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A fuzzy multi-objective balanced scorecard approach for selecting an optimal electronic business process management best practice (e-BPM^{BP})

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Abstract

Purpose – The rapid intensification of the internet and electronic commerce diffusion has given rise to electronic business process management (e-BPM) which enhances the overall connectivity of the business processes. However, when confronted by the range of e-BPM best practices (e-BPM^{BP}s), organizations struggle to identify the one most appropriate to their needs. The paper aims to address these issues.

Design/methodology/approach – The paper proposes a novel fuzzy group multi-objective method for e-BPM^{BP} evaluation and selection. First, a fuzzy group linear assignment method is used to rank the e-BPM^{BP}s drawing on the four perspectives of a balanced scorecard (BSC). Second, a fuzzy group real options approach is used to estimate the financial values of the ranked e-BPM^{BP}s. Third, a four-objective assignment model is used to select the optimal e-BPM^{BP} in deferral time with respect to their rankings, financial values, and a series of pertinent constraints.

Findings – The contribution of the proposed method is threefold: it is grounded in the four perspectives of a BSC, it considers imprecise or vague judgments which lead to ambiguity in the decision process, and it uses a meaningful and robust multi-objective model to aggregate both qualitative judgments and quantitative data. A case study is presented to demonstrate the applicability of the proposed framework and to exhibit the efficacy of the procedures and algorithms.

Originality/value – The novel fuzzy group multi-objective framework for e-BPM^{BP} evaluation and selection proposed in the paper takes into consideration (1) the qualitative and quantitative criteria and their respective value judgments; (2) the verbal expressions and linguistic variables for qualitative judgments which lead to ambiguity in the decision process; and (3) imprecise or vague judgments.

Keywords Business process reengineering, Best practice, Balanced scorecard, Process management

Paper type Research paper

1. Introduction

The rapid evolution of information technology and global competition has drastically increased organizational awareness and responsiveness to interactions between their internal environments and external environments. As a result, organizations are paying

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more attention to supporting business process management (BPM) able to adapt to the new complex environments. Much of the research in BPM has focused on finding best practices to make businesses more efficient and effective. One widely accepted approach for improving the performance of the processes is to reengineer them based on electronic BPM best practices (e-BPM^{BP}s) (Andersson *et al.*, 2005). However, when confronted by the range of e-BPM^{BP}s, organizations struggle to identify the ones most appropriate to their needs. In this study, we propose a novel fuzzy group multi-objective method for e-BPM^{BP} evaluation and selection. The proposed framework utilizes a fuzzy group linear assignment method to rank the e-BPM^{BP}s drawing on the four perspectives of a balanced scorecard (BSC). Next, a fuzzy group real options approach is used to estimate the financial values of the ranked e-BPM^{BP}s. Finally, a four-objective assignment model is used to select the optimal e-BPM^{BP} in deferral time with respect to their rankings, financial values, and a series of applicable constraints.

This paper is organized into six sections. In Section 2, we present a review of the relevant literature. In Section 3, we illustrate the details of the proposed framework. In Section 4, we present a case study to demonstrate the applicability of the proposed framework and exhibit the efficacy of the procedures and algorithms. The paper will conclude with a discussion and implications in Section 5 and conclusions and future research directions in Section 6.

2. Literature review

BPM is a comprehensive and coordinated set of activities or logically related tasks that must be performed to fulfill organizational strategic goals or to deliver value to customers (Strnadl, 2006). A business process reengineering initiative is commonly seen as a twofold challenge:

(1) a technological challenge, resulting from the difficulty of developing a process design that is a radical improvement of the current BPM; and

(2) a socio-cultural challenge, resulting from the difficulty of severe organizational effects on the involved people, which may lead them to react against in the current BPM (Reijers and Liman Mansar, 2005).

Although various empirical research works indicate that there is a positive correlation between BPM and business success (McCormack and Johnson, 2001; McCormack *et al.*, 2009; Skerlavaj *et al.*, 2007), very little research is conducted to help organizations select the BPM practice and BPM still remains largely theoretical (Karim *et al.*, 2007; Melão and Pidd, 2000). As a consequence, there is a gap in BPM research for methods to support researchers and practicing managers choose among the alternative BPM practices (Filipowska *et al.*, 2009).

Following the publication of the fundamental concepts of BPM by Hammer (1990) and Davenport and Short (1990), consultants and researchers are regularly proposing new BPM practices. Most of these practices build on the information technology and internet which have been the driving forces in redefining BPM (Hammer, 1990; Hammer and Champy, 1993). Some researchers have advocated BPM practices by focusing on agility (Ligus, 1993; White *et al.*, 2005; Wang and Wang, 2006; Cummins, 2008), strategy (Talwar, 1993; Chen *et al.*, 2007; Grefen *et al.*, 2009), knowledge management (Weske *et al.*, 2004; Pernici and Weske, 2006; Jung *et al.*, 2007; van der Aalst *et al.*, 2007), and performance measurement (Harmon and Davenport, 2007; Han *et al.*, 2009; Trkman, 2010). Others have focused on principles much like Hammer and Champy's (Klein, 1995; Kim and Ramkaran, 2004; Reijers and Liman Mansar, 2005; Dustdar *et al.*, 2008).

Al-Mashari and Zairi (1999) have provided a holistic view of the BPM implementation process and reviewed the literature relating to the hard and soft factors that cause success and failure for BPM implementation. In addition, they identified key factors of success and failure and explained how these factors influence the process of BPM implementation. Valiris and Glykas (1999) considered three perspectives: structural, behavioral, and process and presented a BPM methodology that goes beyond the limitations of the existing BPM methodologies taking a holistic view of the organization. Filipowska *et al.* (2009) have argued that BPM lacks proper formalized approaches and presented a methodology for the evaluation of BPM methodologies. Hanafizadeh *et al.* (2009) evaluated a total of 29 best practices in the literature. They used the indicators of cost, time, quality, and flexibility in a technique for order preference by similarity to ideal solution (TOPSIS) model to measure the degree of alignment of BPM practices with organization strategy. Ko *et al.* (2009) have identified the strengths and limitations of current BPM standards and developed a classification framework for these standards and further identified the key industry trends in BPM.

The proposed method is draw from the four perspectives of a BSC. The concept of BSC measures organizational performance from four perspectives, including financial, customer, internal business process, and learning and growth (Kaplan and Norton, 1992). The essential principle of the BSC is that standard financial measures must be balanced with non-financial measures (Ballou *et al.*, 2003; Norton *et al.*, 1997; Sinclair and Zairi, 2001). The virtues of BSC lie in its simplicity and generic format for describing the organizational strategies. It is used whenever ideas about causes and effects and/or priorities are to be communicated (Olve and Sjöstrand, 2002). The BSC is a popular tool that is applied by many businesses to assess their performance in diverse aspects of their organization (Banker *et al.*, 2000, 2004; Davis and Albright, 2004; Frigo *et al.*, 2000; Kim and Davidson, 2004; Kuo and Chen, 2008; Leung *et al.*, 2006; Said *et al.*, 2003).

3. The proposed framework

The modular model shown in Figure 1 along with the mathematical notations and definitions presented in Appendix 1 are used to evaluate the e-BPM^{BP}s.

As shown in Figure 1, the process begins in phase 1 by establishing a selection committee comprised of four leaders familiar with the concept of BSC. The committee members are given the responsibility of leading the customer, internal e-business process, learning and growth, and financial sub-groups. Initially, the four sub-groups collectively identify a set of alternative e-BPM^{BP}s in consultation with the top management. Next, each sub-group provides their ranking of the e-BPM^{BP}s in phases 2-5 of the evaluation process. In the final phase, the selection committee selects an optimal e-BPM^{BP} based on the rankings obtained in the preceding phases by the four sub-groups.

Phase 1: establishing the e-BPM committee and sub-groups and determining the initial e-BPM^{BP}s

In this phase, we establish the electronic business process management (e-BPM) selection committee and sub-groups to participate in the evaluation process and select an initial set of e-BPM^{BP}s for further consideration.

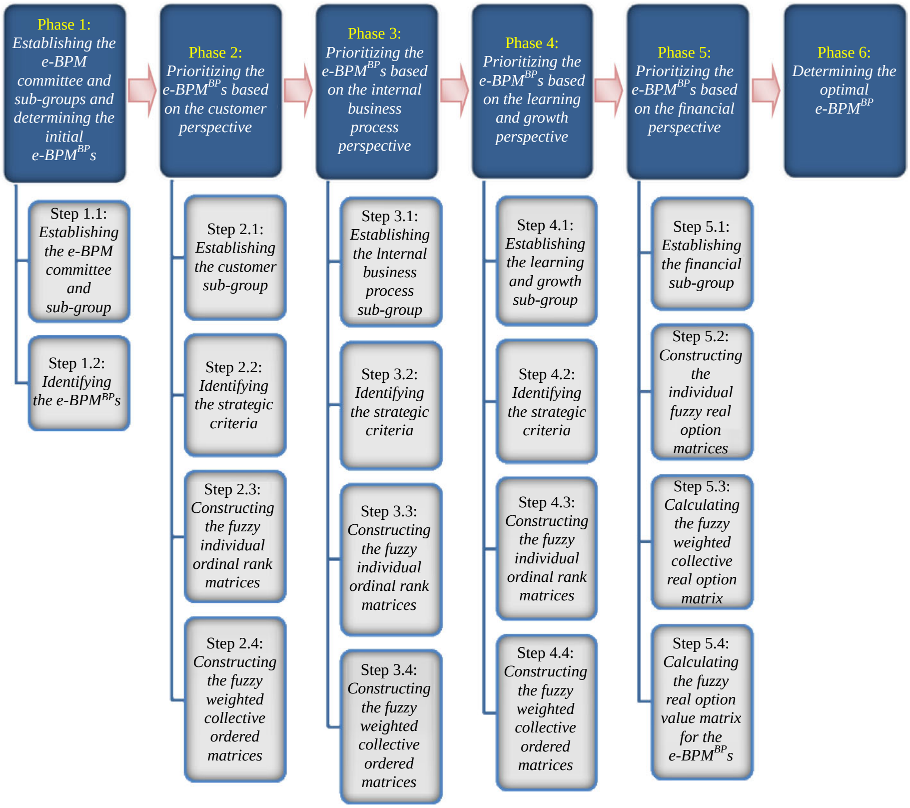

Figure 1.
The proposed framework for selecting the optimal e-BPM^{BP}

Step 1.1: establishing the e-BPM committee and sub-groups. In the first step, we establish an e-BPM selection committee who oversee the e-BPM selection process. Drawing on the four perspectives of a BSC, we establish four sub-groups to prioritize the e-BPMs based on the customer perspective, the internal business process perspective, the learning and growth perspective, and the financial perspective as follows:

$$\underline{e - BPMG} = (CG(l), PG(l), LG(l), FG(l)) \tag{1}$$

where:

$CG(l)$: The customer sub-group leader.

