Quantitative risk level estimation of business process reengineering efforts

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Abstract With risk defined as the possibility of deviation in the results from the expected goals, business process reengineering (BPR) initiatives clearly involve risk taking. However, due to the high expected returns of such efforts, the acceptable risk levels of BPR will tend to be greater than those of less ambitious projects. This research reports the development of a tool to quantitatively estimate the potential risk level of a BPR effort before an organization commits its resources to that effort. The underlying research employed a survey of BPR-experienced organizations to collect assessment information in order to build a BPR risk estimation model. The developed tool uses triangular fuzzy numbers to approximate the degree of success/failure of proposed BPR initiatives. The tool can be applied by any organization contemplating BPR, thus giving such organizations a heretofore unavailable estimate of the risk level of proposed BPR efforts. Validation was performed based upon an 18-month BPR project conducted at the Missouri Lottery.

Introduction

In 1992 Goll defined BPR as “total transformation of a business, an unconstrained reshaping of all business processes, technologies and management systems, as well as organizational structure and values, to achieve quantum leaps in performance throughout the business” (Goll, 1992, p. 29). Clearly BPR is synonymous with change, and resistance to change is human nature. The fear of the dramatic changes from BPR, even before they take place, needs to be anticipated and addressed to ensure the success of projects. The major element engendering the fear is the uncertainties associated with BPR, and these uncertainties translate into risks.

The risk of a project is the possibility of deviation in the results from the expected goals. So risk does not equal loss as is sometimes perceived; in fact, it can be an opportunity. Thus risk is a relative concept not an absolute one (Spaulding, 1997). To evaluate the risk of a BPR project it is important not only to look at the risk involved but also at the return. Since BPR projects are
intended to deliver significant improvements, the acceptable risks may be relatively higher than with less aggressive projects.

In order to assist managers in presenting BPR projects to upper management before committing resources, a quantitative risk-assessment tool is needed. Managers are often stranded with limited tools to assess risks and since no formal tools are available, each employs different and often questionable mechanisms to determine the potential benefits BPR can bring to their organizations. The risk of such a practice is even greater than the BPR projects, since the opportunity cost of not implementing BPR can outweigh all the possible difficulties.

The tool developed in this research can be used by any organization contemplating BPR to quantitatively estimate the risks associated with its BPR efforts.

**Literature review**

*Risk – success and failure in BPR*

Previous research has been reported to determine the critical success and failure factors in BPR implementations (Lee, 1995; Crowe and Rolfes, 1998). These success and failure factors equate to risk and will be reviewed in some detail.

**Critical success factors.** Detailed studies have identified four critical success factors in BPR (Lee, 1995). These four factors are:

1. Egalitarian leadership.
2. Collaborative working environment.
3. Top management commitment.
4. Change in management systems.

Due to the nature of BPR, which stresses radical redesign of cross-functional business processes, organizational culture tends to be the focus of these changes. Organizational culture defines the identity of an organization through the common understanding of all business units about the mechanism of the daily operation at that organization (Quinn and Cameron, 1988). This common understanding consists of organizational purpose, performance criteria, chain of authority, legitimate base of power, decision making mechanism, leadership style, compliance, evaluation and motivation (Quinn and Cameron, 1988).

Egalitarian culture fosters a set of common beliefs giving value to positive communication, the cooperative workplace, active information flow, and empowerment of employees. Ideally with BPR employees are to be empowered and to work cooperatively in the new system. Egalitarian culture allows such positive changes to take place with little resistance. Egalitarian leadership is ideologically centered in a democratic system. The interactions between chains of command reflect the organization’s ability to adapt to changes. The major components of such leadership that have proven to affect positively BPR efforts are (Lee, 1995):
Closely related to the egalitarian leadership, collaborative working environment is also identified as one of the BPR critical success factors. Working environment refers to the interactions between coworkers and the level of cooperation shown at the workplace. To be considered a collaborative working environment, the following conditions have to be maintained in the workplace (Lee, 1995):

- friendly interactions;
- confidence and trust;
- teamwork performance;
- cooperative environment; and
- recognition among employees.

Top management commitment is significant throughout the course of the BPR project. In order to achieve maximum potential in a BPR effort changes have to be made to align with the organizational strategic direction, so it is vital to secure commitment from upper management to steer the project. At the same time resistance confronted during the course of the project can be handled most expeditiously with clear top management commitment. In order to have a successful BPR effort upper management must communicate to the affected business units, motivate movement and step in to resolve differences (Stanton et al., 1993). Therefore the following circumstances have to be displayed:

- sufficient knowledge about the BPR project;
- realistic expectation of BPR results; and
- frequent communication with BPR team and users.

