# The Establishment of AHP-Fuzzy Model for Comprehensive Evaluation of "City Obesity" Degree

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**Abstract.** With the increasingly rapid urbanization process in China, there is an urban disease called "City Obesity" which can hinder the normal and fast development of the city. Symptoms are the rapid urban population growth, too much traffic congestion, and the deepening social conflicts and so on. In this paper, the various elements of the city are attributed to the city's "nine systems" as a person which has nine systems too. Firstly, the comprehensive assessment evaluation index system of "City Obesity" degree is established, then put forward the evaluation model of "City Obesity" degree based on AHP-Fuzzy, which provides the theoretic guidance on evaluating "City Obesity" degree. At the end of this paper, through application analysis, we explain this model how to use in actual problems.

## Introduction

In recent years, China's urbanization process becomes faster and faster. The unreasonable and excessive speed growth of urban space expansion caused the City Obesity problem. Excessive "obesity" will lead to "City Obesity" whose main symptoms are too much traffic congestion, the rapid urban population growth, the less per capita amount of land tenure (per capita green area, per capita living space etc.), the widening gap between urban and rural areas, the increased unemployment population, the deepening social conflicts, the increase number of various types of cases and so on. Therefore, the research of the City Obesity degree has very important theoretical and practical value.

There are many studies on urban expansion in foreign countries, but most of them focused on the study of urban expansion mechanism. In the study of the phenomenon of urban expansion in Canada city which has a population of more than 25,000 people, Pierce made a point that the power of urban expansion includes the growth of urban population, the economic development level of the region, the location of the urban, the farmland fertile degree and so on [1]. Form WH held an opinion that there were two kinds of power which influenced the urban land use change which are market drivers and the right force. Social driving forces include the wealth gap, economic growth, policy and economic structures [2]. China began to research on urban expansion from the late 1980s. The content covered Categories of the urban form, the urban expansion mode and speed, the driving force of urban expansion analysis, and the simulation and prediction of urban expansion [3-4]. At present, there are fewer scholars who study City Obesity degree [5-6]. In this paper, the city is likened to the human body [7-8]. We put forward the comprehensive evaluation of City Obesity degree based on AHP-Fuzzy which can provide some theoretical guidance for the evaluation of the City Obesity degree.

Evaluation Index System of City Obesity Degree

The human body is an organism that includes nine systems which are blood circulatory system, respiratory system, digestive system, immune system, nervous system, motor system, urinary system, reproductive system, endocrine system. In this paper, we will metaphor city for human body to define the city's nine major systems. ①Blood circulatory system includes transport

 

situation, logistics situation and population growth situation;②Respiratory System includes environmental quality and greening situation; ③Immune System includes city security guarantee system, per capita level of education and urban-rural gap; ④Nervous system includes disseminate information situation and popularization of basic resources; ⑤Digestive and other systems includes sewage treatment capacity, social Finance and residents economic level.

The urban disease which is caused by the unreasonable and too fast growth of the urban space and which can hinder the normal and fast development of the city can be called "City Obesity". To assess the "City Obesity" degree, we must fully consider the characteristic factors which influence it and establish a comprehensive, scientific, comprehensive and integrated evaluation system combined with the actual situation of the city. In the design of the index system required to follow three principles that are scientific, completeness and operability, combine with relevant literature in domestic and abroad, systematic analysis and rational integration those factors which affect "City Obesity" degree, the comprehensive evaluation index system is established. The whole evaluation index system consists of 5 evaluation objectives, 13 evaluation factor and 31 evaluation indexes which are shown in Table 1 [9].

## The AHP-Fuzzy model for Comprehensive Evaluation of "City Obesity" Degree

We can see from Tab 1 that the factors which affect the "City Obesity" degree is represented as a hierarchical structure and it can be divided into qualitative and quantitative indicators. Here, we combine AHP and Fuzzy to establish the evaluation model of "City Obesity" degree.

**The Method for Assigning Weight of Evaluation Index.** AHP is the acronym of analytical hierarchy process. It emphasizes the role of people's thinking judgment in the decision-making process. It normalizes decision-making process through a certain mode, and is applied for the problem of a combination of qualitative and quantitative factors, especially for the problem that the qualitative factors play the leading role. And comprehensive evaluation of "City Obesity" degree is just the problem that the qualitative factors play the leading role. So, we use AHP to determine the relative weight of all factors in this paper. The main steps of AHP are as follows: establish the hierarchy; construct the comparison matrix; seek the largest eigenvalue of this matrix and its corresponding eigenvector; determine the weights; and check the consistency. The detail description of the algorithm can be found in reference.