$PG(l)$: The internal e-business process sub-group leader.

$LG(l)$: The learning and growth sub-group leader.

$FG(l)$: The financial sub-group leader.

Next, we determine a voting power weight to each of the four e-BPM perspectives as follows:

$$\underline{W}(leader) = [w(c), w(p), w(l), w(f)] \tag{2}$$

where:

c : The customer perspective.

p : The internal e-business process perspective.

l : The learning and growth perspective.

f : The financial perspective.

There are many techniques to elicit voting power or attribute weights from a group of decision makers (for a review see Pöyhönen and Hämäläinen (2001), Stewart (1992) and Weber and Borcherding (1993)). Direct point allocation, tradeoff procedure (Keeney and Raiffa, 1976), simple multi-attribute rating technique method (Edwards, 1977), swing weighting (von Winterfeldt and Edwards, 1986), simple multi-attribute rating technique extended to ranking method (Edwards and Barron, 1994), and the analytic hierarchy process (AHP) (Saaty, 1994) are among the most widely used weight determination methods. In this study, we use AHP to determine a voting power weight for each of the four e-BPM perspectives.

Step 1.2: identifying the e-BPM^{BP}s. In this step, the e-BPM selection committee and their sub-groups collectively identifies the alternative e-BPM^{BP}s. Let us assume that the group has identified n e-BPM^{BP}s for further consideration with the maximum deferral time of T_m as follows:

$$\underline{A} = [A_1, A_2, \ldots, A_i, \ldots, A_n]$$

Phase 2: prioritizing the e-BPM^{BP}s based on the customer perspective

A successful implementation of an e-BPM is highly dependent on the customer satisfaction. In this phase, the group ordinal approach is used to prioritize the e-BPM^{BP}s based on the customer perspective with regard to a set of criteria. This phase is divided into the following four steps.

Step 2.1: establishing the customer sub-group. In the first step, we establish a customer sub-group with $q_1 + 1$ members as follows:

$$\underline{CG} = [(CG(l)), (CG_1), (CG_2), \ldots, (CG_{q_1+1})] \tag{3}$$

Next, we determine a voting power weight for each customer sub-group member as follows:

$$\underline{V}(c) = [v(c), v_1(c), \ldots, v_j(c), \ldots, v_{q_1+1}(c)] \tag{4}$$

Step 2.2: identifying the strategic criteria. In this step, the customer sub-group determines a list of the strategic criteria relevant to the customer perspective. Let us consider $S_1(c), S_2(c), \ldots, S_{m_1}(c)$ as the strategic criteria for this perspective.

Step 2.3: constructing the fuzzy individual ordinal rank matrices. The fuzzy individual ordinal rank matrix of the e-BPM^{BP}s evaluated by the customer sub-group member CG_k is constructed as follows:

$$\tilde{A}^k(c) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} S_1(c) & S_2(c) & \cdots & S_{m_1}(c) \end{array} \\ \begin{bmatrix} \tilde{a}^k_{11}(c) & \tilde{a}^k_{12}(c) & \cdots & \tilde{a}^k_{1m_1}(c) \\ \tilde{a}^k_{21}(c) & \tilde{a}^k_{22}(c) & \cdots & \tilde{a}^k_{2m_1}(c) \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{a}^k_{n1}(c) & \tilde{a}^k_{n2}(c) & \cdots & \tilde{a}^k_{nm_1}(c) \end{bmatrix} \end{array} \tag{5}$$

Therefore, we have:

$$E^k(c) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} S_1(c) & S_2(c) & \cdots & S_{m_1}(c) \end{array} \\ \begin{bmatrix} E\left[\tilde{a}^k_{11}(c)\right] & E\left[\tilde{a}^k_{12}(c)\right] & \cdots & E\left[\tilde{a}^k_{1m_1}(c)\right] \\ E\left[\tilde{a}^k_{21}(c)\right] & E\left[\tilde{a}^k_{22}(c)\right] & \cdots & E\left[\tilde{a}^k_{2m_1}(c)\right] \\ \vdots & \vdots & \cdots & \vdots \\ E\left[\tilde{a}^k_{n1}(c)\right] & E\left[\tilde{a}^k_{n2}(c)\right] & \cdots & E\left[\tilde{a}^k_{nm_1}(c)\right] \end{bmatrix} \end{array} \tag{6}$$

Because $\tilde{a}^k_{ij}(c)$ is a trapezoidal fuzzy number:

$$\tilde{a}^k_{ij}(c) = \left(\left(a^k_{ij}(c)\right)^c, \left(a^k_{ij}(c)\right)^d, \left(a^k_{ij}(c)\right)^\alpha, \left(a^k_{ij}(c)\right)^\beta \right) \tag{7}$$

its expected value can be derived as follows:

$$E\left(\tilde{a}^k_{ij}(c)\right) = \frac{\left(a^k_{ij}(c)\right)^c + \left(a^k_{ij}(c)\right)^d}{2} + \frac{\left(a^k_{ij}(c)\right)^\beta - \left(a^k_{ij}(c)\right)^\alpha}{6} \tag{8}$$

Next, for the preference ordering criterion, we assign the scores of $(n-1),(n-2),\ldots,1,0$ to the first-, second-, [...], last-ranked e-BPM$^{\mathrm{BP}}$s. Then, we calculate the following matrix based on the importance weight vector $\underline{W}^k(c) = \left[w^k_1(c), w^k_2(c), \ldots, w^k_{m_1}(c)\right]$:

$$R^k(c) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} 1^{st} & 2^{nd} & \cdots & n^{th} \end{array} \\ \begin{bmatrix} r^k_{11}(c) & r^k_{12}(c) & \cdots & r^k_{1n}(c) \\ r^k_{21}(c) & r^k_{22}(c) & \cdots & r^k_{2n}(c) \\ \vdots & \vdots & \cdots & \vdots \\ r^k_{n1}(c) & r^k_{n2}(c) & \cdots & r^k_{nn}(c) \end{bmatrix} \end{array} \tag{9}$$

or:

$$
R^k(c) = \begin{array}{c} \\ \\ A_1 \\ A_2 \\ \vdots \\ A_n \\ \\ \\ \end{array}
\begin{array}{c}
\begin{array}{cc} 1^{st} & 2^{nd} \\ \cdots & n^{th} \end{array} \\
\left[\begin{array}{cc}
w_1^k(c).x_{11}^1(k,c) + \cdots + w_{m_1}^k(c).x_{1m_1}^1(k,c) & w_1^k(c).x_{11}^2(k,c) + \cdots + w_{m_1}^k(c).x_{1m_1}^2(k,c) \\
\cdots & w_1^k.(c)x_{11}^n(k,c) + \cdots + w_{m_1}^k(c).x_{1m_1}^n(k,c) \\
w_1^k(c).x_{21}^1(k,c) + \cdots + w_{m_1}^k(c).x_{2m_1}^1(k,c) & w_1^k(c).x_{21}^2(k,c) + \cdots + w_{m_1}^k(c).x_{2m_1}^2(k,c) \\
\cdots & w_1^k(c).x_{21}^n(k,c) + \cdots + w_{m_1}^k(c).x_{2m_1}^n(k,c) \\
\vdots & \vdots \\
\cdots & \vdots \\
w_1^k(c).x_{n1}^1(k,c) + \cdots + w_{m_1}^k(c).x_{nm_1}^1(k,c) & w_1^k(c).x_{n1}^2(k,c) + \cdots + w_{m_1}^k(c).x_{nm_1}^2(k,c) \\
\cdots & w_1^k(c).x_{n1}^n(k,c) + \cdots + w_{m_1}^k(c).x_{nm_1}^n[k,c]
\end{array}\right]
\end{array}
\quad (10)
$$

where $x_{ij}^r(k,c) = 1$ if the ith e-BPMBP with respect to the jth investment criterion evaluated by the customer sub-group member CGk based on the customer perspective is assigned to rank r, and $x_{ij}^r(k,c) = 0$ otherwise.

Step 2.4: constructing the fuzzy weighted collective ordered matrices. Finally, the fuzzy weighted collective ordered matrices evaluated by the customer sub-group based on the customer perspective is constructed as follows:

$$
R(c) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array}
\begin{array}{c}
\begin{array}{cccc} 1^{st} & 2^{nd} & \cdots & n^{th} \end{array} \\
\left[\begin{array}{cccc}
\bar{r}_{11}(c) & \bar{r}_{12}(c) & \cdots & \bar{r}_{1n}(c) \\
\bar{r}_{21}(c) & \bar{r}_{22}(c) & \cdots & \bar{r}_{2n}(c) \\
\vdots & \vdots & \cdots & \vdots \\
\bar{r}_{n1}(c) & \bar{r}_{n2}(c) & \cdots & \bar{r}_{nn}(c)
\end{array}\right]
\end{array}
\quad (11)
$$

or:

$$
R(c) == \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array}
\begin{array}{c}
\begin{array}{cccc} 1^{\mathrm{st}} & 2^{\mathrm{nd}} & \cdots & n^{\mathrm{th}} \end{array} \\
\left[\begin{array}{cccc}
\frac{\sum_{k=1}^{q_2} v_k(c).r_{11}^k(c)}{q_2} & \frac{\sum_{k=1}^{q_2} v_k(c).r_{12}^k(c)}{q_2} & \cdots & \frac{\sum_{k=1}^{q_2} v_k(c).r_{1n}^k(c)}{q_2} \\
\frac{\sum_{k=1}^{q_2} v_k(c)r_{21}^k(c)}{q_2} & \frac{\sum_{k=1}^{q_2} v_k(c).r_{22}^k(c)}{q_2} & \cdots & \frac{\sum_{k=1}^{q_2} v_k(c).r_{2n}^k(c)}{q_2} \\
\vdots & \vdots & \cdots & \vdots \\
\frac{\sum_{k=1}^{q_2} v_k(c).r_{n1}^k(c)}{q_2} & \frac{\sum_{k=1}^{q_2} v_k(c).r_{n2}^k(c)}{q_2} & \cdots & \frac{\sum_{k=1}^{q_2} v_k(c).r_{nn}^k(c)}{q_2}
\end{array}\right]
\end{array}
\quad (12)
$$

Phase 3: prioritizing the e-BPM^{BP}s based on the internal business process perspective

In this phase, the group ordinal approach is used to prioritize the e-BPM^{BP}s based on the internal e-business process perspective. This phase is divided into the following four steps.

