Venture Investment Decision Modeling Using Analytic Hierarchy Process

Kyung-shik Shin[1], Seung-yoon Lee[2]

Ewha Womans University, College of Business Administration, Seoul, Korea
(kishin@ewha.ac.kr[1], lee1204@hanmail.net[2])

Abstract

More venture capitalists than ever before are deciding to become active in venture investing. As a result, venture investing is having a great impact on the entrepreneurial community. When considering an investment, venture capitalists carefully screen the technical and business merits of the proposed company. To do this, they must evaluate and analysis each certain companies' business features using the most scientific and rational way.

Recent Studies were on venture investment mainly focused on success factors or evaluation points for venture companies not proposing any decision support models. This is partly due to the fact that the model is very hard to acquire. The decision models should include the qualitative factors such as CEO's capability, technical level and market strength, etc. In addition, the model takes multi-attribute decision-making process.

In this paper, methodology employed to build a model to evaluate a venture company's future capability is based on the Analytic Hierarchy Process (AHP). AHP is a multi-criteria decision making approach in which factors are arranged in a hierarchical manner, which can also be divided by a number of sub-criteria. AHP will systematically examine the priorities of the alternatives using the derived weight of each factor.

Through this research, most of evaluation criteria which called 'elements' will be defined in each part with well-structured hierarchy for evaluation process. And the importance of each element will give us information to define whether it is worth to invest or not.

1. Introduction

Months after the contagious Asian economic crisis hit Korea in late 1997, venture businesses began sprouting, creating a new job market. Now the industry has grown into an economic magnet of over 6,000 firms. This growth is an encouraging sign in a country at the cusp of a global information technology age.

But there is some worry about whether the boom will continue or turn into a bust. Now for the venture capitals, the question is how many of these venture enterprises across the country will become successful, despite the risk involved. It is obvious that not all will overcome the risk. Some will close up companies. Some may seek more aid from the government, lending credence to the contention by critics that the administration's current policy for the venture industry can create moral hazard, unless it is reviewed and improved.

The most important thing for the venture capital is to invest to the proper company. In order to figure out the appropriate, evaluation and analysis among each certain company's business features using the most scienti fic and rational way is necessary. Recent Studies were on venture investment mainly focused on success facto rs or evaluation points for venture companies not proposing any decision support models. This is partly due t o the fact that the model is very hard to acquire. The decision models should include the qualitative factors s uch as CEO's capability, technical level and market strength, etc. In addition, the model takes multi-attribute decision-making process. Therefore, choosing the exact method to build a scientific structure applying the qual itative factor should be mainly focused building the decision support model.

In this paper, methodology employed to build a model to evaluate a venture company's future capability is based on the Analytic Hierarchy Process. AHP (Analytic Hierarchy Process) is a multicriteria decision making approach in which factors are arranged in a hierarchic structure, which can also be divided by qualitative fac tors. AHP will systematically examine the alternatives and the priority and weight of each factor will be give n by evaluating not only the quantitative data but also the qualitative factors. Through this research, all points will be defined in each part with well-structured hierarchy for evaluation process. And the importance of eac h point will give us information to define whether it is worth to invest or not.

The remainder of this paper is organized as follows. After reviewing studies related to venture company evaluation, brief description of analytic hierarchy process will be provided. The model for evaluating venture company in the

investor's point of view using AHP will be proposed in the next section. This will include the hierarchy of the model and the priority of each criteria. And the model will show which criteria is more important by comparing with each other in the lowest level. The final section discusses the conclusion and future research issues.

2. Related Studies

Venture capital investments, however, differ in several important aspects [1]. First, venture capital is usually invested in new firms which have very little performance history. As a result, the investor cannot rely on historical performance data, such as financial stock market. Second, the investment is typically in small firms and the nature of the investor and investee relationship involves a high degree of direct involvement as compared to relatively inactive role of investors in publicly traded companies. Third, venture capital investments are illiquid in the short term because of the lack of efficient capital markets for equity shares of privately held companies. Long horizons of product and market development make a valuation difficult. Moreover, the legal restrictions that apply to the rescale of such investments lock the investor in for a certain period. Fourth, when a venture capitalist invests in a new startup, it is usually with the implicit realization that future rounds of capital infusion may have to be financed before the initial investment can bear fruit [2].

