Using fuzzy analytical hierarchy process to evaluate main dimensions of business process reengineering

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Abstract. The goal of business process reengineering (BPR) is to achieve dramatic improvements in measures of business performance by radically changing the process design. The aim of this study is to develop a Fuzzy Analytic Hierarchy Process (FAHP) for the evaluation of BPR dimensions and taking judgments of decision makers into consideration. Drawing on the four dimensions of the BPR, this research first summarized the evaluation indices synthesized from the literature relating to BPR. Then, for screening these indices, 11 sub-indices fit for BPR evaluation were selected through expert questionnaires. FAHP method is used for determining the weights of the criteria by decision makers. The results show that organizational culture is the most important dimension of business process reengineering while BPR is implemented.

Keywords: business process reengineering; fuzzy analytical hierarchy process; multi criteria decision-making

Received August 2011. Accepted April 2012

Introduction

One of the techniques that is available to management for gaining substantial operational improvement is business process reengineering (BPR) (Beugre, 1998). For almost one decade now there has been considerable discussion in the literature on BPR and today there still remains considerable confusion, particularly amongst managers, as to exactly what constitutes BPR and how it is different from other change initiatives such as Total Quality Management (TQM). BPR has become a popular management tool for dealing with rapid technological and business change in today competitive environment (Beugre, 1998; Tang, 2009). It refers to the analysis and design of work flow and processes within and between organizations. Literature is full of examples explain how BPR has helped firms to achieve excellent performance in terms of a variety of parameters like delivery time, customer service and quality (Goel and Chen, 2008). As the basis of competition changes from cost and quality to flexibility and responsiveness, the value of process management is now being recognized. The role that process management can play in creating sustainable competitive advantage was termed BPR, and was first introduced by Hammer (1990); Davenport and Short (1990). These authors outlined a new approach to the management of processes, which, it was claimed, was producing radical improvements in performance.

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In this paper we proposed a fuzzy framework to evaluate the organizational dimensions that BPR have most influence on them. The framework is based on Analytical Hierarchy Process (AHP) method and cluster analysis. Different from other studies in the literature, Fuzzy Analytic Hierarchy Process (FAHP) method is used in this study. FAHP is utilized for determining the weights of main dimensions of BPR and their subcategories. The remainder of this paper is organized as follows. In the second section FAHP is defined and presented. In the third section, review of some related literature is presented. In the fourth section, BPR is briefly explained. An application of FAHP to the evaluation of the basic dimensions of BPR is provided. And finally in section six, results of the application are presented and suggestions for the future studies are clarified. This section concludes the paper.

**Fuzzy analytic hierarchy process**

AHP was devised by Saaty (1980, 1994). It is a useful approach to solve complex decision problems. It prioritizes the relative importance of a list of criteria (critical factors and sub-factors) through pair-wise comparisons amongst the factors by relevant experts using a nine-point scale. Buckley (1985) incorporated the fuzzy theory into the AHP, called the FAHP. It generalizes the calculation of the consistent ratio (CR) into a fuzzy matrix. The procedure of FAHP for determining the evaluation weights are explained as follows:

**Step 1:** Construct fuzzy pair-wise comparison matrices. Through expert questionnaires, each expert is asked to assign linguistic terms by triangular fuzzy number (TFN) to the pairwise comparisons among all criteria in the dimensions of a hierarchy system (see Figure 1). The result of the comparisons is constructed as fuzzy pair-wise comparison matrices $\tilde{A}$ as shown in Equation (1).

**Step 2:** Examine the consistency of the fuzzy pair-wise comparison matrices. According to the research of Buckley (1985), it proves that if $A=[a_{ij}]$ is a positive reciprocal matrix then $\tilde{A}=[\tilde{a}_{ij}]$ is a fuzzy positive reciprocal matrix. That is, if the result of the comparisons of $A=[a_{ij}]$ is consistent, then it can imply that the result of the comparisons of $\tilde{A}=[\tilde{a}_{ij}]$ is also consistent. Therefore, this research employs this method to validate the questionnaire.

