The Fuzzy MCDM Algorithms for the M&A Due Diligence

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ABSTRACT

An M&A due diligence is the process in which one of the parties to the transaction undertakes to investigate the other in order to judge whether to go forward with the transaction on the terms proposed. It encompasses the missions in three phases: searching and preliminary screening potential candidates, evaluating the candidates and deciding the target, and assisting the after-transaction integration. This work suggests using a Fuzzy Multiple Criteria Decision Making approach (Fuzzy MCDM) and develops detailed algorithms to carry out the second-phase task. The approach of MCDM is able to facilitate the analysis and integration of information from different aspects and criteria. The theory of Fuzzy Sets can include qualitative information in addition to quantitative information. In the developed algorithms the evaluators' subjective judgments are expressed in linguistic terms which can better reflect human intuitive thought than the quantitative scores. These linguistic judgments are transformed into fuzzy numbers and made subsequent synthesis with quantitative financial figures. The order of candidates can be ranked after a defuzzification. Then the acquiring firm can work out a more specific study, including pricing and costing, on the priority candidates so as to decide the target.

Keywords: M&A due diligence, Fuzzy Sets, MCDM

1. INTRODUCTION

It has been a common consensus that the activities of mergers and acquisitions (M&As) can provide boundless chances from the external environment and therefore play the role of achieving rapid growth and maintaining competitive advantages of a business. They indeed have been prospering like a raging fire at the cycle since the late 1990s worldwide [19]. However, there seems to be a gap between the consensus and results. A comprehensive study of combined returns in a large sample of 3,688 mergers from 1973 to 1998 found that the combined return in excess of market required returns to targets and bidders was a positive 2%. Another empirical study reported that the shareholders lost money in 61% of 302 major mergers (over $500 million) that occurred between July 1995 and August 2001 in the U.S. Even a year after these losing deals closed, the returns of these newly merged companies were lower than those of their S&P peers by 25 percentage-points. The reasons of failures include overpaying, overestimating synergies, trouble integrating operations of the merged companies, overemphasizing cost cutting, etc. [23] Many acquiring firms found that the cost of acquisitions was not just the price paid at the purchase, but rather all that paid to remedy the uncovered problems after the purchase [10]. In anther word, the acquisition investments just like an iceberg, the acquiring firm often perceive only part but not all of it [9].

In order to reduce the mistakes and risks, it is necessary to perform a more rigorous and broad due diligence before exercising a transaction [15]. An M&A due diligence can be defined as the process that one of the parties to an M&A transaction undertakes to investigate the other to judge whether to forward with the transaction on the terms proposed [14]. Due diligence is most often performed in according with an exhaustive checklist [16]. But can the very cumbersome item-by-item check precisely reflect evaluators' judgments? How do these judgments be synthesized reasonably to a conclusion? This work suggests using a multi-disciplined method – the Fuzzy Multiple Criteria Decision Making approach (Fuzzy MCDM) – to strengthen the traditional checklist methods.

Among the evaluators' judgments, some are in quantitative forms and some are in qualitative forms (e.g., the intuitive thought). The judgments for different items may conflict each other. By applying Fuzzy Sets, the qualitative information can be measured and transformed to computable elements, therefore paralleling the difficulty on measuring qualitative information by ordinary sets [20,21]. And by applying MCDM approach, the conflicting judgments can be effectively integrated. The combination of Fuzzy Sets and MCDM is therefore an appropriate use to the M&A due diligence process.

The rest of this work is organized as follows. Section 2 summaries the concepts of MCDM and Fuzzy Sets. Section 3 describes the broad due diligence process. Section 4 develops the Fuzzy MCDM algorithms for the evaluating the candidates. A numerical example is presented in Section 5 and conclusions are made in Section 6.

2. MCDM AND FUZZY SETS

The MCDM approach is to aggregate the information for decision-making problems. It was introduced in the early 1970s and has been continuing to grow vitally since then. Hwang and Yoon [12] described that MCDM problems include Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM). MADM is applied in evaluation facet, and MODM is fitted in design/planning facet.

Zadeh in 1965 proposed the notion of Fuzzy Sets [20]. He argued that the classes of objects encountered in the real physical world may not have precisely defined criteria of membership. The Fuzzy Set is a "class" with a continuum of grades of membership, that can provide a convenient point of departure for the construction of a conceptual framework which parallels in many respects the framework used in the case of ordinary sets. Subsequently, Fuzzy Set Theory was extended into the field of decision-making [5,22], and as applied to finance began in 1980s [4,6].

The coherence of Fuzzy Sets and MCDM evolves to a new family of method – Fuzzy MCDM, which is a process of aggregating the performance scores with respect to each alternative/strategy and then ranking all alternatives/strategies by their synthetic value with incomplete information and/or in vague environment [7,8].