Studies related to venture company evaluation is mainly focused on two fields, success and failure factors in venture business [3], [4], [5] and investment screening criterion for the venturing capital [6], [7], [8]. Recent studies of screening criterion and elicitation of its weight is done by using factor analysis, regression analysis and ANOVA, etc. In these studies, screening criterion is much different in venture companies than that of other corporate. Normally, when evaluating a company, the management, the product, the market and the financial part must be taken into consideration. But most of the studies show that in venture companies the top manager's ability is mainly concerned.

In this paper, to approach this decision problem in a systematic fashion we use a multi- criteria decision algorithm, the analytic hierarchy process. In all cases the AHP serves as a convenient methodology that is available to experts.

Related studies using AHP has a flow. Starting from proposing the algorithm [9], using AHP as an application for selecting alternatives in certain situation has been done in lots of different cases until now [10], [11], [12], [13]. Aggregating individual judgments and priorities as a group model with AHP is also proposed [14], [15]. And the comparison between AHP and other methods are studied quite often [16]. Recently, the focus of pairwise comparison using the eigenvector has been changed questioning the probability of using fuzzy programming method [17], [18]. Although there are different issues approaching AHP, using it to propose a selecting model is still a very interesting research area.

3. Research Methodology

When we measure something with respect to a property, we usually use some known scale for that purpose. A basic contribution to the subject of this paper, the AHP is how to derive relative scales using judgment or data from a standard scale, and how to perform the subsequent arithmetic operation on such scales avoiding useless number crunching. The judgments are given in the form of paired comparisons. One of the uses of a hierarchy is that it allows us to focus judgment separately on each of several properties essential for making a sound decision. The most effective way to concentrate judgment is to take a pair of elements and compare them on a single property without concern for other properties or other elements. This is why paired comparisons in combination with the hierarchy structure are so useful in deriving measurement [9].

The AHP, which enables the user to determine the relative importance of criteria sets underlying their choice behaviors [18], is selected as the appropriate model. The AHP of Saaty - is theory and reality - an often used procedure to solve strategic decision problems [18], [19], [20], [21], [22], [23], [24], [25], [26].

According to Saaty's original proposal, a complex system is decomposed into subsystem and represented in the hierarchical form. The element at the highest level is called the goal. The elements at each level are the criteria(factors) of the elements at the level below. The elements at the bottom level are called the alternatives. In this way, AHP organizes the basic rationality of the priority setting process by breaking down a multi-element complex system into its smaller constituent parts called components (or levels). The process setting can be divided into three phases which are system structuring, pairwise comparison and priorities synthesis.

The principle of comparative judgment calls fort setting up a matrix to carry out the pairwise comparisons of the relative importance of the elements in a component with respect to the criteria, elements in a dominating component at a higher level in the hierarchy. This matrix, denoted by A in our notation, is called the pairwise comparison matrix. Let the pairwise comparison matrix be

$$A = \begin{pmatrix} 1 & A_{12} & \ldots\ldots & A_{1n} \\ A_{21} & 1 & \ldots\ldots & A_{2n} \\ \ldots\ldots & \ldots\ldots & 1 & \ldots\ldots \\ A_{n1} & \ldots\ldots & \ldots\ldots & 1 \end{pmatrix} \quad (1)$$

where N is the number of elements in the component. The entry Aij > 0 measures the relative importance of the impact on the criterion from element i against that from element j There are some obvious properties of A (1), among which the consistency is the most important one. When I matrix A satisfies the following equation, it is said to be consistent.

$$Aij = Aik / Akj \quad \text{for any k.} \quad (2)$$

It is straightforward to show that when A is consistent, the weight vector W, which gives the relative priorities of the elements, is identical to any one of the columns of A within a normalization factor. One can further show that W is the dominant eigenvector of the matrix, namely

$$A*W = N * W \quad (3)$$

Since the relative importance of the elements depends only on the relative amplitudes of the components of the vector W, we may normalize W by requiring

$$\sum_i W_i = 1 \quad (4)$$

Generally, a vector is said to be normalized if it satisfies the above equation.
In fact the fuzzy nature of the comparison process dictates that inconsistency cannot be completely eliminated. It has been argued that even when A is not consistent, the weight vector W is still determined by the dominant eigenvector of A, namely

$$A \times W = \lambda max\ W \quad (5)$$

where λmax is the largest eigenvalue of the matrix A. It can be shown that λmax ≥ N for any positive reciprocal matrix. The equality is reached only when the matrix is consistent. To measure the consistency of the matrix A, we define the consistency Index (C.1.) as follows:

$$C.I = \lambda max - N / N\text{-}1 \quad (6)$$

In practice, we consider A is very consistent if the consistency index ratio C.R. = (C.I)/(R.I.) is less than 0.1(Random Index: R.I.), which is the average consistency index of a random reciprocal matrix of the same dimension. And also the consistency of A is acceptable if the ratio of CI is about 20% or less), we accept the estimate of W, Otherwise, we attempt to improve consistency [27], [28], [29], [30].