Step 3.1: establishing the internal business process sub-group. In the first step, we establish an internal e-business process sub-group with $q_2 + 1$ members as follows:

$$\underline{PG} = [(PG(l)), (PG_1), (PG_2), \ldots, (PG_{q_2+1})] \tag{13}$$

Next, we determine a voting power weight for each internal e-business process sub-group member as follows:

$$\underline{V}(P) = [v(p), v_1(p), \ldots, v_j(p), \ldots, v_{q_2+1}(p)] \tag{14}$$

Step 3.2: identifying the strategic criteria. In this step, the internal e-business process sub-group determines a list of the strategic criteria relevant to the internal e-business process perspective. Let us consider $S_1(p), S_2(p), \ldots, S_{m_2}(p)$ as the strategic criteria for this perspective.

Step 3.3: constructing the fuzzy individual ordinal rank matrices. The fuzzy individual ordinal rank matrix of the e-BPM^{BP}s evaluated by the internal e-business process sub-group member PG_k is constructed as follows:

$$\tilde{A}^k(p) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} S_1(p) & S_2(p) & \cdots & S_{m_2}(p) \end{array} \\ \begin{bmatrix} \tilde{a}^k_{11}(p) & \tilde{a}^k_{12}(p) & \cdots & \tilde{a}^k_{1m_2}(p) \\ \tilde{a}^k_{21}(p) & \tilde{a}^k_{22}(p) & \cdots & \tilde{a}^k_{2m_2}(p) \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{a}^k_{n1}(p) & \tilde{a}^k_{n2}(p) & \cdots & \tilde{a}^k_{nm_2}(p) \end{bmatrix} \end{array} \tag{15}$$

Therefore, we have:

$$E^k(p) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} S_1(p) & S_2(p) & \cdots & S_{m_2}(p) \end{array} \\ \begin{bmatrix} E\left[\tilde{a}^k_{11}(p)\right] & E\left[\tilde{a}^k_{12}(p)\right] & \cdots & E\left[\tilde{a}^k_{1m_1}(p)\right] \\ E\left[\tilde{a}^k_{21}(p)\right] & E\left[\tilde{a}^k_{22}(p)\right] & \cdots & E\left[\tilde{a}^k_{2m_1}(p)\right] \\ \vdots & \vdots & \cdots & \vdots \\ E\left[\tilde{a}^k_{n1}(p)\right] & E\left[\tilde{a}^k_{n2}(p)\right] & \cdots & E\left[\tilde{a}^k_{nm_1}(p)\right] \end{bmatrix} \end{array} \tag{16}$$

Because $\tilde{a}^k_{ij}(c)$ is a trapezoidal fuzzy number:

$$\tilde{a}^k_{ij}(p) = \left(\left(a^k_{ij}(p)\right)^c, \left(a^k_{ij}(p)\right)^d, \left(a^k_{ij}(p)\right)^\alpha, \left(a^k_{ij}(p)\right)^\beta \right) \tag{17}$$

its expected value can be derived as follows:

$$E\left(\tilde{a}_{ij}^{k}(p)\right)=\frac{\left(a_{ij}^{k}(p)\right)^{c}+\left(a_{ij}^{k}(p)\right)^{d}}{2}+\frac{\left(a_{ij}^{k}(p)\right)^{\beta}-\left(a_{ij}^{k}(p)\right)^{\alpha}}{6} \tag{18}$$

Next, for the preference ordering criterion, we assign the scores of $(n-1),(n-2),\ldots,1,0$ to the first-, second-, [. . .], last-ranked e-BPM^{BP}. Then, we calculate the following matrix based on the importance weight vector $\underline{W}^{k}(P)=\left[w_{1}^{k}(p),w_{2}^{k}(p),\ \ldots,w_{m_2}^{k}(p)\right]$:

$$R^{k}(p)=\begin{array}{c} \\ A_1\\ A_2\\ \vdots\\ A_n\end{array}\begin{array}{c}\begin{array}{cccc}1^{st} & 2^{nd} & \cdots & n^{th}\end{array}\\ \begin{bmatrix} r_{11}^{k}(p) & r_{12}^{k}(p) & \cdots & r_{1n}^{k}(p)\\ r_{21}^{k}(p) & r_{22}^{k}(p) & \cdots & r_{2n}^{k}(p)\\ \vdots & \vdots & \cdots & \vdots\\ r_{n1}^{k}(p) & r_{n2}^{k}(p) & \cdots & r_{nn}^{k}(p)\end{bmatrix}\end{array} \tag{19}$$

or:

$$R^{k}(p)=\begin{array}{c} A_1\\ A_2\\ \vdots\\ A_n\end{array}\begin{array}{c}\begin{array}{cc}1^{st} & 2^{nd}\\ \cdots & n^{th}\end{array}\\ \begin{bmatrix} w_1^k(p).x_{11}^1(k,p)+\cdots+w_{m_2}^k(p).x_{1m_2}^1(k,p) & w_1^k(p).x_{11}^2(k,p)+\cdots+w_{m_2}^k(p).x_{1m_2}^2(k,p)\\ \cdots & w_1^k.(p)x_{11}^n(k,p)+\cdots+w_{m_2}^k(p).x_{1m_2}^n(k,p)\\ w_1^k(p).x_{21}^1(k,p)+\cdots+w_{m_2}^k(p).x_{2m_2}^1(k,p) & w_1^k(p).x_{21}^2(k,p)+\cdots+w_{m_2}^k(p).x_{2m_2}^2(k,p)\\ \cdots & w_1^k(p).x_{21}^n(k,p)+\cdots+w_{m_2}^k(p).x_{2m_2}^n(k,p)\\ \vdots & \vdots\\ \cdots & \vdots\\ w_1^k(p).x_{n1}^1(k,p)+\cdots+w_{m_2}^k(p).x_{nm_2}^1(k,p) & w_1^k(p).x_{n1}^2(k,p)+\cdots+w_{m_2}^k(p).x_{nm_2}^2(k,p)\\ \cdots & w_1^k(p).x_{n1}^n(k,p)+\cdots+w_{m_2}^k(p).x_{nm_2}^n[k,p]\end{bmatrix}\end{array} \tag{20}$$

where $x_{ij}^{r}(k,p)=1$ if the ith e-BPM^{BP} with respect to the jth investment criterion evaluated by the internal e-business process sub-group member PG_k based on the internal e-business process perspective is assigned to rank r, and $x_{ij}^{r}(k,p)=0$ otherwise.

Step 3.4: constructing the fuzzy weighted collective ordered matrices. Finally, the fuzzy weighted collective ordered matrices evaluated by the internal e-business process sub-group based on the internal e-business process perspective are constructed as follows:

$$
\begin{array}{cc} & \begin{array}{cccc} 1^{st} & 2^{nd} & \cdots & n^{th} \end{array} \\ R(p) = \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_n \end{array} & \begin{bmatrix} \bar{r}_{11}(p) & \bar{r}_{12}(p) & \cdots & \bar{r}_{1n}(p) \\ \bar{r}_{21}(p) & \bar{r}_{22}(p) & \cdots & \bar{r}_{2n}(p) \\ \vdots & \vdots & \cdots & \vdots \\ \bar{r}_{n1}(p) & \bar{r}_{n2}(p) & \cdots & \bar{r}_{nn}(p) \end{bmatrix} \end{array} \tag{21}
$$

or:

$$
\begin{array}{cc} & \begin{array}{cccc} 1^{st} & 2^{nd} & \cdots & n^{th} \end{array} \\ R(p) = \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_n \end{array} & \begin{bmatrix} \frac{\sum_{k=1}^{q_2} v_k(p).r_{11}^k(p)}{q_2} & \frac{\sum_{k=1}^{q_2} v_k(p).r_{12}^k(p)}{q_2} & \cdots & \frac{\sum_{k=1}^{q_2} v_k(p).r_{1n}^k(p)}{q_2} \\ \frac{\sum_{k=1}^{q_2} v_k(p) r_{21}^k(p)}{q_2} & \frac{\sum_{k=1}^{q_2} v_k(p).r_{22}^k(p)}{q_2} & \cdots & \frac{\sum_{k=1}^{q_2} v_k(p).r_{2n}^k(p)}{q_2} \\ \vdots & \vdots & \cdots & \vdots \\ \frac{\sum_{k=1}^{q_2} v_k(p).r_{n1}^k(p)}{q_2} & \frac{\sum_{k=1}^{q_2} v_k(p).r_{n2}^k(p)}{q_2} & \cdots & \frac{\sum_{k=1}^{q_2} v_k(p).r_{nn}^k(p)}{q_2} \end{bmatrix} \end{array} \tag{22}
$$

Phase 4: prioritizing the e-BPM^{BP}s based on the learning and growth perspective
In this phase, the group ordinal approach is used to prioritize the e-BPM$^{\mathrm{BP}}$s based on the learning and growth perspective. This phase is divided into the following four steps.

Step 4.1: establishing the learning and growth sub-group. In the first step, we establish a learning and growth sub-group with $q_3 + 1$ members as follows:

$$
\underline{LG} = [(LG(l)), (LG_1), (LG_2), \ldots, (LG_{q_3+1})] \tag{23}
$$

Next, we determine a voting power weight for each learning and growth sub-group member as follows:

$$
\underline{V}(L) = [v(l), v_1(l), \ldots, v_j(l), \ldots, v_{q_3+1}(l)] \tag{24}
$$

Step 4.2: identifying the strategic criteria. In this step, the learning and growth sub-group determines a list of strategic criteria relevant to the learning and growth perspective. Let us consider $S_1(l), S_2(l), \ldots, S_{m_3}(l)$ as the strategic criteria for this perspective.

