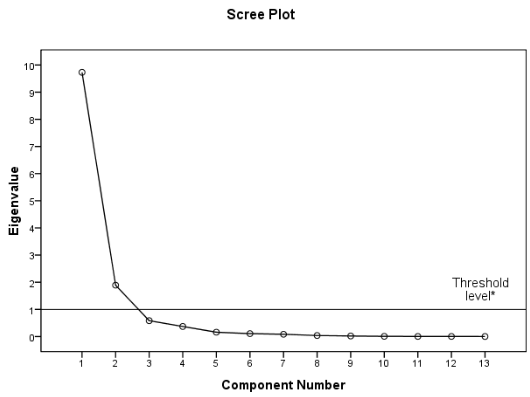


Figure 3. Scree plot of eigenvalues

Note: * only factors with eigenvalues > 1 are retained

TABLE V.
RANKING OF 25 MAJOR CITIES IN YANGTZE RIVER DELTA REGION OF CHINA ON INDICATORS OF ENVIRONMENT (USING 13 VARIABLES)

Name	PC_1 score	PC_1 ranking	PC_2 score	PC_2 ranking	GDP	GDP ranking	PC score	PC ranking	DEA score	DEA ranking	Cluster[a]	Remark
Shanghai	13.141	1	-1.562	23	7450	1	10.748	1	1	1	1	Benchmark
Ningbo	2.145	3	1.476	3	2158	5	2.037	3	0.958	2	1	
Hangzhou	1.918	4	1.437	4	2515	3	1.839	4	1	1	1	
Wenzhou	0.618	7	2.997	1	1403	7	1.005	5	1	1	1	
Nanjing	1.304	5	-1.719	24	1910	6	0.812	7	1	1	1	
Suzhou	2.671	2	0.176	13	3450	2	2.265	2	0.563	13	2	Efficiency
Wuxi	1.133	6	0.020	14	2350	4	0.952	6	0.567	12	2	
Shaoxing	0.181	8	1.416	5	1314	8	0.382	8	1	1	3	Effectiveness
Taozhu	-0.275	10	2.175	2	1174	10	0.124	9	0.939	3	3	
Jinhua	-0.331	11	0.791	7	978	14	-0.149	11	1	1	3	
Huzhou	-0.894	14	0.707	9	591	19	-0.633	14	1	1	3	
Xuzhou	-1.109	15	-1.531	22	1096	12	-1.177	15	1	1	3	
Zhoushan	-1.829	20	0.651	10	172	25	-1.425	17	1	1	3	
Yancheng	-1.700	19	-0.694	15	871	15	-1.537	19	1	1	3	
Qyzhou	-2.025	21	0.430	11	284	23	-1.626	21	1	1	3	
Lianyungang	-2.028	22	-1.287	21	416	21	-1.907	23	1	1	3	
Jiaxing	-0.144	9	1.375	6	1051	13	0.104	10	0.711	8	4	Weakness
Changzhou	-0.461	12	0.209	12	1101	11	-0.352	12	0.507	14	4	
Nantong	-0.461	13	-1.225	19	1226	9	-0.585	13	0.860	4	4	
Zhenjiang	-1.347	16	-0.833	16	781	17	-1.264	16	0.794	5	4	
Yangzhou	-1.476	17	-1.199	17	788	16	-1.431	18	0.777	6	4	
Taizhou	-1.696	18	-1.245	20	705	18	-1.622	20	0.707	10	4	
Lishui	-2.246	23	0.789	8	265	24	-1.752	22	0.708	9	4	
Huai'an	-2.324	24	-1.221	18	501	20	-2.145	24	0.727	7	4	
Xiuqian	-2.765	25	-2.133	25	336	22	-2.662	25	0.598	11	4	

Source: calculated by the author

Note: [a] cluster 1: PC score >= 0.6 and DEA score >= 0.9; cluster 2: PC score >= 0.6 and DEA score < 0.9; cluster 3: PC score < 0.6 and DEA score >= 0.9; cluster 4: PC score < 0.6 and DEA score < 0.9.