4. Model Development

The purpose of the venture investment decision model is to provide investors with a static, venture company's potential, given a theater of criteria in each level and a decision posture (invest or not). The model is valued essentially by a weighted aggregation of its component investment system's strengths.

4.1 Method of Estimating Evaluation Hierarchy and Priority Weight

Each criteria and alternatives have been selected by six investment experts through questionnaire. Paired comparisons are performed to derive priorities for criteria with respect to the goal. In relative measurement, paired comparisons are performed throughout the hierarchy including on the alternatives in the lowest level of the hierarchy with respect to the criteria in the level above.

When dealing with group judgments, Satty has proposed that any rule to combine the judgements of several individuals should also satisfy the reciprocal property [31]. A proof that the geometric mean, which makes no requirement on who should vote first, satisfies this condition was later generalized in a paper by Aczel and Satty [32] and by Aczel and Alsina [33].
Group judgment differences can be resolved through a consistency check. When several people propose radically different judgments in certain positions of the matrix these can be tested with other judgments on which there is wide agreement by

solving the problem separately for each controversial judgment and measuring the consistency. The judgment yield the highest consistency in the overall problem is retained. The following consistency comparison for each individual's judgment with those of the scale vector *w* derived from group judgments has been proposed:

$$\sum_{i,j=1} b_{ij} w_j / w_i - n^2 \sim 0.1. \quad (4)$$

Probabilistic judgments have been studied extensively by Vargas [30]. In particular he showed that when the judgments are given by a γ–distribution the derived vector belongs to a Dirichlet distribution with a β–distribution of each component. [34]

4.2 The Hierarchical Structure of the Model

The first step is the structuring of the problem as a hierarchy by breaking down the decision problem into a hierarchy of interrelated decision elements. In the first level is the overall goal of 'Evaluation of Venture Companies'. In the second level are three criteria which contributes to the goal, and the third and lower level are criteria which contributes to each upper level. Each criterion at the lowest level has its own alternatives, which is mostly, but not all, divided into three levels, high –middle-low.

In the first level, the main criteria is divided in to 3 categories, management, technical ability, and market capability. Usually when evaluating a company, the 'earning power' is normally concerned very importantly. But when evaluating venture companies, the investment experts have excluded this part. Most of the companies they invest are under 3 years old. Therefore it is difficult to collect their financial data. This is why it is better not to concern earning power in this model. It is not too late concerning this point after knowing whether it is worthy to invest or not. The hierarchy is shown in Figure 1.

4.3 Pairwise Comparison

The second step is the elicitation of pairwise comparison judgment. In other words, collecting input data by pairwise comparison of decision elements. Arrange the elements in the second level into a matrix and elicit judgments from the people who have answered to the questionnaire with respect to the overall goal. The scale to use in making the judgments is given by 1 to 9 based on intensity of importance on a scale of 1-9. This scale has been validated for effectiveness, not only in many applications by a number of people, but also through theoretical comparisons with a large number of other scales. [35]

Table 1. The fundamental Scale [26]

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly Favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity I has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

Absolute measurement (scoring) is applied to rank the alternatives in terms of the criteria or else in terms of ratings (intensities) of the criteria: e.g. excellent, average, poor. After setting priorities on the criteria (or subcriteria, if there are any) pairwise comparison are also performed on the ratings themselves to set priorities for them under each criterion. Finally, alternatives are scored by checking off their rating under each criterion and summing these ratings for all the criteria. This produces a ration scale score for the alternative. The scores thus obtained of the alternatives can be normalized.

