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# The Impact of Bike Sharing on Urban Transportation

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***Abstract:*** *The emergence of shared bicycle systems, such as Citi Bike, has greatly changed the pattern of urban mobility in New York City. It has not only provided a new choice for people to travel, but also greatly changed the way people live. In this paper we discuss the impact of Citi Bike on economics, society, environment and other relevant aspects. On the basis of considering people's favorable choices of travel mode, we choose car, walk, subway, bus, bike and For-Hire-Vehicle, totally four modes, to study. We select several representative indicators to evaluate the travel modes, such as the average number of users within one year, the speed, the operating cost and the impact on the environment. Then the data is standardized by the method of Deviation Standardization and we draw the data table using Excel.Then we choose the Entropy Weight Method to calculate the weight of different modes using Matlab, calculate the respective score of travel modes, and finally we get the Citywide Mobility Mode to quantitatively assess the impact of shared bikes on economics, environment and society. We reach a conclusion that without a shared bike system, the way people travel will mostly be replaced by driving. It will lead to more fuel consumption and extraneous expenses, which will increase the burden on consumers and bring pollution to the environment. During our process of modelling, the biggest challenge is to build a reasonable model to simulate the situation without a shared bicycle system, but the assumption itself is unreasonable, so this paper establishes a unified framework for all kinds of travel modes. When the shared bicycle system is not included, the proportion of it is reduced to zero, so the change of the model is observed to evaluate the impact of the shared bicycle system on the city. We hope this research helps to support the construction of transportation systems in New York and other cities around the world.*

***Key words:*** *Entropy Weight Method, MATLAB, Excel, Deviation Standardization, Citywide Mobility Model*

## 1. Introduction

The bike sharing system has been popular among citizens since it was launched. It was designed for quick trips with convenience in mind, and it’s a fun and affordable way to get around town.

New York City’s Citi Bike can be cited as a typical case. Launched in May 2013,

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Citi Bike is the America's largest bike share program, with 12,000 bikes and 750 stations across Manhattan, Brooklyn, queens and jersey city. More context on the deployment and its phases could be found in supplementary information s1[1].

There were 136,702 active annual members of Citi Bike by the end of December, 2017. The number of daily cycling trips continues to grow, with 10,000 additional daily trips between 2015 and 2016, leading to an 84% increase from 2010 totals. According to data from Citi Bike, this number is still rising[2].

In this paper, we do a comparative study of shared bikes and several other travel modes to quantitatively assess the impact of shared bicycles on urban traffic, as well as the associated economic, social and environmental impacts.

## 2. The Description of the Problem

### *2.1 Restatement of the Problem*

Shared bicycles play an important role in improving urban traffic conditions, which accordingly has an impact on other fields, such as economics, society and environment.

We need to quantitatively assess the impact of shared bicycles in these fields. The key to this problem is to establish a reasonable model to predict people’s traffic behavior if there is no shared bicycles in a city.

As an attachment to the paper, we need to submit a formal report to the transportation department on the changes that the shared bicycle caused to the city.

### *2.2 Problem Analysis*

First, we select several typical travel modes to analyze. In this problem, we choose car, walk, subway, bus, bike and For-Hire-Vehicle (FHV), totally four modes, to study.

Then we select several important representative indicators to evaluate the travel modes. In this paper, we choose average number of users within one year, the speed, the operating cost and the impact on the environment as our indicators.

After referring to a huge amount of datum, we get the time series data (data of each year) corresponding to each indicator of these six travel modes, standardize them by the method of Deviation Standardization, and draw the data table using Excel. We calculated the specific weight value of each travel mode (the proportion of usage) . By using the entropy weight method (EWM) we get the weight value (degree of variation) of each indicator, and furthermore through a series of calculation we get the "score" (the acceptance degree of citizens) of each travel mode. .

When we predict the traffic behaviors of people in cities where there is no shared

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bike, we make the weight of shared bikes zero, repeat the above process, and compare the results with the previous ones. Finally, we get the impact of shared bikes on economics, society, environment and other aspects[3].

## 3. Models

### *3.1 Entropy Weight Method*

3.1.1 What is entropy weight method

The entropy weight method (EWM) is an objective assignment method. In the process of concrete use, entropy weight method calculates the entropy weight of each index by using information entropy according to the degree of variation of each index, and then modifies the weight of each index through entropy weight, thus obtains the more objective index weight.

Generally speaking, if the entropy weight method of an index is smaller, it shows that the greater the variation degree of the index is, the more information can be provided, and the greater the role it can play in the comprehensive evaluation, the greater its weight will be.

On the contrary, if the information entropy index weight determination method of a certain index is bigger, the smaller the variation degree of the index is, the less information is provided, and the smaller the function in the comprehensive evaluation is, the smaller the weight will be.

