The Study on the Back Propagation Neural Networks in the Prediction of Management Associate Work Retention for Small and Medium Enterprises

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Abstract. Because the investment in employee education and development represents a significant capital expenditure, the recruitment how employees' characteristics, professional skills and abilities meet the required standards is an important issue of business management. In small and medium enterprises selecting appropriate individuals to fill management positions has a significant challenge. This paper focused on the case study utilizing the data of 100 management trainees using back propagation neural networks to determine the probability of retaining management associates. Several surprising findings were obtained. Implications for win-win employee-employer relations and practice are addressed.

Introduction

Since Schultz (1961) introduced the notion of “human capital” in the early 1960s, enterprises have increasingly emphasized the development of human resources. Over the decades “personnel affairs” became “human resources (HR)”, and firms began to initiate holistic programs to promote the overall well-being of employees, rather than focusing solely on their working competence. This inspired a great deal of corresponding discussions on the concept of “value-creation through employees” among academic community. Hurrell and Scholarios (2014), for example, investigated the effect of corporate-staff relations on brand values, Ployhart and Moliterno (2011) evaluated mechanisms for sharing professional knowledge, experience, judgement, and preferences and Barney et al. (2011; 1991) used resource-based theory to describe corporate HR development practices.

The recruitment and training new employees is an important issue of corporate HR development. The relationship between the psychological changes in a new employee, and employee fulfillments and contributions as perceived by the employer is a widely argued in HR (Fitzsimmons and Stamper 2014; Bambacas and Kulik 2013; Björkman et al. 2013; Lee et al. 2011; Hui et al. 2004).

Wright and McMahan (2011) claimed the difficulties of increasing hired talent in order to produce management associates (MAs). They focused on decreasing the “rial-and-error cost” of between employee and employer and creating an optimal trade-off between investment in employee training and the retention of effective employees. In order to ensure to recruit the right person who works in the right place, HR management entails not only the initial stage of staff recruitment and professional training, but also subsequent performance screening. The
development appropriate internal management in the small and medium enterprises (SME), in particular, is important, because the external recruitment is difficult and the cost of training is expensive for these small firms. A lack of effective MAs will hinder long-term development of firms. The existing scholarship, however, has not tackle this problem, the cost of recruitment and training MAs is greater than that of the ordinary staff.

This study applied neural networks, which has been widely used as a prediction tool in the field of HR over the last 20 years (Jantan et al. 2009). Examples include studies into employee career development (Huang et al. 2006), recruitment and selection (Chien and Chen 2008), and professional attitudes (Tung et al. 2005). In the perspective of the considerable body of research regarding human resource management, Strohmeier and Piazza (2012) argued that the technique will continue to undergo development. Due to the human activities depending the learning and making process, the neural network technique assists decision making process. This study therefore applied neural networks to construct the prediction model of the personal and professional performance of MAs.

This paper divided into four sections: introduction, secondly I briefly interpret the back propagation (BP) neural network method, thirdly the establishment of the prediction model, the purpose of which was to determine the possibility of that the MAs observed in the case study retaining their jobs. It also reveals the preliminary analysis and results. Conclusions are drawn in the final section.

**Back Propagation (BP) Neural Network Method**

The BP method is derived from the artificial neural network (ANN) technique developed by Rumelhart et al (1985). The inclusion of BP increases the accuracy of prediction through its consideration of the interaction between inputs and outputs (Liu and Xiong 2007; Hecht-Nielsen 1989). This makes it a more effective evaluative model than traditional discriminant analysis and multiple logistic regression.

The BP neural network method comprises three layers: an input layer, a hidden layer, and an output layer. Nodes occur on each layer and these nodes are connected by forward and back propagation. This two-way propagation strengthens the indicators. If the desired result does not achieve the output layer, the network automatically enters back propagation; next, it searches for appropriate weighting values to realize the correct network output.