**Step 3:** Compute the fuzzy geometric mean for each criterion. The geometric technique is used to calculate the geometric mean ($\tilde{r}_i$) of the fuzzy comparison values of criterion $i$ to each criterion, as shown in Equation (2), where $\tilde{a}_{in}$ is a fuzzy value of the pair-wise comparison of criterion $i$ to criterion $n$ (Buckley, 1985).

$$\tilde{r}_i = [\tilde{a}_{i1} \otimes \ldots \otimes \tilde{a}_{in}]^{1/n}$$
**Step 4:** Compute the fuzzy weights by normalization. The fuzzy weight of the \( i \)th criterion \( (\tilde{w}_i) \), can be derived as Equation (3), where \( \tilde{w}_i = (L_{w_i}, M_{w_i}, U_{w_i}) \) by a TFN and \( L_{w_i}, M_{w_i} \) and \( U_{w_i} \) represent the lower, middle and upper values of the fuzzy weight of the \( i \)th criterion.

\[
\tilde{w}_i = (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \ldots \oplus \tilde{r}_n)^{-1}
\]  

Due to the differences in the subjective judgments among the experts for each evaluation criterion, the overall valuation of the fuzzy judgment is employed to synthesize the various experts’ opinions in order to achieve a reasonable and objective evaluation. The calculation steps to obtain the synthetic value are explained in steps 5 and 6.

**Step 5:** Performance evaluation of the alternatives. As shown in Figure 2, “very dissatisfied”, “not satisfied”, “fair”, “satisfied”, and “very satisfied” are the five linguistic variables used to measure the performance of the alternatives against the evaluation criteria. Each linguistic variable can be presented by a TFN with a range of 0–100. Assume that \( \tilde{E}_{ij} \) denotes the fuzzy valuation of performance given by the evaluator \( k \) towards alternative \( i \) under criterion \( j \) as Equation (4) shows, then:

\[
\tilde{E}_{ij} = (LE_{ij}^k, ME_{ij}^k, UE_{ij}^k)
\]  

where \( \tilde{E}_{ij} \) represents the average fuzzy judgment values integrated by \( m \) evaluators as:

\[
\tilde{E}_{ij} = (\sqrt[m]{E_{ij}^1} \oplus \tilde{E}_{ij}^2 \oplus \ldots \oplus \tilde{E}_{ij}^m)
\]  

According to Buckley (1985), the three end points of \( \tilde{E}_{ij} \) can be computed as

\[
LE_{ij} = \frac{\sum_{k=1}^{m} LE_{ij}^k}{m}, ME_{ij} = \frac{\sum_{k=1}^{m} ME_{ij}^k}{m}, UE_{ij} = \frac{\sum_{k=1}^{m} UE_{ij}^k}{m}
\]

![Fig. 2. Membership functions of the five levels of linguistic variables](image)

**Step 6:** Fuzzy synthetic judgment. According to the fuzzy weight, \( \tilde{w}_i \) of each criterion calculated by FAHP, the criteria vector \( (\tilde{w}_i) \) is derived as Equation (7). And, the fuzzy performance matrix \( (\tilde{E}) \), as presented in Equation (8), of all the alternatives can be acquired from the fuzzy performance value of each alternative under \( n \) criteria.

\[
\tilde{w} = (\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n)^T
\]  

\[
\tilde{E} = [\tilde{e}_{ij}]
\]

The approximate fuzzy number \( \tilde{R}_i \) of the fuzzy synthetic decision of the alternative \( i \) is denoted as Equation (9), where \( LR_i \), \( MR_i \), and \( UR_i \) are the lower, middle, and upper synthetic performance values of alternative \( i \), respectively, and the calculations of each are illustrated as Equation (10)

\[
\tilde{R}_i = (LR_i, MR_i, UR_i)
\]
Next, the procedure of defuzzification (Hsieh et al., 2004; Opricovic & Tzeng, 2003) locates the Best Nonfuzzy Performance value (BNP). Therefore it is used in this study. The BNP value of the fuzzy number $\bar{R}_i$ can be found by

$$\text{BNP} = \frac{[(UR_i - LR_i) + (MR_i - LR_i)]}{3} + LR_i.$$  \hspace{1cm} (10)

The ranking of the alternatives then proceeds based on the value of the derived BNP for each of the alternatives.

