The Index Construction and Evaluation Modeling on the Scientific and Technological Innovation of University

Shen Xiaogang
School of management, Henan University of Technology, Zhengzhou, China, 450001
(E-mail: Sxg200411@163.com)

Abstract: The universities are the main source of national and regional scientific and technical innovation. Furthermore, universities' scientific and technological innovation ability determines a country or regional scientific and technological developing level. How to evaluate the innovation and performance of the universities is still unsolved currently. In this paper, the indexes for evaluating the innovation capacity and performance are proposed, and a systematic analytical method is introduced. In order to test the validity, a university in Henan province of China is selected as an example to evaluate its innovation capacity. The search results indicate that the index and method mentioned in this paper is suit to the scientific research evaluation.

Key words: Scientific and technological innovation ability; Evaluation; Analytic nierarchy process

1 Introduction

The university is the important component of the system of scientific and technical innovation. It is one of the important subjects of the knowledge innovation, and the important source of technological innovation, and having influential impact on development of the regional economy. High-level talents and scientific and technological resources have gathered in the campus, a large number of experts from many aspects, which can contribute for the scientific and technological innovations for regions. In Henan province, however, the scientific and technological innovation ability of the university is still weak on the whole. Thus in order to promote the development of university's scientific and technological innovations of our province better and improve the scientific and technological innovation ability of the university of our province, it is very necessary to develop the activity of rational appraisal.

This paper is arranged as following: the second section is literature review on the early study on the scientific and technological innovation (STI); then the study method AHP (analytic hierarchy process) is briefly introduced; section 3 is the index design for the evaluation of the STI of the university. Section 4 is an empirical study on the index selected in the paper; finally, the conclusion is reached in the end of section.

2 Literature Review

The OECD, in close interaction with its members' statistical offices, has been particularly influential and constructive over the last 40 years in developing international standards for research and development measurement and in stimulating and improving input and output measurement of both R&D and other services. Together with others at the OECD, in particular Yvan Fabian and Alison Young, one of us part of those early discussions in the 1960s on the inclusion or exclusion of particular activities in the Frascati Manual8 OECD (1981)[3;5]. It appeared particularly difficult to separate research and experimental development activities from the broader spectrum of scientific and technological services (STS) concerned with providing support for R&D, disseminating the results, applying new knowledge in various ways, and producing and selling new products. Not surprisingly, organizations that were engaged in research and experimental development were often also engaged in such STS activities as well. The Frascati Manual tried to distinguish between research and experimental development and related scientific activities. The latter included

such activities as general scientific library, information and documentation services; training and education of research workers in specialized educational institutions such as universities; general purpose data collection, for example routine geological and geophysical survey work, mapping and exploration activities, routine oceanographic survey work, daily meteorological records, monthly production statistics, collection and arrangement of specimens for museums, zoological and botanical gardens; routine testing and standardization activities, and also design and engineering activities.

The main theoretical criterion in the Frascati scheme for the separation of the R&D function from related scientific activities was the distinction between novelty and routine.

"In so far as the activity follows an established routine pattern it is not R&D. In so far as it departs from routine and breaks new ground, it qualifies as R&D. Thus, for example, the collection of daily routine statistics on temperature or atmospheric pressure is not R&D, but the investigation of new methods of measuring temperature or the investigation of temperatures under circumstances in which they have never been previously recorded (for example, outer space or the interior of the earth) is research. Likewise, the publication of a book which simply records daily information on the temperature or pressure is not R&D, but general purpose data collection. The systematic analysis of these recordings with a view to explaining long-term changes in climate, or the possible effects of changes in ocean currents, is research activity. To take another example: in the field of medicine, routine general autopsy on the causes of death is not research, but special investigation of a particular mortality in order to establish the side effects of certain forms of cancer treatments is research. Routine tests on patients, carried out for doctors, as for example, blood tests and bacteriological tests, are not research. But a special plan of blood tests in connection with the introduction of a new drug is research." On the basis of this criterion, most of the activities of central government testing and standardization institutes, major scientific libraries and information services, museums and geological and meteorological survey organizations became excluded from research and experimental development as routine-based scientific activities. Also excluded were many scientific and technical activities at the enterprise level, including consultancy, project feasibility studies, much design and engineering, production engineering and quality control as well as training and information services.

