DEA Based Efficiency Analysis of the Logistics Industry in Wuhan

Yan Li¹, Jiao Yang¹, Feida Liu¹

¹School of Business, Jianghan University, Wuhan, China

Abstract. This paper presents a study of the efficiency of the logistics industry in Wuhan with the use of data envelopment analysis. Such a study bases on the careful consideration of specific input variables and the output variables. The former includes the number of trucks, the transportation and warehousing and postal fixed investment, the urban road area, and the urban road length, and the latter consists of the freight volume and the freight turnover. The data are in the period from 2004 to 2016. The results demonstrate that Wuhan realizes efficient inputs and outputs in 2004, 2005, 2009-2011, 2014, 2016. In addition, there are redundant inputs in other years. Therefore, this paper puts forward some suggestion on improving efficiency of logistics industry in Wuhan.

1.Introduction

Wuhan is located in the center of China with an increasingly important role to play in the development of Chinese economy. With the aim of developing a national logistics center, it is necessary to improve all aspects of the urban logistics industry. As a result, evaluating the efficiency of the logistics industry is becoming a top priority.

There are various initiatives that have been taken for improving the development of the logistics industry at Wuhan. In December 2016, the “Thirteenth Five-Year Plan for the Development of the Modern Logistics Industry in Wuhan” was formulated. It is clearly stated that by 2020, the Wuhan's total social logistics will reach 5 trillion yuan and the logistics industry's added value will reach 200 billion yuan.

Much research has been done in evaluating the efficiency of the logistics industry in specific cities with the use of various inputs and outputs with respect to the adoption of data envelopment analysis (DEA). Gen [1], for example, presents a study of the efficiency of the logistics industry with the selection of four variables including the delivery reliability, the delivery flexibility, the delivery cycle and the inventory level. Hamdan [2] investigates the efficiency of the logistics industry with a focus on the rate of return, the delayed arrival rate, and the price. Such studies have demonstrated the importance of selecting specific input and output variables under various circumstances for evaluating the efficiency of the logistics industry.

There are several attempts in China for assessing the efficiency of the logistics industry with the use of DEA. Liu [3], for example, presents a study of the efficiency of the logistics industry with the use of the grade of highway road length, the number of civil vehicle ownership, transportation, warehousing and postal communication industry as the input variables and the amount of road cargo transportation and urban GDP as the output variables. Guo [4] conducts a super-efficiency study by taking the grade highway mileage, the fixed investment in the logistics industry, and the number of employees in the logistics industry as the input variables and the freight turnover and the total output...
value of the logistics industry as the output variables. According to logistics industry input-output data of 31 provinces, cities and autonomous regions in 2008, Lei, Qiu and Liu [5] used Deap2.1 and DEA-Solver-LV software to make empirical study on logistics industry input-output efficiency on the basis of CCR and super-efficiency model of DEA. These studies have shown the applicability of DEA for assessing the efficiency of the logistics industry in China.

Now logistics industry is the most developing one of Wuhan. However, seldom research on the efficiency of logistics industry in Wuhan has been done. This paper presents a study of the efficiency of the logistics industry in Wuhan with the use of data envelopment analysis. Such a study is based on the careful consideration of specific input variables including the number of trucks, the transportation and warehousing and postal fixed investment, the urban road area, and the urban road length and the output variables consisting of the freight volume and the freight turnover in the period between 2004 to 2013. According to this study, some suggestion are put forward to promote the rapid development of Wuhan's logistics industry.

2. The DEA-CCR model

DEA is commonly used for evaluating the efficiency of comparable business units referred to as the decision-making unit (DMU). In a given situation, there are \( n \) DMUs. Each DMU has \( m \) input variables and \( s \) output variables. To evaluate the relative efficiency of these DMUs with respect to the selected input and output variables, a DEA-CCR model for the DMU \( j_0 \) can be represented as follows:

\[
\begin{align*}
\min \theta & \quad \text{s.t.} \\
\sum_{j=1}^{n} \lambda_j X_j + S^- & = \theta X_{j_0}, \\
\sum_{j=1}^{n} Y_j \lambda_j - S^+ & = Y_{j_0}, \\
\lambda_j, S^+, S^- & \geq 0, j = 1, 2, \ldots, n,
\end{align*}
\]

(1)

Where \( X_{j_0} \) denotes the input vector of the DMU \( j_0 \), and \( Y_{j_0} \) represents the output vector of the DMU \( j_0 \), \( \theta \) denotes the input reduction ratio, and \( E \) denotes the coefficient of the linear combination of the DMUs.