**Calculation of The Membership Function Value.** Before the comprehensive assessment, the assessed value of each index (the value of membership function) in the index system should be confirmed first. However, for the differences of the types of evaluation indexes, the method for calculating the value of membership function should also be different, which can be mainly divided into two categories: determine the membership function value of qualitative indexes and determine the membership function value of quantitative indexes.

Table 1: The comprehensive evaluation index system of "City Obesity" degree.

| Evaluation objectives | Evaluation Factors | Evaluation indexes |
|---|---|---|
| Blood circulatory system $X_1$ | Transport situation $X_{11}$ | Average daily traffic $X_{111}$ |
| | | Car ownership $X_{112}$ |
| | | Traffic congestion index $X_{113}$ |
| | Logistics situation $X_{12}$ | Passenger Turnover Quantity $X_{121}$ |
| | | Cargo turnover $X_{122}$ |
| | | The total amount of post and telecommunication services $X_{123}$ |
| | Population growth situation $X_{13}$ | The net population growth $X_{131}$ |
| | | Resident population $X_{132}$ |
| | | The proportion of non-agricultural population $X_{133}$ |
| Respiratory System $X_2$ | Environmental Quality $X_{21}$ | Air quality rate $X_{211}$ |
| | | Urban environmental noise averages $X_{212}$ |
| | Greening situation $X_{22}$ | Green coverage $X_{221}$ |
| | | Forest coverage $X_{222}$ |

| | | |
|---|---|---|
| Immune System $X_3$ | City Security guarantee system $X_{31}$ | The registered urban unemployment rate $X_{311}$ |
| | | Various cases settlement rate $X_{312}$ |
| | Per capita level of education $X_{32}$ | The average years of schooling of labor $X_{321}$ |
| | | The average education $X_{322}$ |
| | | The per capita amount of reading $X_{323}$ |
| | Urban-rural gap $X_{33}$ | The net income gap between urban and rural residents $X_{331}$ |
| | | Consumer spending gap between urban and rural residents $X_{332}$ |
| Nervous system $X_4$ | Disseminate information situation $X_{41}$ | Fiber / Cable / Network coverage degree $X_{411}$ |
| | | WIFI coverage degree $X_{412}$ |
| | Popularization of basic resources $X_{42}$ | Water penetration rate $X_{421}$ |
| | | Electricity penetration rate $X_{422}$ |
| | | Gas penetration rate $X_{423}$ |
| Digestive and other systems $X_5$ | Sewage treatment capacity $X_{51}$ | Sewage treatment rate $X_{511}$ |
| | | Solid Waste Disposal situation $X_{512}$ |
| | Social Finance $X_{52}$ | The total retail sales of social consumer goods $X_{521}$ |
| | | The deposit/loan situation of financial institutions $X_{522}$ |
| | Residents economic level $X_{53}$ | Residents per capita savings $X_{531}$ |
| | | Food prices / retail price index $X_{532}$ |

**(1) Determine the Membership Function Value of Qualitative Indexes.** Facing the indexes which are difficult to be quantified by numbers, such as fiber / cable / network coverage degree and the solid waste disposal situation, we apply the fuzzy statistical method to determine the relationship between the membership function. Assuming the evaluation set for:

V= {asymptomatic, mild, moderate, severe, very severe} $\equiv \{v_1, v_2, \cdots, v_5\}$ ①

The specific approach is to let the experts involved in the assessment (with n experts) determine a hierarchy of evaluation indexes through a predetermined assessment set V, and then, count the frequency $m_{ijkt}$ of each evaluation index $x_{ijk}$ to each evaluation grade $v_t$, denote

$$x_{ijk}^t = \frac{m_{ijkt}}{n} \quad ②$$

Where $x_{ijk}^t$ represents the membership grade of evaluation index$x_{ijk}$ attaches to grade $v_t$.

**(2) Determine the Membership Function Value of Quantitative Indexes.** In order to determine the relationship of membership functions of quantitative indexes (such as Air quality rate, the registered urban unemployment rate, etc.) in evaluation index system, these quantitative indexes are divided into two types, one is the benefit type indexes (the greater the better type), and another is the cost type indexes (the lower the better type).