In this study the development of the Fuzzy MCDM algorithms begins with the following definition of fuzzy numbers. An any-shape fuzzy number $\tilde{A}=[a,b,c,d]$ (in square bracket), $-\infty<a\le b\le c\le d<\infty$, $a,b,c,d\in R$, is described as any fuzzy subset of the real line R with the membership function $f_{\tilde{A}}(x)$. The membership function $f_{\tilde{A}}(x)$ is a continuous mapping from R to the closed interval [0,1]; $f_{\tilde{A}}(x)$ is strictly increasing on $x \in [a,b]$; $f_{\tilde{A}}(x)=1$ for $x \in [b,c]$; $f_{\tilde{A}}(x)$ is strictly decreasing on $x \in [c,d]$; $f_{\tilde{A}}(x)=0$ for all $x \in (-\infty,a]$ and $x \in [d,\infty)$ [7]. A fuzzy number $\tilde{B}=(e,f,g,h)$ (in round bracket) is defined as a trapezoidal one if $f_{\tilde{B}}(x)$ is given by [13]:

$$f_{\tilde{B}}(x)=\begin{cases} f_{\tilde{B}}^{L}(x)=(x-e)/(f-e), & e \le x \le f, \\ 1 & f \le x \le g \\ f_{\tilde{B}}^{R}(x)=(x-h)/(g-h), & g \le x \le h, \\ 0, & otherwise, \end{cases} \tag{1}$$

where $f_{\tilde{B}}^{L}(x)$ and $f_{\tilde{B}}^{R}(x)$ respectively denote the left and right membership functions.

The α-cut of a fuzzy number $\tilde{A}$ is denoted by ${}^{\alpha}\tilde{A}=[{}^{\alpha}\underline{A},{}^{\alpha}\overline{A}]$, where ${}^{\alpha}\underline{A}$ and ${}^{\alpha}\overline{A}$ are respectively the lower and upper bounds of the closed interval for the level of α, $\alpha \in [0,1]$. The α-cut of a trapezoidal fuzzy number $\tilde{B}=(e,f,g,h)$ is expressed as [13]:

$${}^{\alpha}\tilde{B}=[{}^{\alpha}\underline{B},{}^{\alpha}\overline{B}]=\left[(f-e)\alpha+e,(g-h)\alpha+h\right], \tag{2}$$

Equations (3)~(5) are the standard fuzzy-arithmetic operational rules applied in this work [13]:

$${}^{\alpha}(\tilde{A}+\tilde{B})={}^{\alpha}\tilde{A}+{}^{\alpha}\tilde{B}=\left[{}^{\alpha}\underline{A}+{}^{\alpha}\underline{B},\ {}^{\alpha}\overline{A}+{}^{\alpha}\overline{B}\right], \tag{3}$$

$${}^{\alpha}(\tilde{A}-\tilde{B})={}^{\alpha}\tilde{A}-{}^{\alpha}\tilde{B}=\left[{}^{\alpha}\underline{A}-{}^{\alpha}\overline{B},\ {}^{\alpha}\overline{A}-{}^{\alpha}\underline{B}\right], \tag{4}$$

$$\begin{aligned} {}^{\alpha}(\tilde{A}\times\tilde{B})=\big[&\min({}^{\alpha}\underline{A}\cdot{}^{\alpha}\underline{B},\ {}^{\alpha}\underline{A}\cdot{}^{\alpha}\overline{B},{}^{\alpha}\overline{A}\cdot{}^{\alpha}\underline{B},{}^{\alpha}\overline{A}\cdot{}^{\alpha}\overline{B}), \\ &\max({}^{\alpha}\underline{A}\cdot{}^{\alpha}\underline{B},\ {}^{\alpha}\underline{A}\cdot{}^{\alpha}\overline{B},{}^{\alpha}\overline{A}\cdot{}^{\alpha}\underline{B},{}^{\alpha}\overline{A}\cdot{}^{\alpha}\overline{B})\big]. \end{aligned} \tag{5}$$

3. THE DUE DILIGENCE PROCESS

A broad M&A due diligence process encompasses three phases: searching and preliminary screening the potential candidates, evaluating the candidates and deciding the ranking order, and assisting in the after-transaction integration [10]. The following subsections outline the main points at each phase. The Fuzzy MCDM algorithms as applied at the second phase are developed independently in Section 4.

3.1. Phase I – Searching for the potential candidates

Identifying the motivation and purposes and setting up the transaction strategy

It is the first thing that an enterprise has to do before contributing to the M&A activities to identify its expectation from the transaction. That is, to figure out explicitly the motivation and purpose of doing the transaction. In another word, it is to confirm the transaction strategic theorem which is consistent with the firm strategic goals. The transaction strategy can be clarified by the strategic value generated from the transaction, such as protective value (by defending existing business), enhancing value (by building the existing competitive position), synergistic value (by capturing joint value-chain benefits), future opportunity value (through generating a platform, or stream of future opportunities), and sweat value (tightening operational and financial controls) [9,12]. And the acquirer projects itself as the role in the industry through and after the transaction.

Drawing up the qualifications: It would be the best to list the qualifications for the target item-by-item in the plan. They are used as the key to search for potential candidates. The items generally include: the category of the industry, specific techniques, products/services, geographic location, market, minimal and/or maximal size, etc.

Searching for the potential candidates: The candidates satisfy the qualifications may exist somewhere beyond the acquirer's intuitive vision. It therefore is better to systematically access the potential candidates in stead of relying on insiders' clues [11]. It'll be efficient to take up the potential candidates from some business databases, using the key of items found in the previous subsection.