Step 4.3: constructing the fuzzy individual ordinal rank matrices. The fuzzy individual ordinal rank matrix of the e-BPM$^{\mathrm{BP}}$s evaluated by the learning and growth sub-group member LG_k is constructed as follows:

$$\tilde{A}^k(l)=\begin{array}{c c} & \begin{array}{cccc} S_1(l) & S_2(l) & \cdots & S_{m_3}(l) \end{array} \\ \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_n \end{array} & \begin{bmatrix} \tilde{a}^k_{11}(l) & \tilde{a}^k_{12}(l) & \cdots & \tilde{a}^k_{1m_3}(l) \\ \tilde{a}^k_{21}(l) & \tilde{a}^k_{22}(l) & \cdots & \tilde{a}^k_{2m_3}(l) \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{a}^k_{n1}(l) & \tilde{a}^k_{n2}(l) & \cdots & \tilde{a}^k_{nm_3}(l) \end{bmatrix} \end{array} \tag{25}$$

Therefore, we have:

$$E^k(l)=\begin{array}{c c} & \begin{array}{cccc} S_1(l) & S_2(l) & \cdots & S_{m_3}(l) \end{array} \\ \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_n \end{array} & \begin{bmatrix} E\left[\tilde{a}^k_{11}(l)\right] & E\left[\tilde{a}^k_{12}(l)\right] & \cdots & E\left[\tilde{a}^k_{1m_1}(l)\right] \\ E\left[\tilde{a}^k_{21}(l)\right] & E\left[\tilde{a}^k_{22}(l)\right] & \cdots & E\left[\tilde{a}^k_{2m_1}(l)\right] \\ \vdots & \vdots & \cdots & \vdots \\ E\left[\tilde{a}^k_{n1}(l)\right] & E\left[\tilde{a}^k_{n2}(l)\right] & \cdots & E\left[\tilde{a}^k_{nm_1}(l)\right] \end{bmatrix} \end{array} \tag{26}$$

Because $\tilde{a}^k_{ij}(c)$ is a trapezoidal fuzzy number:

$$\tilde{a}^k_{ij}(l)=\left(\left(a^k_{ij}(l)\right)^c,\left(a^k_{ij}(l)\right)^d,\left(a^k_{ij}(l)\right)^\alpha,\left(a^k_{ij}(l)\right)^\beta\right) \tag{27}$$

its expected value can be derived as follows:

$$E\left(\tilde{a}^k_{ij}(l)\right)=\frac{\left(a^k_{ij}(l)\right)^c+\left(a^k_{ij}(l)\right)^d}{2}+\frac{\left(a^k_{ij}(l)\right)^\beta-\left(a^k_{ij}(l)\right)^\alpha}{6} \tag{28}$$

Next, for the preference ordering criterion, we assign the scores of $(n-1),(n-2),\ldots,1,0$ to the first-, second-, [...], last-ranked e-BPM^{BP}. Then, we calculate the following matrix based on the importance weight vector $\underline{W}^k(L)=\left[w^k_1(l),w^k_2(l),\ \ldots,w^k_{m_3}(l)\right]$:

$$R^k(l)=\begin{array}{c c} & \begin{array}{cccc} 1^{st} & 2^{nd} & \cdots & n^{th} \end{array} \\ \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_n \end{array} & \begin{bmatrix} r^k_{11}(l) & r^k_{12}(l) & \cdots & r^k_{1n}(l) \\ r^k_{21}(l) & r^k_{22}(l) & \cdots & r^k_{2n}(l) \\ \vdots & \vdots & \cdots & \vdots \\ r^k_{n1}(l) & r^k_{n2}(l) & \cdots & r^k_{nn}(l) \end{bmatrix} \end{array} \tag{29}$$

or:

$$R^k(l) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} 1^{st} & 2^{nd} & \cdots & n^{th} \end{array} \\ \left[\begin{array}{cccc} w_1^k(l).x_{11}^1(k,l)+\cdots+w_{m_3}^k(l).x_{1m_3}^1(k,l) & w_1^k(l).x_{11}^2(k,l)+\cdots+w_{m_3}^k(l).x_{1m_3}^2(k,l) & \cdots & w_1^k.(l)x_{11}^n(k,l)+\cdots+w_{m_3}^k(l).x_{1m_3}^n(k,l) \\ w_1^k(l).x_{21}^1(k,l)+\cdots+w_{m_3}^k(l).x_{2m_3}(k,l) & w_1^k(l).x_{21}^2(k,l)+\cdots+w_{m_3}^k(l).x_{2m_3}^2(k,l) & \cdots & w_1^k(l).x_{21}^n(k,l)+\cdots+w_{m_3}^k(l).x_{2m_3}^n(k,l) \\ \vdots & \vdots & \cdots & \vdots \\ w_1^k(l).x_{n1}^1(k,l)+\cdots+w_{m_3}^k(l).x_{nm_3}^1(k,l) & w_1^k(l).x_{n1}^2(k,l)+\cdots+w_{m_3}^k(l).x_{nm_3}^2(k,l) & \cdots & w_1^k(l).x_{n1}^n(k,l)+\cdots+w_{m_3}^k(l).x_{nm_3}^n[k,l] \end{array}\right] \end{array} \quad (30)$$

where $x_{ij}^r(k,l) = 1$ if the ith e-BPM$^{\mathrm{BP}}$ with respect to the jth investment criterion evaluated by the learning and growth sub-group member LG_k based on the learning and growth perspective is assigned to rank r, and $x_{ij}^r(k,l) = 0$ otherwise.

Step 4.4: constructing the fuzzy weighted collective ordered matrices. Finally, the fuzzy weighted collective ordered matrices evaluated by the learning and growth sub-group based on the learning and growth perspective is constructed as follows:

$$R(l) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} 1^{st} & 2^{nd} & \cdots & n^{th} \end{array} \\ \left[\begin{array}{cccc} \bar{r}_{11}(l) & \bar{r}_{12}(l) & \cdots & \bar{r}_{1n}(l) \\ \bar{r}_{21}(l) & \bar{r}_{22}(l) & \cdots & \bar{r}_{2n}(l) \\ \vdots & \vdots & \cdots & \vdots \\ \bar{r}_{n1}(l) & \bar{r}_{n2}(l) & \cdots & \bar{r}_{nn}(l) \end{array}\right] \end{array} \quad (31)$$

or:

$$R(l) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} 1^{st} & 2^{nd} & \cdots & n^{th} \end{array} \\ \left[\begin{array}{cccc} \frac{\sum_{k=1}^{q_3} v_k(l).r_{11}^k(l)}{q_3} & \frac{\sum_{k=1}^{q_3} v_k(l).r_{12}^k(l)}{q_3} & \cdots & \frac{\sum_{k=1}^{q_3} v_k(l).r_{1n}^k(l)}{q_3} \\ \frac{\sum_{k=1}^{q_3} v_k(l)r_{21}^k(l)}{q_3} & \frac{\sum_{k=1}^{q_3} v_k(l).r_{22}^k(l)}{q_3} & \cdots & \frac{\sum_{k=1}^{q_3} v_k(l).r_{2n}^k(l)}{q_3} \\ \vdots & \vdots & \cdots & \vdots \\ \frac{\sum_{k=1}^{q_3} v_k(l).r_{n1}^k(l)}{q_3} & \frac{\sum_{k=1}^{q_3} v_k(l).r_{n2}^k(l)}{q_3} & \cdots & \frac{\sum_{k=1}^{q_3} v_k(l).r_{nn}^k(l)}{q_3} \end{array}\right] \end{array} \quad (32)$$

Phase 5: prioritizing the e-BPM^{BP}s based on the financial perspective

In this phase, the Dos Santos (1994) real options equations are used to evaluate the e-BPM$^{\mathrm{BP}}$s. This phase is divided into the following four steps.

Step 5.1: establishing the financial sub-group. In the first step, we establish a finance sub-group with $q_4 + 1$ members as follows:

$$\underline{FG} = [(FG(l)), (FG_1), (FG_2), \ldots, (FG_{q_4+1})] \tag{33}$$

Next, we determine a voting power weight for each finance sub-group member as follows:

$$\underline{V}(F) = [v(f), v_1(f), \ldots, v_j(f), \ldots, v_{q_4+1}(f)] \tag{34}$$

Step 5.2: constructing the individual fuzzy real option matrices. The following individual real option matrices are constructed for each finance sub-group member:

$$\tilde{A}^k(f) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccccccc} \tilde{s}_{t_1} & \tilde{s}_{t_2} & \cdots & \tilde{s}_{t_m} & \tilde{x}_{t_1} & \tilde{x}_{t_2} & \cdots & \tilde{x}_{t_m} \end{array} \\ \begin{bmatrix} \tilde{s}^k_{1,t_1} & \tilde{s}^k_{1,t_2} & \cdots & \tilde{s}^k_{1,t_m} & \tilde{x}^k_{1,t_1} & \tilde{x}^k_{1,t_2} & \cdots & \tilde{x}^k_{1,t_m} \\ \tilde{s}^k_{2,t_1} & \tilde{s}^k_{2,t_2} & \cdots & \tilde{s}^k_{2,t_m} & \tilde{x}^k_{2,t_1} & \tilde{x}^k_{2,t_2} & \cdots & \tilde{x}^k_{2,t_m} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ \tilde{s}^k_{n,t_1} & \tilde{s}^k_{n,t_2} & \cdots & \tilde{s}^k_{n,t_m} & \tilde{x}^k_{n,t_1} & \tilde{x}^k_{n,t_2} & \cdots & \tilde{x}^k_{n,t_m} \end{bmatrix} \end{array} \tag{35}$$

$$k = 1, 2, \ldots, l$$

Step 5.3: calculating the fuzzy weighted collective real option matrix. Next, the individual fuzzy real option matrices are aggregated by the voting powers to form a fuzzy weighted collective real option matrix as follows:

$$\tilde{A}(f) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccccccc} \tilde{s}_{t_1} & \tilde{s}_{t_2} & \cdots & \tilde{s}_{t_m} & \tilde{x}_{t_1} & \tilde{x}_{t_2} & \cdots & \tilde{x}_{t_m} \end{array} \\ \begin{bmatrix} \tilde{s}_{1,t_1} & \tilde{s}_{1,t_2} & \cdots & \tilde{s}_{1,t_m} & \tilde{x}_{1,t_1} & \tilde{x}_{1,t_2} & \cdots & \tilde{x}_{1,t_m} \\ \tilde{s}_{2,t_1} & \tilde{s}_{2,t_2} & \cdots & \tilde{s}_{2,t_m} & \tilde{x}_{2,t_1} & \tilde{x}_{2,t_2} & \cdots & \tilde{x}_{2,t_m} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ \tilde{s}_{n,t_1} & \tilde{s}_{n,t_2} & \cdots & \tilde{s}_{n,t_m} & \tilde{x}_{n,t_1} & \tilde{x}_{n,t_2} & \cdots & \tilde{x}_{n,t_m} \end{bmatrix} \end{array} \tag{36}$$

$$k = 1, 2, \ldots, l$$

where:

$$\tilde{s}_{i,t_j} = \frac{\sum_{k=1}^{q_4+1} (v_k(f)) \left(\tilde{s}^k_{i,t_j}\right)}{\sum_{k=1}^{q_4+1} v_k(f)} \tag{37}$$

$$\tilde{x}_{i,t_j} = \frac{\sum_{k=1}^{q_4+1} (v_k(f)) \left(\tilde{x}^k_{i,t_j}\right)}{\sum_{k=1}^{q_4+1} v_k(f)} \tag{38}$$