In an effort that radically changes the organizational structure, management systems have to be modified to support the newly redesigned processes. Effective management systems monitor behavioral change in BPR efforts by assisting employees in the transition period to the new working environment. Such an effective change management system is characterized by the following managerial support (Lee, 1995):

- new reward systems;
- up-to-date communication methods;
- performance measurement;
- employee empowerment; and
- timely training and education.
Critical failure factors. The seemingly high failure rate of BPR projects has always been one of the major roadblocks in convincing organizations to commit to BPR effort. Based on a 1995 study by the Standish Group International (USA) consisting of 8,380 BPR projects at 365 companies, 84 percent of all projects failed or at least experienced some major problems (Valimaki and Tissari, 1997). Given this unusually high failure rate compared to other types of improvement efforts, finding critical failure factors becomes an important topic for research. Past research shows that there are two primary reasons for such incidents: employee resistance to change (Stanton et al., 1992); and lack of resources for the BPR effort (Bashein et al., 1994).

BPR efforts have always stressed the importance of introducing radical changes to obtain quantum leap improvements. On top of such merit objectives, the effort also demands radical changes in employees’ behavior at work. Since it is human nature to develop inertia, it is their instinctive reaction to resist changes instituted by BPR efforts. The resistance is especially high among employees who are directly affected by these changes. In fact if no resistance is detected, the BPR effort probably is not being done right.

Usually BPR projects require serious commitment of resources from the start until the end. Restructuring an organization is an expensive operation, and on many occasions heavy investment is indispensable to upgrade the information technology system to support newly redesigned business processes. At the same time BPR efforts often call for full-time dedication of personnel directly involved, causing their normal jobs and responsibilities to have to be delegated during the course of the project.

Of the two reasons for BPR failure, quantitative research has concluded that only employee resistance is statistically qualified (Lee, 1995). Employee resistance comes from fear of uncertainties that BPR changes will bring. The most common fear is the fear of downsizing, which has been stereotypically associated with the BPR effort. Even though the objectives of BPR efforts do not include laying off employees, downsizing has been a result of many BPR efforts. Below are the components of this critical failure factor that measure the level of employee resistance (Lee, 1995):

- middle management fear of losing authority;
- employees fear of losing job;
- skepticism about project results; and
- feeling uncomfortable with new working environment.

Definition and assessment of risk
Risk is the potential, or probability, of an adverse event. We deal with risk in our daily lives, simply driving to work and eating our dinner. Even though driving nowadays translates to higher risk than flying due to the higher car accident rate, people tend to believe that flying is riskier because the impact of a flight accident is bigger. People tend to overestimate the likelihood of low probability events (death by tornado) and underestimate higher risk levels
Similarly BPR efforts have been continually viewed as risky business since the changes involved are dramatic. As with any kind of investment BPR projects introduce uncertainties. These uncertainties can result from changes in the working environment, job duties, and organizational structure. It is human nature to resist changes, even if the changes are for the better. From the employees’ perspective this resistance is reinforced by the fear of losing direction in the new system or even not being included in the new system. From the management point of view it is heightened by the uncertainty in estimating the risk and return on the investment due to the limited knowledge.

However, an investment should never be judged based only on the risk, but also on the return. There are two elements of risk:

1. the expected risk of the investment; and
2. the expected return relative to the risk (Spaulding, 1997).

There is no doubt that the potential benefits of BPR effort are huge, thus relatively the risk involved can be high.

Risk assessment has been researched in various areas; for example, finance/investment, conservation biology, insurance business, and so on. Rowe (1977) defines risk assessment as the process of obtaining quantitative or qualitative measures of risk levels. Many risk-assessing methods have been developed in different research areas, especially in the finance/investment domain. These methods range from simple statistical measurements to sophisticated estimating models, including standard deviation, semi-variance, value-at-risk (VAR), and the sharpe ratio (Spaulding, 1997).

**Standard deviation.** Standard deviation is a very commonly used statistical measurement due to its relative ease of calculation. It is a measure of uncertainties and is often considered a tool to measure risk. This measure of dispersion is based on the normal distribution, and the generic formula for calculating standard deviation in terms of investment portfolio is (Spaulding, 1997):

\[
S_c = \sqrt{\frac{\sum (R_i - R(x))^2}{n}},
\]

where:

- \(R_i\) = the return of the \(i\)th portfolio;
- \(R(x)\) = the arithmetic average of all portfolios;
- \(n\) = the number of portfolios.

