APPLICATION OF ANALYTICAL HIERARCHY PROCESS IN DECIDING URBAN LAND USE --TAKING CHAO HU CITY AS AN EXAMPLE

Zhu Dewei Feng Changchun

Department of Geography, Peking University
Beijing, China

ABSTRACT

This paper is an application of Analytic Hierarchy Process in deciding urban land use of Chao Hu in Anhui Province. We will first analyze a variety of factors related to the decision of land use, set up a strategic decision model of hierarchy multi-level and multiobject, further obtain quantitative results through an analog operation by means of a computer, and finally based upon total ordering of levels, decide the best one from four projects.

I. INTRODUCTION

It's an important task for an urban planning to decide the land use, which relates whether the development and structure of a city can be achieved in a regional space suitable.

There are many factors related to decide urban land use, such as the conditions of nature, environment, society, economy, techique modernization and the like. Therefore, the decision presents a very complicated problem which involves not only the economical benifit but also the social and environment benefits. This means that the decision should be able to achieve the maximum synthetical benefit for a city in its future development and construction.

As mentioned above, the decision consists in a lot of factors which are interdependent and interrelated, so that if we only employ a quantitative analysis to set up a mathematical model, it will be very complex and very difficult to describe the factors quantitatively. On the contrary, if we simply adopt a qualitative analysis, it is quite hard to decide a land use project meeting a variety of demands to persons who treat the function and importance of the factors in relative different points of view. We consider that AHP described here will be effective to complete the aforesaid task.

II. Application of AHP to Decide Land Use In the Development of Chao Hu City

1. Analysis of problems

Chao Hu City is situated in the south of hills neighboured Yantze River and Huai River with mountains around its three sides and the Chao Lake to its west. It has a complicated geography in different types which comprise, steep stopes and high hills, the gradually lower mounds and the inclined plains in front of mountains; as well as the river terraces, and the beaches of lake and the shallows. In addition, the present arrangement of the City is scattered and the functions involved are in mix up, moreover, railways, highways and high voltage corridors run through it, so it is more difficult to decide the land use in the City for urban development than in the general ones. The four directions which may contribute to land use are shown by arrows in fig. 1, Each direction has some advantages as well as disadvantage. Though the factors related to the decision of land use cannot be quantitated exactly since there exists a so called 'fuzziness' and the contributions of individual factors, i.e. their importance are different from each other, yet we may describe the factors systematically, orderly and quantitatively through a certain analysis and judgment, further obtain quantitative results through an analog operation by means of a computer.

