Journal of Business Economics and Management
ISSN 1611-1699 print / ISSN 2029-4433 online
2011 Volume 12(2): 219–233
doi:10.3846/16111699.2011.573284

THE STUDY ON VENTURE INVESTMENT EVALUATION BASED ON LINGUISTIC VARIABLES FOR CHINESE CASE

Peide Liu

Information Management School, Shandong Economic University,
Jinan 250014, Shandong Province, China
E-mail: peide.liu@gmail.com

Received 20 November 2009; accepted 15 Januar 2011

Abstract. The venture investment evaluation plays a very important role in the venture investment operation process. The goal of the paper is development of evaluation index systems and evaluation methods for venture investment. Firstly, the evaluation index systems of venture investment project are constructed in accordance with China's practical situation. Then evaluation models have been presented. In the models, operational laws of linguistic variables and distance of two linguistic variables are defined; and a single objective optimization model is constructed by maximizing deviation method to get the objective weights of indexes, and alternatives are ranked by TOPSIS and grey relation methods respectively. Finally, a numerical example is given to illustrate the evaluation procedures of two approaches. The case shows that two different approaches get the same result, but TOPSIS is simpler apparently.

Keywords: TOPSIS; grey relation; relative closeness; venture investment.

Reference to this paper should be made as follows: Liu, P. 2011. The study on venture investment evaluation based on linguistic variables for Chinese case, *Journal of Business Economics and Management* 12(2): 219–233.

JEL classification: C44.

1. Introduction

The venture investment evaluation plays a very important role in the venture investment operation process which can have direct influence on the venture investment's success or failure. At present, a large number of studies have been carried on the choice of venture investment projects. All of the studies can be divided into two aspects: the research of evaluation index system and the research of evaluation approaches.

Venture capital (VC) researchers frequently address questions of venture capitalists' investment behavior, along with due diligence and its related issues, by focusing on venture capitalists' investment criteria. Tyebjee and Bruno (1984) got 23 factors which should be considered by the venture investment company during their track interview with 90 venture investment organizations, and they divided them into four parts: the market, the product differences, the management capacity and the resisting strength to environmental threat. The seminal study by MacMillan *et al*. (1985) proposes that five of the 10 most important decision criteria are related to the personality or experience of the entrepreneurs. Muzyka *et al.* (1996) provide some evidence that European venture capitalists, especially, attach importance to management team criteria rather than the characteristics of the lone entrepreneur. According to these authors, product and market criteria are only of average importance, while criteria of the fund and the respective terms of a deal's structure are of minor importance. Zustshi *et al.* (1999) investigated 31 of Singapore's 58 risk entities; the results however reveal that criteria adopted by Singapore VCs are not very different from those adopted by VCs in other countries including U.S. The results also confirm that the entrepreneur's characteristics or the top management's capabilities are seen as being primary indicators of the venture's potential. Further examination of VCs investment process revealed that the investment criteria adopted by successful VCs were no different from those adopted by less successful VCs. This confirms that investment selection is a multi-stage process wherein venture assessment is only one of the steps in this process. Tang (2002) proposed an evaluation index system which can be used by all investment companies. This evaluation index system could be summarized as the following three aspects: the characteristics of risk entrepreneurs, venture enterprises' own characteristics and the market environment, for a total of 28 indicators. Zhao (2007) constructed the index systems for venture investment evaluation, included one-level indicators of Management, Market, Product and technology and Financial characteristics, and 20 two-level indicators. Shi (2005) embarks the form evaluating anticipated income and risk, constructs the appraisal target system that contains seven core targets, which are entrepreneur, management, product and technology, marketing, finance, society effects and withdrawal of venture capital, and forty-seven concrete targets. Kollmann and Kuckertz (2010) analyzed the decision process of venture capitalists and focused on aligning the evaluation uncertainty in the decision criteria of venture capitalists with the progress of the process, and concentrated on 15 important investment criteria (Table 1) based on the relevant literature. Despite the reduced number of criteria, this is a catalogue that a venture capitalist would most likely perceive as largely complete. However, these evaluation criteria did not consider the situation in China. Jiang and Ruan (2010) constructed the risk assessment index for high-tech projects which considered each side of project risks and at the same time classify the risks in accordance with a certain standard. Combined with China's national conditions and domestic high-tech industries, the investment risks of high-tech projects can be divided into six aspects: R&D risks, technology risks, production risks, management risks, market risks and environmental risks. Hu (2009) established the venture investment project evaluation indexes system, including risk assessment (it had the indicators of technology risk, market risk, management risk, exit risk and environmental risk) and effectiveness evaluation (it had the indicators of product efficiency, market efficiency, and corporate capacity, economic and social benefit).

As for the evaluation methods, Hu (2009) proposed the approach based on coefficient of variation to get the weight of indicators and to assess the risk and effectiveness of venture capital investment projects synthetically in detail in China. Li and Wei (2009) proposed the intuitionistic fuzzy weighted average (IFWA) operator and the intuitionistic

Table 1. Venture capitalists' investment criteria (Kollmann, Kuckertz 2010)