Step 5.4: calculating the fuzzy real option value matrix for the e-BPM^{BP}s. The real option values of the e-BPM^{BP}s at times $t_1, t_2, \ldots, t_m$ can be determined by the following fuzzy real option value matrix:

$$\tilde{V}(f) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} t_1 & t_2 & \cdots & t_m \end{array} \\ \begin{bmatrix} \tilde{v}_{1,t_1}(ro) & \tilde{v}_{1,t_2}(ro) & \cdots & \tilde{v}_{1,t_m}(ro) \\ \tilde{v}_{2,t_1}(ro) & \tilde{v}_{2,t_2}(ro) & \cdots & \tilde{v}_{2,t_m}(ro) \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{v}_{n,t_1}(ro) & \tilde{v}_{n,t_2}(ro) & \cdots & \tilde{v}_{n,t_m}(ro) \end{bmatrix} \end{array} \tag{39}$$

where:

$$\tilde{v}_{i,t_j}(ro) = \tilde{s}_{i,t_j}.e^{-\delta.t_j}.n\{d_{11,t_j}\} - \tilde{x}_i, t_j.e^{-r.t_j}.n\{d_{21,t_j}\} \tag{40}$$

where the ith e-BPM^{BP} cumulative normal probabilities for the d_1 and d_2 are as follows:

$$N(f) = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccccccc} n\{d_{1,t_1}\} & n\{d_{1,t_2}\} & \cdots & n\{d_{1,t_m}\} & n\{d_{2,t_1}\} & n\{d_{2,t_2}\} & \cdots & n\{d_{2,t_m}\} \end{array} \\ \begin{bmatrix} n\{d_{11,t_1}\} & n\{d_{11,t_2}\} & \cdots & n\{d_{11,t_m}\} & n\{d_{21,t_1}\} & n\{d_{21,t_2}\} & \cdots & n\{d_{21,t_m}\} \\ n\{d_{12,t_1}\} & n\{d_{12,t_2}\} & \cdots & n\{d_{12,t_m}\} & n\{d_{22,t_1}\} & n\{d_{22,t_2}\} & \cdots & n\{d_{22,t_m}\} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & & \vdots \\ n\{d_{1n,t_1}\} & n\{d_{1n,t_2}\} & \cdots & n\{d_{1n,t_m}\} & n\{d_{2n,t_1}\} & n\{d_{2n,t_2}\} & \cdots & n\{d_{2n,t_m}\} \end{bmatrix} \\ k = 1, 2, \ldots, l \end{array} \tag{41}$$

where:

$$d_{1i,t_j} = \frac{\ln(E(\tilde{s}_{i,t_j})/(\tilde{x}_{i,t_j})) + t_j.\left(r_i - \delta_i + \left(\sigma^2_{i,t_j}/2\right)\right)}{\sigma_{i,t_j}.\sqrt{t_j}} \tag{42}$$

$$d_{2i,t_j} = \frac{\ln(E(\tilde{s}_{i,t_j})/(\tilde{x}_{i,t_j})) + t_j.\left(r_i - \delta_i - \left(\sigma^2_{i,t_j}/2\right)\right)}{\sigma_{i,t_j}.\sqrt{t_j}} \tag{43}$$

The following trapezoidal fuzzy numbers are used to find the individual fuzzy present values of the expected payoffs and cost of the ith e-BPM^{BP} at time T_j by the financial sub-group member FG_k:

$$\begin{aligned} \tilde{s}^k_{i,t_j} &= \left(\left(s^k_{i,t_j}\right)^c, \left(s^k_{i,t_j}\right)^d, \left(s^k_{i,t_j}\right)^\alpha, \left(s^k_{i,t_j}\right)^\beta \right) \\ \tilde{x}^k_{i,t_j} &= \left(\left(x^k_{i,t_j}\right)^c, \left(x^k_{i,t_j}\right)^d, \left(x^k_{i,t_j}\right)^\alpha, \left(x^k_{i,t_j}\right)^\beta \right) \\ j &= 1, 2, \ldots, m \end{aligned} \tag{44}$$

and the formulas proposed by Carlsson and Fullér (2003) are used to find their expected value and variance:

$$
\begin{aligned}
E(\tilde{s}_{i,t_j}) &= \frac{(s_{i,t_j})^c + (s_{i,t_j})^d}{2} + \frac{(s_{i,t_j})^\beta - (s_{i,t_j})^\alpha}{6} \\
E(\tilde{x}_{i,t_j}) &= \frac{(x_{i,t_j})^c + (x_{i,t_j})^\alpha}{2} + \frac{(x_{i,t_j})^\gamma - (x_{i,t_j})^\beta}{6} \\
\sigma^2_{i,t_j} &= \frac{((s_{i,t_j})^d - (s_{i,t_j})^c)^2}{4} + \frac{\left((s_{i,t_j})^d - (s_{i,t_j})^c\right)\left((s_{i,t_j})^\alpha + (s_{i,t_j})^\beta\right)}{6} + \frac{\left((s_{i,t_j})^\alpha + (s_{i,t_j})^\beta\right)^2}{24}
\end{aligned}
\tag{45}
$$

Phase 6: determining the optimal e-BPM^{BP}

Next, we select the optimal e-BPM^{BP} based on the rankings obtained in phases 2-5. These rankings are used as the coefficients of the objective functions in the following proposed four-objective assignment model with regard to a series of applicable e-business and e-BPM^{BP}s constraints:

$$
\begin{aligned}
Max\, Z_c &= \frac{\bar{r}_{11}(c)}{\bar{r}_{11}(c) + \cdots + \bar{r}_{n1}(c)}\, z_{11} + \cdots + \frac{\bar{r}_{nn}(c)}{\bar{r}_{1n}(c) + \cdots + \bar{r}_{nn}(c)} .z_{nn} \\
Max\, Z_p &= \frac{\bar{r}_{11}(p)}{\bar{r}_{11}(p) + \cdots + \bar{r}_{n1}(p)} .z_{11} + \cdots + \frac{\bar{r}_{nn}(p)}{\bar{r}_{1n}(p) + \cdots + \bar{r}_{nn}(p)} .z_{nn} \\
Max\, Z_l &= \frac{\bar{r}_{11}(l)}{\bar{r}_{11}(l) + \cdots + \bar{r}_{n1}(l)} .z_{11} + \cdots + \frac{\bar{r}_{nn}(l)}{\bar{r}_{1n}(l) + \cdots + \bar{r}_{nn}(l)} .z_{nn} \\
Max\, Z_f &= \frac{E[\tilde{v}_{1,t_1}(ro)]}{E[\tilde{v}_{1,t_1}(ro)] + \cdots + E[\tilde{v}_{n,t_1}(ro)]} .z_1^{t_1} + \cdots + \frac{E[\tilde{v}_{1,t_m}(ro)]}{E[\tilde{v}_{1,t_m}(ro)] + \cdots + E[\tilde{v}_{n,t_m}(ro)]} .z_n^{t_m}
\end{aligned}
$$

Subject to (Model *P*):

$$
\begin{aligned}
f_1\left(y_{11}^{t_1}, y_{12}^{t_2} \ldots, y_{nn}^{t_m}\right) &\le 0 \\
f_2\left(y_{11}^{t_1}, y_{12}^{t_2} \ldots, y_{nn}^{t_m}\right) &\le 0 \\
&\vdots \\
f_r\left(y_{11}^{t_1}, y_{12}^{t_2} \ldots, y_{nn}^{t_m}\right) &\le 0 \\
z_{11} + z_{12} + \cdots + z_{nn} &\le 1 \\
z_{11} &= y_{11}^{t_1} + y_{11}^{t_2} + \cdots + y_{11}^{t_m} \\
z_{12} &= y_{12}^{t_1} + y_{12}^{t_2} + \cdots + y_{12}^{t_m} \\
&\vdots \\
z_{nn} &= y_{nn}^{t_1} + y_{nn}^{t_2} + \cdots + y_{nn}^{t_m}
\end{aligned}
$$

$$
\begin{aligned}
z_1^{t_1} &= y_{11}^{t_1} + y_{12}^{t_1} + \cdots + y_{1n}^{t_1} \\
z_1^{t_2} &= y_{11}^{t_2} + y_{12}^{t_2} + \cdots + y_{1n}^{t_2} \\
&\vdots \\
z_n^{t_m} &= y_{n1}^{t_m} + y_{n2}^{t_m} + \cdots + y_{nn}^{t_m}
\end{aligned}
$$

$$y_{ij}^{t_h} = 0, 1$$

$$i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, n \quad \text{and} \quad h = 1, 2, \ldots, m$$

where $f_1\left(y_{11}^{t_1}, y_{12}^{t_2} \ldots, y_{nn}^{t_m}\right)$ is a given function of the n e-BPM^{BP}s. The optimal solution for model (P) is the optimal e-BPM^{BP} at the time t_i. In the next section, we present a case study to demonstrate the applicability of the proposed framework and exhibit the efficacy of the procedures and algorithms.

4. Case study

The proposed fuzzy group multi-objective BSC method was used to evaluate and select an optimal e-BPM^{BP} at the Oriental Rug Brokers (ORB)[1]. ORB is the largest clearing house in the world for oriental rugs and carpets. ORB has a staff of 860 employees with offices in 22 cities throughout the Middle East, Far East, and Europe. ORB has the largest selection of hand knotted, hand woven or handmade rugs, old or antique, wool or silk from Iran, Afghanistan, Russia, India, China, Pakistan, and many more countries. ORB is considering streamlining their business processes and implementing an online electronic business model for rug sales and distribution. The company is looking into two electronic business models: consumer to business (C2B) and consumer to consumer (C2C). In the C2B model, consumers can post their product(s) and businesses answer with bid proposals. In the C2C model, consumers can post their product(s) and other consumers answer with bid proposals. The functionality of buying and selling over the internet will be made possible through eBPM software which regulates the various processes involved.