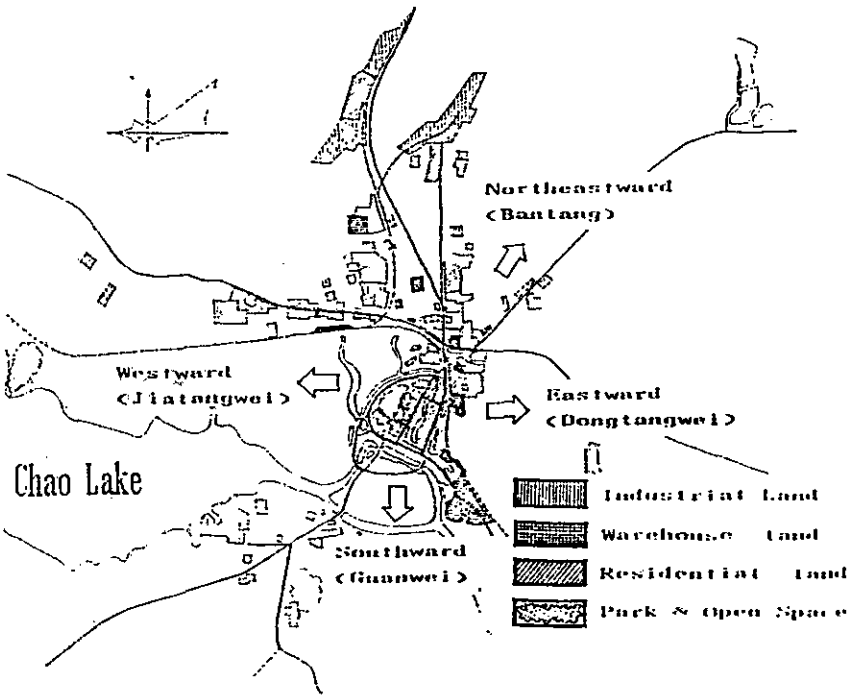


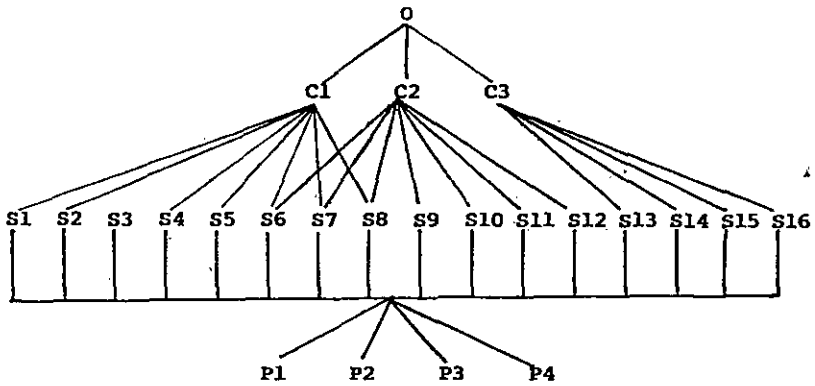
Fig 1 Four Extended Direction of Chao Hu Built up Area

2. Set up of a multi-level Hierarchy Structural Model

In application of AHP to decide urban land use, we will first analyze a variety of factors related to the decision of land use systematically in order to select out the factors of most importance as estimation indices, then based upon the dependence relation of the factors, devide the hierarchy system, set up strategic decision model of hierarchy multi-level and multi-object and represent the relations of the hierarchy levels schematically.

According to an analysis of the present condition in Chao Hu City, we devide the strategic decision model of its urban land use into four levels: object, estimate criteria, related factors, and projects.

Fig.2 AHP strategic decision model trees of Chao Hu Land Use



O: Achieving the highest urban synthetical benefit.
C1: Gaining the most economization in total investment for a city construction.
C2: Achieving the best urban social benefit.
C3: Obtaining a good urban environment.
S1: Economizing construction ivestment in the near future.
S2: The total cost of fundation handled being low.
S3: Saving land and occupying little fertile farmland.
S4: Land use in future development being flexible enough.
S5: Reducing costs of railway station and conveniencing for management and administration.
S6: Advantages for preventing flood and draining flooded fields.
S7: Making full use of the facilities of old city and saving investment of basic facilities.
S8: The urban arrangment being concentrated and compact.
S9: Daily life and service being convenient for passengers.
S10: Spending less commuter time.
S11: Advantages for organization of city traffic.
S12: Making the transport station convenient for passengers.
S13: Advantages for protecting the environment against pollution.
S14: Fine urban landscape.
S15: Emboding the characteristics of a lakeside city.
S16: External traffic doing little disturbance to urban districts.
P1: The westward development project.
P2: The eastward development project.

P3: The southward development project.
P4: The northeastward development project.

3. Construction of Judgement Matrix in Single Object

The judgement matrix can be constructed by comparing all the factors pairwise. Thus, we may form twenty judgement matrices by taking each factor (an element) in every level of fig.2 as a judgement object (an index) and comparing it with each one appeared in the next level respectively. For example, by setting the sixth element S6 of the third level (S-level) as a judgement object and comparing it with four elements in the next level (P-level) repectively, we can construct a 4x4 matrix (Tab.1), wherein, $P_{ij}=W_i/W_j$ represents the ratio of weights characterizing the importance between the element i and element j. Generally, in comparing the importance of the element i and relative to that of the element j as the importance of the element i being equal to that of the element j, we set $P_{ij}=1$; as the former being a little more important than the later, we set $P_{ij}=3$; obviously more important, $P_{ij}=5$; further more important, $P_{ij}=7$ and the most important, $P_{ij}=9$. Conversely, $P_{ij}=1/P_{ij}$, and we should write as 1/3, 1/5, 1/7 and 1/9.

4. Inviting Specialists to Fill in Judgement Matrices

To fill in judgement Matrix is a key step in AHP and it is necessary to invite a lot of specialists for doing this. The requirements for filling in the matrix are as follows:

Tab. 1

	S6	P1	P2	P3	P4
P1		P_{11}	P_{12}	P_{13}	P_{14}
P2		P_{21}	P_{22}	P_{23}	P_{24}
P3		P_{31}	P_{32}	P_{33}	P_{34}
P4		P_{41}	P_{42}	P_{43}	P_{44}

(1). The specialists should fill in the matrices individually without any discussion which is to avoid some specialists' completely following opinions of the authorictive ones, so they will have essentially different points of view and hardly submit a common conclusion;

(2).It's only necessary for the specialits to fill in the upper or lower portion relative to the diagonal in matrix; and

(3). The specialists should arrange a simple order in importances of all the factors related to the object involved and estimate by comparison, otherwise there will be a mistake, and the matrix filled may not be received due to a too large error in the test of consistency.

5. Single Ordering of Levels

A single ordering of levels consists in seeking for weights in the judgement matrix of single object, which is to calculate the weights coresponding to importance order of elements in some one level relative to a certain element in the upper level.