3.1.2 The weighting steps of the entropy weight method

Step 1: The normalization of index values

Normalize the data of each index. Assume that k indicators are given:

$$X_i = \{x_1, x_2, \dots, x_n\}, Y_1, Y_2, \dots Y_k$$

Assume that the normalized values for each indicator data are

$$X_1, X_2, \dots, X_k$$

Meanwhile

$$Y_{ij} = \frac{X_{ij} - min(X_i)}{max(X_i) - min(X_i)}$$

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Step 2: Calculate the specific gravity of the index value of item i under the j index $p_{ij}$ :

$$p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}}$$

Step 3: Calculate the entropy of item j:

According to the definition of information entropy in information theory, the information entropy of a group of data is

$$E_j = -ln(n)^{-1} \sum_{i=1}^{n} p_{ij} \, ln(p_{ij})$$

If

$$p_{ij} = 0$$

then define

$$\lim_{p_{ij} \sim 0} p_{ij} \bullet ln(p_{ij}) = 0$$

Step 4: Calculate the weights of the indicators:

According to the calculation formula of information entropy, the information entropy of each index is calculated as follows:

$E_1, E_2, \ldots, E_k$

The weight of each index is calculated by information entropy:

$$W_i = \frac{1 - E_i}{k - \sum E_i} (i = 1, 2, \ldots, k)$$

3.1.3 Terms, Definitions and Symbols

*Table 1 Symbolic description table*

| Symbols | Explanations |
|---|---|
| $X_i(i = 1, 2, \ldots, k)$ | The given k indicators |
| $Y_i(i = 1, 2, \ldots, k)$ | Values after standardization of data for each indicator |

| | |
|---|---|
| $E_i(i=1,2,...,k)$ | Information entropy of each indicator |
| $W_i(i=1,2,...,k)$ | Weights of indicators |
| $p_{ij}(i=1,2,...,n;\ j=1,2,...,k)$ | The specific gravity of the index value of item i under the j index |

3.1.4 The Model Assumptions

A. Assume that US policy does not affect the use frequency of shared bikes.

B. Assume that the data sources we found are truthful, scientific and reasonable.

C. Assume that shared bikes are not used for cycling related sports events

3.1.5 Standardization of the Data

A. What is Data Normalization

In a multi-index evaluation system, due to the different properties of each evaluation index, it usually has different dimensions and orders of magnitude. When the level of each index is very different, if the original index value is used directly, the function of the higher value index in the comprehensive analysis will be emphasized, and the function of the lower

value index will be weakened. Therefore, in order to ensure the reliability of the results, it is necessary to standardize the original index data.

How to Normalize the Data

Transform the sequence : $X_1,\ X_2,...,\ X_n$ into the new sequence:

$$=\frac{x_i-min_{1\le j\le n}\{x_j\}}{max_{1\le j\le n}\{x_j\}-min_{1\le j\le n}\{x_j\}}$$

It has no dimension.

### *3.2 Single Scenario Model*

If we want to estimate the impact of shared bikes on environment, society and other aspects, a single scenario analysis replacing Citi Bike with another single alternative, such as walking, could help us better understand the upper bounds for the impacts.

We replace the cumulative bike travel distance with another travel mode, and then get approximate estimates. The chart will be illustrated in the following contents.

### *3.3 Modeling Establishment and Solution*

The shared bike system has played an important role in citizens' life. If we want to estimate the impact of shared bikes on environment, society and other aspects, a single scenario analysis replacing Citi Bike with another single alternative, such as walking, could help us better understand the upper bounds for the impacts.

We replace the cumulative bike travel distance with another travel mode, and then get approximate estimates as follows. The assumptions are all made under the time range: from July, 2013 to June, 2014.

But the assumption itself is unreasonable, so we establishes a unified framework for all kinds of travel modes. When the shared bicycle system is included, the proportion of the shared bicycle system in the model is reduced to zero, and the change of the model is observed to evaluate the impact of the shared bicycle system on the city.

So we select several typical travel modes to analyze. In this problem, we choose car, walk, subway, bus, bike and For-Hire-Vehicle (FHV) ,totally four modes , to study.

Then we select several important representative indicators to evaluate the travel modes. In this paper, we choose average number of users within one year, the speed, the operating cost and the impact on the environment as our indicators.

After referring to a huge amount of datum, we get the time series data (data of each year) corresponding to each indicator of these six travel modes.

*Table 2 The time series data table*

| Scenario | Savings in Travel Cost / hours | Savings in Gas / liters | Savings in Travel Time / hours |
|---|---|---|---|
| All walking | 191,199 | -- | 3204 |
| All taking taxi | 363,411 | 4,996 | 2274.8 |
| All public transit | 24,012 | -- | -191.9 |
| All driving | -32,237 | 4,996 | -897.3 |

By using the entropy weight method (EWM) we get the weight value (degree of variation) of each indicator, and furthermore through a series of calculation we get the "score" (the acceptance degree of citizens) of each travel mode.