**Benefit type indexes (the greater the better type).** First, according to related Information, the minimum critical value $a$ and the maximal critical value $b$ ($a < b$) of the index $x_{ijk}$ can be determined. Then, in the interval ($a$, $b$), we insert three equidistant points $x_1$, $x_2$, $x_3$. Thus, the membership grade of evaluation index $x_{ijk}$ attaches to grade $v_t$ is as follows:

$$x_{ijk}^1 = \begin{cases} 1 & p \geq b \\ \frac{p - x_3}{d} & x_3 \leq p < b \\ 0 & p < x_3 \end{cases} \quad ③$$

$$x_{ijk}^t = \begin{cases} 0 & p \geq x_{6-t} \\ \frac{[x(6-t)-p]}{d} & x_{5-t} \leq p < x_{6-t} \\ \frac{[p-x(6-t)]}{d} & x_{4-t} \leq p < x_{5-t} \\ 0 & p < x_{4-t} \end{cases} \quad ④$$

$$x_{ijk}^5 = \begin{cases} 1 & p < a \\ \frac{x1-p}{d} & a \leq p < x_1 \\ 0 & p \geq x_1 \end{cases} \quad ⑤$$

Where $t$ =2, 3, 4; $d$ = ($b$-$a$)/4; $x_0$=$a$, $x_4$=$b$; $p$ is the actual value of index $x_{ijk}$.

**Cost type indexes (the lower the better type).** With the similar method above, the membership grade of evaluation index $x_{ijk}$ (cost type index) attaches to grade $v_t$ is as follows:

$$x_{ijk}^{1} = \begin{cases} 1 & p < a \\ \frac{x1-p}{d} & a \le p < x_1 \\ 0 & p \ge x_1 \end{cases} \quad ⑥$$

$$x_{ijk}^{t} = \begin{cases} 0 & p < x_{t-2} \\ \frac{[p-x(t-2)]}{d} & x_{t-2} \le p < x_{t-1} \\ \frac{xt-p}{d} & x_{t-1} \le p < x_t \\ 0 & p \ge x_t \end{cases} \quad ⑦$$

$$x_{ijk}^{5} = \begin{cases} 0 & p < x_3 \\ \frac{x1-p}{d} & x_3 \le p < b \\ 1 & p \ge b \end{cases} \quad ⑧$$

Where $t$=2, 3, 4; $d = (b-a)/4$; $x_0=a$, $x_4=b$; $p$ is the actual value of index $x_{ijk}$.

**The Establishment of Comprehensive Evaluation Model for "City Obesity" Degree.** The basic idea of using the AHP-Fuzzy method to evaluate the "City Obesity" degree is that the large number of indexes is divided into several elements according to their different nature, which leads every element includes fewer indexes. Every element is evaluated firstly, and then all elements are evaluated comprehensively.

1）The index set $X$ is classified as $m$-element sets $X_1$，$X_2$,…,$X_m$, and met:

$\cup_{i=1}^{m} X_i = X$，　$X_j \cap X_k = \emptyset$，j≠k，k∈{1,2，…，m}

2）The AHP method is used to establish the weight set, which includes these elements weight set W={$w_1$,…，$w_m$}and these indexes weight set $W_i$={$w_{i1}$,…，$w_{im}$} and $W_{ij}$={$w_{ij1}$,…，$w_{ijm}$}. And:

$\sum_{i=1}^{m} w_1 = 1$　　$\sum_{j=1}^{n} w_{ij} = 1$　　$\sum_{k=1}^{q} w_{ijk} = 1$，　$w_i$、$w_{ij}$、$w_{ijk}$>0，I=1，2，…，m.

3） Establish the evaluation set V={$v_1, v_2,\ldots, v_p$ }, which is consisted of p grades.

4）After each index of $X_{ij}$ is evaluated, the evaluation matrix $R_{ij}$= $(r_{ijkt})_{m\times p}$ is achieved. The Fuzzy method is used to calculate the fuzzy comprehensive evaluation $B_{ij}$= $W_{ij}$o$R_{ij}$ =($b_{ij1}$，…，$b_{ijp}$) of the $i$-th class's $j$-th evaluation element. Let $R_i$ = ($B_{i1}$，…，$B_{in}$)$^T$, Then use Fuzzy method to calculate the fuzzy comprehensive evaluation $B_i$= $W_i$o$R_i$ =( $b_{i1}$，…，$b_{ip}$) of the $i$-th class again. Where $r_{ijkt}$ is a membership degree of the k-th index of $j$-th factor of the $i$-th element $x_{ijk}$ in regard to the $t$-th grade of the evaluation set, $p$ is the number of grade of the evaluation set, "o" is fuzzy composition operator. In this paper, we let the fuzzy composition operator be M（·，⊕）.

5）After the $m$ elements of $X$ are evaluated, the total evaluation matrix A=($B_1$，…，$B_m$)$^T$ can be achieved. So the value of the comprehensive evaluation is $B$=$W$ o $A$, then the fuzzy comprehensive evaluation conclusion is given based on the principle of maximum degree of membership.