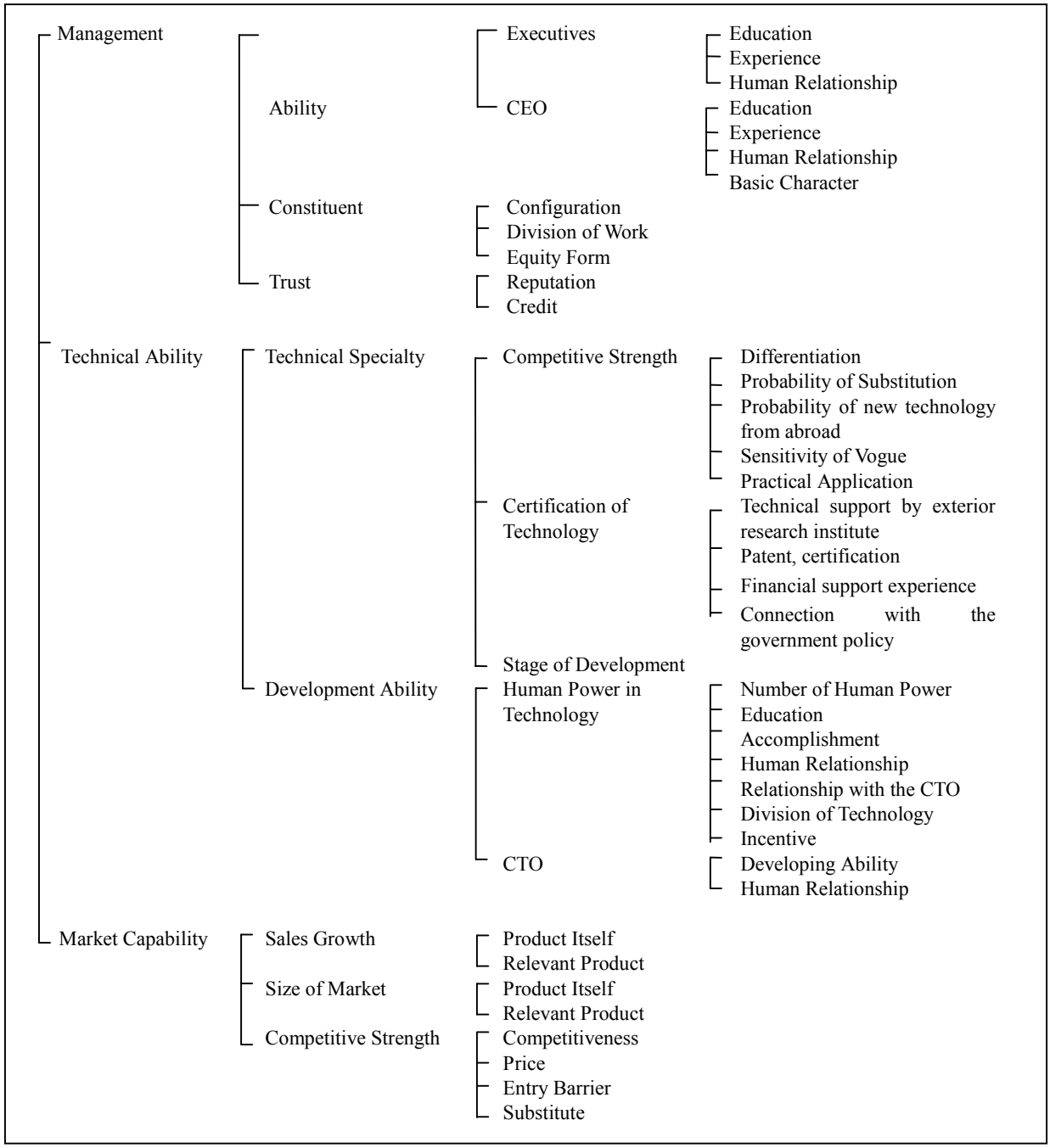

Figure 1. Hierarchy of the Model

Using absolute measurement, no matter how many new alternatives are introduced, or old ones deleted, the ranks of the alternatives cannot reverse. Absolute measurement needs standards, often set by society for its convenience, and sometimes having little to do with the values and objectives of the judge making the comparisons. [35]

4.4 Priority Weight

The third step is to establish the composite or global priorities of each index in the lowest level by using the 'eigenvalue' method to estimate the relative weights of decision elements. We lay out the local priorities of each in the lowest level with respect to each column of vectors by the priority of the corresponding criterion and add across each row which results in the desired vector of each index.

The weight of each evaluation point is related with its each higher and lower node which means adding up the children node will be the weight of the each parent node. At the lowest level, which is the alternatives, it is based on the ideal mode. The alternatives are directly related to scoring. The highest alternative will be recognized as the weight of its upper node. And the others will be scored relatively based on this weight. Once it is scored, it will be added across each row which results in the final rating.