*Table 3 Travel mode score table*

| | Travel Mode | Number of users | Speed | Running Cost |
|---|---|---|---|---|
| | Car | 2,794,440 | 10 | 4.7 |
| | Walk | 60,700,000 | 2.8 | 0 |
| | Subway | 118,605,560 | 22.4 | 2.75 |

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| | | | | |
|---|---|---|---|---|
| 2016 | Bus | 176,511,120 | 10.44 | 2.75 |
| | Bike | 234,416,680 | 9.3 | 6 |
| | For-Hire-Vehicle | 292,322,240 | 7.1 | 3.76 |
| | Travel Mode | Number of users | Speed | Running Cost |
| | Car | 2,794,400 | 11 | 4.8 |
| 2017 | Walk | 60,700,010 | 2.8 | 0 |
| | Subway | 118,605,620 | 23 | 2.85 |
| | Bus | 176,511,230 | 10 | 2.8 |
| | Bike | 234,416,840 | 9.4 | 5 |
| | For-Hire-Vehicle | 292,322,450 | 7.3 | 3.8 |
| 2018 | Travel Mode | Number of users | Speed | Running Cost |
| | Car | 2,794,000 | 11.5 | 4.8 |
| | Walk | 60,700,100 | 2.8 | 0 |
| | Subway | 118,606,200 | 22.5 | 2.8 |
| | Bus | 176,512,300 | 9.8 | 2.85 |
| | Bike | 234,418,400 | 9.5 | 6.5 |
| | For-Hire-Vehicle | 292,324,500 | 7.2 | 3.85 |

We calculated the specific weight value of each travel mode (the proportion of sage) .

The results are presented in the following chart

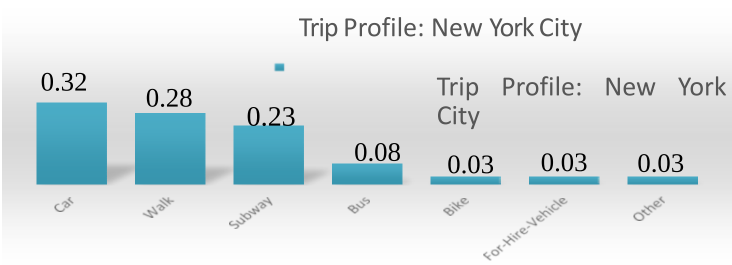


*Fig.1 Travel mode specific gravity value diagram*

When we predict the traffic behaviors of people in cities where there is no shared bike, we make the weight of shared bikes zero, repeat the above process, and compare the results with the previous ones.

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Below is the flow chart of our process:

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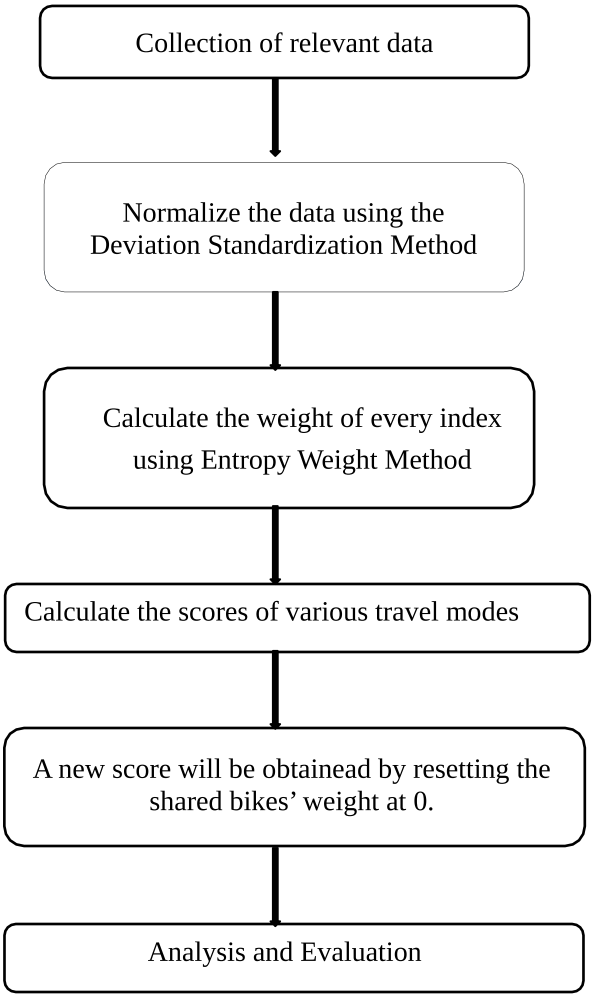


*Fig.2 flow-process diagram*

Finally we get the impact of shared bikes on economics, society, environment and other aspects.