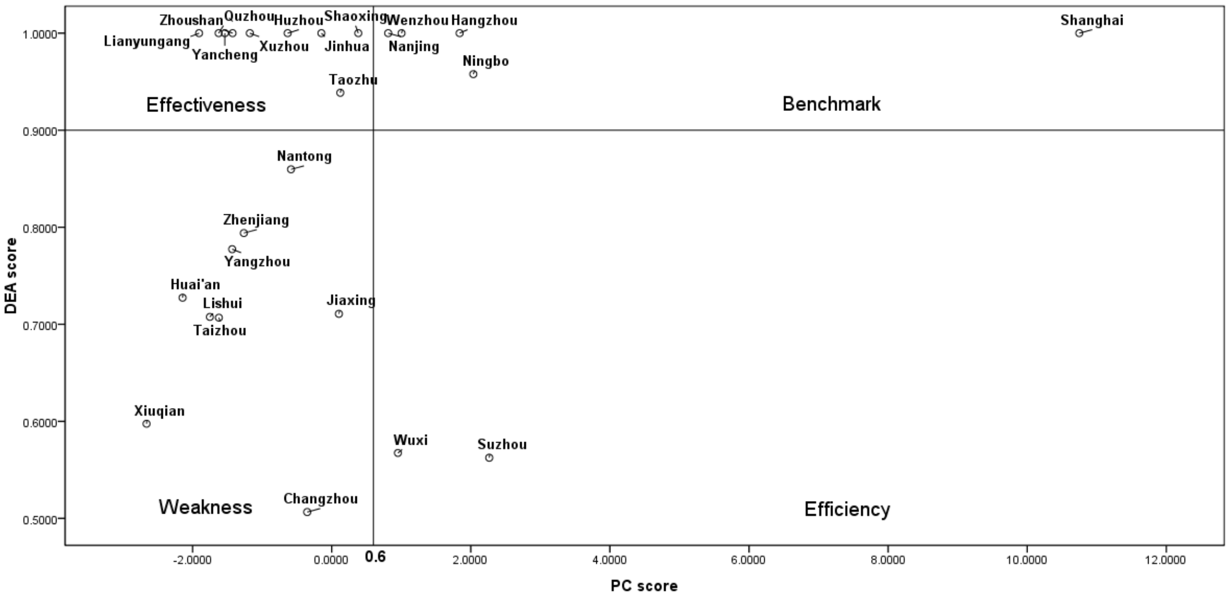


Figure 4. The four clusters of LNI of 25 major cities in Yangtze River Delta Region of China