**Semi-variance.** Semi-variance was introduced to the investment world as a better way to measure risk than standard deviation. Unlike standard deviation, which does not take into consideration that “over-performers” should not be discounted like the “under-achievers”, the semi-variance will only measure the “downside risk”. The semi-variance is simply half the variance of the differences between all
possible points spaced a constant distance apart (Hoskins, 1973). Thus, the formula for the semi-variance for portfolio evaluation is (Spaulding, 1997):

\[ SV(t) = \sum R_i \sigma_i p_i (t - R_i)^2, \]

where

\( R_i = \) a possible return;
\( \sigma_t = \) standard deviation;
\( p_i = \) the probability of the actual return being \( R_i; \)
\( t = \) the target return.

**Value at risk.** Value at risk (VAR) is a new concept in financial risk measurement, which is used extensively for measuring the market risk of portfolios of assets and/or liabilities (Jorion, 1996a, b). VAR summarizes the worst expected loss over a target horizon within a given confidence interval. The one advantage of this risk measurement tool is that its unit is currency, which is more easily understood by common investors.

The two most frequently used VARs are the closed-form VAR and the Monte-Carlo VAR. The closed-form VAR (which is also referred to as the linear- or parametric-VAR) is used to estimate financial risks for simple portfolios by assuming the portfolio’s profitability to be normally distributed. The formula for the closed-form VAR is (Jorion, 1996a, b):

\[ \text{VAR}(t) = PF^* K\% \]

where:

\( t = \) observation time period;
\( PF = \) portfolio;
\( K\% = \sum R(P_RL), \) all occurrences of returns less than \( K\% \) add up to \( P_RL \)
\( \) of the total number of \( t; \)
\( PRL = 100\% – \) desirable confidence interval.

On the other hand, the Monte-Carlo VAR applies Monte-Carlo simulation to randomly construct a histogram of possible profits or losses for a portfolio over a specific time period. The analysis uses the same formula, but the data are the result of the simulation instead of historical information. Relative to the closed-form VAR, Monte-Carlo VAR is difficult to implement in terms of the modeling and the time to run the model (Glasserman et al., 2000).

**Sharpe ratio.** The Sharpe ratio was first introduced in 1966 as a fresh model for financial portfolio management, and was then widely accepted as a common measure of risk. This ratio is a direct measure of reward-to-risk by measuring the excess return that a portfolio provides over the cash return, divided by the standard deviation of the portfolio’s return. The formula for the Sharpe ratio is (Sharpe, 1994):
\[ S(x) = \frac{[R(x) - R_S]}{\sigma(x)}, \]

where:
- \( x \) = amount of investment;
- \( R(x) \) = average annual rate of return of \( x \);
- \( R_S \) = best available rate of return of a “riskless” security (i.e. cash);
- \( \sigma(x) \) = standard deviation of \( x \).

Even though there is a wide array of risk assessment tools readily available, these tools focus mainly on different sets of criteria, based on different sets of factors, and under different sets of assumptions. Since there is very limited research in the area of BPR risk assessment and even less on quantitative methods, the goal of this research is to develop a quantitative risk-assessment tool for managers to evaluate the risk-level of a BPR effort at their organizations before committing themselves to the investment.

**Research methodology**

This research developed a tool that utilizes the critical success factors (CSFs) and critical failure factor (CFF) to assess the risk level of a potential BPR project. In order to develop this tool, a series of activities were performed as follows:

1. define underlying elements;
2. construct questionnaires;
3. conduct survey;
4. analyze data; and
5. present results.

In a previous section the critical factors affecting BPR effort, as discovered by Lee (1995), have been discussed at length. The critical success factors (CSFs) are egalitarian leadership, collaborative working environment, top management commitment, and change in management systems. The only significant critical failure factor (CFF) is employee resistance. These factors will be used to construct the questionnaires.