Phase 1: establishing the e-BPM committee and sub-groups and determining the initial e-BPM^{BP}s

In step 1.1, the chief operating officer of ORB established an e-BPM selection committee comprised of the following four members to lead the customer, internal e-business process, learning and growth, and financial sub-groups:

(1) the e-customer relations manager ($CG(l)$);

(2) the e-business process manager ($PG(l)$);

(3) the e-learning manager ($LG(l)$); and

(4) the capital budgeting manager ($FG(l)$).

In addition to the above sub-group leaders, the chief executive officer, the e-marketing manager, the technical support manager, the information technology manager, the research and development manager, a management representative, and an executive board representative agreed to participate in the process.

In step 1.2, the four sub-groups collectively, in consultation with top management, identified the following two e-BPM models suggested by Khanfar *et al.* (2009) for further consideration (see Appendix 2 for a detailed description of the two models):

(1) the consumer to consumer (C2C) e-BPM model (A_1); and

(2) the consumer to business (C2B) e-BPM model (A_2).

Phase 2: prioritizing the e-BPM^{BP}s based on the customer perspective

In step 2.1, the selection committee established the customer sub-group comprised of the e-customer relations manager ($CG(l)$) and the e-marketing manager (CG_1). In step 2.2, the customer sub-group identified the following three strategic criteria for the evaluation of the C2C and C2B e-BPM models based on the customer perspective:

(1) providing a single point of contact ($S_1(c)$);

(2) evaluating the outputs of the e-processes ($S_2(c)$); and

(3) customer control of the e-processes ($S_3(c)$).

In step 2.3, the customer sub-group used equations (5)-(10) and the importance weight vectors $\underline{W}^1(C)$ and $\underline{W}^2(C)$ given below to determine the fuzzy individual ordinal rank matrices shown in Tables I and II for the customer sub-group:

$$\underline{W}^1(C) = \left[w_1^1(c), w_2^1(c), w_3^1(c)\right] = (0.35, 0.45, 0.2)$$

$$\underline{W}^2(C) = \left[w_1^2(c), w_2^2(c), w_3^2(c)\right] = (0.3, 0.5, 0.2)$$

Table I presents the individual trapezoidal fuzzy scores and rankings for the C2C and C2B models provided by the e-customer relations manager ($CG(l)$) based on the following three criteria: providing a single point of contact ($S_1(c)$), evaluating the outputs of the e-processes ($S_2(c)$), and customer control of the e-processes ($S_3(c)$) in the customer perspective.

e-BPM^{BP}	Providing a single point of contact ($S_1(c)$)		Evaluating the outputs of the e-processes ($S_2(c)$)		Customer control of the e-processes ($S_3(c)$)	
C2C model	(1.5,2.5,0.5,0.5)	2	(0.5,1.5,0.5,0.5)	1	(0.5,1.5,0.5,0.5)	1
C2B model	(0.5,1.5,0.5,0.5)	1	(1.5,2.5,0.5,0.5)	2	(1.5,2.5,0.5,0.5)	2

Table I. The trapezoidal fuzzy individual ordinal rankings and the expected values of the fuzzy scores for the e-customer relations manager ($CG(l)$)

e-BPM^{BP}	Providing a single point of contact ($S_1(c)$)		Evaluating the outputs of the e-processes ($S_2(c)$)		Customer control of the e-processes ($S_3(c)$)	
C2C model	(0.75,1.25,0.25,0.25)	1	(1.75,2.25,0.25,0.25)	2	(0.75,1.25,0.25,0.25)	1
C2B model	(1.75,2.25,0.25,0.25)	2	(0.75,1.25,0.25,0.25)	1	(1.75,2.25,0.25,0.25)	2

Table II. The trapezoidal fuzzy individual ordinal rankings and the expected values of the fuzzy scores for the e-marketing manager (CG_1)

As a result of the judgments provided by the e-customer relations manager for the criterion of providing a single point of contact, the C2B model received a fuzzy score of 1 (as the first place e-BPM^{BP}) and the C2C model received a fuzzy score of 2 (as the second place e-BPM^{BP}). The score of 2 with a most possible score of [1.5, 2.5] was calculated using the trapezoidal fuzzy number (1.5, 2.5, 0.5, 0.5) as in Figure 3. Similarly, the score of 1 with a most possible score of [0.5, 1.5] was calculated using the trapezoidal fuzzy number (0.5, 1.5, 0.5, 0.5) as in Figure 2. Similarly, the score of 2 with a most possible score of [1.5, 2.5] was calculated using the trapezoidal fuzzy number (1.5, 2.5, 0.5, 0.5) as in Figure 3.

Table II presents the individual trapezoidal fuzzy scores and rankings for the C2C and C2B models provided by the e-marketing manager (CG_1) based on the following three criteria: $S_1(c)$, $S_2(c)$, and $S_3(c)$ in the customer perspective.

As a result of the judgments provided by the e-marketing manager for the criterion of providing a single point of contact, the C2C model received a fuzzy score of 1 and the C2B model received a fuzzy score of 2.

In step 2.4, the customer sub-group used equations (11) and (12) and the voting power vector $\underline{V}(C)$ given below to determine the weighted collective ordered matrix shown in Table III for their sub-group:

$$\underline{V}(C) = [v(c), v_1(c)] = (0.65, 0.35)$$

As shown in Table III, the frequency of the C2C model ranked as the first and second place e-BPM^{BP} is 0.4125 and 0.0875, respectively. Additionally, the frequency of the C2B model ranked as the first and second place e-BPM^{BP} is 0.0875 and 0.4125,

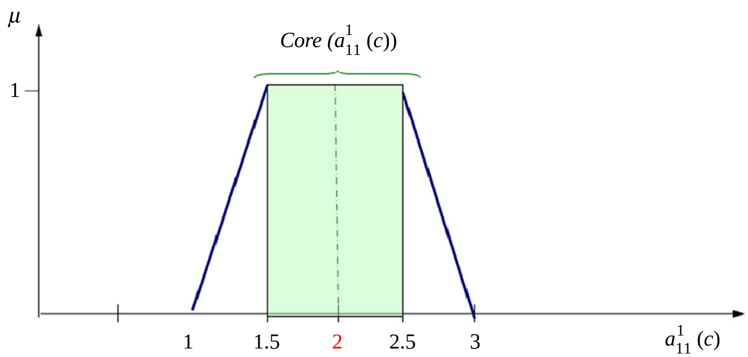

Figure 2.
The trapezoidal membership function of $\tilde{a}^1_{11}(c)$ applied by $CG(l)$

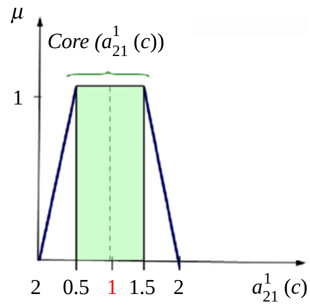

Figure 3.
The trapezoidal membership function of $\tilde{a}^1_{21}(c)$ applied by $CG(l)$

respectively. Consequently, the C2C model was the e-BPM^{BP} according to the customer perspective.

Phase 3: prioritizing the e-BPM^{BP}s based on the internal business process perspective
In step 3.1, the selection committee established the internal e-business process sub-group which included the e-business process manager ($PG(l)$), the technical support manager (PG_1), and the information technology manager (PG_2). In step 3.2, the internal e-business process sub-group identified the following three strategic criteria suggested by Kim and Ramkaran (2004) for the evaluation of the C2C and C2B e-BPM models based on the internal e-business process perspective:

(1) linking the parallel activities ($S_1(p)$);

(2) building controls into the e-processes ($S_2(p)$); and

(3) organizing around results and outcomes ($S_3(p)$).

In step 3.3, the internal e-business process sub-group used equations (15)-(20) and the importance weight vectors $\underline{W}^1(P)$, $\underline{W}^2(P)$, and $\underline{W}^3(P)$ given below to determine the fuzzy individual ordinal rank matrices shown in Tables IV-VI for the internal e-business process sub-group:

$$\underline{W}^1(P) = \left[w_1^1(p), w_2^1(p), w_3^1(p)\right] = (0.4, 0.2, 0.4)$$

$$\underline{W}^2(P) = \left[w_1^2(p), w_2^2(p), w_3^2(p)\right] = (0.32, 0.28, 0.4)$$

$$\underline{W}^3(P) = \left[w_1^3(p), w_2^3(p), w_3^3(p)\right] = (0.3, 0.22, 0.48)$$

e-BPM^{BP}	First	Second
C2C model	0.4125	0.0875
C2B model	0.0875	0.4215

Table III. The weighted collective ordered matrix based on the customer perspective

e-BPM^{BP}	Linking the parallel activities ($S_1(p)$)		Building controls into the e-processes ($S_2(p)$)		Organizing around results and outcomes ($S_3(p)$)	
C2C model	(0.5,1.5,0.5,0.5)	1	(1.5,2.5,0.5,0.5)	2	(0.5,1.5,0.5,0.5)	1
C2B model	(1.5,2.5,0.5,0.5)	2	(0.5,1.5,0.5,0.5)	1	(1.5,2.5,0.5,0.5)	2

Table IV. The trapezoidal fuzzy individual ordinal rankings and the expected values of the fuzzy scores for the e-business process manager ($PG(l)$)

e-BPM^{BP}	Linking the parallel activities ($S_1(p)$)		Building controls into the e-processes ($S_2(p)$)		Organizing around results and outcomes ($S_3(p)$)	
C2C model	(1.75,2.25,0.25,0.25)	2	(1.75,2.25,0.25,0.25)	2	(0.75,1.25,0.25,0.25)	1
C2B model	(0.75,1.25,0.25,0.25)	1	(0.75,1.25,0.25,0.25)	1	(1.75,2.25,0.25,0.25)	2

Table V. The trapezoidal fuzzy individual ordinal rankings and the expected values of the fuzzy scores for the technical support manager (PG_1)

As shown in Tables IV-VI, the e-business process manager, the technical support manager, and the information technology manager ranked the C2C and C2B e-BPM models according to each of the three internal e-business process perspective criteria: linking the parallel activities, building controls into the e-processes, and organizing around results and outcomes based on the internal e-business process perspective.