## Empirical Study

We use the method above to evaluate the "City Obesity" degree of Chengdu. The detailed steps of evaluation are as follows:

1）Establish the comprehensive evaluation index system of "City Obesity" degree (See Tab 1).

2）According to AHP, the relative weights of each index can be determined. The weight vector of evaluation objectives, evaluation factors and evaluation index are w={$w_1$，…，$w_5$}，$w_i$={$w_{i1}$，…，$w_{in}$}，$w_{ij}$={$w_{ij1}$，…，$w_{ijq}$}. And $\sum_{i=1}^{5} w_1 = 1$, $\sum_{j=1}^{n} w_{ij} = 1$, $\sum_{k=1}^{q} w_{ijk} = 1$, $w_i$、$w_{ij}$、$w_{ijk}$>0，i=1，2，…，5. Every weight vector is shown in Table 2.

3）Establish the Evaluation Set V= {asymptomatic, mild, moderate, severe, very severe}≡{$v_1$, $v_2$,…, $v_5$}.

4）Calculate the membership function value of each index based on the equation from ① to ⑧. Then establish the evaluation matrix of each factor according to the index's membership function

value and calculate each factor's comprehensive fuzzy evaluation value. The Fuzzy evaluation matrixes of each index that belongs to blood circulatory system are as follows:

The Fuzzy evaluation matrix of transport situation: $R_{11}=\begin{bmatrix} 0.67 & 0.29 & 0.14 & 0 & 0 \\ 0.43 & 0.43 & 0.14 & 0 & 0 \\ 0 & 0 & 0.14 & 0.29 & 0.57 \end{bmatrix}$

Table 2: The relative weight vector

| | | | |
|---|---|---|---|
| $(X_1, X_2, X_3, X_4, X_5)$ | (0.27, 0.27, 0.22, 0.12, 0.14) | $(X_{321}, X_{322}, X_{323})$ | (0.43, 0.43, 0.14) |
| $(X_{11}, X_{12}, X_{13})$ | (0.3, 0.3, 0.4) | $(X_{331}, X_{332})$ | (0.5, 0.5) |
| $(X_{111}, X_{112}, X_{113})$ | (0.2, 0.2, 0.6) | $(X_{41}, X_{42})$ | (0.4, 0.6) |
| $(X_{121}, X_{122}, X_{123})$ | (0.43, 0.43, 0.14) | $(X_{411}, X_{412})$ | (0.5, 0.5) |
| $(X_{131}, X_{132}, X_{133})$ | (0.33, 0.33, 0.33) | $(X_{421}, X_{422}, X_{423})$ | (0.33, 0.33, 0.33) |
| $(X_{21}, X_{22})$ | (0.5, 0.5) | $(X_{51}, X_{52}, X_{53})$ | (0.6, 0.2, 0.2) |
| $(X_{211}, X_{212})$ | (0.6, 0.4) | $(X_{511}, X_{512})$ | (0.5, 0.5) |
| $(X_{221}, X_{222})$ | (0.6, 0.4) | $(X_{521}, X_{522})$ | (0.6, 0.4) |
| $(X_{31}, X_{32}, X_{33})$ | (0.3, 0.3, 0.4) | $(X_{521}, X_{522})$ | (0.5, 0.5) |
| $(X_{311}, X_{312})$ | (0.6, 0.4) | | |

According to Table 2 we can calculate this: $W_{11}$=(0.2 0.2 0.6), $B_{11}=W_{11}\circ R_{11}$=(0.21 0.14 0.14 0.17 0.34);

Similarly, we can get this:

$B_{12}=W_{12}\circ R_{12}$=(0.29 0.55 0.16 0 0)

$B_{13}=W_{13}\circ R_{13}$=(0 0.33 0.57 0.1 0)

And so

$$R_1=\begin{bmatrix} B_{11} \\ B_{12} \\ B_{13} \end{bmatrix}=\begin{bmatrix} 0.21 & 0.14 & 0.14 & 0.17 & 0.34 \\ 0.29 & 0.55 & 0.16 & 0 & 0 \\ 0 & 0.33 & 0.57 & 0.1 & 0 \end{bmatrix}$$

Therefore, the fuzzy evaluation vector of "blood circulatory system" is

$B_1=W_1\circ R_1$=(0.15 0.34 0.32 0.09 0.1)

Similarly, we can obtain fuzzy evaluation vectors of other elements:

$B_2=W_2\circ R_2$=(0.03 0.2 0.48 0.16 0.13)