3 Methodology

3.1 AHP Methodology

The analytic hierarchy process (AHP) pioneered in 1971 by Saaty[6] is a widespread decision-making analysis tool for modeling unstructured problems in areas such as political, economic, social, and management sciences. AHP addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem. The process makes it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria[1]. AHP method is based on three principles: first, structure of the model; second, comparative judgment of the alternatives and the criteria; third, synthesis of the priorities. In the literature, AHP, has been widely used in solving many complicated decision-making problems [2][4].

In the first step, a complex decision problem is structured as a hierarchy. AHP initially breaks down a complex multi-criteria decision-making problem into a hierarchy of interrelated decision elements (criteria, decision alternatives). With the AHP, the objectives, criteria and alternatives are arranged in a hierarchical structure similar to a family tree. A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria that define alternatives in the middle, and decision alternatives at the bottom [8][7].

The second step is the comparison of the alternatives and the criteria. Once the problem has been decomposed and the hierarchy is constructed, prioritization procedure starts

in order to determine the relative importance of each level. The pair wise judgment starts from the second level and finishes in the lowest level, alternatives. In each level, the criteria are compared pair wise according to their levels of influence and based on the specified criteria in the higher level. In AHP, multiple pair wise comparisons are based on a standardized comparison scale of nine levels.

Let $c = \{c_j \mid j = 1, 2, \ldots, n\}$ be the set of criteria. The result of the pair wise comparison on ^{n} criteria can be summarized in na $^{(nxn)}$ evaluation matrix A in which every elemento a_{ij}(i , j = 1,2, ... , n) is the quotient of weights of the criteria, as shown:

$$A=\begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \ldots & & & \\ a_{n1} & a_{n2} & \ldots & a_{nn} \end{bmatrix} a_{ii} = 1, a_{ji} = 1/a_{ij}, a_{ij} \neq 0 \qquad (1)$$

At the last step, the mathematical process commences to normalize and find the relative weights for each matrix. The relative weights are given by the right eigenvector (w) corresponding to the largest Eigen value ($^{\lambda\ max}$), as

$$A_w = \lambda_{max}\ W \qquad (2)$$

Table 1 - Nine-point Intensity of Importance Scale and Its Description.

Definition	Intensity of importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2, 4, 6, 8

If the pair wise comparisons are completely consistent, the matrix A has rank 1 and max λ_{max} = n . In this case, weights can be obtained by normalizing any of the rows or columns of A.

It should be noted that the quality of the output of the AHP is strictly related to the consistency of the pair wise comparison judgments. The consistency is defined by the relation between the entries of A: $a_{ij} \times a_{jk} = a_{ik}$. The consistency index (CI) is

$$CI = (\lambda_{max} - n) / (n - 1) \qquad (3)$$

The final consistency ratio (CR), usage of which let someone to conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as indicated.

$$CR = CI / RI \qquad (4)$$

The number 0.1 is the accepted upper limit for CR. If the final consistency ratio exceeds this value, the evaluation procedure has to be repeated to improve consistency. The measurement of consistency can be used to evaluate the consistency of decision-makers as

well as the consistency of overall hierarchy.

3.2 Indexes

The evaluation of the university's STI ability is a complicated systematic process, involving every aspect of university's scientific and technical innovation. Due to the complexity of the innovation, the AHP has many advantages in appraise and thus is suit to this situation. Firstly, on the basis of consulting relevant experts, construct stratum's structure once of ladder of the evaluation index system, then the indexes at all levels of the system is set up. Then, invite expert's indexes at all levels to the scientific and technological innovation ability evaluation index system of university of Henan Province are set up and compared with the matrix of judging, get at all levels weight of index, shown as Figure 1.