Studies of venture company evaluation propose that the main and probably the only issue to focus on is how much

ability does the CEO have [6]. But by comparing the priority weight in the lowest level criteria, the top five are, reputation of the executives, the technical development ability of the CTO, credit, sales growth in its product, and price competitiveness strength. As shown below, it is not only the executives that is important but also other points must be included in examining the venture company properly. The comparison of each criteria in the lowest level is show in figure 2.

Table 2 Hierarchy and Priority

Management (0.400)					Technical Ability (0.360)					Market Capability (0.24)			
Ability 0.158	Executives 0.043	Education 0.004	PH D	0.004	Technical Specialty 0.134	Competitive Strength 0.089	Differentiation 0.038	High	0.038	Sales Growth 0.066	Product Itself 0.048	High	0.048
			MBA	0.004				Middle	0.019			Middle	0.024
			RelatedMA	0.004				Low	0.00			low	0.00
			MA	0.003			Probability of Substitution 0.014	High	0.014		Relevant Product 0.018	High	0.018
			Bus. BA	0.003				Middle	0.007			Middle	0.009
			relatedBA	0.002				Low	0.00			Low	0.00
			BA	0.002			Probability of new technology from abroad 0.009	High	0.009	Size Of Market 0.045	Product Itself 0.033	Quickening period	0.026
			Under BA	<0.001				Middle	0.005			Growth period	0.033
		Experience 0.019	Same area over 5years	0.019				Low	0.00			Maturity	0.010
			Same area 3-5	0.015			Sensitivity of Vogue 0.008	High	0.008			Decadency	0.00
			Same area under 3	0.011				Middle	0.004		Relevant Product 0.012	Quickening period	0.010
			Other area	0.007				Low	0.00			Growth period	0.012
			none	0.00			Practical Application 0.020	High	0.020			Maturity	0.004
		Human Relationship 0.019	High	0.019				Middle	0.010			Decadency	0.00
			Middle	0.012				Low	0.00	Compe-titive Strength 0.129	Competitiveness 0.034	High	0.034
			Low	0.004		Certification of Technology 0.014	Technical support by exterior research institute 0.002	High	0.002			Middle	0.017
	CEO 0.115	Education 0.011	PH D	0.011				Middle	0.001			Low	0.00
			MBA	0.011				Low	0.00		Price 0.039	High	0.039
			RelatedMA	0.009			Patent, certification 0.007	acquisition	0.005			Middle	0.019
			MA	0.006				application	0.004			Low	0.00
			Bus. BA	0.006				none	0.002		Entry Barrier 0.037	High	0.037
			Related BA	0.005				None but high tech.	0.007			Middle	0.019
			BA	0.004			Financial support experience 0.002	Yes from relient	<0.001			Low	0.00
			Under BA	0.002				Yes from ordinary	<0.001		Substitute 0.019	High	0.019
		Experience 0.038	Same area over 5years	0.038				Yes from individual	<0.001			Middle	0.009
			Same area 3-5	0.030				none	<0.001			Low	0.00
			Same area under 3	0.023			Connection with the government policy 0.004	High	0.004				
			Other area	0.015				Middle	0.002				
			none	0.00				Low	<0.001				
		Human Relationship 0.038	High	0.038		Stage of Development 0.032	Idea made		0.006				
			Middle	0.023			Designed		0.013				
			Low	0.008			Tested		0.025				
		Basic Character 0.029	Entrepreneur	0.029			Produce		0.032				
			Technician	0.014	Develop-ment Ability 0.226	Human Power In Technology 0.113	Number of Human Power 0.005	High	0.005				
			Marketer	0.012				Middle	0.002				
			Administrator	0.006				Low	0.00				
Consti-tuent 0.044	Configuration 0.021	Under 2years, Founder=ceo		0.021			Education 0.008	High	0.008				
		Under 2years, Founder≠ceo		0.012				Middle	0.004				
		Over 2years		0.021				Low	0.00				
	Division of Work 0.012	High		0.012			Accomplishment 0.003	High	0.033				
		Middle		0.007				Middle	0.016				
		Low		0.002				Low	0.00				
	Equity Form 0.010	Under 2year, centralized		0.010			Human Relationship 0.014	High	0.014				
		Under 2year, decentralized		0.005				Middle	0.009				
		Over 2year, centralized		0.008				Low	0.003				
		Over 2year, average		0.010			Relationship with the CTO 0.018	High	0.018				
		Over 2year, decentralized		0.004				Middle	0.011				
Trust 0.200	Reputation 0.117	High		0.117				Low	0.004				
		Middle		0.058			Division of Technology 0.019	High	0.019				
		Low		0.00				Middle	0.011				
	Credit 0.083	High		0.083				Low	0.004				
		Middle		0.041			Incentive 0.016	High	0.016				
		Low		0.00				Middle	0.008				
								Low	0.00				
						CTO 0.113	Developing Ability 0.085	High	0.085				
								Middle	0.043				
								Low	0.00				
							Human Relationship 0.027	High	0.027				
								Middle	0.016				
								Low	0.005				