When \( \theta=1 \), and \( s^+=0, s^-=0 \), DMU \( j_0 \) is valid. It shows that the DMU has the best technical efficiency and the best scale efficiency. When \( \theta=1 \), and at least one \( s^+ \) or \( s^- \) is greater than 0, the DMU \( j_0 \) is valid for weak DEA. It means that the DMU is not technically efficient. It is however, scale effective. When \( \theta<1 \), DMU \( j_0 \) is not valid for DEA. It shows that the DMU is neither technically optimal nor scale efficient.

With the use of the DEA model above, the efficiency of the logistics industry at Wuhan can be investigated. The empirical data used for this investigation is from the statistical yearbook published by the government department. Based on the nature of this study, specific input and output variables have to be selected.

There are many input and output variables that are commonly used for evaluating the efficiency of the logistics industry. The selection of these input and output variables is based on the nature of the study and the characteristics of a specific efficiency evaluation situation. After a comprehensive review of the related studies, specific input and output variables as shown in Table 1 have been selected.

The input variables that have been selected for this study include the number of trucks, the urban road area, the urban road length and the transportation and warehousing and postal fixed investment. Transportation is one of the most important logistics functions. And road transport in China and Wuhan accounts for the largest proportion of transportation, reaching around 70%, so The number of trucks (vehicle) is used to represent the variables of the transportation vehicle. Urban road length is used to indicate the construction of the city's transportation infrastructure. It is worthwhile to point out
that the grade road mileage index is commonly used in many existing studies. With the consideration of the situation at Wuhan, non-grade roads are available. Furthermore, the width of the road also affects the efficiency of the logistics industry. As a result, the urban road area is adopted as an input variable for better reflecting this special situation. The transportation and warehousing and postal fixed investment shows the investment in logistics industry.

Due to lack of data on logistics industry value added, total social logistics and total logistics in the current Chinese statistics, the freight volume and the freight turnover have been selected as the output variables in this study.

### 3. A longitudinal efficiency evaluation

The data in this study are all from the Wuhan Statistical Yearbook. The latest statistical yearbooks that can be consulted by the Wuhan Municipal Bureau of Statistics are the 2017 Statistical Yearbook, which reflects the 2016 data. The analysis data of the logistics industry at the Wuhan City from the year of 2004 to 2016 are selected. The specific data is shown in Table 1.

| Year | The number of trucks (Vehicle) | Trans and W.h. and postal fixed investment (Ten thousand yuan) | Urban road area (Ten thousand square meters) | Urban road length (km) | Freight volume (Ten thousand tons) | Freight turnover (100 million tons * km) |
|------|--------------------------------|---------------------------------------------------------------|---------------------------------------------|-----------------------|-----------------------------------|----------------------------------------|
| 2004 | 92572                          | 553326                                                         | 3132.19                                     | 3583.13               | 17044.8                           | 835.2                                  |
| 2005 | 85421                          | 942321                                                         | 4100                                         | 2300.45               | 19611.7                           | 1277.7                                 |
| 2006 | 19139                          | 1668086                                                        | 4328                                         | 2369                  | 20817.75                          | 1312.73                                |
| 2007 | 99816                          | 1535431                                                        | 4771                                         | 2515                  | 22554.93                          | 1418                                   |
| 2008 | 106391                         | 1975175                                                        | 5909                                         | 3034.7                | 29142.98                          | 1750                                   |
| 2009 | 118772                         | 2771175                                                        | 6802                                         | 2542                  | 34409.19                          | 1900.05                                |
| 2010 | 127911                         | 3858315                                                        | 7273                                         | 2682.2                | 40287.93                          | 2263.6                                 |
| 2011 | 139646                         | 3630295                                                        | 7726.2                                       | 2840.1                | 41804.45                          | 2644.18                                |
| 2012 | 140820                         | 3816137                                                        | 9027                                         | 5245                  | 43892.49                          | 2910.22                                |
| 2013 | 146060                         | 4190317                                                        | 8383.71                                      | 4833.12               | 44528.75                          | 2555.96                                |
| 2014 | 152687                         | 4547044                                                        | 8879.63                                      | 5143.4                | 48529.99                          | 3025.72                                |
| 2015 | 134780                         | 5709380                                                        | 9495                                         | 5354                  | 48185.19                          | 2951.92                                |
| 2016 | 123535                         | 1824514                                                        | 10154                                        | 5704                  | 49981.81                          | 3082.35                                |

With the collected input and output data from the Wuhan City for thirteen years, the efficiency of the logistics industry at Wuhan can be evaluated using the DEA model shown above. The results are shown in Table 2.