### *3.4 The Matlab Code*

3.4.1 Entropy Weight Method

function weights = Entropy Weight(R) R=[];

[rows, cols]=size(R); k=1/log(rows); f=zeros(rows, cols); sumBycols=sum(R,1); for i=1:rows

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```
        for j=1:cols
             f(i,j)=R(i,j)./sumBycols(1,j);
        end
    end
lnfij=zeros(rows,cols); for i=1:rows
        for j=1:cols
             if f(i,j)==0
                  lnfij(i,j)=0;
            else
                 lnfij(i,j)=log(f(i,j));
                 end
          end
    end
```

The weight of the indicators for three consecutive years is calculated as follows:

*Table 4 Index weight table*

| Year | Number of users | Speed | Running cost |
|---|---|---|---|
| 2016 | 0.60 | 0.24 | 0.16 |
| 2017 | 0.61 | 0.24 | 0.15 |
| 2018 | 0.60 | 0.23 | 0.17 |

Scores for various types of travel mode are as follows:

*Table5 Tourism model rating table*

| Year | Car | Walk | Subway | Bus | Bike | For-Hire-Vehicle |
|---|---|---|---|---|---|---|
| 2016 | 0.07 | 0.01 | 0.21 | 0.03 | 0.01 | 0.01 |
| 2017 | 0.08 | 0.01 | 0.22 | 0.03 | 0.01 | 0.01 |
| 2018 | 0.07 | 0.01 | 0.21 | 0.03 | 0.01 | 0.00 |

Scores for all types of modes after reducing the proportion of bicycles to zero are as follows:

*Table 6 Scoring table for all kinds of patterns*

| Year | Car | Walk | Subway | Bus | Bike | For-Hire-Vehicle |
|---|---|---|---|---|---|---|
| 2016 | 0.07 | 0.01 | 0.22 | 0.03 | 0.00 | 0.01 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2017 | 0.08 | 0.01 | 0.22 | 0.03 | 0.00 | 0.01 |
| 2018 | 0.08 | 0.01 | 0.22 | 0.03 | 0.00 | 0.00 |

### *3.6 Analysis of the Result*

The proportion of passengers was the highest for three years in a row, and relatively stable. After determining the weights of various indexes, we further calculate the scores of various travel modes by using the proportion of people's travel modes, and then make a more intuitive comparison of the various travel modes.

The urban mobility model we constructed explains the changes in urban traffic if Citi bikes do not exist, and the weights of each index obtained by entropy weight method are shown in the table above. Among them, “the average number of users within one year” is the indicator weighing highest and the most stable in three consecutive years. It is followed by “the speed”, which suggests whether people need to travel fast or not.

### *3.7 Strength and Weakness*

3.7.1 Strength:

On the basis of correct analysis and understanding of the problem, a comprehensive and objective evaluation model is established.

Compared with the subjective assignment method, the entropy weight method has higher accuracy and objectivity, and can better explain the results obtained, and it is applicable to any process that needs to determine the weight.

The model is simple and easy to understand, the data used are from official statistics, with real reliability.

3.7.2 Weakness:

The data search is not perfect, and the coverage is not wide enough, the model evaluation index is not perfect, and not objective enough.

## *4. Conclusions*

### *4.1 Conclusions of the problem*

Citi's bicycle and other shared bicycle systems are now found in almost every corner of New York City, bringing great convenience to travel and a huge change to the city's transportation.

the average number of users within one year, the speed, the operating cost and

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the impact on the environment

The urban mobility model we constructed explains the changes in urban traffic if Citi bikes do not exist, and the weights of each index obtained by entropy weight method are shown in the table above. Among them, “the average number of users within one year” is the indicator weighing highest and the most stable in three consecutive years. It is followed by “the speed”, which suggests whether people need to travel fast or not.

After determining the weights of various indexes, we further calculate the scores of various travel modes by using the proportion of people's travel modes, and then make a more intuitive comparison of the various travel modes.

Our assumption excludes the various recreational and sporting uses of bicycles, just taking their effects under normal use into account. After calculating the score of all kinds of travel modes and turning the proportion of people choosing bicycle as a travel mode into zero, we add the proportion of other ways at the ratio. Finally we compare the change of people's travel mode without bicycle.

Summing up all identified impacts into monetary conditions allows us to conclude that Citi Bicycle as an overall assessment of urban innovation is positive.

The study may help to provide a comprehensive picture of the efficiency of Citi's bicycle deployment to different types of economic, social and environmental stakeholders, including urban institutions, and inform future decisions to deploy bikes elsewhere.

### *4.2 Methods used in our models*

A. Entropy Weight Method

B. Deviation Standardization Method

C. Single Scenario Method

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