Preliminary screening: In order to delete the unfitted candidates, the potential ones are be filtered by some negative factors, such as: the critical weakness, critical litigation, huge liabilities, labor problems, legal obstacles (Antitrust or government regulations), and/or political instability on doing the transaction [17]? After the screening, the retained candidates are further evaluated in next phase.

Phase II – Evaluating and ranking the candidates (See Section 4)

3.2. Phase III – Assisting the after-transaction integration

This phase is to integrate the two operating entities after finalizing the purchase. The key concern is the multi-business coordination to increase the sales, improve the operations, take the expected new markets, and increase the stockholders' wealth. Since the committee members who executed the previous two phases have the most detailed information of the whole transaction, they should continue to offer the necessary assistance to the integration [11].

4. THE FUZZY MCDM ALGORITHMS

In this section a set of Fuzzy MCDM algorithms are suggested to evaluate the candidates.

4.1. Setting up the analytical hierarchy

The analytical hierarchy can be one-level, two-level, or multi-level, by the preference or demands of the committee. This work adopts the two-level structure. The first level is composed of several aspects, such as marketing, production, finance, information, R&D, human resources, legality, environment, intangible assets, etc. [10] The second level consists of the subordinate evaluation criteria. The committee members have to review and make their judgments on the importance of each aspect and criterion, and on the ratings for each candidate versus each criterion. The judgments are in either linguistic terms or quantitative values (to be detailed later). Here, all criteria are categorized into the benefit-nature, cost-nature, and medium-nature ones. For benefit-nature criteria, a greater value is better (e.g. earnings per share). For cost-nature criteria, a smaller value is better (e.g. bankruptcy probability and the debt ratio). For the medium nature, the median is the best case whereas a value farther away from the median is a worse case (e.g. the ratio of current asset to current liability).

4.2. Determining the linguistic sets and the corresponding fuzzy numbers for importance weights and ratings

Let x'_{ijkl} denote the original rating assessed for candidate *i* versus criterion *k* under aspect *j* by evaluator *l*; x'_{ijkl} is either a linguistic term or a quantitative value. Let W_{jl} and w_{jkl} respectively represent the importance weights assigned by evaluator *l* to aspect *j* and to criterion *k* under aspect *j*; W_{jl} and w_{jkl} are assessed in linguistic terms [17]. Suppose that the committee agrees with using the linguistic weighting set $\Omega = \{\varpi_1,...,\varpi_b\}$ and the linguistic rating set $\Re = \{\gamma_1,...,\gamma_a\}$ to measure the qualitative ratings and the importance weights, where $\gamma_1,...,\gamma_a$ and $\varpi_1,...,\varpi_b$ are the linguistic terms; $a,b \in N$. Let trapezoidal fuzzy number $\tilde{w}_{jkl} = (a_{jkl}, b_{jkl}, c_{jkl}, d_{jkl})$ denote the importance weight given to criterion *k* under aspect *j* by evaluator *l*, where $0 \le a_{jkl} \le b_{jkl} \le c_{jkl} \le d_{jkl} \le 1$; let trapezoidal fuzzy number $\tilde{W}_{jl} = (w_{jl}, x_{jl}, y_{jl}, z_{jl})$ be the weight assigned to aspect *j* by evaluator *l*, where $0 \le w_{jl} \le x_{jl} \le y_{jl} \le z_{jl} \le 1$; let trapezoidal fuzzy number $\tilde{x}_{ijkl} = (o_{ijkl}, p_{ijkl}, q_{ijkl}, r_{ijkl})$ denote the fuzzy ratings representing the linguistic terms given to candidate *i* versus criterion *k* under aspect *j* by evaluator *l*, where $0 \le o_{ijkl} \le p_{ijkl} \le q_{ijkl} \le r_{ijkl} \le 1$.

The committee can discretionarily set up the linguistic terms and corresponding fuzzy numbers to fit for the needs. This study assumes $\Omega = \{\varpi_1, \varpi_2, \varpi_3, \varpi_4\}$ and $\Re = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4\}$, where ϖ_1 =*Unimportant*=(0,0,0.1,0.3), ϖ_2 =*fair*=(0.1,0.3,0.4,0.6), ϖ_3 =*Important*=(0.4,0.6,0.7,0.9), ϖ_4 =*Extremely Important* =(0.7,0.9,1,1), λ_1 =*poor*=(0,0,0.1,0.3), λ_2 =*fair*=(0.1,0.3,0.4,0.6), λ_3 =*Good*=(0.4,0.6,0.7,0.9), λ_4 =*Excellent*=(0.7,0.9,1,1). The scales of $\Re$ and Ω are assigned to be the same here for simplicity and consistency.