Factor	Investment criteria	Evidence of criterion's relevance
Personality of the entrepreneur	"VC character"	Pretest
	Leadership capabilities	MacMillan *et al*. (1985), Robinson (1987)
	Commitment	Dixon (1991), Muzyka *et al*. (1996)
Experience of the entrepreneur	Track record	Flynn (1991)
	Technical qualification	Shepherd (1999), Franke *et al*. (2006)
	Business qualification	Shepherd (1999), Franke *et al*. (2006)
Product or service	Innovativeness	MacMillan *et al*. (1985), Mason and Stark (2004)
	Patentability	Tyebjee and Bruno (1984), MacMillan *et al*. (1985)
	Unique selling proposition	Mason and Stark (2004)
Market characteristics	Market volume	Tyebjee and Bruno (1984), Mason and Stark (2004)
	Market growth	Tyebjee and Bruno (1984), Mason and Stark (2004)
	Market acceptance	Tyebjee and Bruno (1984), Mason and Stark (2004)
Financial characteristics	Fit to investment strategy	Muzyka *et al*. (1996), Mason and Stark (2004)
	Return on investment	Tyebjee and Bruno (1984), MacMillan *et al*. (1985)
	Exit possibilities	Muzyka *et al*. (1996), Mason and Stark (2004)

fuzzy hybrid average (IFHA) operator based on intuitionistic fuzzy set to assess the venture investment. Jiang and Ruan (2010) combined Analytic Hierarchy Process (AHP) with BP Neural Network to establish a new and suitable risk assessment model of high-tech projects. Firstly, they applied AHP to construct a comprehensive risk assessment index system and screened the assessment indexes according to their weights. Then, using MATLAB software with BP Neural Network model to simulate and analyze the example. The results showed that the combination model of Analytic Hierarchy Process with BP Neural Network model (AHP-BPNN) is effective. Guo (2010) made an analysis on the financial yield of risk investment in engineering projects from the perspectives of sameness, difference and reverse based on Set Pair Theory. Combining the Set Pair Theory with the penalty-incentive mechanism of target weight, it forms a model profit varying weight of the risk investing project and takes maximum connection as a principle to judge the profits of the project. Jia and Zhao (2009) proposed a comprehensive evaluation method for determining the evaluation indexes weight based on entropy coefficient and established a comprehensive evaluation model of multi-objective decision-making, and then they carried on a reasonable and effective evaluation for the venture capital management. Ke *et al.* (2010) proposed an improved model to evaluate the risk in real estate investment. This model first avoided the information overlap caused by the fuzziness and complexity of the indices and by the orthogonal transformation. It also adopted entropy method to reduce the subjectivity during the evaluating process. Fang and Zhang (2006) proposed a risk control method which combined the Fuzzy evaluation model and the AHP model with respect to the investment evaluation indicators' characteristics of fuzzy and difficult to control; Su (2005) used the principal component analysis method to evaluate the risk investment projects; Zhang and Yang (2006) proposed a venture investment project risk evaluation index system from the aspects of production risk, market risk, technical risk, management risk, financial risks and natural risk, and on this basis they gave a multi-level gray evaluation method which used the theory of gray system and combined with examples for risk investment projects. Wang (2006) proposed a venture investment comprehensive evaluation mathematical mode by use of pair analysis theory. Kuang and Chen (2006) studied the investment risks in real estate by use of improved genetic algorithm. Fu and Huang (2002) proposed integrated evaluation methods for risk investment projects on the base of KENDALL – W test and multi-attribute utility function (MAUF) theory. Ginevicius and Zubrecovas (2009) developed the model of real estate projects' efficiency evaluation. The proposed model is designed for alternative projects, variants selection, investment resources allocation as well as real estate value maintenance and enhancement problems solution. The model of real estate projects‘ efficiency evaluation covers all the investment decision-making cycle, the hierarchically-structured projects' evaluation criteria system, risk evaluation basing on stochastic dimensions as well as the mathematical methods adaptation for multiple criteria evaluation problems solution, risk assessment and adjusted mathematical methods. Hui, Lau and Lo (2009) proposed two fuzzy mathematical programming models to incorporate expert knowledge into the classical quadratic programming approach, i.e. Modern Portfolio Theory (MPT), through fuzzy set theory, in obtaining portfolio return optimization involving direct real estate investment. Kahraman and Kaya (2010) proposed two types of investment analyses. First, fuzzy parameters are used in the stochastic investment analysis. Then, another investment analysis is examined by using the concept of probability of a fuzzy event. Rutkauskas *et al.* (2008) proposed the conception of sustainable return investment decisions strategy in capital and money markets and modeling of investment decisions along sustainable development concept in capital and money markets.

In summary, there is not a widespread consensus on selection of the venture investment's evaluation index now, and the evaluation indexes constructed are also different. So this paper will establish a relatively scientific and sound risk evaluation index system from the perspective of selected investment projects for venture capital firms. In the evaluation method, considered that the risk evaluation indexes are mostly the qualitative indexes, this paper will mainly use the linguistic evaluation method to overcome the disadvantage of the evaluation methods mentioned above, which mainly depend on qualitative data. Moreover, considered that the indicators' weight is also very difficult to determine beforehand, the principle of deviation maximization will be used to determine the objective weight by establishing a single-objective optimization model, and the TOPSIS method and the grey relational method will be used to rank the alternatives. In order to achieve these tasks, the remainder of this paper is structured as follows. In Section 2, the index system of venture investment evaluation is established by investigation of the venture capital firms. In Section 3, the evaluation methods for venture investment evaluation based on linguistic variables are proposed, including a single-objective optimization model for getting the objective weights of indexes, which will be constructed by maximizing deviation method, and TOPSIS and grey relation method which are used to rank the alternatives respectively. In Section 4, an application example of venture investment evaluation is given by the proposed methods, and some conclusions are pointed out in Section 5.

