AN APPLICATION OF THE AHP TO THE STUDY OF THE STRATEGY AND GAME FOR DEVELOPMENT OF NEW TECHNOLOGIES IN NINGXIA THROUGH THE YEAR 2000

Mao Dongkui
Second Northwest College for Nationalities, Yinchuan, Ningxia, China

ABSTRACT

New technologies development anywhere is closely relative to social, economic and environmental lissues. The subject constitutes a complex multi-objective and multi-level decision-making system, which has a hierarchical structure. Thus, the Analytical Hierarchy Process is best suited to solve the problem.

This paper presents the hierarchical structure of the analytical decision making system for the study of the strategy and game for development of new technologies in Ningxia through the year 2000,describes the application of the AHP to the group decision-making process used for the study and acquired data processing methods, gives the holistic weights and ranks of all attributes at every level of the system, explains the significance of the outcome, finally discusses the major findings of the study as well as its imperfection and possibilities of improving it.

1. IDENTIFICATION OF THE PROBLEM

Ningxia, an autonomous region of China, is now facing a challenge of the new technological revolution, as is everywhere all over the world. Only an appropriate development strategy of new technologies to the local actual conditions is formulated can we take full advantage of opportunities afforded by the revolution to vitalize the economy in the region as soon as possible and make Ningxia prosperous around the turn of the century. This is the overall goal (G) of the development strategy study. According to a preliminary analysis, the locally possible new technologies to be developed include the ones associated with computer (P1), bioengineering (P2), new materials (P3), laser (P4), optical fibre (P5), robot(P6), and new energy sources (P7), which constitute the development objective set. Development of any technology is closely relative to social, economic and environmental issues,therefore any development options in new technologies has to take a number of factors such as effects, constraints and solutions into account. Obviously, the above development objectives must give three kinds of benefit: economic (B1), social (B2) and environmental (B3). The economic benefit, which is referred to only direct one in this research, essentially means small input-output ratio (g1) and short cycle time for transformation of input into output (g2). The social benefit mainly includes increase of business efficiency (g3) in the whole society, improvement or people's life quanlity (g4), improvement of working conditions (g5) and increase of employment opportunities (g6). The environmental benefit chiefly signifys improvement of ecosystem (g7) and control of pollution (g8). All of them make up the subgoal set. In order to get these benefits from development of hte new technologies, following constraints: short capital (C1), low technological development power (C2), which mainly refers to less quantity and poor quanlity of technical manpower and means, incomplete ripeness (C3) and limited range of applications (C4) of each new technology, low level of management of economy and technology (C5), poor infrastructure such as transportation and comunication (C6), institutional barrier (C7) and limited natural resources (C8) have to be overcome. These constraints form the constraint set. With the view to overcoming the above constraints, such alternative measures as increase of national investement (M1) and financial allocation of the local government (M2), raising capital fprm the society (M3), practising technical introduction and tie-up (M4), which means introducing technical know-how,talented personnl and capital from other provinces and regions as well as abroad, and practising tie-up in the region, the country and the world, training personnl (M5), improvement of management of technology and economy (M6), and reform of economic structure and scientific and technological structure (M7). The measures from M1 to M7 constitute the measure set.

The above description is just a formulation which simplified and outlined the real decision-making system, but has been clearly seen that the subject of the study was a complex multi-objective and multi-level decision-making system composed of 6 levels and 34 elements. The system has a hierarchical structure. Thus the Analytical Hierarchy Process developed first by Prof. T.L. saaty, Univesity of Pittsburgh, USA in early 1970s may be well suitable to the problem. This is the major reason why we decided to use the AHP for the study. In addition, we also gained a good deal of enlightenment from the method itself. Namely, its essence may be a quantification of process of thinking before making a decision. This clue is very important because it makes us to achieve a possibility of quantifying opinion of a group of consultant experts so as to do our research, which is essential as historical statistical data concerned with the dynamic relationship between the economy and technology in Ningxia, Which are necessary to our study, are now unavailable.