**Fuzzy sets and fuzzy numbers**

“The key elements in human thinking are not numbers, but labels of fuzzy sets, that is, classes of objects in which the transition from membership to non-membership is gradual rather than abrupt” (Zadeh, 1973). In addition, the process of human thinking often involves approximate reasoning rather than precise determination (Kaufmann and Gupta, 1988). Thus, a fuzzy set is defined as class \( A \) in \( X \) by a membership function \( A(x) \) which associates with each element of \( X \), say \( x \), a real number in \([0, 1]\). \( A(x) \) represents the grade of membership of \( x \) to \( A \); for \( A(x) = 1 \), one has a total belonging, while for \( A(x) = 0 \), one does not belong to class \( A \) (Nola and Sessa, 1989).
Triangular fuzzy numbers (TFN). A TFN, as illustrated in Figure 1, can be defined by a triplet \((a_1, a_2, a_3)\), where the membership function of the TFN is defined as (Kaufmann and Gupta, 1988):

\[
\mu_A(x) = \begin{cases} 
0, & x < a_1, \\
(x - a_1)/(a_2 - a_1), & a_1 \leq x \leq a_2, \\
(a_3 - x)/(a_3 - a_2), & a_2 \leq x \leq a_3, \\
0, & x > a_3.
\end{cases}
\]

**TFN example.** Participants in the research survey used human reasoning to respond to the questions and to rate the success/failure of the BPR efforts they were involved in. Since the underlying data collected are approximate reasoning and fuzzy in nature, TFNs are appropriate to estimate the degree of fuzziness in the success/failure of past BPR efforts.

The only algebraic operation on TFNs that will be applied in this study is the addition of TFNs. Addition of TFNs is proven to yield a TFN: define two TFNs \(A\) and \(B\) by the triplets as \(A = (a_1, a_2, a_3)\) and \(B = (b_1, b_2, b_3)\). Thus the addition of \(A\) and \(B\) will be (Kaufmann and Gupta, 1988):

\[
A(+)B = (a_1, a_2, a_3)(+) (b_1, b_2, b_3) \\
= (a_1 + b_1, a_2 + b_2, a_3 + b_3), a\text{TFN},
\]

where (+) indicates a fuzzy addition.

**Questionnaire development**
As mentioned above the four CSFs (egalitarian leadership, collaborative working environment, top management commitment, and change in

![TFN example](image)
management systems) and one CFF (employee resistance) are used to construct the questionnaire. These factors are further broken down into smaller significant elements of three to five per factor. Each of these elements is represented in a question in the questionnaire. These significant elements are derived from the definitions of the critical factors in Lee’s work (Lee, 1995).

This survey was intended to collect information from organizations that have been through BPR efforts. The main purpose of this survey is not to assess the success or failure of the BPR effort, but to collect information reflective of the general organizational characteristics at the time of the reengineering. The questionnaires were distributed to the leader of or personnel involved in the BPR project at each organization. The survey involved minimal personal exposure and the information obtained was held in strict confidence. No reference was made to specific individuals, names of organization, or types of organization in any report. The participation in this study was completely voluntary, and the participants were free to withdraw from the study at any time without penalty. In fact, a non-disclosure agreement accompanied the survey for privacy protection. The survey questionnaire is shown in Figure 2.

The questionnaire (Figure 2) was used to collect data from organizations identified through various sources to have undergone BPR efforts. Questionnaires were sent to 25 selected organizations in two phases. These organizations were given a period of one month to reply to the survey. Two weeks into the period follow up through e-mail and regular postal mails were done to remind participating organizations of the survey.

Data analysis
Data collection was started as soon as the first survey reply was received. This process took place in approximately two and a half months, and the information collected was compiled into a library of “organizational characteristics” for analysis. While compiling this library, preliminary application of the proposed methodology was initiated with available information. For each organization, an “organizational profile” was created. This profile contained organizational characteristics related to the CSFs and CFF.

To calculate the point for each critical factor two considerations were taken into account: the score for each significant element of the factor, and the weight for each significant element. A score of “1” (strongly agree) would yield a full mark of 1 towards that element; a score of “2” (agree) would yield a mark of 0.5 towards that element; a score of “3” (neutral) would not yield any mark towards the element; a score of “4” (disagree) would yield a negative mark of 0.5 towards the element; and a score of “5” (strongly disagree) would yield a full negative mark of –1 towards the element. Each significant element would carry equal weight towards each critical factor. For example, for a critical factor with four significant elements of scores 2, 3, 1, 4 each, the point for that critical factor would be:
PART A: BPR Effort

On a scale of 0 to 10, please indicate scores for a project that will be considered a total failure, an average, or a great success: Total failure (  ) average (  ) great success (  )

On the same scale, please indicate the score for the BPR project conducted at your organization: (  )

PART B: Egalitarian Leadership

This part contains questions about the characteristics of the general leadership style in your organization. Please answer the questions based on your experience and observation. Please record your answer at the space provided, by the scale indicator.

(1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree)

1. Do managers usually share vision and information with their subordinates? (  )
2. Is there open communication between supervisors and their subordinates? (  )
3. Do managers place confidence and trust in their subordinates? (  )
4. Do managers constructively use their subordinates’ ideas? (  )

PART C: Working Environment

This part contains questions about the attributes of the working environment in your organization. Please answer the questions based on your experience and observation. Please record your answer at the space provided, by the scale indicator.