2. The Index System of Venture Investment Evaluation

2.1. Index System Establishment

Establishing an index system for venture investment evaluation directly affects the investment projects and success or failure of investment projects. So the prerequisite of venture investment evaluation is determining the scientific and sound venture evaluation indexes. On the foundation of the following principles as systematization, hierarchy, comprehensiveness, economy, comparability, operability, practicability and precedence, this paper establishes the index system as follows according to the proposals of 12 venture investment enterprises (shown in Table 2).

Table 2. Index system for venture investment evaluation

Index Classification	indicators
o_1 the index of affecting investment venture	c_1 management venture
	c_2 technology venture
	c_3 market venture
	c_4 finance venture
	c_5 exit venture
o_2 the index of affecting investment income	c_6 entrepreneur quality
	c_7 enterprise management level
	c_8 product and technology specificity
	c_9 enterprise profit capacity
	c_{10} market environment
	c_{11} policy environment

2.2. Evaluation index explanation

(1) The index of affecting investment venture

Management venture: This venture means that the possibility is causing investment success or failure because of ill management.The management usually concerns about scientific research and development management, production management, marketing management, personnel management. It mainly includes enterprise management decision level, the scientific applicability of organization institution and structure, personnel management and performance evaluation, production management venture, the capacity of enterprise marketing and so on.

Technology venture: This venture means that the uncertainty of causing investment success or failure is because of the uncertainty of product and technology. It mainly includes intellectual property rights, technological advance, technological reliability, technological substitution, the degree of preventing technological imitation, the compatibility between technology and policy and industry standard and so on.

Market venture: This venture means that the uncertainty of causing investment success or failure is because of the uncertainty of promoting product and technology in the markets. It mainly includes market stability, the difficulty of market development, market acceptance capacity, market service capacity, competitor status, and the tendency of policy change and so on.

Finance venture: This venture means that the uncertainty of causing investment success or failure is because of the uncertainty of enterprise financing operation. It mainly includes the standardization of finance institution and the authenticity of finance information, the smooth of financing channels, the rationality of investment plan and so on.

Exit venture: This venture means that the uncertainty of causing investment success or failure is because of the uncertainty of venture investment exiting. It mainly includes the status of exit channel, possible exit time, and possible exit ways (as public offering, merger and purchase, venture enterprise repurchase, bankrupt liquidation) and so on.

(2) The index of affecting investment revenue

Entrepreneur quality: At present, most positive analysis proves that venture investors pay the most attention to the qualities and abilities of venture entrepreneurs when they choose projects. Before venture investors invest in venture enterprises, they focus on the evaluation of venture entrepreneurs' character, on the qualities and abilities of venture entrepreneurs in order to make an investment decision through researching the influences these abilities exert on the future development of venture enterprises. Entrepreneur qualities mainly include entrepreneurs' personal qualities, entrepreneurs' knowledge qualities, entrepreneurs' abilities of integrating resources, entrepreneurs' abilities of meeting an emergency and forecasting ventures, entrepreneurs' prior achievement and so on.

Enterprise management level: Effective management can reduce, even defuse the invest venture. So venture invest enterprises almost regard management as an important evaluation index of venture invest projects without exception. Concretely, they mainly evaluate these projects from several aspects as follows: enterprises' strategic planning, the qualities and abilities of management teams, enterprises' business culture and ideas, enterprises' organization structure, enterprises' job responsibilities and C&B, enterprises' personnel reserve, enterprises' information level and inner communication status and so on.

Product and technology specificity: Venture investors' interest on advanced and adaptive product and technology. Their most basic goal is to make use of the technology to satisfy present and potential requirement and acquire rich invest return finally. So there is certain request for the product and technology of venture enterprises when evaluating projects and the product and technology should have comparative advantage. It mainly includes technology patent level, product practicability, product adaptability, unique characteristic of product and so on.

Enterprise profit capacity: Enterprise profit capacity affects directly the return ability of enterprise. It is indispensable indexes when the venture investors invest and it has a decisive influence on invest decision. The aspects of examining the enterprise profit capacity mainly include enterprise revenue level and growth potential of revenue. When the enterprise revenue level is higher, venture investors are more likely to invest. The index of evaluating revenue level mainly include sale net profit, asset payment rate, rights and interest of shareholder payment rate and so on; Growth potential of revenue reflects the development prospect of enterprises. It is the core guarantee that venture invest can acquire high return. So when growth potential of revenue is higher, venture investors are more likely to invest. The index of evaluating growth potential of revenue mainly includes sale growth rate, profit growth rate and so on.

Market environment: Due to venture enterprises facing the future market, market evaluation of venture invest projects focuses on the development trend of market (that is, market current). It mainly includes the industry of venture enterprise, market scale, market growth, technical barrier and lead time, market competition status and so on.

Policy environment: The operation of venture enterprises needs certain policy support. The evaluation of policy environment is also an important index when venture investors consider investing. It mainly includes the relative degree with the development direction of government industry, the relation with government correlation institution, tax incentive method and so on.

3. The Evaluation Method

3.1. Description of the Decision Problems

Suppose that there are m evaluation objects $A = (a_1, a_2, ..., a_m)$; n evaluation index $C = (c_1, c_2, ..., c_n)$; the evaluation index value of each object composes a matrix $T = [t_{ij}]_{m \times n}$, t_{ij} is the j-th index evaluation value of the i-th evaluation object, t_{ij} is an element of an linguistic (or linguistic symbol) evaluation set S which is predefined. Here, linguistic evaluation set S is an ordered set which is composed of odd elements. For example, linguistic evaluation set S = (very poor, poor, slightly poor, middle, slightly good, good, very good) which is composed of 5 elements. This decision problem is: Aiming at linguistic decision matrix $T = [t_{ij}]_{m \times n}$ given by each decision maker to solve index weight W and get the rank result of the project finally through certain decision analysis method.