Figure 1 shows the hierarchical structure and relationship between elements (i.e. attributes) in the analytical decision system of the study of the strategy and game for development of new technologies in Ningxia, through

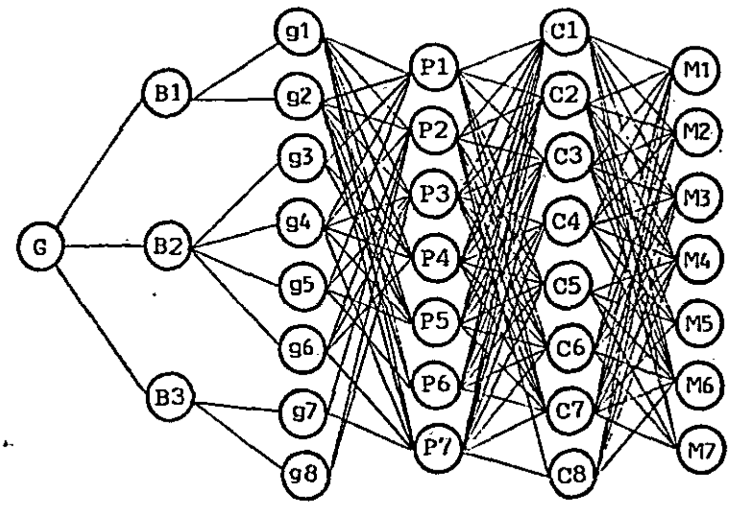

Figure 1. Hierarchical structure of Analytical Decision System

the year 2000.Using the approaches noted by references 1 or 2 judgement matrices may be constructed, as well as consistency check could be conducted, the detailed procedure of which is omitted to save space.

2. GROUP DECISION MAKING

Decision makers are often different in their educational background, experience in work, knowledge of the problem and so on. Consequently, each of them may give a different hierarchical structure and relative importance judgement between attributes in an analytical decision-making system. This will lesd to uncertainty of an outcome from individual decision-making. In order to avoid onesidness and possible faults of individual decision making as well as guarantee to get a rational and objective outcome, a group decision making process was adopted in the study. Its procedure is as follows:

Subjects

Subjects were 34 consultant experts chosen out of varieties of trades and professions, including system engineering, biotechnology, chemical engineering, electrical and electronic engineering, computer engineering, communication engineering, energy, power and resources, environmental science and pollution control, industrial engineering, materials science, metallurgy, mineral processing, mechanical engineering, agricultural engineering, food science, madical science and so on. They were scientists, researchers, engineers and managers familiarized with the techno-economic scenario and particular conditions in Ningxia, meanwhile with practical experience. Therefore, they were appointed to be the consultant experts of the study.

Procedure

Two turns of consultation about the problem were carried out with well-designed sheets. Subjects were run individually. They were given each time a set of consultant sheets describing the nature of the problem, attribute definitions, quantitative criteria of relative importance and writing-in methods so that the subjects could refer to them and were encouraged thoroughly understand them, then gave their responses. Completion of the task required approximately 6 hours per subject. The first turn of consultation aimed at making the analysers know whether the sheets design was rational or not so that they could revise and optimize it. The subjects'major task in the second turn of cosultation was in fact to write in elements of each judgement matrix, namely, first make a evaluation of relative importance of each two attributes at a lower level with respect to an upper level attribute, then gave a rate by previously mentioned quantitative criteria.In the course of that the subjects were instructed that relative importance of each two lower level attributes in regard to an upper level was judged and rated by a sequence from the lowest level to the upmost level so that their answers could be more objective and reliable.

Data Processing

There are three methods to process the data provided by the subjedcts: weighted summing,arithmetic averaging and geometric averaging. If $W^1, W^2, \ldots, W^s$ are respectively the weight vectors calculated through holistic ranking the data provided by s experts, w_i^k is a component of the calculated weight vector from the data by expert No. k, the component of the comprehensive weight vector of the s experts corresponding to w_i^k, i.e. w_i^c will be:

(1) by weighted summing, $w_i^c = \sum_{k=1}^{s} r^k w_i^k$ (1)

where r^k is the weight of the expert No. k himself, which is usually determined by his fmae, obviously $\sum_{k=1}^{s} r^k = 1$;

(2) by arithmetic averaging, $w_i^c = \frac{1}{s} \sum_{k=1}^{s} w_i^k$ (2)

in fact method (2) is an exception of method (1) when all of r^k are the same.

(3) by geometric averaging, $w_i^c = \sqrt[s]{\prod_{k=1}^{s} w_i^k}$ (3)

In the study we used the above three methods to process the importance weight set of every level of the system, which were computed from the data provided by the 34 experts through holistic assessment, obtaining the comprehensive importance weight sets of every level of the analytical decision system. Subsequently, we compared the different results of the three methods,meanwhile examined differences and similarities among the three results. It was found that method (1) was sensitive to the weight of expert himself, i.e. r^k, a change of option of r^k set would cause a great difference in holistic weights and ordinal properties of a importance weight set. However, method (2) and (3) showed a substantial agreement on ordinal properties if all attributes of the analytical decision system were well defined.

3. OUTCOME

Method(2) gave a stable result summarized in Table 1, which may be regarded as the major outcome of the study. It could be used for an important basis to determine an effective strategy scheme for development of the new technologies in Ningxia through the year 2000, especially when choosing priorities of developmental objectives and strategical measures.