![Figure. 1 Typical structure of BP neural network](image)

Consider sample set x(x=1, 2,..., X) and set output k(k=1,2,...,K) from output layer O_{kx} of a BP neural network. Assume input layer wkjand hidden layer vji are linked due to equivalent weight values. The output then consists of the hidden layer and output layer and utilizes the bipolar function. The error function E can be defined as a square function:
\[ E = \frac{1}{2} \sum_{x=1}^{X} \sum_{k=1}^{K} (d_k - O_{kx})^2 \]  
(2.1)

Where \( d_k \) denotes the corresponding desired output value.

Learning process is the essential part of the BP neural network, so weight values must be constantly revised in order to shift the error function \( E \) to zero. According to the principle of error gradient decline, the adjustment of \( w_{kj} \) and \( v_{ji} \) can be described as follows:

\[
\Delta w_{kj} = -\eta \frac{\partial E}{\partial w_{kj}} 
\]  
(2.2)

\[
\Delta v_{ji} = -\eta' \frac{\partial E}{\partial v_{ji}} 
\]  
(2.3)

where \( \eta \) and \( \eta' \) denote the rate of learning.

Amending weight values is an iterative process, that is

\[
\begin{align*}
    w_{kj}(n+1) &= w_{kj}(n) + \eta \sum_{x=1}^{X} \delta_{kx} O_{jx} \\
    v_{ji}(n+1) &= v_{ji}(n) + \eta' \sum_{x=1}^{X} \delta_{jx} O_{jx}
\end{align*}
\]

In this equation:

\[
\begin{align*}
    \delta_{kx} &= (d_k - O_{kx}) O_{kx} (1 - O_{kx}) \\
    \delta_{jx} &= (\sum_{k=1}^{K} \delta_{kx} w_{kj}) O_{jx} (1 - O_{jx})
\end{align*}
\]  
(2.4)

The procedure of the BP neural network is summarized in the following steps:

1. Set up the weight value, given a random number e.g. from zero to one.
2. Input raw data with a maximum acceptable error value of the sample which can attempt to meet the expectations of the output layer neural.
3. Compute the real output in each layer.
4. Amend the weight value through back propagation, moving from the output layer to the preceding hidden layer.
5. Repeat Steps (1) to (4) until error function returns a value below that specified in (2).

**An Illustrative Example**

Firm Y is a leading apparel company with twenty years experience and over 1,600 employees. The management found a waning level of performance attributable to their aging workforce. There were no procedures in place to facilitate the training of younger employees. High-level, experienced personnel with engineering and management graduate degrees were required to replace outgoing managers. Firm Y hired 20 professionals and positioned them in...
the following departments as part of their MA training program: accounting, engineering design, executive assistance, manufacturing, and marketing.

Firm Y then constructed a knowledge-based system to avoid the human resource gap from re-occurring. To predict the probability of retaining their MA trainees, the system used 100 management trainees from the past two decades to create the learning process, and took the current 20 MA program participants as the inference sample. During their probationary period, the following characteristics were considered: professional background, adaptation to the new work environment, knowledge sharing, and job performance.

To create a predictive model, two quantitative indicators for job performance were defined: previous working experience, and family status (single/married/married with children). Three qualitative criteria were also introduced, namely professional proficiency, cooperative ability, and work stress tolerance. These were evaluated by an immediate superior using a 1-10 scale rating (10=extremely satisfied; 1=extremely unsatisfied). Table 1 presents the definition of each indicator.

Table 1 Definitions of inputs and outputs for firm Y’s MA evaluation

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Definition</th>
<th>Data type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous working experience</td>
<td>Working years before report-for-duty of firm X</td>
<td>Continuous</td>
</tr>
<tr>
<td>Family status</td>
<td>Single=0; Married=1; Married with children=2</td>
<td>Discrete</td>
</tr>
<tr>
<td>Professional proficiency</td>
<td>1-10 rating scale given by immediate superior</td>
<td>Discrete</td>
</tr>
<tr>
<td>Cooperative ability</td>
<td>1-10 rating scale given by immediate superior</td>
<td>Discrete</td>
</tr>
<tr>
<td>Work stress tolerance</td>
<td>1-10 rating scale given by immediate superior</td>
<td>Discrete</td>
</tr>
<tr>
<td>The probability of staying in firm X</td>
<td>0=Stay; 1=Leave</td>
<td>Discrete</td>
</tr>
</tbody>
</table>

In terms of factors affecting the MA’s willingness to continue working in firm Y, Table 2 shows that work stress tolerance was the most significant indicator, followed by cooperative ability. The least important factor was family status. These results indicate that working attitude is far more important than personal characteristics.