4.3. Transforming the quantitative ratings

The quantitative figures may be in different nature and/or units, e.g. as monetary value or percentage. These figures need to be transformed to assure compatibility with each other. This work proposes the percentile method, which is to cut the observations by the tenth, fiftieth, and ninetieth percentiles and group the ratings versus each criterion into four sets of fuzzy numbers:

$$\tilde{x}_{ijkl} = \begin{cases} \gamma_1, & x_{ijkl} \le \delta_{jk10}, \\ \gamma_2, & \delta_{jk10} < x_{ijkl} \le \delta_{jk50}, \\ \gamma_3, & \delta_{jk50} < x_{ijkl} \le \delta_{jk90}, \\ \gamma_4, & x_{ijkl} > \delta_{jk90}, \end{cases} \quad x_{ijkl} \in B, \tag{6}$$

$$\tilde{x}_{ijkl} = \begin{cases} \gamma_4, & x_{ijkl} \le \delta_{jk10}, \\ \gamma_3, & \delta_{jk10} < x_{ijkl} \le \delta_{jk50}, \\ \gamma_2, & \delta_{jk50} < x_{ijkl} \le \delta_{jk90}, \\ \gamma_1, & x_{ijkl} > \delta_{jk90}, \end{cases} \quad x_{ijkl} \in C, \tag{7}$$

$$\tilde{x}_{ijkl} = \begin{cases} \gamma_1, & x_{ijkl} \le \delta_{jk5}, x_{ijkl} > \delta_{jk95}, \\ \gamma_2, & \delta_{jk5} < x_{ijkl} \le \delta_{jk10}, \delta_{jk90} < x_{ijkl} \le \delta_{jk95}, \\ \gamma_3, & \delta_{jk10} < x_{ijkl} \le \delta_{jk25}, \delta_{jk75} < x_{ijkl} \le \delta_{jk90}, \\ \gamma_4, & \delta_{jk25} < x_{ijkl} \le \delta_{jk50}, \delta_{jk50} < x_{ijkl} \le \delta_{jk75}, \end{cases} \quad x_{ijkl} \in M, \tag{8}$$

where x_{ijkl} and $\tilde{x}_{ijkl}$ respectively denote the original quantitative rating in crisp numbers and the transformed rating in fuzzy numbers. Terms δ_{jk5}, δ_{jk10}, δ_{jk25}, δ_{jk50}, δ_{jk75}, δ_{jk90} and δ_{jk95} are the fifth, tenth, twenty-fifth, fiftieth, seventy-fifth, ninetieth, and ninety-fifth percentiles, respectively. Symbols *B*, *C*, and *M* respectively denote the benefit, cost, and medium natures. The scales $\gamma_1, \cdots, \gamma_4$ are set the same as the qualitative ratings for consistency. The transformation method is based on the assumption of approximate normal distribution. In a normal distribution 99.7% observations are in the range of $\mu \pm 3\sigma$. Cutting the range into four equal distances, $(\mu - 3\sigma, \mu - 1.5\sigma]$, $(\mu - 1.5\sigma, \mu]$, $(\mu, \mu + 1.5\sigma]$, and $(\mu + 1.5\sigma, \mu + 3\sigma)$ respectively account for 6.7%, 43.3%, 43.3%, and 6.7% probabilities. These four numbers are rounded into 10%, 40%, 40%, and 10%. They are the corresponding probabilities cut by the first, fifth, and ninth percentiles.

4.4. The synthesis using standard fuzzy arithmetic

The synthesis of evaluation is performed by the standard fuzzy arithmetic [13]. Applying Eq. (2):

$${}^{\alpha}\tilde{x}_{ijkl} = \left[(p_{ijkl} - o_{ijkl})\alpha + o_{ijkl}, (q_{ijkl} - r_{ijkl})\alpha + r_{ijkl} \right], \tag{9}$$

$${}^{\alpha}\tilde{w}_{jkl} = \left[(b_{jkl} - a_{jkl})\alpha + a_{jkl}, (c_{jkl} - d_{jkl})\alpha + d_{jkl} \right], \tag{10}$$

$${}^{\alpha}\tilde{W}_{jl} = \left[(x_{jl} - w_{jl})\alpha + w_{jl}, (y_{jl} - z_{jl})\alpha + z_{jl} \right]. \tag{11}$$

The synthesis is performed as follows:

$$\begin{aligned}
{}^{\alpha}\tilde{S}_i &= \left(\sum_{l=1}^{\delta} {}^{\alpha}\tilde{S}_{il} \right) / \delta = \left(\sum_{l=1}^{\delta} \sum_{j=1}^{m} ({}^{\alpha}\tilde{W}_{jl} \times {}^{\alpha}\tilde{S}_{ijl}) \right) / \delta \\
&= \left(\sum_{l=1}^{\delta} \sum_{j=1}^{m} \left({}^{\alpha}\tilde{W}_{jl} \times \sum_{k=1}^{n_j} ({}^{\alpha}\tilde{w}_{jkl} \times {}^{\alpha}\tilde{x}_{ijkl})\right) \right) / \delta \\
&= \Bigg[\Bigg(\Bigg(\sum_{l=1}^{\delta} \sum_{j=1}^{m} \Bigg((x_{jl} - w_{jl}) \cdot \sum_{k=1}^{n_j} [(b_{jkl} - a_{jkl})(p_{ijkl} - o_{ijkl})] \Bigg) \Bigg) / \delta \Bigg) \alpha^3 \\
&\quad + \Bigg(\Bigg(\sum_{l=1}^{\delta} \sum_{j=1}^{m} \Bigg(w_{jl} \cdot \sum_{k=1}^{n_j} [(b_{jkl} - a_{jkl})(p_{ijkl} - o_{ijkl})] \\
&\quad + (x_{jl} - w_{jl}) \cdot \sum_{k=1}^{n_j} [a_{jkl}(p_{ijkl} - o_{ijkl}) + o_{ijkl}(b_{jkl} - a_{jkl})] \Bigg) \Bigg) / \delta \Bigg) \alpha^2 \\
&\quad + \Bigg(\Bigg(\sum_{l=1}^{\delta} \sum_{j=1}^{m} \Bigg(w_{jl} \cdot \sum_{k=1}^{n_j} [a_{jkl}(p_{ijkl} - o_{ijkl}) + o_{ijkl}(b_{jkl} - a_{jkl})] \\
&\quad + (x_{jl} - w_{jl}) \cdot \sum_{k=1}^{n_j} a_{jkl} o_{ijkl} \Bigg) \Bigg) / \delta \Bigg) \alpha \\
&\quad + \left(\sum_{l=1}^{\delta} \sum_{j=1}^{m} \left(w_{jl} \cdot \sum_{k=1}^{n_j} a_{jkl} o_{ijkl}\right) \right) / \delta, \\
&\quad \Bigg(\Bigg(\sum_{l=1}^{\delta} \sum_{j=1}^{m} \Bigg((y_{jl} - z_{jl}) \cdot \sum_{k=1}^{n_j} (c_{jkl} - d_{jkl})(q_{ijkl} - r_{ijkl}) \Bigg) \Bigg) / \delta \Bigg) \alpha^3 \\
&\quad + \Bigg(\Bigg(\sum_{l=1}^{\delta} \sum_{l=1}^{m} \Bigg(z_{jl} \cdot \sum_{k=1}^{n_j} (c_{jkl} - d_{jkl})(q_{ijkl} - r_{ijkl}) \\
&\quad + (y_{jl} - z_{jl}) \cdot \sum_{k=1}^{n_j} [d_{jkl}(q_{ijkl} - r_{ijkl}) + r_{ijkl}(c_{jkl} - d_{jkl})] \Bigg) \Bigg) / \delta \Bigg) \alpha^2 \\
&\quad + \Bigg(\Bigg(\sum_{l=1}^{\delta} \sum_{j=1}^{m} \Bigg(z_{jl} \cdot \sum_{k=1}^{n_j} [d_{jkl}(q_{ijkl} - r_{ijkl}) + r_{ijkl}(c_{jkl} - d_{jkl})] \\
&\quad + (y_{jl} - z_{jl}) \cdot \sum_{k=1}^{n_j} d_{jkl} r_{ijkl} \Bigg) \Bigg) / \delta \Bigg) \alpha
\end{aligned}$$

$$+\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left(z_{jl}\cdot\sum_{k=1}^{n_j} d_{jkl}r_{ijkl}\right)\right)/\delta\Bigg], \tag{12}$$

where $\tilde{S}_i$ denotes the final fuzzy synthesis value for candidate i, $\tilde{S}_{il}$ denotes the fuzzy synthesis value for candidate i by evaluator l, $\tilde{S}_{ijl}$ denotes the fuzzy synthesis value for candidate i versus aspect j by evaluator l, and δ is the number of evaluators. Let

$$E_{Li}=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left((x_{jl}-w_{jl})\cdot\sum_{k=1}^{n_j}[(b_{jkl}-a_{jkl})(p_{ijkl}-o_{ijkl})]\right)\right)/\delta,$$

$$F_{Li}=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left(w_{jl}\cdot\sum_{k=1}^{n_j}[(b_{jkl}-a_{jkl})(p_{ijkl}-o_{ijkl})]\right.\right.$$
$$\left.\left.+(x_{jl}-w_{jl})\cdot\sum_{k=1}^{n_j}[a_{jkl}(p_{ijkl}-o_{ijkl})+o_{ijkl}(b_{jkl}-a_{jkl})]\right)\right)/\delta,$$

$$H_{Li}=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left(w_{jl}\cdot\sum_{k=1}^{n_j}[a_{jkl}(p_{ijkl}-o_{ijkl})+o_{ijkl}(b_{jkl}-a_{jkl})]\right.\right.$$
$$\left.\left.+(x_{jl}-w_{jl})\cdot\sum_{k=1}^{n_j}a_{jkl}o_{ijkl}\right)\right)/\delta,$$

$$Q_i=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}(w_{jl}\cdot\sum_{k=1}^{n_j}a_{jkl}o_{ijkl})\right)/\delta,$$

$$E_{Ri}=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left((y_{jl}-z_{jl})\cdot\sum_{k=1}^{n_j}(c_{jkl}-d_{jkl})(q_{ijkl}-r_{ijkl})\right)\right)/\delta,$$

$$F_{Ri}=\left(\sum_{l=1}^{\delta}\sum_{l=1}^{m}\left(z_{jl}\cdot\sum_{k=1}^{n_j}(c_{jkl}-d_{jkl})(q_{ijkl}-r_{ijkl})\right.\right.$$
$$\left.\left.+(y_{jl}-z_{jl})\cdot\sum_{k=1}^{n_j}[d_{jkl}(q_{ijkl}-r_{ijkl})+r_{ijkl}(c_{jkl}-d_{jkl})]\right)\right)/\delta,$$