3.2. Linguistic Evaluation Set and its Extension

Linguistic evaluation set $S = (s_0, s_1, ..., s_{l-1})$ should be composed of odd elements (that is, l should be an odd number). In actual application, the value of l is as of 3,5,7,9. This paper uses $l = 7$, so S can be represented as follows:

$S = (s_0, s_1, s_2, s_3, s_4, s_5, s_6)$ = (very poor, poor, slightly poor, middle, slightly good, good, very good).

For linguistic set S, it should satisfy the following conditions:
(1) if $i > j$, then $s_i \succ s_j$ (that is, s_i superior to s_j);
(2) negative operator $\mathrm{neg}(s_i) = s_j$ to make $j = l - i$;
(3) if $s_i \geq s_j$ (that is, s_i is not inferior to s_j) then $\max(s_i, s_j) = s_i$;
(4) if $s_i \leq s_j$ (that is, s_i is not superior to s_j) then $\min(s_i, s_j) = s_i$.

For linguistic scale $S = (s_0, s_1, ..., s_{l-1})$, there exists strict monotonic increasing relation between element s_i and its subscript i (Herrera *et al.* 1996). So it can define function $f: s_i = f(i)$, obviously, $f(i)$ is the monotonic increasing function to subscript i. In order to prevent loss of linguistic decision information, original discrete linguistic scale $S = (s_0, s_1, ..., s_{l-1})$ should be expanded to continuous linguistic scale $s = \{s_\alpha | \alpha \in R\}$ and the continuous linguistic scale still satisfies the upper strict monotonic increasing relation. The operational rules about linguistic variables refer to Wei *et al.*(2006).

Definition 1 (Wei *et al.* 2006): suppose s_α, s_β are two linguistic variables, then the distance between s_α and s_β can be defined as follows:

$$d(s_\alpha, s_\beta) = |\alpha - \beta|. \tag{1}$$

3.3. Using maximum deviation method to determine the index weight *W*

The uncertainty of attribute weight can cause the uncertainty of decision project ranking, so maximum deviation method is used to make the weight more accurate. Generally, the smaller the difference between the value $t_{ij}(j = 1, 2, ..., n)$ of attribute c_j in all decision project, the less important the function which the attribute weight exerts on project decision; conversely, the bigger the difference among the value $t_{ij}(j = 1, 2, ..., n)$ of attribute c_j in all decision project, the more important the function which the attribute weight exerts on project decision. So, from the aspect of ranking the decision projects or choosing the best one, the bigger the deviation between attribute values of all projects, the bigger the weight which should be assigned; the smaller the deviation between attribute values of all projects, the smaller the weight which should be assigned.

For index c_j, if let $D_{ij}(w_j) = \sum_{l=1}^{m} d(t_{ij}, t_{lj}) w_j$ represents the deviation between project A_i and all the other projects, then $D_j(w_j) = \sum_{i=1}^{m} D_{ij}(w_j) = \sum_{i=1}^{m}\sum_{l=1}^{m} d(t_{ij}, t_{lj}) w_j$ represents total deviation between a project and all the other projects, $D(w_j) = \sum_{j=1}^{n} D_j(w_j) = \sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{l=1}^{m} d(t_{ij}, t_{lj}) w_j$ represents the total deviation of all indices in all projects.

Constructing the following Maximum Deviation model:

$$\begin{cases} \max D(w_j) = \sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{l=1}^{m} d(t_{ij}, t_{lj}) w_j, \\ \text{s.t} \sum_{j=1}^{n} w_j^2 = 1, w_j \geq 0, j = 1, 2, \ldots, n. \end{cases} \tag{2}$$

Constructing the following Lagrange multiplier function:

$$L(w_j,\lambda)=\sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{l=1}^{m}d(t_{ij},t_{lj})w_j+\lambda(\sum_{j=1}^{n}w_j^2-1).$$

Supposed

$$\begin{cases}\dfrac{\partial L(w_j,\lambda)}{\partial w_j}=\sum_{i=1}^{m}\sum_{l=1}^{m}d(t_{ij},t_{lj})+2\lambda w_j=0,\\ \dfrac{\partial L(w_j,\lambda)}{\partial \lambda}=\sum_{j=1}^{n}w_j^2-1=0.\end{cases}$$

Solving the model, the following expression is obtained:

$$\begin{cases}2\lambda=\sqrt{\sum_{j=1}^{n}(\sum_{i=1}^{m}\sum_{l=1}^{m}d(t_{ij},t_{lj}))^2},\\ w_j=\dfrac{\sum_{i=1}^{m}\sum_{l=1}^{m}d(t_{ij},t_{lj})}{\sqrt{\sum_{j=1}^{n}(\sum_{i=1}^{m}\sum_{l=1}^{m}d(t_{ij},t_{lj}))^2}}.\end{cases} \quad (3)$$

After being normalized, the w_j can be obtained:

$$w_j=\frac{\sum_{i=1}^{m}\sum_{l=1}^{m}d(t_{ij},t_{lj})}{\sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{l=1}^{m}d(t_{ij},t_{lj})}. \quad (4)$$

3.4. Using TOPSIS to Determine Project Ranking

(1) Determining PIS and NIS

PIS (Positive Ideal Solution) is the best project of a project set A_i (i = 1, 2, ..., m), each attribute value is the corresponding best value of decision matrix; NIS(Negative Ideal Solution) is the worst project of a project set A_i (i = 1, 2, ..., m), each attribute value is the corresponding worst value of decision matrix.