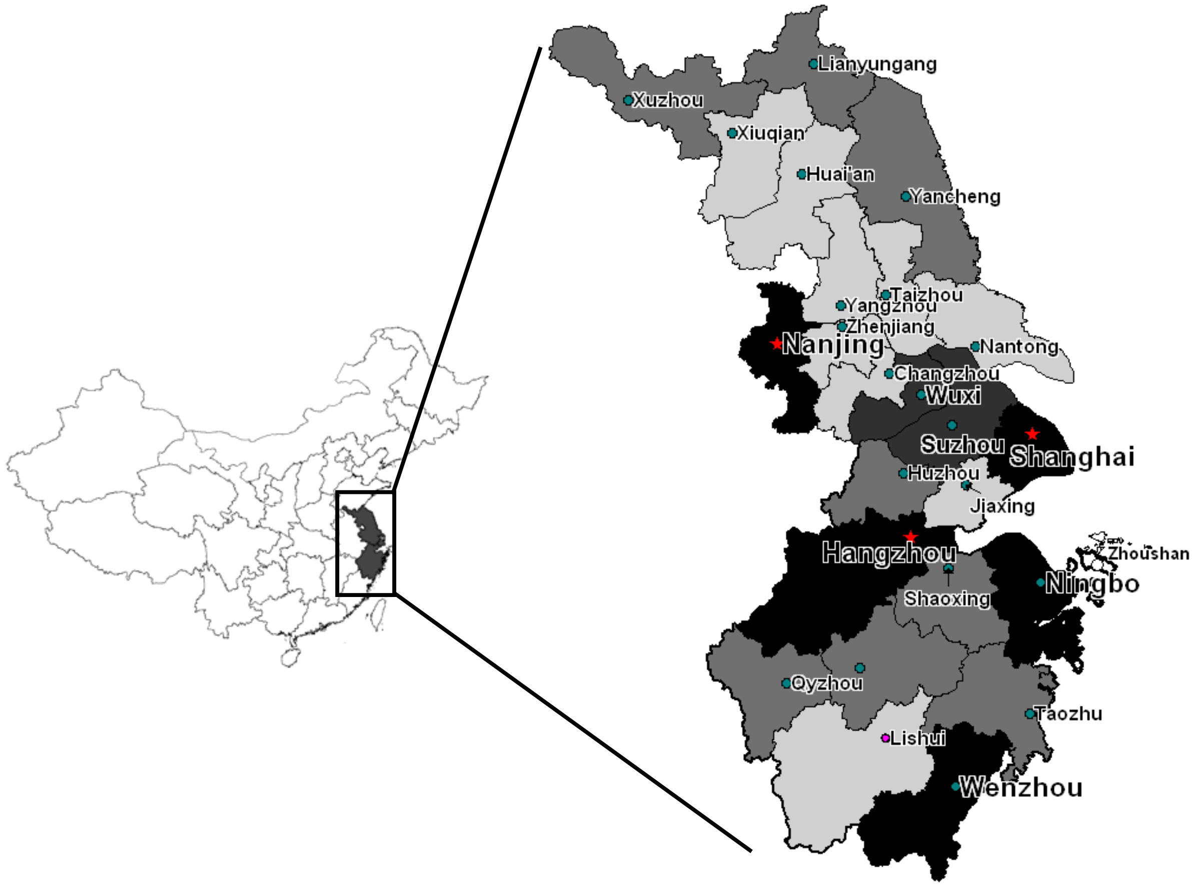
IV. LOGISTICS NETWORK INFRASTRUCTURE

Logistics Network Infrastructure includes Logistics Direction, Logistics Line and Logistics Node (see Fig. 6). Logistics infrastructure uses the analogy between the packages transported in the network and the packets transmitted through the Internet, a package in logistics infrastructure could, for example, be sent from a retail store and then routed through a sequence of Logistics Node located throughout the metropolitan area and then delivered to a customer's home in a matter of hours by Logistics Lines, making a car trip to the store to get the package unnecessary. The Logistics Node in the network, functioning like the routers in the Internet, could also be located at major highway interchanges for longer distance transport. We should design different LNI for different LIC.

A. Category of Logistics Network Infrastructure

1. Logistics direction

Logistics direction includes inbound and outbound logistics.



Note: Benchmark cluster (the Hub cities), includes 5 cities: Shanghai, Ningbo, Hangzhou, Wenzhou and Nanjing;
Effectiveness cluster (the CDC cities), includes 2 cities: Suzhou and Wuxi;
Efficiency cluster (the RDC cities), includes 9 cities: Shaoxing, Taozhu, Jinhua, Huzhou ect.;
Weakness cluster (the DC cities), includes 9 cities: Jiaxing, Changzhou, Nantong, Zhenjiang ect.

Figure 5. Classification of 25 major cities in Yangtze River Delta Region of China according to LNI

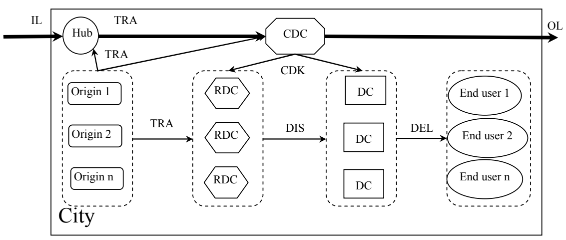


Figure 6. A conceptual model of logistics network infrastructure

Source: arranged by the author.

Note: Logistics Direction includes Inbound Logistics (IL) and Outbound Logistics (OL), Logistics Line includes Transportation (TRA), Distribution (DIS), Delivery (DEL) and Cross Docking (CDK), Logistics Node includes Hub, Central Distribution Center & Cross Docking Center (CDC), Regional Distribution Center (RDC), and Distribution Center (DC);

(1)Inbound logistics: Inbound logistics represents one of the major business processes in transportation planning. Beyond excellence in operations, the main challenge is to plan inbound logistics jointly with outbound transportation volumes to increase consolidation where ever possible.

(2)Outbound logistics: Outbound logistics represents the process related to the movement and storage of products from the end of the production line to the end user.