$$H_{Ri}=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left(z_{jl}\cdot\sum_{k=1}^{n_j}[d_{jkl}(q_{ijkl}-r_{ijkl})+r_{ijkl}(c_{jkl}-d_{jkl})]\right.\right.$$
$$\left.\left.+(y_{jl}-z_{jl})\cdot\sum_{k=1}^{n_j}d_{jkl}r_{ijkl}\right)\right)/\delta,$$

$$Z_i=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left(z_{jl}\cdot\sum_{k=1}^{n_j}d_{jkl}r_{ijkl}\right)\right)/\delta.$$

The complicated Eq. (12) can be abbreviated to Eq. (13) :

$$^{\alpha}\tilde{S}_i=\left[E_{Li}\alpha^3+F_{Li}\alpha^2+H_{Li}\alpha+Q_i,E_{Ri}\alpha^3+F_{Ri}\alpha^2+H_{Ri}\alpha+Z_i\right]. \tag{13}$$

The left and right membership functions of $\tilde{S}_i$ are then obtained respectively:

$$f^{L}_{\tilde{S}_i}(x)=(A_{Li}+B_{Li})^{1/3}+(A_{Li}-B_{Li})^{1/3}-F_{Li}/3E_{Li},\quad E_{Li}\neq 0,\quad Q_i\le x\le R_i, \tag{14}$$

$$f^{R}_{\tilde{S}_i}(x)=(A_{Ri}+B_{Ri})^{1/3}+(A_{Ri}-B_{Ri})^{1/3}-F_{Ri}/3E_{Ri},\quad E_{Ri}\neq 0,\quad Y_i\le x\le Z_i, \tag{15}$$

where $R_i=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left(x_{jl}\cdot\sum_{k=1}^{n_j}b_{jkl}p_{ijkl}\right)\right)/\delta$,

$$A_{Li}=-\frac{1}{2}\left[\frac{Q_i-x}{E_{Li}}-\frac{1}{3}\left(\frac{F_{Li}}{E_{Li}}\cdot\frac{H_{Li}}{E_{Li}}\right)+\frac{2}{27}\left(\frac{F_{Li}}{E_{Li}}\right)^3\right],$$

$$B_{Li}=\left[\frac{1}{4}\left(\frac{Q_i-x}{E_{Li}}-\frac{1}{3}\left(\frac{F_{Li}}{E_{Li}}\cdot\frac{H_{Li}}{E_{Li}}\right)+\frac{2}{27}\left(\frac{F_{Li}}{E_{Li}}\right)^3\right)^2+\frac{1}{27}\left(\frac{H_{Li}}{E_{Li}}-\frac{1}{3}\left(\frac{F_{Li}}{E_{Li}}\right)^2\right)^3\right]^{1/2},$$

$$Y_i=\left(\sum_{l=1}^{\delta}\sum_{j=1}^{m}\left(y_{jl}\cdot\sum_{k=1}^{n_j}c_{jkl}q_{ijkl}\right)\right)/\delta,$$

$$A_{Ri}=-\frac{1}{2}\left[\frac{Z_i-x}{E_{Ri}}-\frac{1}{3}\left(\frac{F_{Ri}}{E_{Ri}}\cdot\frac{H_{Ri}}{E_{Ri}}\right)+\frac{2}{27}\left(\frac{F_{Ri}}{E_{Ri}}\right)^3\right],$$

$$B_{Ri}=\left[\frac{1}{4}\left(\frac{Z_i-x}{E_{Ri}}-\frac{1}{3}\left(\frac{F_{Ri}}{E_{Ri}}\cdot\frac{H_{Ri}}{E_{Ri}}\right)+\frac{2}{27}\left(\frac{F_{Ri}}{E_{Ri}}\right)^3\right)^2+\frac{1}{27}\left(\frac{H_{Ri}}{E_{Ri}}-\frac{1}{3}\left(\frac{F_{Ri}}{E_{Ri}}\right)^2\right)^3\right]^{1/2}.$$

4.5. Ranking the order of the candidates

The fuzzy synthesis values are defuzzified to rank their order. The method of the average of the relative regions [18], which can consistently rank the fuzzy numbers in the positive and negative intervals, is applied to this work. Let $D(\tilde{S}_i)$ denote the defuzzified value of $\tilde{S}_i$,

$$D(\tilde{S}_i)=\left[D_L(\tilde{S}_i)+D_R(\tilde{S}_i)\right]/2$$
$$=\left[\left(R_i-\min Q_i-\int_{Q_i}^{R_i}f^{L}_{\tilde{S}_i}(x)\right)+\left(Y_i-\min Q_i+\int_{Y_i}^{Z_i}f^{R}_{\tilde{S}_i}(x)\right)\right]/2, \tag{16}$$

where $D_L(\tilde{S}_i)$ and $D_R(\tilde{S}_i)$ respectively denote the left relative region and right relative region; $D_L(\tilde{S}_i)$ is the stretch from the left membership function of $\tilde{S}_i$ to the axis at minimum value of Q_i; $D_R(\tilde{S}_i)$ is the stretch from the right membership function of to the axis at minimum value of Q_i. The candidate with a larger $D(\tilde{S}_i)$ implies a better constitution.