4.5 Practical Application

The last step is aggregating the relative weights of decision elements to arrive at a set of ratings for the decision alternatives (or outcomes). After Structuring the model with all its priority weights, the investor is able to use this system in its practical business field by selecting which level the venture company is in among the alternatives in each lowest criteria. The evaluation result will be between zero to one. This means if there is a perfect company in all criteria being evaluated in this system, the total score will be rated as one.

The result doesn't give any direct answers of whether the venture capital should invest or not. It gives the venture capital a comparison point of view towards each venture companies that they concern.

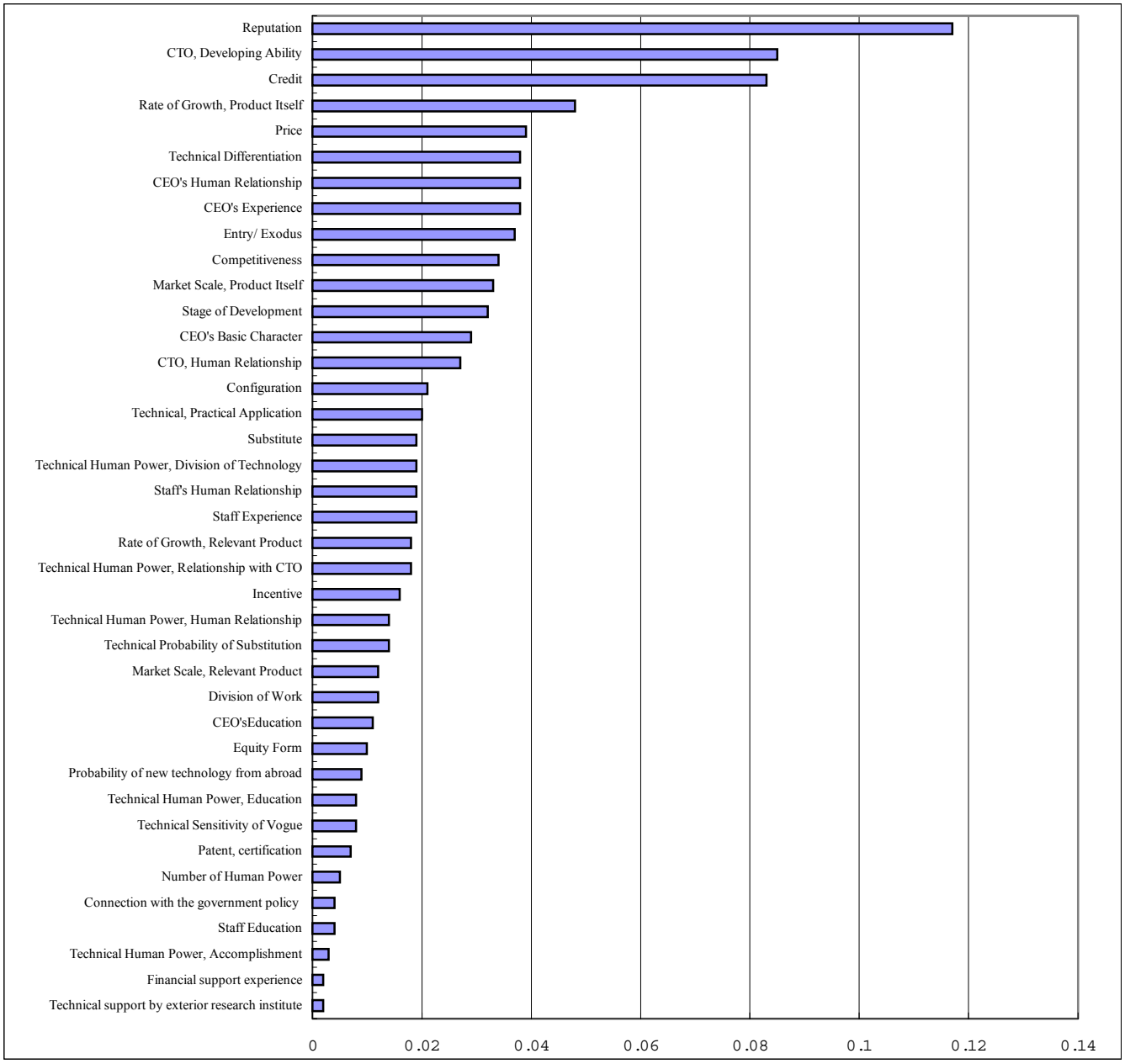

Figure 2. Comparison of The Most Concrete Criteria

5. Conclusion

Building an evaluation model to support decision for venture investors is one of the hottest issues. And the necessity of a full model for evaluation is growing higher. The keynote of this model is to organize all the criteria in a well-formed hierarchy and set up the exact alternatives in each by brainstorming with the professional investors and getting answers by questionnaires from them. The questionnaires are made up of pairwise comparison by each criterion in each hierarchy level. And through this the priority rates are derived.

The model organized in this paper is not just about getting information to help decide selecting one of the candidate alternatives directly. It gives a result by scoring each company in which the investor concerns. This score is different with answers like ‘yes or no’ or ‘excellent or poor’. Instead, it ables to compare each company relatively and gives a positioning map among those candidates.

The reason why the venture capitals need to systemize this model can be proposed by two main reasons. Usually when the investors make decisions, it is mainly based on their perceptual process. As they are human beings, the consistency cannot be promised. The hierarchy structure that is built as a model will not only help the investors maintain each decision’s consistency, but also give a visual configuration of how it is evaluated and will put the process in a definite shape.

The second reason is that once it is built as a model, other people in the organization can use it as a guideline to make decision. As for the venture company organization, it is much difficult to train new employees as professional investors who have no experience.