**FAHP literature review**

The first study on FAHP was carried out by Van Laarhoven and Pedrycz (1983) and in this study; fuzzy ratios which were defined by triangular membership functions were compared. Buckley (1985) used the comparison ratios based on trapezoidal membership functions. Stam, Minghe, and Haines (1996) revealed how to use artificial intelligence techniques in the determination or quasi-determination of preference ratings in the analytic hierarchy method. Chang (1996) proposed the extent analysis method based on the utilization of triangular fuzzy numbers for pair-wise comparisons. Cheng (1997) put forward a new algorithm for the assessment of tactical missile systems using fuzzy AHP. Kahraman, Ulukan, and Tolga (1998) proposed a fuzzy objective and subjective method based on fuzzy AHP. Deng (1999) presented a multiple criteria analysis with fuzzy pair-wise comparisons to consider qualitative evaluations. Lee, Pham, and Zhang (1999) revised the main ideas underlying AHP and proposed a methodology based on stochastic optimization to ensure global coherence and to take into account the fuzzy character of the comparison process. Deng (1999) presented a fuzzy approach for tackling qualitative multi-criteria analysis problems in a simple and straightforward manner. Zhu, Jing, and Chang (1999) proved the basic theory of the triangular fuzzy number and improved the formulation of comparing the triangular fuzzy number’s size. On this basis, they introduced a practical example on petroleum prospecting. Leung and Cao (2000) proposed a fuzzy consistency definition with consideration of a tolerance deviation. Essentially, the fuzzy ratios of relative importance, allowing certain tolerance deviation, were formulated as constraints on the membership values of the local priorities. Chou and Liang (2001) proposed a fuzzy multi-criteria decision making model by combining fuzzy set theory, AHP and concept of entropy, for shipping company performance evaluation. Bozdag, Kahraman, and Ruan (2003) proposed four different fuzzy multi-attribute group decision making methods to select the best computer integrated manufacturing system. One of these methods is FAHP and the others are Yager’s weighted goals method, Blin’s approach and fuzzy synthetic evaluation. Chang, Cheng, and Wang (2003) developed a methodology for performance evaluation of airports. They used the gray statistics method in selecting the criteria, and FAHP method in determining the weights of criteria. And finally they adopted fuzzy synthetic and TOPSIS approach for the ranking of airport performance. Kahraman et al. (2003) used FAHP to select the best supplier firm providing the most satisfaction for the criteria determined. They used four different fuzzy multiattribute group decision making approaches for facility location selection. These approaches are; a fuzzy model proposed by Blin, fuzzy synthetic evaluation, Yager’s weighted goals method and FAHP respectively. Hsieh, Lu, and Tzeng (2004) presented a fuzzy multi-criteria analysis approach for selecting of planning and design alternatives in public office buildings. The FAHP method is used to determine the weightings for evaluation criteria among decision makers. Mikhailov and Tsvetinov (2004) applied a new fuzzy modification of the AHP for evaluating services. The proposed fuzzy prioritization method uses fuzzy pair-wise comparison judgments rather than exact numerical values of the comparison ratios and transforms initial fuzzy prioritization problem into non-linear program. Enea and Piazza (2004) focused on the constraints that have to be considered within FAHP. They used constrained FAHP in project selection. Kahraman, Cebeci, and Ruan (2004) used the FAHP for comparing catering firms in Turkey. The means of the triangular fuzzy numbers produced by the customers and experts for each comparison were successfully used in the pair-wise comparison matrices. Tang and Beynon (2005) used FAHP method for the application and development of a capital investment study. They tried to select the type of fleet car to be adopted by a car rental company. Baslugil (2005) provided an analytical tool to select the best software providing the most customer satisfaction. Tang et al. (2005, Chap. XI) proposed a multi-objective model for Taiwan notebook computer distribution problem. Their model involves a mixed integer programming and fuzzy analytic hierarchy process approach. Gu and Zhu (2006) constructed fuzzy symmetry matrix as attribute evaluation space based on
fuzzy decision matrix and improved the FAHP method using the approximate fuzzy eigenvector of such fuzzy symmetry matrix. Tu’ysu’z and Kahraman (2006) provided an analytical tool to evaluate the project risks under incomplete and vague information. They used FAHP to evaluate the riskiness of an information technology project of a Turkish company. Wang, Chu, and Wu (2007) made a choice in optimum maintenance strategies using fuzzy AHP. Different maintenance strategies were evaluated for different machineries in this study. Bozbura, Beskse, and Kahraman (2007) proposed a fuzzy AHP model to improve the quality of the prioritization of human capital measurement indicators under fuzziness. Lee, Chen, and Chang (2008) utilized the fuzzy AHP and Balanced Scorecard method for assessment of an IT department in the manufacturing sector in Taiwan. Ertug’rul and Karakasoglu (2009) used fuzzy AHP for performance evaluation of Turkish cement firms and ranked the involved companies in terms of their performances by applying the TOPSIS method. Tang (2009) provided a fuzzy multi-objective approach for budget allocation in an aerospace company with using FAHP and Artificial Neural Network (ANN). Abdi (2009) proposed FAHP model for evaluating reconfigurable machines. This model is proposed to integrate the decisive factors for the equipment selection process under uncertainty. Torfi, Farahai & Rezapour (2010) presented a fuzzy multi-criteria analysis approach. They used FAHP for determine the relative weights of evaluation criteria and FTOPSIS to rank the alternatives. Zhang, Shi, Ging & Zheng (2010) developing a FAHP model for building energy conservation assessment. Hsu, Lee & Kreng (2010) used FAHP in lubricant regenerative technology selection and FAHP is applied to find the importance degree of each criterion as the measurable indices of the regenerative technologies.