In step 3.4, the internal e-business process sub-group used equations (21) and (22) and the voting power vector $\underline{V}(P)$ given below to determine the weighted collective ordered matrix shown in Table VII for the internal e-business process sub-group:

$$\underline{V}(P) = [v(p), v_1(p), v_2(p)] = (0.5, 0.25, 0.25)$$

As shown in Table VII, the frequency of the C2C model ranked as the first and second place e-BPM^{BP} is 0.25 and 0.125, respectively. Additionally, the frequency of the C2B model ranked as the first and second place e-BPM^{BP} is 0.125 and 0.25, respectively. Consequently, the C2C model was the e-BPM^{BP} according to the internal e-business process perspective.

Phase 4: prioritizing the e-BPM^{BP}s based on the learning and growth perspective

In step 4.1, the selection committee established the learning and growth sub-group which included the e-learning manager ($LG(l)$), the management representative (LG_1), and the research and development manager (LG_2). In step 4.2, the learning and growth sub-group identified the following two strategic criteria for the evaluation of the C2C and C2B e-BPM models based on the learning and growth perspective:

(1) capturing knowledge and information ($S_1(l)$); and

(2) focusing on the value networks ($S_2(l)$).

In step 4.3, the learning and growth sub-group used equations (25)-(30) and the importance weight vectors $\underline{W}^1(L)$, $\underline{W}^2(L)$, and $\underline{W}^3(L)$ given below to determine the fuzzy individual ordinal rank matrices shown in Tables VIII-X for their sub-group:

$$\underline{W}^1(L) = \left[w_1^1(l), w_2^1(l)\right] = (0.5, 0.5)$$

Table VI.
The trapezoidal fuzzy individual ordinal rankings and the expected values of the fuzzy scores for the information technology manager (PG_2)

e-BPM^{BP}	Linking the parallel activities ($S_1(p)$)		Building controls into the e-processes ($S_2(p)$)		Organizing around results and outcomes ($S_3(p)$)	
C2C model	(0.8,1.2,0.2,0.2)	1	(0.8,1.2,0.2,0.2)	1	(0.8,1.2,0.2,0.2)	1
C2B model	(1.8,2.2,0.2,0.2)	2	(1.8,2.2,0.2,0.2)	2	(1.8,2.2,0.2,0.2)	2

Table VII.
The weighted collective ordered matrix based on the internal e-business process perspective

e-BPM^{BP}	First	Second
C2C model	0.25	0.125
C2B model	0.125	0.25

$$\underline{W}^2(L) = \left[w_1^2(l), w_2^2(l))\right] = (0.35, 0.65)$$

$$\underline{W}^3(L) = \left[w_1^3(l), w_2^3(l)\right] = (0.65, 0.35)$$

As shown in Tables VIII-X, the e-learning manager, the management representative, and the research and development manager ranked the C2C and C2B e-BPM models according to each of the two learning and growth perspective criteria: capturing knowledge and information and focusing on the value networks based on the learning and growth perspective.

In step 4.4, the learning and growth sub-group used equations (31) and (32) and the voting power vector $\underline{V}(L)$ given below to determine the weighted collective ordered matrix shown in Table XI for their sub-group:

$$\underline{V}(L) = [v(l), v_1(l), v_2(l)] = (0.35, 0.35, 0.3)$$

As shown in Table XI, the frequency of the C2C model ranked as the first and second place e-BPM^{BP} is 0.298 and 0.035, respectively. Additionally, the frequency of the C2B

Table VIII. The trapezoidal fuzzy individual ordinal rankings and the expected values of the fuzzy scores for the e-learning manager ($LG(l)$)

e-BPM^{BP}	Capturing knowledge and information ($S_1(l)$)		Focusing on the value networks ($S_2(l)$)	
C2C model	(0.5,1.5,0.5,0.5)	1	(0.5,1.5,0.5,0.5)	1
C2B model	(1.5,2.5,0.5,0.5)	2	(1.5,2.5,0.5,0.5)	2

Table IX. The trapezoidal fuzzy individual ordinal rankings and the expected values of the fuzzy scores for the management representative (LG_1)

e-BPM^{BP}	Capturing knowledge and information ($S_1(l)$)		Focusing on the value networks ($S_2(l)$)	
C2C model	(0.75,1.25,0.25,0.25)	1	(0.75,1.25,0.25,0.25)	1
C2B model	(1.75,2.25,0.25,0.25)	2	(1.75,2.25,0.25,0.25)	2

Table X. The trapezoidal fuzzy individual ordinal rankings and the expected values of the fuzzy scores for the research and development manager (LG_2)

e-BPM^{BP}	Capturing knowledge and information ($S_1(l)$)		Focusing on the value networks ($S_2(l)$)	
C2C model	(0.8,1.2,0.2,0.2)	1	(1.8,2.2,0.2,0.2)	2
C2B model	(1.8,2.2,0.2,0.2)	2	(0.8,1.2,0.2,0.2)	1

Table XI. The weighted collective ordered matrix based on the learning and growth perspective

e-BPM^{BP}	First	Second
C2C model	0.298	0.035
C2B model	0.035	0.298

model ranked as the first and second place e-BPM^{BP} is 0.035 and 0.298, respectively. Consequently, the C2C model was the e-BPM^{BP} according to the learning and growth perspective.

Phase 5: prioritizing the e-BPM^{BP}s based on the financial perspective

In this phase, the selection committee established the financial sub-group which included the capital budgeting manager ($FG(l)$), the chief executive officer (FG_1), and the executive board representative (FG_2). Next, the financial sub-group used equations (33)-(45) and the voting power vector $\underline{V}(F)$ given below to determine the normalized real option values of the C2C and C2B e-BPM models for years 0, 1 and 2 as shown in Table XII:

$$\underline{V}(F) = [v(f), v_1(f), v_2(f)] = (0.35, 0.35, 0.3)$$

As shown in Table XII, the normalized real option values of the C2C model for years 0, 1, and 2 were 0.22, 0.25, and 0.2, respectively. Additionally, the normalized real option values of the C2B model for years 0, 1, and 2 were 0.13, 0.17, and 0.15, respectively. Consequently, year 1 was the best time for implementation of the C2C and C2B e-BPM models according to the financial perspective.

Phase 6: determining the optimal e-BPM^{BP}

In this phase, the selection committee considered additional business constraints and utilized the following four-objective assignment model to select the optimal e-BPM^{BP} based on the rankings obtained in phase 5:

$$Max\, Z_c = 0.4125z_{11} + 0.0875\, z_{12} + 0.0875z_{21} + 0.4125z_{22}$$

$$Max\, Z_p = 0.25z_{11} + 0.125\, z_{12} + 0.125z_{21} + 0.25z_{22}$$

$$Max\, Z_l = 0.298z_{11} + 0.035\, z_{12} + 0.035z_{21} + 0.298z_{22}$$

$$Max z_f = 0.22z_1^0 + 0.25z_1^1 + 0.21z_1^2 + 0.13z_2^0 + 0.17z_2^1 + 0.15z_2^2$$

Subject to (Model P):

$$z_{11} + z_{12} + z_{21} + z_{22} \leq 1$$

$$z_{11} = y_{11}^0 + y_{11}^1 + y_{11}^2$$

$$z_{12} = y_{12}^0 + y_{12}^1 + y_{12}^2$$

$$z_{21} = y_{21}^0 + y_{21}^1 + y_{21}^2$$

$$z_{22} = y_{22}^0 + y_{22}^1 + y_{22}^2$$

Table XII.
The normalized real option values of the C2C and C2B models

Deferral time	0	1	2
C2C model	0.22	0.25	0.2
C2B model	0.13	0.17	0.15

$$z_1^0 = y_{11}^0 + y_{12}^0$$
$$z_1^1 = y_{11}^1 + y_{12}^1$$
$$z_1^2 = y_{11}^2 + y_{12}^2$$
$$z_2^0 = y_{21}^0 + y_{22}^0$$
$$z_2^1 = y_{21}^1 + y_{22}^1$$
$$z_2^2 = y_{21}^2 + y_{22}^2$$
$$y_{ij}^h = 0, 1 \quad (i = 1, 2; \quad j = 1, 2 \quad \text{and} \quad h = 0, 1, 2)$$

According to the optimal solution obtained from the model *P*, the C2C model was selected as the optimal e-BPM^{BP} and recommended to the chief operating officer of ORB for implementation in year 0.

5. Discussion and implications

It is hard to say for sure what e-BPM^{BP} is optimal, but, we can make the e-BPM evaluation more comprehensive and systematic. The fuzzy group multi-objective method used at ORB was intended to enhance decision making. The four e-BPM selection committee members were highly educated. Two committee members held graduate degrees in management, one held a graduate degree in engineering, and one held a graduate degree in economics. To this end, a more logical and persuasive multi-criteria framework was necessary to gain the confidence and support of the decision makers. Although the members of the selection committee were educated, their managerial judgment and intuition were limited by their background and experience. Nevertheless, all four individuals were veteran mangers with 18-27 years of experience in BPM. Each person had a range of expertise including risk-benefit analysis, engineering management, financial management, and budgeting. Upon completion of the e-BPM evaluation process, the selection committee met to discuss the results and finalize its recommendations. The committee members unanimously agreed that the proposed framework provided invaluable analysis aids and information processing support. They were convinced that the result was unbiased and consistent with their goals and objectives.

Armed with this feedback, the committee members were confident that they could sell their recommendation to the chief operating officer and other senior management at ORB. In spite of this confidence, they were all aware that convincing management was a difficult task. The committee members and their sub-groups agreed to target various stakeholders and key people in order to gain their support and ultimately the support of top management. This process involved fostering collaboration and avoiding alienation of potential allies. They discussed the tangible and intangible benefits of the selected e-BPM^{BP} with the key people who in turn agreed to support the proposed recommendation. The selection committee and the sub-groups were also charged with developing a long-term plan to measure the e-BPM^{BP} success.

The analysis of this case study allows the articulation of a series of key factors that can be considered as important in contributing to the successful evaluation and selection of the e-BPM^{BP}s. The first element is getting the key people on board.

The second factor is building internal alliances. The third key ingredient is the persistent and systematic processes in place to evaluate the e-BPM^{BP} success.