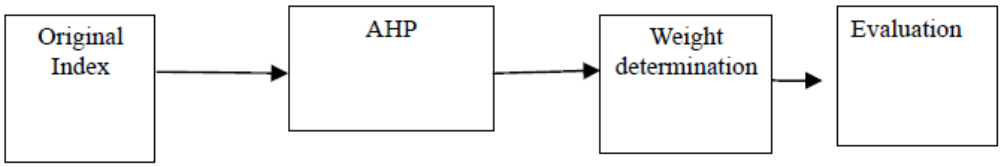

Figure 1 - the Process for Index Design

According to university composition and the characteristics of STI, we can get the evaluation indexes as shown below.

4 Empirical Study

4.1 Introduction to the case –A university

A university is that one takes industry science as the core, engineering, Neo-Confucianism, management, economics <the people's government of Henan Province of coordinated development of discipline such as , literature, law science, agronomy focuses the construction on the university, it is the university that the national grains bureau and Henan Government province department built together, enter the batch of key undergraduate course of Henan Province to enroll new students in the university of the array. At present, the school has already become one and taken industry science as the core, disciplines such as engineering, Neo-Confucianism, management, economics, literature, law science, agronomy etc, which are developed in harmony, and have many department universities of personnel training of two grades systems of bachelor, master, have MBA, project same educational level of master and on-the-job personnel to apply for professional degree gift such as the master's degree and foreign student, Hong Kong, Macao and Taiwan students right of enrolling new students. School take education of undergraduate course as the core, graduate education fast development, recruit jointly whom Ministry of Education authorize, whom Henan Province set up focus the construction on, train doctoral candidate unit. The school has 18 teaching units now, 51 bachelor degrees, 3 national-level characteristic professional construction are lighted, 8 provincial famous brands or characteristic specialties, 25 provincial key disciplines, 4 first class discipline master's degrees are authorized and clicked, second discipline master station of 47. There are more than 25000 students at school now, undergraduate is more than 20000 among them, and Master degree candidate is more than 900.

4.2 Empirical study

4.2.1 Basic resource distribution

In human resources, A university has paid much attention to the introduction of outstanding talents in recent years, have expand one's own high-tech talent's team, has established several outstanding scientific and technical innovation groups too. By the end of 2009, there are 2040 teaching and administrative staff in all in the school, among them the number of full-time teacher is 1501, the person who has doctors, master's degree more than

1100 people of the full-time teachers, the person who has high title more than 600 people, accounts for 40%, have pair to engage in the teaching body and specially engage 10 visiting academicians, Henan Province professor invited specially 3, enjoy to special subsidy expert of the State Council government 28, national-level outstanding teacher, 83 of outstanding teacher and expert at provincial and ministerial levels, serve as 10 doctoral supervisors of the domestic key university, remarkable young fund winner, cross-centennial academic leader, academy technological leader, key teacher of young man of province in the province subsidize 128 marriage partners, the great teacher of provincial teaching is 3. It seems synthetically that the quantity of the duty scientific research personnel of full-time teachers' special secondary school has accounted for about 10%. In addition, the graduate student of the school trains ability to grow up rapidly; there are 276 the number of graduate student that will graduate in 2009, compared with last year has increased by about 20%.

In physical resources, by 2009, the school had 11495 of seating capacity in multimedia classrooms, the seating capacity of pronunciation room is 1608, accounts for 31.3% of the seating capacity in all classrooms. Since 2005, the school will invest the fund of 60 million Renminbi Yuan for the construction of laboratory together. There are 25 experimental centers now in the school, including a provincial key laboratory and the demonstration centre of 3 provincial experiments teaching, 3 are key one batch such as the open laboratory of discipline there are laboratories of larger influence in country and trade. Teaching instrument and equipment total value are up to 154 million Renminbi Yuan, instrument and equipment value are 6952.96 Renminbi Yuan to grow. The total amount of Chinese and foreign literature in storage of the school is 2,245,000 volumes, more than 5300 kinds periodicals of Chinese and foreign language.