This model is on the assumption that it is based on the most generalized venture company. Generally, venture companies are classified as ‘internet businesses, ‘information communication businesses, ‘bioengineering’, ‘ceramic engineering’, etc. As shown above each business area cannot be compared. It has its own specific features. Therefore, the evaluation model should be specified and also generalized in each business area. Based on the model proposed in this paper, the hierarchy and the priority weight must be restructured which be can apply to each sphere.

Acknowledgement

This research is funded by the Brain Korea 21 Project, Ministry of Education, Korea

Reference

[1] Poindexter, J. B.: Selecting Profitable Products, Harvard Business Review, Vol. 39, pp84-85, 1961

[2] Cooper, I.A and W. T. Carleton: Dynamics of Borrower-Lender Interaction: Partitioning Final Payoff in Venture Capital Finance, Journal of Finance, Vol. 34, pp517-529, 1979

[3] MacMillan, Ian C., Lauriann Zemann and P. N. Subba Narasimha: Criteria Distinguishing Successful from Unsuccessful Venture in the Venture Screening process, Journal of Business Venture, Vol. 2, pp123-138, 1987

[4] Miller, D.: Relation Poter's Business Strategies to Environment Structure, Academy of Management Journal, Vol. 31, pp280-308, 1988

[5] Rothwell, R.: The Characteristics of Successful Innovators and Technically Progressive Firms, R&D Management, Vol. 7, pp191-206, 1977

[6] Tyebjee, Tyzoon T. and Albert V. Bruno: A Model of Venture Capitalist Investment Activity, Management Science, Vol. 30, No. 9, pp1051-1066, 1984

[7] Kryzanovski, Lawrece and Roger Giraldean: Venture Capital Management: A survey of Attitudes towards Selection Criteria, American Journal of Small Business, Vol. 4, pp465, 1977

[8] MacMillan, Ian C., Robin Siegel and P. N. Subba Narasimha: Criteria Used by Venture Capitalists to Evaluate New Venture Proposals, Journal of Business Venturing, Vol. 1, pp119-128, 1985

[9] Satty, T. L.: How to Make a Decision: The Analytic Hierarchy Process, European Journal of Operational Research Vol.48, pp9-26, 1990

[10] Kwank, N K, Lee, Changwon: A Multicriteria Decision-Making Approach to University resource allocations and information infrastructure, European Journal of Operational Research, Vol. 110, pp234-242, 1998.