2. Logistics line

There are three categories logistics line such as transportation (TRA), distribution (DIS), delivery (DEL) and Cross Docking (CDK).

(1)Transportation: Transportation consists of several forms or modes and effective as well as efficient mode selection is key to a successful logistics function. Modes under the strategic and usually tactical control of the transportation include air, water or ocean, truck, and rail. Transportation is usual longer distance.

(2)Distribution: The activities associated with the movement of material, usually finished goods or service parts, from the manufacturer to the customer. These activities encompass the functions of transportation, warehousing, inventory control, material handling, order administration, site and location analysis, industrial packaging, data processing, and the communications network necessary for effective management. It includes all activities related to physical distribution, as well as the return of goods to the manufacturer. In many cases, this movement is made through one or more levels of field warehouses.

(3)Delivery: The activities associated with a carrier to pick up finished goods at a logistics node and deliver

them to end user. In other words, we also can define delivery to be the "Last Mile" transportation.

(4)Cross docking: A distribution system in which merchandise received at the warehouse or distribution center is not put away, but instead is readied for shipment to retail stores. Cross docking requires close synchronization of all inbound and outbound shipment movements. By eliminating the put-away, storage, and selection operations, it can significantly reduce distribution costs.

3. Logistics node

There are four categories Logistics Network Infrastructure in China, such as Hub, Central Distribution Center & Cross Docking Center, Regional Distribution Center and Distribution Center [11].

(1)Hub: According to DOD in USA, Hub refers to an organization that sorts and distributes inbound cargo from wholesale supply sources (airlifted, sealifted, and ground transportable) and/or from within the theater. Suppliers can arrange material and product in Hub to supply the large Hub or logistics center in service destination by long distance transportation to concentrate the supply, take advantage of common transport and combined loading, improve the logistics active efficiency and productivity, and decrease the procurement and supply cost.

(2)CDC (Central Distribution Center & Cross Docking Center): Cross Docking Center is the facility where the material or products are received from suppliers, sorted directly to be shipped to a consolidated batch (often including other orders from other suppliers) to the customers by the same vehicle or different without putting them in storage. Its particular advantages reside at the minimization of warehousing and economies of scale in outbound flows (from the Distribution Center to the customers), and it helps reduce operating costs, increase throughput, reduces inventory levels, and helps in increase of sales space. The material or products handled in CDC are usually of large-size, small-item, and low-frequency.

(3)RDC (Regional Distribution Center): A Regional Distribution Center (RDC) is a collection and consolidation center for finished goods, components and spare parts to be distributed to the Distribution Center belongs to dealers, importers or other unrelated organizations within or outside the region. Among the functions involved are information network service, repackaging and labeling, and distribution. The material or products handled in CDC are usually of small-size, multiple-item, and personality.

(4)DC (Distribution Center): Distribution Centers are foundation of Logistics Network Infrastructure, which usually is a model "warehouse" or other specialized building which is stocked with products to be re-distributed to retailers or wholesalers. In the Logistics Network Infrastructure discussed in this paper, up-level facilities will ship truckload of products to the Distribution Center, and then the Distribution Center will store the product until needed by the retail location and ship the proper quantity to the retails, stores, even the end users.

B. Planning of Urban Logistics Facility

Based on above quantitative analysis of the sample data, and qualitative analysis of four categories urban logistics facility, we locate different facility in different city clusters, and draw up different developing policy respectively.

1. Developing policy for Hub city

In Hub city, four tier logistics network is designed, in which goods is transported from the Hub to the CDC, and then distributed to RDC, finally reaches DC, as illustrated in Fig. 7.

There is a relatively perfect operation system in Hub city, the focus of Logistics Network Infrastructure planning is on enhancing the improvement and integration of the logistics systematic function, strengthening the mechanization, automatization and informationization, improving the capacity of handling and efficiency of different logistics facility, developing multimode transportation, facilitating efficient connection between facilities and transport line, optimizing operation process to control the cost.

In practice, advanced operation model should be introduced, i.e. synthetic logistics facility should be built to attract supplier of components and spare parts, and integrated operation system with supply-produce-sale and quick response should be instructed.

2. Developing Policy for CDC City

In CDC city, three tier logistics network is designed, in which goods is transported from the CDC to the RDC, and then distributed to DC, as illustrated in Fig. 8.