**Business process reengineering**

One of the techniques that is available to management for gaining substantial operational improvement is BPR. The technique was developed at MIT and popularized by Michael Hammer (Beugre, 1998; Goel and Chen, 2008; Thong et al 2000). BPR fundamentally differs from the scientific management approach; whereas scientific management concentrated on the optimizing functional tasks, BPR aims to deliver dramatic improvements in response time, service and quality by focusing on customer orientated business process.

For almost a decade now there has been considerable discussion in the literature on Business Process Reengineering (BPR) and today there still remains considerable confusion, particularly amongst managers, as to exactly what constitutes BPR and how it is different from other change initiatives such as Total Quality Management (Hammer, 1990). Several authors have provided their own interpretation of the changes being applied to organizations. For example Davenport and Short (1990) have described BPR as the analysis and design of work flows and processes within and between organizations.

Hammer and Champy (1993) have promoted the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed. Other authors such as Talwar (1993) have focused on the rethinking, restructuring and streamlining of the business structure, processes, methods of working, management systems and external relationships through which value is created and delivered.

The development in information technology has allowed organizations to start the process of integrating various functions within the organization as well as between different organizations. Many organizations are beginning to use IT and their IT infrastructure to gain a competitive advantage. The requirement for sharing data and information between financial institutions, markets, clients as well as regulatory agencies has meant that organizational boundaries are much more permeable to IT. These electronic links allow organizations to share information and thus can help expand their joint capabilities (Andrews and Stalick, 1992).

BPR is a fundamental shift in the way of doing business. It rejects the task-orientated approach and attempts to find new ways of accomplishing work, which is now organized around customer requirements and outcomes. It is therefore essential that there is absolute management commitment to the process. BPR provides a more customer focused approach and it is instrumental in breaking down functional and departmental barriers (Beugre, 1998; Goel and Chen, 2008). Some stages need to be addressed during a BPR programs. The key process is to establish the objectives. Defining objectives is a powerful way to change organizations. To do this, the managers have to fundamentally challenge their current way of doing things. The objectives need to be radical and aim for quantum leaps in performance rather than incremental change.
The application of FAHP to evaluate BPR dimensions

The aim of this study is to evaluate the basic components of BPR with the help of FAHP in banking sector of Iran. Based on the review of BPR literature, we proposed 4 basic components that BPR in organization effect on them. The components are organizational culture (C), organizational structure (S), organizational processes (P), and technology (T). 21 indices related to BPR were summarized. Then, expert questionnaires were used for screening the indices fit for BPR. Eleven indices were selected by the committee of experts, comprised of twelve professionals from practice and the academia. The 11 indices grouped into four BPR dimensions, “C: organizational culture contains customer orientation (C1), creativity (C2) and team work (C3)”, “S: organizational structure contains centralization (S1), complexity (S2) and formality (S3)”, “P: organizational processes contains cost (P1), time (P2) and quality (P3)”, and finally “T: technology contains software (T1) and hardware (T2)”. The hierarchical framework of this research (i.e. four dimensions and 11 subcategory indices) is shown in Figure 3.