$$V^+=(v_1^+,v_2^+,\cdots,v_n^+)=\left(\max_i(t_{i1}),\max_i(t_{i2}),\cdots,\max_i(t_{in})\right), \quad (5)$$

$$V^-=(v_1^-,v_2^-,\cdots,v_n^-)=\left(\min_i(t_{i1}),\min_i(t_{i2}),\cdots,\min_i(t_{in})\right). \quad (6)$$

(2) Calculating the weighting distance between each project and PIS, NIS

$$d_i^+=\sum_{j=1}^{n}w_jd(v_j^+,t_{ij}), \quad (7)$$

$$d_i^-=\sum_{j=1}^{n}w_jd(v_j^-,t_{ij}). \quad (8)$$

(3) Determining relative closeness degree

The relative closeness degree between evaluation project and PIS:

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-}.(i = 1, 2, \cdots, m). \quad (9)$$

According to the size of relative closeness degree, evaluation projects can be ranked. The bigger the relative closeness degree is, the better the project is. So the most suitable project can be obtained.

3.5. Gray Correlation TOPSIS Evaluation Method

(1) Calculating the gray correlation coefficient between the *i*-th project and the ideal project for the *j*-th index:

$$\xi_{ij}^+ = \frac{l + \rho M}{\Delta_{ij}^+ + \rho M}, \ \rho \in (0,1). \quad (10)$$

Here, Δ_{ij}^+ is the distance between v_j^+ and t_{ij}, $l = \underbrace{\min}_{i}\underbrace{\min}_{j}\Delta_{ij}^+$, $M = \underbrace{\max}_{i}\underbrace{\max}_{j}\Delta_{ij}^+$, ρ is distinguishing coefficient (Generally assigned the value 0.5).

Thus gray correlation coefficient matrix between each project and positive ideal project is as follows:

$$\xi^+ = \begin{bmatrix} \xi_{11}^+ & \xi_{12}^+ & \cdots & \xi_{1n}^+ \\ \xi_{21}^+ & \xi_{22}^+ & \cdots & \xi_{2n}^+ \\ \vdots & \vdots & \vdots & \vdots \\ \xi_{m1}^+ & \xi_{m2}^+ & \cdots & \xi_{mn}^+ \end{bmatrix}.$$

Gray correlation degree between the *i*-th project and positive ideal project is as follows:

$$R_i^+ = \sum_{j=1}^{n} w_j \xi_{ij}^+, (i = 1, 2, \cdots, m). \quad (11)$$

(2) Calculating correlation degree coefficient between the *i*-th project and negative ideal project for the *j*-th index:

$$\xi_{ij}^- = \frac{l + \rho M}{\Delta_{ij}^- + \rho M}, \ \rho \in (0,1). \quad (12)$$

Here, Δ_{ij}^- is the distance between v_j^- and t_{ij}, $l = \underbrace{\min}_{i}\underbrace{\min}_{j}\Delta_{ij}^-$, $M = \underbrace{\max}_{i}\underbrace{\max}_{j}\Delta_{ij}^-$, ρ is distinguishing coefficient (Generally assigned the value 0.5).

Thus gray correlation coefficient matrix between each project and negative ideal project is as follows:

$$\xi^- = \begin{bmatrix} \xi_{11}^- & \xi_{12}^- & \cdots & \xi_{1n}^- \\ \xi_{21}^- & \xi_{22}^- & \cdots & \xi_{2n}^- \\ \vdots & \vdots & \vdots & \vdots \\ \xi_{m1}^- & \xi_{m2}^- & \cdots & \xi_{mn}^- \end{bmatrix}.$$

Gray correlation degree between the *i*-th project and negative ideal project is as follows:

$$R_i^- = \sum_{j=1}^{n} w_j \xi_{ij}^-, (i = 1, 2, \cdots, m). \quad (13)$$

(3) Calculating the gray correlation relative closeness degree of each project:

$$Y_i = \frac{R_i^+}{R_i^+ + R_i^-}, (i = 1, 2, \cdots, m). \quad (14)$$

According to the size of relative closeness degree, evaluation projects can be ranked. The bigger the gray correlation relative closeness degree is, the better the project is. So, the most suitable project can be obtained.

4. Application Examples

A venture capitalist has 4 invest projects; experts evaluate each project according to 11 indices which are shown in Table 2. Evaluation linguistic set $S = (s_0, s_1, s_2, s_3, s_4, s_5, s_6)$ = (very poor, poor, slightly poor, middle, slightly good, good, very good). The attribute values of each index in each project are shown in Table 3.The weight of each index is unknown. Then rank the projects to choose the best project.