$B_3=W_3\circ R_3$=(0.05 0.45 0.35 0.14 0.01)

$B_4=W_4\circ R_4$=(0.38 0.54 0.08 0 0)

$B_5=W_5\circ R_5$=(0.19 0.21 0.24 0.25 0.11)

In accordance with the principle of maximum membership, the comprehensive evaluation grades for each element of Chengdu are achieved, which are shown in Table3

5) The fuzzy comprehensive evaluation. After evaluating 5 elements of "City Obesity" degree of Chengdu , the total evaluation matrix R=$(B_1, \ldots, B_5)^T$ is achieved. Thus, the comprehensive evaluation value is:

$$B=W\circ R=(0.27,\ 0.27,\ 0.22,\ 0.12,\ 0.14)\circ\begin{bmatrix} 0.15 & 0.34 & 0.32 & 0.09 & 0.1 \\ 0.03 & 0.2 & 0.48 & 0.16 & 0.13 \\ 0.05 & 0.45 & 0.35 & 0.14 & 0.01 \\ 0.38 & 0.54 & 0.08 & 0 & 0 \\ 0.19 & 0.21 & 0.24 & 0.25 & 0.11 \end{bmatrix}$$

$$=(0.13\ 0.34\ 0.33\ 0.13\ 0.07)$$

In accordance with the principle of maximum membership, the comprehensive evaluation grade of Chengdu is achieved, which is shown in Table3.

From Table 3 we can know that the "City of obesity" degree of Chengdu is "mild ". Blood circulation system which is represented by transportation situation, logistics situation and population growth situation, immune system which is represented by city security guarantee system and per capita level of education, and nervous system are in good condition with a mild "City

Obesity" symptom. Respiratory System which is represented by environmental quality and greening

Table 3:The comprehensive evaluation results of "City Obesity" degree of Chengdu

| Evaluation objectives | Evaluation Factors | comprehensive fuzzy evaluation value | | Grade |
|---|---|---|---|---|
| Blood circulatory system | Transport situation | (0.21 0.14 0.14 0.17 0.34) | (0.15 0.34 0.32 0.09 0.1) | $v_2$ |
| | Logistics situation | (0.29 0.55 0.16 0.00 0.00) | | |
| | Population growth situation | (0.00 0.33 0.57 0.10 0.00) | | |
| Respiratory System | Environmental Quality | (0.05 0.17 0.26 0.26 0.26) | (0.03 0.2 0.48 0.16 0.13) | $v_3$ |
| | Greening situation | (0.00 0.23 0.71 0.06 0.13) | | |
| Immune System | City Security guarantee system | (0.00 0.73 0.27 0.00 0.00) | (0.05 0.45 0.35 0.14 0.01) | $v_2$ |
| | Per capita level of education | (0.18 0.47 0.23 0.10 0.02) | | |
| | Urban-rural gap | (0.00 0.22 0.49 0.29 0.00) | | |
| Nervous system | Disseminate information situation | (0.43 0.43 0.14 0.00 0.00) | (0.380.540.080.00 0.00) | $v_2$ |
| | Popularization of basic resources | (0.34 0.61 0.05 0.00 0.00) | | |
| Digestive and other systems | Sewage treatment capacity | (0.30 0.22 0.22 0.13 0.13) | (0.19 0.21 0.24 0.25 0.11) | $v_4$ |
| | Social Finance | (0.00 0.12 0.38 0.5 0.00) | | |
| | Residents economic level | (0.07 0.29 0.14 0.38 0.12) | | |
| "City Obesity" degree of Chengdu | | (0.13 0.34 0.33 0.13 0.07) | | $v_2$ |

Situation should be improved because of the moderate "City Obesity" symptoms. The situation of digestive and other systems is not optimistic. Chengdu should guard against all kinds of urban problems and prevent to aggravate "City Obesity" symptoms when it focus on its own development and urban expansion.

## Conclusions

In recent years, China's urbanization process is accelerated. In the way of urban space expansion and pursuit of economic interests, every province tends to ignore the resulting "urban obesity" symptoms: the rapid urban population growth, too much traffic congestion, and the living environment becomes worse and so on. The evaluation model of "City Obesity" degree based on AHP-Fuzzy is described in this paper, using the combination of qualitative and quantitative, expert evaluation and scientific computing complementary analysis method. It has the characteristics of systematic and comprehensive, scientific and reliable, simple and practical. The method provides certain theoretical guidance for the comprehensive evaluation of "City Obesity" degree. The practical application results show that the method can not only determinate the level of "City Obesity" degree of cities, but also identify the deficiency of the city, which in order to give advices for urban planners.

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