Fig. 3. Hierarchical framework of the research

In fact BPR project influence on four main dimensions of organization. Based on this framework, the FAHP was used to determine the fuzzy weights of the indices.

Data collection and analysis

Based on the hierarchical framework, the FAHP questionnaire using FTN was developed and distributed among the experts for soliciting their professional opinions. The relative importance (fuzzy weight) for each performance index were determined by FAHP. The results listed in Table 1. The result shows that the critical order of the four BPR dimensions is “S: Structure (0.326)”, “P: Process (0.254)”, “C: Culture (0.220)”, and “T: Technology (0.202)”. The top five important subcategories are “S1: Centralization (0.177)”, “S2: Complexity (0.136)”, “P1: Cost (0.117)”, “P2: Time (0.102)”, and “S3: Formality (0.098)”. The least important evaluation subcategories
are “‘T1: Software (0.042)”. Results are shown in Table 1. In Table 1, STD BNP denotes as standard value for BNP. The Best Non-fuzzy Performance (BNP) value of the fuzzy number $\hat{R}_i$ can be found by

$$BNP = \frac{[(UR_i - LR_i) + (MR_i - LR_i)]}{3} + LR_i.$$

Table 1. Fuzzy weights determined by FAHP.

<table>
<thead>
<tr>
<th>Criteria (Dimension &amp; indices)</th>
<th>Local weights</th>
<th>Overall weights</th>
<th>BNP</th>
<th>STD_BNP</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>(0.16,0.193,0.249)</td>
<td>(0.029,0.042,0.068)</td>
<td>0.201</td>
<td>0.220</td>
<td>3</td>
</tr>
<tr>
<td>C_1</td>
<td>(0.181,0.22,0.273)</td>
<td>(0.029,0.042,0.068)</td>
<td>0.046</td>
<td>0.070</td>
<td>7</td>
</tr>
<tr>
<td>C_2</td>
<td>(0.141,0.174,0.208)</td>
<td>(0.022,0.033,0.052)</td>
<td>0.036</td>
<td>0.055</td>
<td>9</td>
</tr>
<tr>
<td>C_3</td>
<td>(0.16,0.199,0.231)</td>
<td>(0.026,0.038,0.057)</td>
<td>0.040</td>
<td>0.061</td>
<td>8</td>
</tr>
<tr>
<td>S</td>
<td>(0.235,0.292,0.367)</td>
<td>(0.064,0.102,0.182)</td>
<td>0.298</td>
<td>0.326</td>
<td>1</td>
</tr>
<tr>
<td>S_1</td>
<td>(0.276,0.35,0.495)</td>
<td>(0.052,0.085,0.129)</td>
<td>0.116</td>
<td>0.177</td>
<td>1</td>
</tr>
<tr>
<td>S_2</td>
<td>(0.222,0.29,0.351)</td>
<td>(0.038,0.061,0.092)</td>
<td>0.089</td>
<td>0.136</td>
<td>2</td>
</tr>
<tr>
<td>S_3</td>
<td>(0.164,0.209,0.25)</td>
<td>(0.038,0.061,0.092)</td>
<td>0.064</td>
<td>0.098</td>
<td>5</td>
</tr>
<tr>
<td>P</td>
<td>(0.181,0.224,0.291)</td>
<td>(0.044,0.075,0.11)</td>
<td>0.232</td>
<td>0.254</td>
<td>2</td>
</tr>
<tr>
<td>P_1</td>
<td>(0.241,0.309,0.377)</td>
<td>(0.039,0.066,0.097)</td>
<td>0.077</td>
<td>0.117</td>
<td>3</td>
</tr>
<tr>
<td>P_2</td>
<td>(0.213,0.271,0.332)</td>
<td>(0.036,0.059,0.086)</td>
<td>0.067</td>
<td>0.102</td>
<td>4</td>
</tr>
<tr>
<td>P_3</td>
<td>(0.199,0.244,0.297)</td>
<td>(0.036,0.059,0.086)</td>
<td>0.060</td>
<td>0.092</td>
<td>6</td>
</tr>
<tr>
<td>T</td>
<td>(0.141,0.173,0.239)</td>
<td>(0.016,0.024,0.042)</td>
<td>0.184</td>
<td>0.202</td>
<td>4</td>
</tr>
<tr>
<td>T_1</td>
<td>(0.111,0.142,0.177)</td>
<td>(0.018,0.027,0.046)</td>
<td>0.028</td>
<td>0.042</td>
<td>11</td>
</tr>
<tr>
<td>T_2</td>
<td>(0.125,0.157,0.191)</td>
<td>(0.018,0.027,0.046)</td>
<td>0.030</td>
<td>0.046</td>
<td>10</td>
</tr>
</tbody>
</table>