Table 3. The evaluation value of different attribute in different project

	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}
a_1	s_4	s_2	s_5	s_5	s_4	s_3	s_3	s_5	s_6	s_2	s_3
a_2	s_5	s_5	s_4	s_3	s_2	s_4	s_3	s_2	s_4	s_6	s_5
a_3	s_4	s_3	s_6	s_2	s_5	s_4	s_6	s_3	s_4	s_4	s_5
a_4	s_3	s_5	s_4	s_6	s_4	s_5	s_3	s_5	s_5	s_4	s_4

4.1. Calculating attribute weight

According to section 3.3 in this paper, we can use maximum deviation method to determine the attribute weight W

(1) Calculating $d_{ij} = \sum_{l=1}^{4} d(t_{ij}, t_{lj})$ for i = 1, 2, 3, 4, j = 1, 2, ..., 11

$d_{1,1}=2$, $d_{1,2}=7$, $d_{1,3}=3$, $d_{1,4}=6$, $d_{1,5}=3$, $d_{1,6}=4$, $d_{1,7}=3$, $d_{1,8}=5$, $d_{1,9}=5$, $d_{1,10}=8$, $d_{1,11}=5$, $d_{2,1}=4$, $d_{2,2}=5$, $d_{2,3}=3$, $d_{2,4}=6$, $d_{2,5}=7$, $d_{2,6}=2$, $d_{2,7}=3$, $d_{2,8}=7$, $d_{2,9}=3$, $d_{2,10}=8$, $d_{2,11}=3$, $d_{3,1}=2$, $d_{3,2}=5$, $d_{3,3}=5$, $d_{3,4}=8$, $d_{3,5}=5$, $d_{3,6}=2$, $d_{3,7}=9$, $d_{3,8}=5$, $d_{3,9}=3$, $d_{3,10}=4$, $d_{3,11}=3$, $d_{4,1}=4$, $d_{4,2}=5$, $d_{4,3}=3$, $d_{4,4}=8$, $d_{4,5}=3$, $d_{4,6}=4$, $d_{4,7}=3$, $d_{4,8}=5$, $d_{4,9}=3$, $d_{4,10}=4$, $d_{4,11}=3$.

(2) Calculating $d_j = \sum_{i=1}^{4}\sum_{l=1}^{4} d(t_{ij}, t_{lj})$ for j = 1, 2, ..., 11

$$(d_j)_{j=1,2,\cdots,11} = (12, 22, 14, 28, 18, 12, 18, 22, 14, 24, 14).$$

(3) Calculating attribute weight W
According to formula (4), we can get

$$W = (0.0606, 0.1111, 0.0707, 0.1414, 0.0909, 0.0606, 0.0909, 0.1111, 0.0707, 0.1212, 0.0707).$$

4.2. Using TOPSIS to rank the projects

(1) Determining positive and negative ideal solution

$V^{+} = \left(s_5, s_5, s_6, s_6, s_5, s_5, s_6, s_5, s_6, s_6, s_5\right),$

$V^{-} = \left(s_3, s_2, s_4, s_2, s_2, s_3, s_3, s_2, s_4, s_2, s_3\right).$

(2) Calculating weighting distance between evaluation project and positive, negative ideal solution

According to $d_i^{+} = \sum_{j=1}^{11} w_j d(v_j^{+}, t_{ij})$ and $d_i^{-} = \sum_{j=1}^{n} w_j d(v_j^{-}, t_{ij})$, we can get

$d^{+} = \{1.7172,\ 1.6465,\ 1.5152,\ 1.0101\},$

$d^{-} = \{$ûûû=ûûû=ûûû=ûûû$\}.$

(3) Determining relative closeness degree

$C = \{$ûûû=ûûû=ûûû=ûûû$\}$

So, the ranking of the 4 projects is:

$a_4 \succ a_3 \succ a_2 \succ a_1$.

4.3. Making use of gray correlation TOPSIS to rank the projects

(1) Solving the correlation coefficient and weighting correlation degree with the positive ideal solution

According to formula (10), we firstly calculate $\Delta_{ij}^{+} = d\left(v_j^{+}, t_{ij}\right)$, and the results are shown as follows:

$$\Delta^{+} = \begin{bmatrix} 1 & 3 & 1 & 1 & 1 & 2 & 3 & 0 & 0 & 4 & 2 \\ 0 & 0 & 2 & 3 & 3 & 1 & 3 & 3 & 2 & 0 & 0 \\ 1 & 2 & 0 & 4 & 0 & 1 & 0 & 2 & 2 & 2 & 0 \\ 2 & 0 & 2 & 0 & 1 & 0 & 3 & 0 & 1 & 2 & 1 \end{bmatrix}.$$

Then we can get $l = \underbrace{\min}_{i} \underbrace{\min}_{j} \Delta_{ij}^{+} = 0$, $M = \underbrace{\max}_{i} \underbrace{\max}_{j} \Delta_{ij}^{+} = 4$.

So, we can calculate ξ_{ij}^{+}, and the results are shown as follows:

$$\xi^{+} = \begin{bmatrix} 0.6667 & 0.4000 & 0.6667 & 0.6667 & 0.6667 & 0.5000 & 0.4000 & 1.0000 & 1.0000 & 0.3333 & 0.5000 \\ 1.0000 & 1.0000 & 0.5000 & 0.4000 & 0.4000 & 0.6667 & 0.4000 & 0.4000 & 0.5000 & 1.0000 & 1.0000 \\ 0.6667 & 0.5000 & 1.0000 & 0.3333 & 1.0000 & 0.6667 & 1.0000 & 0.5000 & 0.5000 & 0.5000 & 1.0000 \\ 0.5000 & 1.0000 & 0.5000 & 1.0000 & 0.6667 & 1.0000 & 0.4000 & 1.0000 & 0.6667 & 0.5000 & 0.6667 \end{bmatrix}.$$

Gray correlation degree between the *i*-th project and the positive ideal project can be calculated by formula (11), and the results are shown as follows:

$R_i^{+} = [0.6111, 0.6485, 0.6582, 0.7418]$

(2) Solving the correlation coefficient and weighting correlation degree with the negative ideal solution