Table 1. Importance Weights and Ranks of Every Level

Level	Attributes' Weight and Rank							
Benefit	B1 0.4784 1	B2 0.3730 2	B3 0.1486 3					
Subgoal	g1 0.2753 1	g2 0.2031 2	g3 0.1527 3	g4 0.0716 6	g5 0.0603 8	g6 0.0884 4	g7 0.0694 7	g8 0.0792 5
Developmental Objective	P1 0.3279 1	P2 0.2852 2	P3 0.0607 5	P4 0.0497 7	P5 0.0843 4	P6 0.1580 3	P7 0.0607 6	
Constraint	C1 0.3394 1	C2 0.2178 3	C3 0.0538 5	C4 0.1077 4	C5 0.2320 2	C6 0.0147 7	C7 0.0309 6	C8 0.0037 8
Measure	M1 0.2539 2	M2 0.1202 4	M3 0.1462 3	M4 0.1190 5	M5 0.0409 6	M6 0.0266 7	M7 0.2932 1	

The outcome implys that the economic and social benefits should be the first and second aims we should make big efforts to achieve until the end of the century. The top priority should be given to computer technology with better economic and social effect, while the next to biotechnology with better comprehensive effect. Such significant measures as the reform of the economic and technological structures, increasing national investment, raising capital from society, increasing finacial allocation of the local government, and technological introduction and tie-up should be taken with emphasis so as to overcome the major constraints:

short capital low-level management of economy and technology, poor technical development power in the region. In this way the overall goal to vitalize Ningxia's economy and make the region prosperous will be smoother realized around the turn of the century.

4. DISCUSSION

Through the study we have three findings. First, a rational design for hierarchical structure of the analytical decision-making system is the key to a correct and reliable outcome. For this reason, design of hierarchical structure should be improved by consultation with experts. Second, all attributes should be well defined and had distinct implication so as to make experts express their opinion by means of number conveniently. Otherwise, a confusion could be caused in writing-in judgement matrices so that obtained data may not be used. Third, it is inadvisable to list too more or much detailed attributes at a level in an analytical decision making system. The more attributes, the harder relative importance between them is to be compared so that experts could not give a set of complete judgement matrices. That may lead to failure in acqisition of data. In addition, the author believes that the AHPis indeed a simple and practical method for socio-economic decision-making analysis.However,in this study it has been used as only an indirect decision approach, which made the consultant experts the decision-making information carriers and employed their subjective judgements for the single basis fo the study. As a result, the conclusion may not be objective enough. With the view to getting a more reliable outcome it may be preferable to our study to manage to acquire certain necessary technological and economic data relevant to the study, if possible, and enter them in judgement matrices of the AHP in accordance with definite quantitative criteria to do a direct decision research for higher decision quanlity. Of course, if necessary data could be acquired, other quantitative approaches may be used to verify and modify the result of the study. For example the C-D or CES Production Function could be utilized to estimate the contribution of technological progress to the growth of Ningxia's industrial output value during a certain historical period. The resultant result will be a good reference for our study. But this is already beyond the scope of the study.

REFERENCES

1, T. L. Saaty, The Analytical Hierarchy Process, McGraw Hill, 1980.

2, Xu Shubo, Fundamentals of Analytical Hierarchy Process, System Engineering Research Institute of Tianjin University 1986,11.

3, He Jingsheng, Applications of Analytical Hierarchy Process, System Engineering Research Institute of Tianjin University, 1986;11.

4, Liu Bao and Xu Shubo, The Applications of the AHP in China and its Development, Mathematical Modelling, Forthcoming, 1987.

5, Jiang Qingfang, Applied Decision-making Analysis, Guizhou People Publishing House, 1985,7.

6, Wang Ruhua, On Group AHP, System Engineering Research Institute of TianJin University, 1987,8.

7, Xiang Yuanwang, Application of System Engineering to Regional Planning, System Engineering Editorial Department. 1987,4.

8, Wang Wenjuan et al., Analytical Hierarchy Model for Choosing Prior Trades to Develop the Capitsl's Economy, People University of china 1987,4.

9, Gorden Crawford, A Note on the Analysis of Subjective Judgement Matrices, Journal of Mathematical Psychology, 1985, No.29, p.387-405.

10, M. Zeleny, Multiple Criteria Decision Making, McGraw Hill, 1982.

11, G. S. William et al., Comparing Hierarchical and Nonhierarchical Weighting Methods for Eliciting Multiattribute Value Models, Management Science, 1987.4. P. 442-450.