Ranking of the BPR dimensions

Four basic dimensions (e.g. C,S,P and T) and eleven subcategories were evaluated by the experts based on the selected evaluation criteria. Since there are differences of subjective judgments among the way experts view each evaluation criterion, the overall evaluation of the fuzzy judgment was employed to synthesize the opinions of the various experts in order to achieve a reasonable and objective evaluation. In this research, the five linguistic variables, “very dissatisfied”, “not satisfied”, “fair”, “satisfied”, and “very satisfied” were used to measure the banking performance with respect to the evaluation criteria. As shown in Figure 2, each linguistic variable is presented by a TFN with a range of 0–100. The average fuzzy judgment values for each criterion of the three banks, integrated by various experts through Equations (4)-(6). The Results summarized in Table 1. Then, the final fuzzy synthetic judgment of the three banks is deduced from the fuzzy criteria weights and the fuzzy judgment values. Table 1 presents the final fuzzy synthetic judgment of the four dimensions based on the evaluation criteria that were calculated by Equations (7) and (8). Consequently, the weights calculated by FAHP. Referring to Table 1, the BNP values computed by Equation (9) and (10). Finally the average fuzzy judgment values for the three banks integrated by various experts.

Conclusions and final remarks

This research conducted an analysis on BPR using a FAHP. The FAHP method was employed for computing the fuzzy weights for the BPR criteria in evaluation of banking performance. Based on the results of the analysis, some essential findings were discussed as follows. In response to the rapid growth of industries and the increased global competition, particularly for the Iranian institutions, the need for change controls and performance measures has attracted much attention. However, researchers are finding it difficult to measure organizational change based on BPR approach because of the intangible nature of its high risk in process of implementation.
In conclusion, we find that integrating all the relevant experts’ opinions, 11 indices are selected as being suitable for BPR effect on organization, and by applying the FAHP, the order of relative importance of the four BPR dimensions is “S: Structure”, “P: Process”, “C: Customer”, and “T:Technology”. The top five priorities of the dimensions indices are “‘S1: centralization”, “S2: complexity”, “P1: cost”, “P2: time” and “S3: Formality”, respectively. Based on the findings, the following suggestions are made. First, since there is no one dimensions of BPR to fit all, dimensions of BPR should be tailored to meet the organization’s overall goals as well as the objectives of each individual unit. Second, the dimensions of BPR may not be mutually independent. Other analytical methods (e.g. fuzzy integral, Analytic Network Process, etc.) can be employed to solve the interactive and feedback relations among indices. Third, future research may utilize several other techniques to investigate the causal relationships among dimensions of BPR to objectively build strategy maps. Finally, exploring more cases and conducting more empirical studies are recommended to further validate the usefulness of the proposed performance evaluation model.

References


Kosmidou et al., 2006). The present research proposed a FAHP evaluation model for BPR dimensions by determining a comprehensive set of criteria based on the concept of the BPR. Our proposed model embraces four main dimensions based on BPR literature review and then rank these main dimensions.