According to formula (12), we firstly calculate $\Delta_{ij}^{-} = d\left(v_j^{-}, t_{ij}\right)$, and the results are shown as follows:

$$\Delta^- = \begin{bmatrix} 1\,0\,1\,3\,2\,0\,0\,3\,2\,0\,0 \\ 2\,3\,0\,1\,0\,1\,0\,0\,0\,4\,2 \\ 1\,1\,2\,0\,3\,1\,3\,1\,0\,2\,2 \\ 0\,3\,0\,4\,2\,2\,0\,3\,1\,2\,1 \end{bmatrix}.$$

Then we can get $l = \underbrace{\min}_{i}\underbrace{\min}_{j}\Delta_{ij}^- = 0$, $M = \underbrace{\max}_{i}\underbrace{\max}_{j}\Delta_{ij}^- = 4$

So, we can calculate ξ_{ij}^-, and the results are shown as follows:

$$\xi^- = \begin{bmatrix} 0.6667\ 1.0000\ 0.6667\ 0.4000\ 0.5000\ 1.0000\ 1.0000\ 0.4000\ 0.5000\ 1.0000\ 1.0000 \\ 0.5000\ 0.4000\ 1.0000\ 0.6667\ 1.0000\ 0.6667\ 1.0000\ 1.0000\ 1.0000\ 0.3333\ 0.5000 \\ 0.6667\ 0.6667\ 0.5000\ 1.0000\ 0.4000\ 0.6667\ 0.4000\ 0.6667\ 1.0000\ 0.5000\ 0.5000 \\ 1.0000\ 0.4000\ 1.0000\ 0.3333\ 0.5000\ 0.5000\ 1.0000\ 0.4000\ 0.6667\ 0.5000\ 0.6667 \end{bmatrix}.$$

Gray correlation degree between the i-th project and negative ideal project can be calculated by formula (13), and the results are shown as follows:

$R_i^- = \left[0.7239\ \ 0.7195\ \ 0.6451\ \ 0.5889\right]$.

(3) Calculating gray correlation relative closeness degree as follows:

$Y = \{$ûûû§ûûû§ûûû§ûûû $\}$.

So, the ranking of the 4 projects is:

$a_4 \succ a_3 \succ a_2 \succ a_1$.

5. Conclusions

The magnitude of venture in venture investment is the important considered factor of venture investment decision, and it directly affects the success or failure of venture invest. Investment evaluation indices are mainly qualitative indices, so this paper adopts linguistic variables to evaluate each index and construct single object optimization model based on maximum deviation principle to solve the objective weight of index; then this paper adopts TOPSIS method and gray correlation method to rank the projects. From the aspect of ranking result, the two methods are consistent. The application of the case indicates that the two methods have same ranking influence. But TOPSIS method is easier to calculate obviously.

Acknowledgment

This paper is supported by the Humanities and Social Sciences Research Project of Ministry of Education of China (No. 10YJA630073, No. 09YJA630088), the Natural Science Foundation of Shandong Province (No. ZR2009HL022), the Social Science Planning Project Fund of Shandong Province (No. 09BSHJ03), the Soft science project Fund of Shandong Province (No. 2009RKA376), and Dr. Foundation of Shandong Economic University. The authors would also like to express appreciation to the anonymous reviewers for their very helpful comments as regards improving the paper.

References

Dixon, R. 1991. Venture capitalists and the appraisal of investments, *OMEGA* 19(5): 333–344. doi:10.1016/0305-0483(91)90052-U

Fang, Y.; Zhang, D. Y. 2006. Fuzzy Evaluation Model of Venture Capital, *Mathematics in Practice and Theory* (12): 76–80.

Flynn, D. 1991. The critical relationship between venture capitalists and entrepreneurs, *Small Business Economic*s 3(3): 185–196. doi:10.1007/BF00400024

Franke, N.; Gruber, M.; Harhoff, D.; Henkel, J. 2006. What you are is what you like – similarity biases in venture capitalists' evaluations of start-up teams, *Journal of Business Venturing* 21(6): 802–826. doi:10.1016/j.jbusvent.2005.07.001

Fu, F. L.; Huang, J. B. 2002. Limitations of the Current Venture Capital Project Appraisal Methods, *Management Sciences in China* 15(1): 68–71.

Ginevicius, R.; Zubrecovas, V. 2009. Selection of the Optimal Real Estate Investment Project Basing On Multiple Criteria Evaluation Using Stochastic Dimensions, *Journal of Business Economics and Management* 10(3): 261–270. doi:10.3846/1611-1699.2009.10.261-270

Guo, M. W. 2010. Evaluation of Profit Variable Weight of Risk Investment Enterprises Financial Profit of Risk Investment Projects Based on Set Pair Theory, *Journal of Wuhan University of Technology* 32(3): 147–150.

Herrera, F.; Herrera Viedma, E.; Verdegay, J. L. 1996. A model of consensus in group decision making under linguistic assessments, *Fuzzy Sets and Systems* 78(1): 73–87. doi:10.1016/0165-0114(95)00107-7

Hu, C. W. 2009. *Research on venture investment project evaluation methods based on based on coefficient of variation*: Master thesis of Zhengzhou University, Zhengzhou.

Hui, E. C. M.; Lau, O. M. F.; Lo, K. K. 2009. A Fuzzy Decision-Making Approach For Portfolio Management With Direct Real Estate Investment, *International Journal of Strategic Property Management* 13(2): 191–204. doi:10.3846/1648-715X.2009.13.191-204

Jia, Z. Y.; Zhao, L. 2009. Research on Probability Distribution Method of Interval Number for Management Evaluation of Venture Capital, *Techno-economics & Management Research* (6): 7–11.