(1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree)

1. Are there friendly interactions between coworkers? (  )
2. Do coworkers have confidence in and trust each other? (  )
3. Is teamwork the typical way to solve problems? (  )
4. Do coworkers feel as if they are working in a cooperative environment? (  )
5. Is there performance recognition among coworkers? (  )

(continued)
PART D: Top Management Commitment

This part contains questions about how committed the top management of your organization is to projects that introduce changes. Please answer the questions based on your experience and observation. Please record your answer at the space provided, by the scale indicator.

(1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree)

1. Does top management generally have realistic expectation of the projects? ( )
2. Does top management usually have sufficient knowledge about the projects? ( )
3. Does top management frequently communicate with project team and users? ( )

PART E: Managerial Support

This part contains questions about how well the managerial support is set up to accommodate changes introduced by projects abroad. Please answer the questions based on your experience and observation. Please record your answer at the space provided, by the scale indicator.

(1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree)

1. Does the reward system adjust to serve the employees after the changes? ( )
2. Is the communication channel efficient to convey necessary information? ( )
3. Does the performance measurement adequately correspond to the changes? ( )
4. Are the employees empowered to make decisions? ( )
5. Are there training and/or educational programs to update employees’ skills? ( )

PART F: Employee Resistance

This part contains questions about employees’ resistance to the introduction and implementation of projects that introduce changes. Please answer the questions based on your experience and observation. Please record your answer at the space provided, by the scale indicator.

(1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree)

1. Are managers anxious about losing their authority after the changes? ( )
2. Are employees worried about losing their job after the changes? ( )
3. Is there skepticism among employees about the results of the projects? ( )
4. Do employees feel uncomfortable with the new environment? ( )
After calculating all the factor points for an organization, the total CF points of that organization would be the summation of these points. However, the point for critical failure factor would carry a negative effect towards the total points. Thus, the calculation for the total points for organization xyz would be:

$$\sum \text{CF}_{xyz} = \text{CSF}(1) + \text{CSF}(2) + \text{CSF}(3) + \text{CSF}(4) - \text{CFF}.$$  

After acquiring all the total CF points from the targeted organizations, the next phase of the data analysis was initiated.

First, the BPR scores were scaled up by the factor of the number of participating organizations, N. This was necessary to ensure the integrity of the calculation concerning the new TFN that would be created by adding the triplets from the survey, which were the past BPR effort ratings. In order for the BPR scores to be meaningful, they have to be on the same basis as the new TFN. Scaling the BPR scores is like adding N number of identical BPR triplets so that the scores would be on the same plane as the new TFN. Second, the total CF points (X-value) for these organizations and the scaled up BPR scores (Y-value) was fitted onto a simple linear regression model:

$$Y = mX + b.$$  

The underlying assumption was that the correlation between the total points and the degree of BPR success is linear: an organization with high total points has high degree of success. The regression model was used to find the score in the TFN_{ijk} (membership value) of a new organization “ijk” by using the total points calculated based on the same questions about the critical factors for organization “ijk”.

The TFN_{ijk} were applied after the regression model was generated. The ratings provided by the organizations representing the “total failure” ($a_1$), “average” ($a_2$), and “great success” ($a_3$), of a project were the triplets for the TFN. By adding these triplets, a new TFN with new triplets was created:

$$\text{TFN}_{\text{model}} = \sum (\text{TFN triplets}).$$  

Figure 3 shows an example of the new TFN when it is constructed.

The membership function of this TFN was divided into eight segments, each representing a degree of success: from “total failure” to “failure” to “moderate failure” to “minimal failure” to “minimal success” to “moderate success” to “success” to “great success”. These segments were determined by the values of the final TFNs and the $\alpha$-cut level. Alternatively, the interval of TFNs can be defined at level $\alpha$ as shown:

$$A_\alpha = [a_1^{(\alpha)}, a_3^{(\alpha)}] = [(a_2a_1)\alpha + a_1, -(a_3a_2)\alpha + a_3],$$
where $a_1$, $a_2$ and $a_3$ were the three triplets of the TFN, and $\alpha$ was the variable used to determine the parallel cut to the x-axis of the TFN (Kaufmann and Gupta, 1988). In order to have eight segments for the TFN, the $\alpha$-cut value was set at an increment of 0.25.