4.2.2 Scientific and technical innovation input

In nearly five years by 2009, the school bore national natural science fund, national social sciences fund, the national key scientific and technical tackle-key-problem plan, country " 863 " 64 items national-level scientific research projects such as Hi-Tech project, undertake all kinds of 470 scientific research projects at provincial and ministerial levels. Among them in 2009, " the basic theories of national granary and key technology will be studied and popularized and applied " in charge of finishing by the schooled (J-221-2-01) Finish with participating in " The technology of development and utilization of resources of protein feed and employing " (J-203-2-01) Two projects obtain two national second prizes of scientific and technological progress, open the beginning that the university of Henan obtains National Prize for Progress in Science and Technology. In input of the cost of scientific research, cost of scientific research reach amount of 15 million Renminbi Yuan 2009 such as university, government's fund is about 5 million Renminbi Yuan among them; it is not the government that invests 10 million Renminbi Yuan, accounts for 66.7% that the cost of scientific research is always put into.

Table 2 - the STI ability Evaluation Index System

	Fist class	Second	Third
STI ability evaluation index system of university of Henan Province D	A1: Basic resource distribution	B1: Human Resource	C1: Group's number of outstanding scientific and technical innovation
			C2: High-level skilled personnel's quantity Academician, professor invited specially, etc.)
			C3: Graduate student's graduation number

(Continued Table 1)

			C4: Scientific research personnel's quantity of the duty of special secondary school of teaching body
		B2: Physical resources	C5: Scientific research instrument and equipment value
			C6: The library collect books Ten thousand volumes
			C7: Electronic resource quantity
		B3: Research Centers	C8: Key laboratory / quantity of research institution at provincial and ministerial levels
			C9: National-level key laboratory / centre / quantity of base
	A2: Input in STI	B4: Project	C10: Quantity of national-level scientific research project
			C11: The scientific research project at provincial and ministerial levels is counted
		B5: expenditure	C12: Government fund
			C13: Non-governmental fund
	A3: Communication in STI	B6: Acdemic Meeting	C14: Participants in international conference
			C15: Participants in domestic, trade meeting
		B7: Visiting	C16:International Visitors
			C17:Received Visitors
	A4: Output in STI	B8: Papersand Books	C18: SCI、EI Indexed papers
			C19:SCI Citations
			C20: Papers published in Key periodicals
			C21:Works
		B9: patents & other intellectual property right	C22: The patent application counts
			C23: The patent is authorized and counted
			C24: The standard formulation of the trade
		B10: Rewarded the situation	C25: National-level prize for the achievement in science and technology
			C26: Prizes for the achievement in science and technology at provincial and ministerial levels
		B11: Technological transfer	C27: Technological transfer income
	A5:STI input-output ratio	B12: HR efficiency	C28: Teacher's per capita thesis of natural science discipline (SCI, EI, key periodical) Number
			C29: Teacher's per capita work of natural science discipline is counted

(Continued Table 1)

			C30: Teacher's per capita patent of natural science discipline is counted
			C31: Per capita cost of scientific research of the natural science teacher
		B13:Expenditure efficiency	C32: SCI, EI, key periodical / million Renminbi Yuan
			C33 ：Patent / million Renminbi Yuan
			C34 ：Scientific and technological reward / million Renminbi Yuan
			C35: Technological transfer income / million Renminbi Yuan

4.2.3 Scientific and technological exchange

The scientific and technological exchange has been a subject paid attention to all the time to A University of Henan Province, in advantageous specialty, international organizations such as this university and scientific and technological association of Food and Agriculture Organization of the United Nations. all keep the relation between cooperation and exchange, there is cooperation and exchange with American wheat association, Canadian wheat office, French wheat association, Australian international agricultural centre of development etc. too, have succeeded in running "The international regional seminar of grain logistics of the United Nations ", " international wheat quality and flour improvement seminar " Wait for the international meeting, has held grain processing with the participation of 14 third world countries, stored and examined the training class, sanctioned storing the technological training project organizer for the national foreign-aid grain in 2008. It seems synthetically that in academic meeting, there will be 106 persons in the number of participants in international conference in the whole year of 2009, the number of participants in domestic, trade meeting is 1700 persons; In visiting research, will send 8 of foreign visiting scholar's number in 2009, will accept 26 visiting researchers.