The proposed framework does not imply a higher-level of "accuracy" in e-BPMBP evaluation. Although the approach has an air of mathematical sophistication, a more logical and persuasive framework was necessary to gain the confidence and support of a group of educated decision makers. Nevertheless, the selection committee members and their sub-groups make a number of value judgments, which may impair the results. Therefore, the success of the framework is highly dependent on involving the "right" individuals with experience and wisdom.

Our framework helps the selection committee members and the sub-groups to think systematically about complex e-BPMBP evaluation problems. We decompose the evaluation process into manageable steps and integrate the results to arrive at a solution consistent with the goals and objectives specified by the management. This decomposition encourages the participants to carefully consider uncertain conditions. The proposed structured framework does not imply a deterministic approach in e-BPMBP evaluation. While our approach enables the selection committee members and the sub-groups to assimilate the precise data and imprecise or ambiguous judgments into a formal systematic approach, it should be used with care and in conjunction with management experience. Managerial judgment is an integral component of the e-BPMBP evaluation; therefore, the effectiveness of the model relies heavily on the cognitive capabilities of the selection committee members and their sub-groups.

6. Conclusions and future research directions

A wide variety of management and engineering techniques are currently used to improve organizational performance. This includes techniques such as activity-based management, business architectures, business process reengineering, change management, enterprise engineering, knowledge management, learning organizations, process improvement, etc. However, the common thread in most of these techniques is the BPM (Hammer, 1996). Managing business processes electronically gives organizations many advantages such as cost reduction and enhanced quality in administrative processing, faster case handling and enhanced customer satisfaction, faster process adjustment, enhanced reporting capabilities, and enhanced capacity planning, among others (Halstenbach, 2007). However, when confronted by the range of e-BPM^{BP}s, organizations struggle to identify the one most appropriate to their needs.

In this study, we proposed a novel fuzzy group multi-objective method for e-BPM^{BP} evaluation and selection. The proposed framework utilized a fuzzy group linear assignment method to rank the e-BPM^{BP}s drawing on the four perspectives of a BSC. A fuzzy group real options approach was used to estimate the financial values of the ranked e-BPM^{BP}s. Then, a four-objective assignment model was used to select the optimal e-BPM^{BP} in deferral time with respect to their rankings, financial values and a series of applicable constraints. Finally, we presented a case study and demonstrated the applicability of the proposed framework and exhibited the efficacy of the procedures and algorithms. The contribution of the proposed method is threefold:

(1) it is grounded on the four perspectives of a BSC;

(2) it considers imprecise or vague judgments which lead to ambiguity in the decision process; and

(3) it uses a meaningful and robust multi-objective model to aggregate both qualitative judgments and quantitative data.

Nevertheless, we stress that our contribution addresses yet a small part of the issues that are involved with the e-BPM^{BP} evaluation and selection. It is safe to say that the e-BPM^{BP} assessment as a discipline is at its infancy. Therefore, we hope that the study presented here can inspire others to pursue further research in this area.

Note

1. The name is changed to protect the anonymity of the company.

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Appendix 1. Mathematical notations and definitions

A_i	The ith e-BPM$^{\mathrm{BP}}$ practice.
n	The number of alternative e-BPM$^{\mathrm{BP}}$s.
$S_j(c)$	The jth customer perspective criterion.
$S_j(p)$	The jth internal e-business process perspective criterion.
$S_j(l)$	The jth learning and growth perspective criterion.
m_1	The number of customer perspective criteria.
m_2	The number of internal e-business process perspective criteria.
m_3	The number of learning and growth perspective criteria.
$q_1 + 1$	The number of the customer perspective sub-group members.
$q_2 + 1$	The number of the internal e-business process perspective sub-group members.
$q_3 + 1$	The number of the learning and growth perspective sub-group members.
$q_4 + 1$	The number of the financial perspective sub-group members.
$w_j^k(c)$	The importance weight of the jth customer perspective criterion evaluated by the customer perspective sub-group member CG_k.
$w_j^k(p)$	The importance weight of the jth internal e-business process perspective criterion evaluated by the internal e-business process perspective sub-group member PG_k.
$w_j^k(l)$	The importance weight of the jth learning and growth perspective criterion evaluated by the learning and growth perspective sub-group member LG_k.
$v_k(c)$	The voting power of the customer perspective sub-group member CG_k ($K = 1, 2, \ldots, q_1 + 1$).

$v_k(p)$	The voting power of the internal e-business process perspective sub-group member $PG_k (K = 1,2, \ldots ,q_2 + 1)$.
$v_k(l)$	The voting power of the learning and growth perspective sub-group member LG_k $(K = 1, 2, \ldots ,q_3 + 1)$.
$v_k(f)$	The voting power of the financial perspective sub-group member FG_k $(K = 1,2, \ldots ,q_4 + 1)$.
$\tilde{A}^k(c)$	The fuzzy individual matrix of the e-BPM^{BP}s evaluated by the customer sub-group member CG_k.
$\tilde{A}^k(p)$	The fuzzy individual matrix of the e-BPM^{BP}s evaluated by the internal e-business process sub-group member PG_k.
$\tilde{A}^k(l)$	The fuzzy individual matrix of the e-BPM^{BP}s evaluated by the learning and growth sub-group member LG_k.
$\tilde{A}^k(f)$	The individual fuzzy real option matrix of the e-BPM^{BP}s evaluated by the financial sub-group member FG_k.
$\tilde{A}(f)$	The fuzzy weighted collective real option matrix of the e-BPM^{BP}s.
$R(c)$	The weighted collective matrix for the assigned scores to e-BPM^{BP} based on the customer perspective.
$R(p)$	The weighted collective matrix for assigned scores to each e-BPM^{BP} based on the internal e-business process perspective.
$R(l)$	The weighted collective matrix for assigned scores to each e-BPM^{BP} based on the learning and growth perspective.
$R^k(c)$	The assigned scores matrix to each e-BPM^{BP} evaluated by the sub-group member CG_k based on the customer perspective.
$R^k(p)$	The assigned scores matrix to each e-BPM^{BP} evaluated by the sub-group member PG_k based on the internal e-business process perspective.
$R^k(l)$	The assigned scores matrix to each e-BPM^{BP} evaluated by the sub-group member LG_k based on the learning and growth perspective.
$r_{ij}^k(c)$	The assigned score to $\tilde{a}_{ij}^k(c)$.
$r_{ij}^k(p)$	The assigned score to $\tilde{a}_{ij}^k(p)$.
$r_{ij}^k(l)$	The assigned score to $\tilde{a}_{ij}^k(l)$.
$\tilde{a}_{ij}^k(c)$	The fuzzy ordinal rank of the ith e-BPM^{BP} with respect to the jth strategic criterion evaluated by the customer sub-group member CG_k.
$\tilde{a}_{ij}^k(p)$	The fuzzy ordinal rank of the ith e-BPM^{BP} with respect to the jth strategic criterion evaluated by the internal e-business process sub-group member PG_k.
$\tilde{a}_{ij}^k(l)$	The fuzzy ordinal rank of the ith e-BPM^{BP} with respect to the jth strategic criterion evaluated by the learning and growth sub-group member LG_k.
$\tilde{s}_{i,t_j}$	The weighted collective fuzzy present value of the expected payoffs of the ith e-BPM^{BP} at time t.

$\tilde{x}_{i,t_j}$	The weighted collective fuzzy present value of the expected cost of the ith e-BPM^{BP} at time t.
$\tilde{s}^k_{i,t_j}$	The individual fuzzy present value of the expected payoffs of the ith e-BPM^{BP} at time t evaluated by the financial sub-group member FG_k.
$\tilde{x}^k_{i,t_j}$	The individual fuzzy present value of the expected cost of the ith e-BPM^{BP} at time t evaluated by the financial sub-group member FG_k.
$E(\tilde{s}_{i,t_j})$	The possibilistic mean value of the weighted collective present value of the expected payoffs for the ith e-BPM^{BP} at time t.
$E(\tilde{x}_{i,t_j})$	The possibilistic mean value of the weighted collective expected costs of the ith e-BPM^{BP} at time t.
σ^2_{i,t_j}	The variance of the weighted collective fuzzy present value of the expected payoffs for the ith e-BPM^{BP} at time t evaluated by the financial sub-group member FG_k.
δ_i	The value loss over the duration of the option.
r_i	The risk-free interest rate.
$n\{d_{1i,t_j}\}$	The e-BPM^{BP} ith cumulative normal probability distribution for the D_1.
$n\{d_{2i,t_j}\}$	The e-BPM^{BP} ith cumulative normal probability distribution for the D_2.
t_m	The maximum deferral time of the e-BPM^{BP}s.
t_1	The minimum deferral time of the e-BPM^{BP}s.
$\tilde{v}_{i,t_j}(ro)$	The fuzzy real option value of the ith e-BPM^{BP} at time T based on the financial perspective.

Appendix 2

e-BPM^{BP}	Descriptions
C2C model (A_1)	The C2C model is a collection of business processes deployed on the internet to enable consumers to exchange products. From the C2C perspective, the value chain does not appear with its traditional shape as the central player in the C2C model is the consumer. The following points describe some features of the C2C e-BPM^{BP}: Have consumers perform the process through online services Information about items and products is exchanged instantly among consumers through the web site. The web site provides the facilities that enable each consumer to view the items provided by other consumers and to select which one to pick. So the information is captured at the source and by the consumers themselves The processes should be designed to deal with unexpected situations When a third party is needed to participate at some point during the process, geographical or organizational boundaries are eliminated. The internet treats them equally to the consumer for participation in order to execute the processes in a natural order
C2B model (A_2)	The C2B model is a collection of business processes deployed on the internet to enable consumers to identify the products and services they need and dictate what they are willing to pay. The business channel direction is from consumers to business, so the natural direction of the flow in the traditional business channel is reversed through the internet. The following points describe some features of the C2B e-BPM^{BP}: The consumers have the decision, they themselves set the rules for the whole process; they define the types and costs of the products and services they wish to get Eliminate boundaries between organizations at the business side; the effective use of the internet can enable the process to be "process oriented" rather than being "organization oriented" Link parallel tasks at the business side using internet-based interfaces instead of integrating task results (processes are comprised of a web of processes and reconciliation is performed within) Have consumers perform the process through online services, some of these interfaces enable them to capture information need to continue performing the process Processes interact with other processes to create a web of interactions to achieve product delivery

Source: Khanfar *et al.* (2009)

Table AI. The C2C and C2B models

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