This new TFN served as a base for computing the likelihood of an organization succeeding in a BPR effort by using the membership value within the TFN, found by utilizing the regression model, as an indicator. The membership value was plotted onto the new TFN and the segment that this value fell onto would indicate the risk level of that new organization if it decides to invest in a BPR effort.

In order to find the risk level ($\alpha$), the indicator has to be set to be equivalent to the following equations:

\[
\text{(i) if } \text{TFN}_{ijk} > a_2, \text{ then } \\
\text{TFN}_{ijk} = A_{\alpha}(IJK) \text{ and } A_{\alpha}(IJK) = -(a_3 - a_2)\alpha + a_3 \\
\text{Thus } \alpha = (\text{TFN}_{ijk} - a_3)/(a_2 - a_3)
\]

\[
\text{(ii) if } \text{TFN}_{ijk} > a_2, \text{ then } \\
\text{TFN}_{ijk} = A_{\alpha}(IJK) \text{ and } A_{\alpha}(IJK) = -(a_2 - a_1)\alpha + a_1 \\
\text{Thus } \alpha = (\text{TFN}_{ijk} - a_1)/(a_2 - a_1).
\]

After finding the $\alpha$ value, it can be interpreted into more user-friendly terms. As discussed above, there would be eight segments where the risk would be assessed. Table I shows a summary of the interpretations.

<table>
<thead>
<tr>
<th>Alpha-value</th>
<th>$\text{TFN}_{ijk} &lt; a^2$</th>
<th>$\text{TFN}_{ijk} &lt; a^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 to 0.25</td>
<td>Total failure</td>
<td>Minimal success</td>
</tr>
<tr>
<td>0.25 to 0.50</td>
<td>Failure</td>
<td>Moderate success</td>
</tr>
<tr>
<td>0.50 to 0.75</td>
<td>Moderate failure</td>
<td>Success</td>
</tr>
<tr>
<td>0.75 to 1.00</td>
<td>Minimal failure</td>
<td>Great success</td>
</tr>
</tbody>
</table>

Table I. Alpha-value risk interpretation
Results and validation

Data collection

To ensure the consistency of the survey results, potential survey participants were prescreened. The BPR projects at these organizations were studied in terms of the magnitude of the projects (e.g. how many departments were involved) and the length of the projects (e.g. two months or two years). All of the research surveys were sent to organizations with projects that were either large (e.g. at least two departments were involved) or lengthy (e.g. lasted at least one year) or both.

Research surveys were sent to organizations across North America to collect data needed to build the proposed methodology. A total of 25 surveys were sent and seven were returned, thus making a return rate of 28 percent. The typical reasons given for declines of participation in the research and non-returned surveys are:

- Personnel involved in previous BPR effort have since left the organizations.
- Lack of resources (e.g. manpower and time).
- Company policy not to participate in survey.
- Difficulty remembering previous BPR effort and the organizational characteristics.

Due to the nature of the survey participation, the returned surveys are anonymous in order to protect the organizational information provided by the organizations. Hence, the specific types of industry these organizations operate in are unrevealed. However, the industry types of the twenty-five organizations were very diverse, ranging from governmental agencies to retail businesses. The summary breakdown of these organizations is presented in Table II.

The majority of these BPR efforts had outside assistance from consultants throughout the whole period of the effort or at a certain time of the reengineering changes. Most of these organizations carried out such effort in order to cut costs and boost productivity in general. Others focused primarily on particular areas for improvements such as supply/demand logistics, procurement systems, technology-related domains (e.g. management

<table>
<thead>
<tr>
<th>Types of industry</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governmental agency</td>
<td>5</td>
<td>0.20</td>
</tr>
<tr>
<td>Technology related</td>
<td>4</td>
<td>0.16</td>
</tr>
<tr>
<td>Consumer products</td>
<td>4</td>
<td>0.16</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>3</td>
<td>0.12</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>2</td>
<td>0.08</td>
</tr>
<tr>
<td>Automotive</td>
<td>2</td>
<td>0.08</td>
</tr>
<tr>
<td>Retail business</td>
<td>2</td>
<td>0.08</td>
</tr>
<tr>
<td>Healthcare</td>
<td>1</td>
<td>0.04</td>
</tr>
<tr>
<td>Utilities</td>
<td>1</td>
<td>0.04</td>
</tr>
<tr>
<td>Insurance</td>
<td>1</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Table II. Industry breakdown of target organizations
information systems and Internet approach), human resources and customer service. Table III summarizes the foci of the BPR efforts.