4.2.4 Science and technology production

A university of Henan Province passes accumulation and construction of nearly 50 years, has obtained certain scientific findings, especially adjust and store grain theory and technology angrily in China, store taxonomy of grain insect, phosphate powder technology and theory, supplies pressure theory of prose style free from parallelism of grain, tube storehouse anti-blast technology, low-temperature pottery ultra to rub, have while being hard to combine pharmaceutical, high-temperature resin combine pharmaceutical to be ultra to rub, have, not soft to able to bear water emery cloth research while being hard, a batch of domestic and international and generally acknowledged research results have emerged. Publish 5098 scientific papers, among them is included 370 by SCI, EI, ISTP etc; Publish 138 academic works. In recent years, this university has still participated in the economic construction of country and locality actively, transfers the technology of the scientific findings, has obtained the considerable technological transfer income.

Particularly, this university SCI, EI will include 274 theses in 2009, SCI is guided the number of times 263 times, our country's key periodical and other thesis quantity of foreign publications are 827, the total number of works is 85, it is 23 items altogether to win the authorized patent, patent 62 items, support or participate in making 8 sector standards, obtain 12 prizes for the achievement in science and technology at provincial and ministerial levels,

technological transfer gains 3,200,000 Renminbi Yuan

4.3 Expert Scoring

In order to reflect the comprehensive scientific and technological innovation ability of A University of Henan Province more jocularly, this will use experts to give a mark according to quantifying the evaluation index system above-mentioned, and then the document used the weight of every index that the analytic approach of the level was obtained to obtain the comprehensive score before, can carry on quantitative appraisal to the comprehensive scientific and technological innovation ability of A University of Henan Province more scientifically (as shown in Table 3) .

Through using the positive research that the scientific and technological innovation ability evaluation index system of university of Henan Province that preceding paragraphs construct carries on to A University of Henan Province , it is 80.2 that the scientific and technological innovation ability that must appear in A University of Henan Province finally grades synthetically, it is a good state, this accords with the actual conditions in the university of Henan Province of A university too, prove the evaluation index system that this text constructs has certain feasibility. On the whole, A University of Henan Province is extremely unbalanced in discipline development, though grain and oil food research field basic resource distribution, scientific and technical innovation drop into of various fields to in front level among Henan Province and even national university, but scientific and technological innovation ability slightly shows insufficiently in the fields of other professional research.

5 Conclusion

The indexes designed in this paper are proper for the evaluation of the STI of university, which can be applied in many other aspects. The evaluation method used in this paper is suit for the STI evaluation for future.

Reference

[1] Badri, M. A. A combined AHP-GP model for quality control systems[J]. International Journal of Production Economics, 2001, (72):27–40

[2] Chang, Y. H. and C. H. Yeh. A survey analysis of service quality for domestic airlines[J]. Journal of Operational Research, 2002(139):166-177

[3] Haibin, L. and L. Zhenling. Recycling utilization patterns of coalmining waste in China[J]. Resource Conservancy, 2010, (24):194-200 (In Chinese)

[4] Kahraman, C. and D. Ruan, et al. Fuzzy group decision-making for facility location selection[J]. Information Sciences, 2003, (157):135–153

[5] Liu, Z. Should sustainable consumption and production be a policy Priority for developing countries and if so, what areas should they focus on?[J]. Natural Resources Forum, 2010, 34(1): 85-88 (In Chinese)

[6] Saaty, T. L. The analytic hierarchy process[M]. New York : McGraw-Hill, 1980

[7] Wang, T. and Y. Chen. Applying fuzzy linguistic preference relations to the improvement of consistency of fuzzy AHP[J]. Information Sciences, 2008, 178(19): 3755-3765 (In Chinese)

[8] Yu, C. A GP-AHP method for solving group decision-making fuzzy AHP problems[J]. Computers & Operations Research, 2002, 29(14): 1969-2001