Jiang, H.; Ruan, J. H. 2010. Investment Risks Assessment on High-tech Projects Based on Analytic Hierarchy Process and BP Neural Network, *Journal of Networks* 5(4): 393–402. doi:10.4304/jnw.5.4.393-402

Kahraman, C.; Kaya, I. 2010. Investment Analyses Using Fuzzy Probability Concept, *Technological and Economic Development of Economy* 16(1): 43–57. doi:10.3846/tede.2010.03

Ke, X. L; Zhu, K. J.; Diao, F. Q. 2010. An Improved Fuzzy Synthetic Evaluation Model of the Risk in Real Estate Investment, *Reformation & Strategy* 26(4): 43–45.

Kollmann, T.; Kuckertz, A. 2010. Evaluation uncertainty of venture capitalists' investment criteria, *Journal of Business Research* 63(7): 741–747. doi:10.1016/j.jbusres.2009.06.004

Kuang, J. C.; Chen, X. H. 2006.The Model of Evaluating Real Estate Investment Risks Based on Upgraded Antigenic Algorithm, *Commercial Research* (21): 114–118.

Li, X. J.; Wei, G. W. 2009. Research on group decision making method of venture investment evaluation based on intuitionistic fuzzy set, *Science and Technology Management Research* (7): 448–450.

Mason, C.; Stark, M. 2004. What Do Investors Look for in a Business Plan? A Comparison of the Investment Criteria of Bankers, Venture Capitalists and Business Angels, *International Small Business Journal* 22(3): 227–248. doi:10.1177/0266242604042377

Muzyka, D.; Birley, S.; Leleux, B. 1996. Trade-offs in the investment decisions of European venture capitalists, *Journal of Business Venturing* 11: 273–287. doi:10.1016/0883-9026(95)00126-3

Robinson, R. 1987. Emerging strategies in the venture capital industry, *Journal of Business Venturing* (2):53–277. doi:10.1016/0883-9026(87)90019-X

Rutkauskas, A. V.; Miecinskiene, A.; Stasytyte, V. 2008. Investment decisions modeling along sustainable development concept on financial markets, *Technological and Economic Development of Economy* 14(3): 417–427. doi:10.3846/1392-8619.2008.14.417-427

Shepherd, D. A. 1999. Venture capitalists' introspection: a comparison of "in use" and "espoused" decision policies, *J Small Bus Manage* (37): 76–87.

Shi, X. Y. 2005. *Research of venture capital itemized appraisal indicator systemXs design and application*. Changsha: Master thesis of Central South University.

Su, Z. X. 2005. Study on Principal Component analysis applied to venture investment project Selecting, *Industrial Technology & Economy* (8): 31–36.

Tang, H. P. 2002. *Venture Investment Decision-Making*. Jinan: Shandong PeopleXs Publishing House.

Tyebjee, T. T.; Bruno, A. V. 1984. A model of venture capitalist investment activity, *Manage Sci* 30(9): 1051–1066. doi:10.1287/mnsc.30.9.1051

Wang, X. F. 2006. A mathematic model on the risk comprehensive evaluation of venture capital, *Statistics and Decision* (10): 50–52.

Wei, G. W.; Luo, Y. J.; Yao, H. S. 2006. PLWC-EOWA operator and its Application to decision making under uncertain linguistic setting, in *The Fifth Wuhan International Conference on E–Business*: *Integration and Innovation through Measurement and Management*, Wuhan, China, 27–28 May, 2369–2372.

Zhang, X. L.; Yang, D. L. 2006. The application of analytic hierarchy process in venture investment project evaluation, *Science & Technology Progress and Policy* (10): 54–59.

Zhao, Z. W. 2007. Evaluation of Venture Investment Projects Based on Fuzzy Simulation Technique, in *The third International Conference on Wireless Communications, Networking and Mobile Computing*, Shanghai, China, 21–25 September, 4157–4160.

Zutshi, R. K.; Tan, W. L.; Allampalli, D. G.; Gibbons, P. G. 1999. Singapore venture capitalists investment evaluation criteria: a re-examination, *Small Business Economics* 13(1): 9–26. doi:10.1023/A:1008011216414

ĮMONĖS INVESTICIJŲ VERTINIMO TYRIMAS KINIJOS PAVYZDŽIU

P. Liu

Santrauka

Šiame straipsnyje analizuojama, kokią įtaką turi įmonės investicijų vertinimas visam investavimo procesui. Šiam tikslui pasiekti autorius pasirinko vertinimo indeksų sistemą ir investicijų vertinimo rizikos metodus. Pirmąjį pasirinktą instrumentą, t. y. vertinimo indeksų sistemą, autorius naudoja analizuodamas ir atlikdamas Kinijoje vykdomų investicinių projektų vertinimo tyrimą. Kitus tyrimo instrumentus ir matematinius metodus, tokius kaip TOPSIS, *Grey* metodas ir pan., taiko apibendrindamas gautus rezultatus.

Reikšminiai žodžiai: TOPSIS, *Grey* metodas, santykinė reikšmė, investicijos.

Peide LIU (China, 1966) obtained his Doctor's degree in Information Management from Beijing Jiaotong University. His main research fields are technology and information management, decision support and electronic-commerce.
He was engaged in the technology development and the technical management in the Inspur Group Ltd. from 1991 to 2004. Now he is a full-time professor in Shandong Economic University and assistant director of the Enterprise's Electronic-commerce Engineering Research Center of Shandong.