The acquiring firm can now find the priority candidates and then recheck some qualifications in detail to decide the target. The qualifications include: best strategic fit to acquiring firm, target willingness, reasonable premium (not overpriced based on the estimated intrinsic value), no potential showstoppers, no multiple bids, and no ownership that will obstacle the deal [17].

5. AN EXAMPLE

The following example is to demonstrate the use of the developed algorithms. Suppose a western-world food company, named W. Co., intends to build the facilities in China to manufacture and distribute its brand products. W. Co. produces beverages, dairy, convenient meals, snacks, cereals, and grocery. It has plants in North America and European Union, but has no experience in the China market, where the politics and culture are totally different from the western world.

After a careful study, W. Co. reaches the conclusion of acquiring a Taiwan food company as the entrance to 1.3-billion-people mega market, based on the following reasons: 1. Many leading food companies in China are held by Over-the-Taiwanese. Most food companies listed on Taiwan Stock Exchange (TSE) and Over The Counter (OTC) have been developing technique in Taiwan and expanding their businesses to China for many years. 2. Taiwan and China are so close in the geographic position and in extraction. The ancestors of Taiwanese (except the minority) came from China. Taiwanese and Chinese speak the same official language and have similar culture. Taiwanese enterprises in China have the least culture problem, compared with those from other countries. 3. Taiwan is a democratic country and has the very friendly business environment to foreign investments. 4. Taiwan's food companies provide the eastern-flavor, or more specifically, the Chinese-flavor product portfolio, which is complimentary to western-style product portfolio of W. Co.. 5. The share prices of Taiwan's food companies are stable from the last few years to date. There are no severe anti-trust statutes to handicap the foreign acquisition transactions.

W. Co. searches for the food companies that listed on TSE and OTC; there are twenty companies for the former and two for the latter. After a preliminary screening, W. Co. eliminates six companies which have no business in China or no related products. The left sixteen candidates are put into the second-phase evaluation. All the data are retrieved from the TSE Market Observation Post System.

Assume that there are three evaluators in the committee. They agree to use the Fuzzy MCDM approach developed in Section 4 to do the evaluation. Table 1 lists the analytical structure. Despite the subjective linguistic assessments on the qualitative ratings and importance weights of aspects and criteria, the evaluators have different measures on the objective quantitative ratings. The first evaluator uses the mean value for the years 2003-2005, the second evaluator prefers the figure for 2005, and the third evaluator adopts the weighted average of 2003-2005 (20%,30%,40%). The original trivial data are skipped here. Table 2 lists the transformed ratings, Table 3 lists the importance weight assessments, and Table 4 shows the final results. W. Co. can then focus on the priority candidates and do the subsequent investigation and negotiation.

Table 1. The Analytical Structure

Aspect	Criteria	Nature*
A_1 Marketing	a_{11} Market share (total sales 2005)	Qn, O, B
	a_{12} Sales growth (sales growth 2003-2005)	Qn, O, B
	a_{13} Brand awareness	Ql, S, B
A_2 Manufacturing and Operation	a_{21} Products portfolio, overlapping or complimentary	Ql, S, B
	a_{22} Operating ability in China (total investments in China)	Qn, O, B
	a_{23} Operating ability worldwide (total investment overseas)	Qn, O, B
A_3 Financial indicators	a_{31} Earnings per share (2003-2005)	Qn, O, B
	a_{32} debt to asset (2003-2005)	Qn, O, C
	a_{33} current asset to current liability (2003-2005)	Qn, O, B
	a_{34} operating income to net income before taxes (2003-2005)	Qn, O, B

*Qn: quantitative, Ql: qualitative, S: subjective, O: objective, B: benefit, C: cost.