The weights of judgement matrix may be obtained through solving a problem of characteristic value: $PW=\lambda_{max}w$ to find out its normalized characteristic vector, wherein λ_{max} is the only one characteristic value of P, and w is the normalized characteristic vetor coresponding to λ_{max}. Then the components w_1 of w are weights in the single ordering relative to the respective elements.

In the following, we take the table 1 as an example to introduce briefly

a method for calculating the characteristic value and vector. Namely the approximate calculation method by geometic means.

The essential idea is that for the P-matrix we multiply all the elements in row i one by one, then find its nth root:

$$w = (w_1, w_2, \ldots, w_n)^T$$

where

$$w_i = w_i / (w_1 w_2 \ldots w_n)^{1/n}$$

Subsequently, by normalization we obtain w_1, $w_2, \ldots, w_n$. The calculating steps are omitted here.

6. The test of Consistency

Theoritically, the judgement matrix satisfies the cardinal consistency relation: $P_{ik} = P_{ij} P_{jk}$, meanwhite $\lambda_{max} = n$. In fact, the judgement matrix filled by specialists in general is impossible to satisty the aforesaid relation and now $\lambda_{max} > n$ since people's knowledges diverse from each other. For the test of consistency, we need to calculate the consistency index CI of a judgement matrix, which is defined by $CI = (\lambda_{max} - n)/(n-1)$. Then we will compare the CI with the mean random consistency index RI to obtain the consistency ratio of the judgement matrix:

$$CR = CI/RI$$

When $CR < 0.1$, we consider that the judgement matrix has a desired consistency.

7. Total Ordering of Levels

(1). The results of the priorities are shown in the following Tab 3., Tab 4 and Tab 5..

Tab. 2 Priority of criteria respect to with to Goal	Criteria	C1	C2	C3	Arerage weight
	Priority	0.4462	0.389	0.165	0.333
	order	1	2	3	

Tab. 3. Priority of the factors respect with to Goal

factors	S1	S2	S3	S4	S5	S6	S7	S8	S9
priority	0.047	0.046	0.034	0.101	0.013	0.114	0.109	0.199	0.070
order	7	8	11	4	16	2	3	1	6
factors	S10	S11	S12	S13	S14	S15	S16	Average weight	
priority	0.041	0.032	0.029	0.086	0.032	0.034	0.014	0.063	
order	9	12	14	5	13	10	15		

Tab. 4. The priority of projects respect with to goal

project	P1	P2	P3	P4	average weight
priority	0.398	0.183	0.240	0.179	0.25
order	1	3	2	4	

(2). Analysis of Results

The result of total ordering shows itself in agreement with the state in Chao Hu City. The ordering of three criteria in the second level (Tab.2) exhibits that since China isn't very large in finances and is not very advanced in technique, a little city as Chao Hu has only finite capital for construction. So on the decision of its land use we should first take maximally saving its total investment for urban construction into account, and then we should consider to provide a good social benefit and environment.

Now, we turn attention to the ordering of sixteen related factors in second level (Tab.3) with the factor "urban arrangement being concentrated and compact" at its head. This factor is stressed because the present arrangement of Chao Hu City is too disperse with a compactness only 20-40%. It contains no more than one hundred thousands population but have a width (west to east) of 11.5kms and a length (north to south) of 10kms. The factor in the second place is "preventing flood and draining flooded fields" because Chao Hu City is beside the Chao Lake, one of the five large fresh lakes in China, and situates on the general outlet of the Chao Lake water system. Chao Hu City is usually under a threat of flood and it is necessary to put the preventing flood and draining flooded fields at an important place. The factor in the third place is "making the best of facilities in the old City and saving the investment for fundamental construction", which is also an important index to embody the economical and social benefit directly relating to the present conditions of the City.

The subsequent one is "to be flexible in land use for its future development", which point out that to decide land use in Chao Hu City we should consider both the present and future conditions and leave room for the development in its future. In general, the ordering in the second level will help us easily appreciating the importance of factors related to the decision in land use of Chao Hu, moreover, it agrees well with the present conditions of the City.

The latest is an ordering in project level, which shows that the City should develop towards west, namely the Jiatangwei project. It would provide for the City the best synthetical benefits and should be the priority.

III. Conclusion

1. AHP can collect the wisdoms and experiences of specialists involved and represent the qualitative analysis with a quantitative form, which help us clearly discover some fuzzy problems.

2. The mathematical methods in AHP are simple, which can be also employed to analyze the production structure of a city, the development direction of industry as well as the development order of branches in the industry and to solve a lot of social and economical problems such as the near future urban construction objects in which an order is to begin.

3. The key of AHP is to set up the structural model of hierarchy and to fill in judgement matrix, therefore require the persons who employ the process or fill in the matrix should be skillful in related subjects.

REFERENCES

Saaty, T.L., The Analytic Hierarchy Process, McGraw-Hill, 1980.