**Survey data analysis**

As revealed in the survey results, each of the participating organizations has different combinations of organizational characteristics. By using the survey results and the methodology discussed above, the “organizational profile” for each of these organizations is constructed. Figures 4-10 represent the “organizational profile” for the survey participants as shown as a summary trend based on the critical factors discussed and the survey results.

Four of the seven organizations exhibited negative critical factor (CF) points and the other three exhibited positive CF points, thus making this a well-balanced organizational base. As discussed above, a regression model of a straight line will be built using these organizational profiles, to find the X-coefficient and the Y-intercept values. Figure 11 shows the relationship between the CF points of these organizations and the scaled BPR scores.

The values for the X-coefficient and the Y-intercept are 7.475 and 38.328 respectively, thus making the straight line of:

\[ Y = 7.475X + 38.328. \]

After building the regression model, the final TFN was constructed. In order to find the triplets for the final TFN, addition of the triplets of the seven survey participants was carried out.

\[
TFN_{model} = \Sigma (TFN \text{ triplets}) = (4, 37, 67).
\]

Thus, \(a_1(\text{model}) = 4\), \(a_2(\text{model}) = 37\), and \(a_3(\text{model}) = 67\). These values were used in validating the methodology as used by a potential organization that wishes to estimate its BPR risk level. By using these final triplets, the final TFN was then established. The final TFN is shown in Figure 12.

After constructing the final TFN, the methodology is set to be tested by the validating research participant, the Missouri Lottery.

**Methodology validation**

To validate the integrity of the proposed technique, the validation was performed by testing the methodology using the survey results from the target research

<table>
<thead>
<tr>
<th>Area of improvement</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>General improvement</td>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td>Supply/demand logistics</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Procurement systems</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Technology-related</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Human resources</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Customer service</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table III. Focus of BPR efforts</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
</table>
organization, the Missouri Lottery. The Missouri Lottery organizational information from the survey was fed into the methodology and the estimation of risk level in terms of success/failure was then compared to the rating given in the survey.

The Missouri Lottery is a “profit-driven” non-profit organization that was approved in 1984 by the State of Missouri. This is a governmental agency that started its operations in 1986, and is housed under the Missouri Department of Revenue. The organization is governed by a five-member commission, which is...
appointed by the Missouri Governor and approved by the State. The Missouri Lottery main office is located in Jefferson City, with three regional offices located in Kansas City, Springfield, and St Louis. There are five divisions within the organization: the Executive Office, the Finance and Administration Division, the Sales and Marketing Division, the Security Division, and the Communication Division. There are a total of 175 employees from all offices, and the average yearly sales for the last five years are US$425 million. The organization has since provided the State of Missouri with US$1.3 billion in support including educational funding.
Business process reengineering efforts

Figure 10. Organizational profile – G

Figure 11. Regression model

Figure 12. Final TFN

BPR project at the Missouri Lottery. The research project started in January 1999 and ended in June 2000. The working group consisted of members from the University of Missouri and the Missouri Lottery representative as a group leader. The group started the project by examining the various business processes at the Missouri Lottery. As a result, a total of 25 processes were identified and documented. From the analysis of the
processes, the group started to address several areas for improvements via reengineering.

A major reengineering effort was recommended, and the group took a multi-phase modular approach suggested by the upper management of the Missouri Lottery. This approach was initiated by the introduction of an empowered task force by the BPR group to dramatically improve the daily operations that involve Missouri Lottery retailers’ special business needs. Then, the second task force that focused on the promotions and events by the Missouri Lottery was proposed to enhance communications, planning and evaluations of these activities. The third module of the effort was to formulate another task force that would serve as a singular channel where Missouri Lottery can better assist its external customers.

Validation target – Missouri Lottery. The Missouri Lottery representative of the working group agreed to participate in the research survey, and the survey result is used to validate the proposed methodology.

An identical research survey was presented to the representative to collect Missouri Lottery organizational characteristics and the degree of success of the BPR effort conducted. Later the data analysis process as outlined above was carried out to compute the critical factor points and the triangular fuzzy Number for the organization. From the analysis, the Missouri Lottery has organizational-characteristics scores of (where the subscript ML indicates the Missouri Lottery):

\[
\begin{align*}
CSF(1) &= -0.625, \\
CSF(2) &= -0.100, \\
CSF(3) &= -0.333, \\
CSF(4) &= -0.200, \text{ and } CFF = 0.125, \text{ thus } \Sigma CF_{ML} = -1.383.
\end{align*}
\]

Figure 13 represents the “organizational profile” for the Missouri Lottery.