Table 2. The Transformed Ratings

	a_{11}			a_{12}			a_{13}			a_{21}			a_{22}			a_{23}			a_{31}			a_{32}			a_{33}			a_{34}		
1201	H	H	H	F	F	F	EH	EH	EH	EH	EH	EH	H	H	H	F	F	F	L	H	L	L	L	L	L	L	L	H	H	H
1210	EH	EH	EH	F	F	F	EH	EH	H	H	H	H	H	H	H	EH	EH	EH	H	H	H	F	F	F	F	F	F	F	F	F
1213	L	L	L	H	H	H	H	H	F	L	L	L	L	L	L	L	L	L	F	F	F	EH	H	EH	EH	EH	EH	H	H	H
1216	EH	EH	EH	F	F	F	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH	H	H	H	H	F	F	H	F	H	F	F	F
1217	F	F	F	F	F	H	H	H	H	H	H	H	F	F	F	H	H	H	F	F	F	F	L	L	L	L	L	EH	H	EH
1218	H	H	H	F	F	F	H	H	H	H	H	H	F	F	F	L	L	L	F	L	F	L	F	F	F	F	F	L	L	L
1219	H	H	H	H	H	H	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	H	H	H	EH	EH	EH	F	H	F
1220	F	F	F	H	H	H	F	F	F	F	F	F	F	F	F	F	F	F	L	L	L	H	H	H	H	H	H	F	L	F
1225	H	H	H	H	H	H	F	F	F	F	F	F	H	H	H	H	H	H	F	F	F	F	F	F	F	F	F	H	EH	H
1227	F	F	F	L	L	L	H	EH	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	F	H
1229	F	F	F	H	EH	EH	F	H	F	F	F	F	EH	EH	EH	H	H	H	H	H	H	EH	EH	H	F	F	F	L	F	L
1231	F	F	F	F	F	F	F	H	F	F	F	F	F	F	F	F	F	F	H	F	H	H	H	F	H	H	H	EH	EH	EH
1232	H	H	H	H	H	F	F	F	F	L	L	L	L	L	L	L	L	L	EH	EH	EH	H	H	H	F	H	F	F	F	F
1234	F	F	F	L	L	L	H	H	H	L	L	L	H	H	H	H	H	H	F	F	F	EH	EH	EH	H	H	H	H	H	H
1236	L	L	L	EH	EH	EH	F	F	F	F	F	F	F	F	F	F	F	F	EH	EH	EH	H	F	F	F	F	F	F	F	F

Table 3. The Importance Weight Assessments

	W_1	w_{11}	w_{12}	w_{13}	W_2	w_{21}	w_{22}	w_{23}	W_3	w_{31}	w_{32}	w_{33}	w_{34}
Evaluator 1	EI	EI	EI	I	EI	EI	EI	F	I	EI	I	I	I
Evaluator 2	EI	EI	I	EI	EI	EI	EI	F	I	EI	EI	F	F
Evaluator 3	EI	EI	EI	EI	E	I	EI	F	I	EI	EI	F	F

6. CONCLUSIONS

This work develops a set of Fuzzy MCDM algorithms for the evaluation of acquiree candidates in an M&A transaction. The developed algorithms are anticipated to comprehend systematically the evaluators' perception with vague information, the assessment with various rating attitudes, and the trade-off among various criteria.

However, the proposed approach is one of the phases in an M&A due diligence procedure. The other phases definitely have important influence on the results. Besides, the outcomes may vary by picking different aspects and criteria, setting different linguistic terms or fuzzy numbers, or applying different ranking methods. Since Fuzzy MCDM allows the decision to be made with incomplete information and/or in vague environment, the best solution can been guaranteed only under the circumstance of good-quality forecast information.

Table 4. The Final Results

	E1	F1	H1	Q	E2	F2	H2	Z	R	Y	Left Q to R	right Y to Z	R-MinQ -(QtoR)	Y-MinQ +(YtoZ)	S(Gi)
1201	0.344	2.964	8.466	7.936	-0.072	1.020	-9.658	37.567	19.710	28.857	6.461	4.205	10.405	30.218	20.311
1210	0.408	3.240	8.910	8.286	-0.072	1.136	-10.142	39.396	20.844	30.318	6.914	4.369	11.086	31.843	21.465
1213	0.240	1.776	4.242	3.219	-0.032	1.048	-13.148	28.560	9.477	16.428	3.481	5.901	3.152	19.485	11.318
1216	0.408	3.456	10.260	10.473	-0.072	1.092	-7.528	41.524	24.597	35.016	6.546	3.809	15.207	35.981	25.594
1217	0.368	2.784	6.504	4.330	-0.056	1.108	-12.422	33.165	13.986	21.795	5.378	5.516	5.764	24.467	15.116
1218	0.368	2.784	6.792	5.068	-0.072	1.208	-12.386	34.236	15.012	22.986	5.522	5.444	6.646	25.586	16.116
1219	0.408	3.000	6.924	4.680	-0.048	1.160	-13.142	35.223	15.012	23.193	5.761	5.835	6.407	26.184	16.296
1220	0.376	2.676	5.778	3.185	-0.072	1.316	-13.064	31.200	12.015	19.380	4.949	5.711	4.222	22.247	13.234
1225	0.408	3.000	7.176	5.346	-0.064	1.236	-12.932	35.997	15.930	24.237	4.992	5.692	8.094	27.085	17.590
1227	0.336	2.580	6.540	5.286	-0.072	1.352	-13.052	34.617	14.742	22.845	5.236	5.681	6.662	25.682	16.172
1229	0.392	3.060	7.860	6.427	-0.056	1.012	-10.496	36.042	17.739	26.502	5.303	4.617	9.592	28.275	18.934
1231	0.408	2.856	5.880	2.844	-0.048	1.172	-13.172	31.515	11.988	19.467	4.366	5.843	4.778	22.466	13.622
1232	0.312	2.268	5.436	4.053	-0.072	1.184	-12.716	31.107	12.069	19.503	3.781	5.624	5.444	22.283	13.864
1234	0.288	2.148	5.136	3.741	-0.048	1.160	-12.944	30.432	11.313	18.600	3.571	5.736	4.898	21.492	13.195
1236	0.336	2.424	5.790	4.302	-0.072	1.028	-10.850	30.369	12.852	20.475	4.034	4.795	5.974	22.426	14.200

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