An analysis of the results in Table 2 shows that the logistics industry is ineffective except for 2006, 2007, 2008, 2012, and 2015. To better understand the rationale behind, the input and output variables across these six years in the logistics industry are examined. Table 3 and Table 4 show a summary of the examination results with respect to the efficiency of the logistics industry at Wuhan.

### Table 2. A summary of the efficiency evaluation result

| Year | Comprehensive efficiency | Pure technical efficiency | Pure scale efficiency | Scale remuneration |
|------|--------------------------|---------------------------|----------------------|--------------------|
| 2004 | 1.000                    | 1.000                     | 1.000                | constant           |
| 2005 | 1.000                    | 1.000                     | 1.000                | constant           |
| 2006 | 0.916                    | 0.988                     | 0.927                | Increment          |
| 2007 | 0.921                    | 0.952                     | 0.967                | Increment          |
| 2008 | 0.943                    | 0.965                     | 0.977                | Increment          |
| 2009 | 1.000                    | 1.000                     | 1.000                | constant           |
| Year | The number of trucks (Vehicle) | Trans and W.h. and postal fixed investment (Ten thousand yuan) | urban road area (Ten thousand square meters) | Urban road length (km) |
|------|-------------------------------|---------------------------------------------------------------|-----------------------------------------------|------------------------|
| 2006 | 88071.692                     | 1112880.445                                                   | 4277.127                                       | 2341.154               |
| 2007 | 92047.045                     | 1345066.328                                                   | 4542.301                                       | 2394.443               |
| 2008 | 102656.826                    | 1905849.143                                                   | 5701.602                                       | 2833.624               |
| 2012 | 138655.945                    | 3342337.925                                                   | 888.277                                        | 4517.090               |
| 2013 | 141888.974                    | 4070654.394                                                   | 8144.297                                       | 4401.518               |
| 2015 | 132966.802                    | 2928542.903                                                   | 9367.264                                       | 5120.265               |

Table 4. DEA effective output target value

| Year | Freight volume (Ten thousand tons) | Freight turnover (100 million tons * km) |
|------|------------------------------------|----------------------------------------|
| 2006 | 20817.750                          | 1330.771                               |
| 2007 | 22554.930                          | 1418.000                               |
| 2008 | 29142.980                          | 1750.000                               |
| 2012 | 46641.151                          | 2910.220                               |
| 2013 | 44528.750                          | 2695.369                               |
| 2015 | 48185.190                          | 2951.920                               |

The technical efficiency describes the difference between the actual and the ideal value of the input variable value and the output variable value when the input variable size is constant. As seen from Table 2, the technical efficiency of the logistics industry at Wuhan does not reach an effective value in the six years of 2006, 2007, 2008, 2012, 2013 and 2015. It can be seen from Tables 1 and 3 that the most input factors in 2006 and 2007 are fixed investment in the transportation and warehousing postal industry. For example, in 2006, the DEA effective transportation and warehousing postal industry fixed investment value of 111,288,045,500 yuan, and the actual investment value is 1,660,086,000 yuan, nearly 1.5 times the effective value of DEA, but the freight volume and freight turnover did not change much. This is also one of the main reasons for the ineffectiveness of DEA in 2006. It can be seen that the more input, does not mean to obtain more benefits. Combined with the development of Wuhan in 2006 and the background of the times, 2006 is just the beginning of the development of logistics industry in Wuhan, and does not pay attention to the development of the logistics industry. It is hoped that relying on the development of the logistics industry to drive the development of the
national economy, and suddenly increase the investment in the logistics industry, but did not bring good results, the output value of output has no major breakthrough.