By substituting the total critical factor points into the regression model, the triangular fuzzy number for the Missouri Lottery is:

\[
\text{TFN}_{ML} = 7.475(-1.383) + 38.328 = 27.990.
\]
Recall the triplets calculated above, \( a_1 \) (model) = 4, \( a_2 \) (model) = 37, and \( a_3 \) (model) = 67. Observe that \( \text{TFN}_{\text{ML}} < a_2 \) (model), so the calculation of the \( \alpha \) value for the Missouri Lottery is:

\[
A_{\text{ML}} = \frac{\text{TFN}_{\text{ML}} - a_1 \text{ (model)}}{a_2 \text{ (model)} - a_1 \text{ (model)}} = \frac{27.990 - 4.000}{37.000 - 4.000} = 0.727.
\]

The triplets of BPR success from the Missouri Lottery were \( a_1 \) (ML) = 0, \( a_2 \) (ML) = 6, and \( a_3 \) (ML) = 8, as shown in Figure 14.

By using simple interpolation, \( \alpha_{\text{ML}} \) of 0.727 is equivalent to \( \text{TFN}_{\text{ML}} \) of 4.362. Remember that the result from the survey indicated a score of 4 by the survey participant. Thus the difference of \( \text{TFN}_{\text{ML}} \) and the BPR score from the survey is 0.362.

By dissecting \( \text{TFN}_{\text{ML}} \) into eight segments that depict the eight levels of success/failure, the increment of 1.5 would indicate the beginning of the adjacent level on the range of 0 to 6 on the Missouri Lottery Triplets (e.g. 0.0 to 1.5 indicates the level of “total failure”). Thus, the BPR score from the survey would be under the category of “moderate failure” since the score falls between the range of 3.0 and 4.5. At the same time, the Missouri Lottery’s BPR effort with (ML of 0.727 or \( \text{TFN}_{\text{ML}} \) of 4.362 would fall under the same category. Subsequently, it indicates that the estimated risk level using the model is aligned with the participant’s rating of the BPR effort.

**Conclusion and discussion**

*Observations and discussion*

Observations have been made throughout the course of the research. The low return rate of the research survey (28 percent) has constituted a small sample size for the basis of the proposed methodology. However, BPR projects are large in nature, in terms of both the investments of resources and time. Thus, there are few organizations that have gone through a complete BPR effort and were able to participate in the research survey. In addition, there are limited numbers of organizations that are willing to participate in such research studies.

![Figure 14. Missouri Lottery Triplets](image)
However, research shows that the process of inducting theory using case studies is especially appropriate in new topic areas even when the sample size is fairly small (Eisenhardt, 1989). There are three strengths of using such an approach:

1. likelihood of establishing novel theory (Cameron and Quinn, 1988);
2. developing methodology is potentially testable with constructs that can be readily measured and hypotheses that can be proven false (Hannan and Freeman, 1977); and
3. resultant theory is likely to be empirically valid (Mintzberg, 1979).

In the future, as increasing number of organizations undertake such endeavors, more organizations are likely to be willing to participate in similar research. In addition, these organizations may become more deeply involved in such research instead of merely supplying information for the studies.

Another noteworthy aspect of the research survey was the fact that it was a retrospective approach versus a longitudinal study because the data collected through the survey were historical information. This matter might have resulted in a potential preconception by the survey participants between the BPR success/failure and the factors presented in the survey.

To recall the validation of the proposed methodology, the Missouri Lottery’s BPR effort has $\alpha_{ML}$ of 0.727 or TFN$_{ML}$ of 4.362, and the survey indicated a four. The difference of 0.362 can be attributed to the fact that the participant in the survey answered the survey with a discrete number, and the calculation of TFN$_{ML}$ is in non-integer number. In a sense, the calculation of TFN$_{ML}$ actually reflects the participant’s rating on the BPR effort.

**Conclusion**

Most research on BPR has focused on approaches to document business processes, and on techniques to identify and select potential candidates for reengineering. Limited research has been conducted in the area of assessing the risk of such efforts, especially on quantitative risk estimation.

By using real world data collected from organizations that have experienced radical changes through BPR efforts, a research model based on triangular fuzzy numbers has been developed and validated. The resultant research model was used to develop a tool that allows any organization considering BPR to quantitatively estimate the potential risk level of those BPR efforts before committing resources to BPR. Heretofore, no such quantitative BPR risk assessment tool was available. Having such a quantitative BPR risk assessment tool will improve management’s a priori insights into the potential outcomes of BPR. Continuing work is expected to show that such insights will improve the overall success rate of BPR initiatives.

**References**