In this system, larger RDCs should be built for outboard transport, which should be located around the industry park with convenient transportation network with the surrounding area, i.e. goods or material can distributed to the surrounding area directly through this facility. And lager DC should be built for distributing goods to retails, stores, even the final consumers.

For transportation network constructing, it is the long distance transportation system that should be constructed with urban distribution network improvement as a supplement, i.e. to construct a smooth outboard transport system.

3. Developing Policy for RDC City

In RDC city, two tier logistics network is designed, in which goods is transported from the RDC to the DC, as illustrated in Fig. 9.

In this system, DCs should be built to enforce the capacity of small-size, multiple-item, and high-frequency goods order-picking, to improve the capacity of automatic handling, and to quick the response activity. And RDCs should also be built to accept the goods supplied by surrounding area and distribute the goods to DCs timely.

4. Developing Policy for DC City

In DC city, goods is transported directly to DC and delivered to the customers, as illustrated in Fig. 10.

For transportation network constructing, it is the urban distribution network that should be constructed by expansion of traffic road network and traffic capacity improvement, thus a distribution channel, in which the routing optimization within urban area is the focus and long distance transportation is a supplement, should be setup based on urban GIS and freight characteristic.

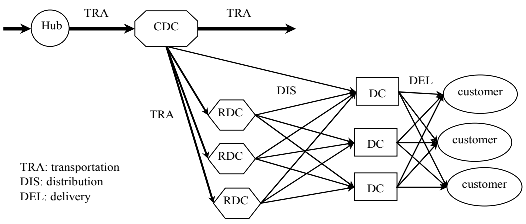


Figure 7. Logistics network infrastructure for Hub city

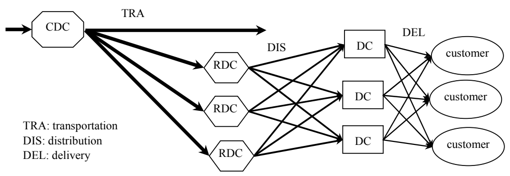


Figure 8. Logistics network infrastructure for CDC city

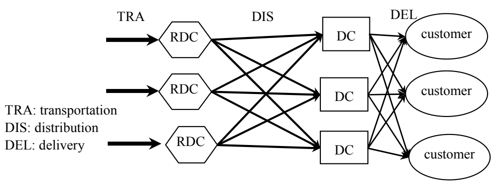


Figure 9. Logistics network infrastructure for RDC city

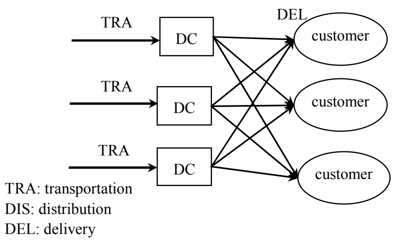


Figure 10. Logistics network infrastructure for DC city

V CONCLUSION

The empirical evidence presented in section 4 gives a better method of classifying LNI. The following conclusions can be drawn:

(1) 25 sample cities' LNI in Yangtze River Delta Region of China are classified into 4 clusters based on hierarchical cluster analysis DEA-PCA method. We define the PCA score as efficiency and DEA score as effectiveness of logistics infrastructure, the 25 major cities are classified into four clusters including benchmark cluster, effectiveness cluster, efficiency cluster and weakness cluster.

(2) We found that Yangtze River Delta Region of China has 5 Hub cities including Shanghai, Ningbo, Hangzhou, Wenzhou and Nanjing, Two CDC cities including Suzhou and Wuxi, nine RDC cities including Shaoxing, Taozhu, Jinhua, Huzhou ect., and the other 9 DC cities including Jiaxing, Changzhou, Nantong, Zhenjiang ect.

(3) The evaluation framework of LNI is partly tested by empirical study and needs further and deeper research.

ACKNOWLEDGMENT

The project is supported by Zhejiang Provincial Natural Science Foundation of China (Y6090015), the Key Foundation of Philosophy and Social Science of Zhejiang Province (09CGYD012Z), National Science Fund(70972137) and the Key Research Institute of Social Sciences and Humanities, Ministry of Education, and is supported by the Contemporary Business and Trade Research Center of Zhejiang Gongshang University (09JDSM25YB).

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