It can be seen from Table 4 that the effective freight volume of DEA in 2012 was 466,411,510 tons, but the actual cargo volume was 438,924,900 tons, nearly 6% of the gap, and the freight volume output was seriously insufficient. It may be related to the financial crisis that broke out in 2012, and the reduction of logistics technology is one of the main reasons for the lack of output. The output of freight turnover in 2013 has not yet reached an effective state. It can be seen from Table 1 that the urban road area in 2013 has been seriously reduce, reducing the area by nearly 8%. 2013 is the peak period of Wuhan rail transit construction. The large-scale reconstruction of Wuhan roads has increased the difficulty of transportation in the logistics industry and reduced the freight turnover. This shows that the road infrastructure in Wuhan is not yet complete, and there are also unreasonable places in the layout planning of logistics enterprises. Therefore, logistics efficiency has a great relationship with logistics input and output, and only the reasonable arrangement of inputs can achieve the best output.

The scale efficiency describes the gap between the actual industry scale and the optimal industry scale. In Table 2, the pure-scale efficiency of Wuhan in 2006, 2007, 2008, 2012, and 2013 were 0.927, 0.967, 0.977, 0.995, and 0.996, respectively, which did not reach the optimal industrial scale. At the same time, the scale efficiency in 2006, 2007, 2008 and 2012 increased, and the scale efficiency decreased in 2013. The abrupt changes in various input factors have a direct link to the fact that Wuhan's logistics efficiency has not reached an effective value. In the future, Wuhan City wants to rely on the logistics industry to build a nationwide central city, and must learn these lessons. The first point is to consider whether the ratio between the various elements is optimal and whether it can achieve twice the result with half the effort when planning the future development direction of the logistics industry in Wuhan. The second point in the process of urban transformation in Wuhan, we must consider the impact that may be affected by various industries during the urban transformation process.

Scale returns describe the effect of a proportional increase in input factors on output. In the past three years, the size of Wuhan has remained unchanged. This means that if Wuhan increases the input factor proportionally, the output will increase proportionally. It shows that the current logistics industry in Wuhan is in good condition and still has extremely high efficiency. This is a good news for the development of logistics industry in Wuhan.

4. Improving the efficiency of the logistics industry

In addition to providing a good development prospect for the logistics industry, the Wuhan Municipal Government should also take some positive measures to give logistics enterprises some preferential policies to attract more competitive and larger-scale logistics enterprises to enter Wuhan for development.

The urban roads and infrastructure in some areas of Wuhan are not complete, so during the road reconstruction in Wuhan, it is not enough to meet the transportation of a large number of items. In the road construction planning of Wuhan, the government should take this into consideration and should focus on building the logistics industry park in Wuhan, and establish a dedicated logistics channel and some basic equipment for this purpose.

At present, the logistics enterprises in Wuhan have problems such as small scale, insufficient management conditions, outdated logistics facilities and equipment, and simple handling of corporate customer relationships. To solve this problem, we must start from two aspects. First, we provide policy support to logistics enterprises. We all know that Chinese enterprises have heavy taxation. We should first reduce the tax and other financial burdens of the company. Specifically, the government can give tax enterprises some tax subsidies, reduce the highway transportation charges for logistics vehicles, and so on. Second, the government encourages logistics companies to integrate and merge, so that the power of small and inefficient logistics companies can be quickly integrated, making it a large enterprise as a whole. This can increase the enterprise resources available to enterprises and improve the competitiveness and logistics efficiency of Wuhan logistics enterprises.
Another problem in the logistics industry in Wuhan is the lack of an efficient public logistics information platform, which has caused the logistics market in Wuhan to be disconnected from the logistics supply enterprises in Wuhan. Wuhan should encourage enterprises in China and the world who are familiar with the construction of logistics platforms to seek development in Wuhan, so that they can help Wuhan to build an efficient public logistics information exchange platform.

The management philosophy of Wuhan logistics enterprises is too traditional, which greatly affects the development of enterprises and logistics efficiency. Therefore, we must improve the management philosophy and corporate development philosophy of logistics companies. The government can organize more logistics enterprise exchange meetings, invite the world's well-developed enterprises to exchange and learn, and effectively improve the management philosophy of logistics entrepreneurs in Wuhan.

5. Conclusion
This paper uses the DEA model to evaluate the logistics efficiency of Wuhan City in the past 13 years, and finds out the reasons why the DEA is invalid in some years in Wuhan, mainly because the input factors are not coordinated. Therefore, Wuhan should pay attention to the proportion of logistics investment, save resources and maximize benefits.

Although on the basis of previous studies, this paper further deepens the logistics efficiency index system, but the calculated urban logistics efficiency values are still different from the actual situation. If the logistics efficiency index system in the evaluation area is more perfect, the research will be more valuable.

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