[11] Rex Karsten and Timothy Garvin: The Use of the Analytic Hierarchy Process in the Selection of Participants for Telecommuting Pilot Project, Proceedings of the 1996 conference on ACM SIGCPR/SIGMIS conference, pp152-160, 1996.

[12] Lai, Vincent S; Trueblood, Robert P; Wong, Bo K: Software Selection: A case of the application of the analytic hierarchy process to the selection of a multimedia authoring system, Information & Management, Vol.36, pp221-232, 1999.

[13] Young-Woo Lee and Byong-hun Ahn: Static Valuation of Combat Force Potential by the Analytic Hierarchy Process, IEEE Transactions on Engineering Management, Vol. 38, No. 3, 1991.

[14] Gass, Saul I & Rapasak, Tamas: A Note on Synthesizing Group Decisions, Decision Support Systems, Vol.22, pp59-63, 1998.

[15] Forman, Earnest & Peniwati, Kirti: Aggregating Individual Judgments and Priorities with the Analytic Hierarchy Process, European Journal of Operational Research, Vol. 108, pp165-169, 1998

[16] H Wang & M Xie, T N Goh: A comparative Study of the Priority Matrix Method and the Analytic Hierarchy

Process Techniques in Quality Funtion Deployment, Total Quality Management, Vol. 9, pp421-430, 1998.
[17] Labib, A W & William, G B & O Connor, R F: An Intelligent Maintenance Model (System): An Application of the Analytic Hierarchy Process and a Fuzzy Logic Rule- Based Controller, The Journal of the Operational Research Society, Vol. 49, pp745-757, 1998.
[18] L Mikhailov: A Fuzzy Programming Method for Deriving Priorities in the Analytic Hierarchy Process, The Journal of the Operational Research Society, Vol. 51, pp341-349, 2000.
[19] Bahmani, N., Javalgi, G. & Blumberg, H.: An Application of the Analytical Hierarchy Process for a Consumer Choice Problem, Dev. Marketing Science Vol. 10, 1986
[20] Wind, Y. & Saaty, T. L: Marketing Applications of the Analytic Hierarchy Process, Management Science, 1980
[21] Ossadnik, W. & Lange: OAHP-Based Evaluation of AHP-Software, European Journal of Operational Research, Vol. 118, 1999
[22] Bahmani, N. & Blumberg, H.: Consumer Preference and Reactive Adaptation to a Corporate Solution of the Over-the-Counter Medication Dilemma - An AHP Analysis, Math Modeling, Vol. 9. No. 3-5, 1987
[23] Arbel, A.: Venturing into New Technological Markets, Math Modeling, Vol. 9. No. 3-5, 1987
[24] Vachnadze, R.G. & Markozashvili, N.I.: Some Applications of the AHP, Math Modeling, Vol. 9. No. 3-5,1987
[25] Cheng, C.H., Yang, K.L. & Hwang, C.L.: Evaluating Attack Helicopters by AHP Based on Linguistic Variable Weight, European Journal of Operational Research 116, 1999
[26] Lee, M., Pham, H. & Zhang, XA: Methodology for Priority Setting with Application to Software Development Process, European Journal of Operational Research 118, 1999
[27] Jung, H.W. & Choi, B. J.: Optimization Models for Quality and Cost of Modular Software Systems, European Journal of Operational Research 112, 1999
[28] Lee, M., Pham, H. & Zhang, X.: A Methodology for Priority Setting with Application to Software Development Process, European Journal of Operational Research 118, 1999
[29] Saaty, T. L. & Vargas, L.G. The Logic of Priorities, Kluwer-Nijhoff Publishing, London, 1982
[30] Saaty, T. L., The Analytic Hierarchy Process, RWS Publication, 1988
[31] L. Vargas: Reciprocal Matrices with Random Coefficients, Journal of Math. Modeling 3, pp69-81, 1982
[32] Saaty, T.L.: Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World, RWS Publications, Pittsburgh, PA, 1986.
[33] J. Aczel and T. L. Saaty: Procedures for synthesiziong ratio judgments, Journal of Math. Psychol. 27(1), pp93-102, 1983
[34] J. Aczel and C. Alsina: Synthesizing Judgments: A Functional Equations Approach, Mathl Modelong Vol.9, pp311-320, 1987
[35] Saaty R. W.: The Analytic Hierarchy Process: What It Is and How It Is Used, Mathl Modeling, Vol.9, No.3-5, pp161-176, 1987