Subsequently, the BP neural network prediction model was applied in the inference case of the 20 current MAs. It ascertained that four of the MAs were likely to resign from their
positions following the probationary period. Table 3 presents the significance of each indicator in terms of its power to predict the retention of MAs. Interestingly, work stress tolerance and cooperative ability were below average. In other words, the phenomenon can be seen that the problem is occurred in the MA her/himself working attitude or recognition.

Table 2 Weight value of each factor as assigned by BP neural network

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Weight values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous working experience</td>
<td>0.0068</td>
</tr>
<tr>
<td>Family status</td>
<td>0.0010</td>
</tr>
<tr>
<td>Professional proficiency</td>
<td>0.0215</td>
</tr>
<tr>
<td>Cooperative ability</td>
<td>0.0349</td>
</tr>
<tr>
<td>Work stress tolerance</td>
<td>0.0354</td>
</tr>
</tbody>
</table>

Subsequently, the BP neural network prediction model was applied in the inference case of the 20 current MAs. It ascertained that four of the MAs were likely to resign from their positions following the probationary period. Table 3 presents the significance of each indicator in terms of its power to predict the retention of MAs. Interestingly, work stress tolerance and cooperative ability were below average. In other words, the phenomenon can be seen that the problem is occurred in the MA her/himself working attitude or recognition.

Table 3 Indicators showing probability of retention of current MAs

<table>
<thead>
<tr>
<th>MA</th>
<th>Previous experience</th>
<th>Family status</th>
<th>Professional proficiency</th>
<th>Cooperative ability</th>
<th>Work stress tolerance</th>
<th>The probability of staying in firm Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>5</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
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<tr>
<td>6</td>
<td>3</td>
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<td>2</td>
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<td>4</td>
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<tr>
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<td>1</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
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<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
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<td>4</td>
<td>4</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
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<td>1</td>
<td>4</td>
<td>6</td>
<td>8</td>
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<td>0</td>
<td>5</td>
<td>5</td>
<td>7</td>
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<tr>
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<td>5</td>
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<td>2</td>
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<td>6</td>
<td>6</td>
<td>0</td>
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<tr>
<td>16</td>
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<td>0</td>
<td>4</td>
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<td>4</td>
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</tr>
<tr>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>5</td>
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<tr>
<td>18</td>
<td>2</td>
<td>1</td>
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<td>2</td>
<td>7</td>
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<tr>
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<td>1</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

In order to examine the accuracy of the BP prediction model, in the week before the end of the probationary period firm Y issued an anonymous questionnaire to evaluate the current MAs’ intention of remaining in their positions. The results were in accordance with the
predictions presented in Table 3: #4, #16, and #20, which intended to leave firm Y and while #17 expressed the intention to stay, his performance was considered to be ‘unfit for the position’ by the management of firm Y. The example clearly indicates the high level of accuracy of the proposed BP network prediction model.

Discussion and Conclusion

Based on our Results, This Study Makes the Following Recommendations:

1. Effective long-term employee-employer relations are based on mutual compatibility, especially for higher level positions. Integrating the corporate reserve cadre into the organizational culture is obviously an important issue because of the ‘talent shortage phenomenon’ is widely common in SMEs. It is also important for firms to work to develop as a transparent, inclusive, and collaborative organization in order to attract quality talent.

2. Despite advancements in recruitment procedures such as multi-dimensional career psychology tests, professional skill tests, and face-to-face interviews, many blind spots remain. The probationary period plays the role of gatekeeper, but involves high costs in terms of training time and financial resources. Enterprises, particularly SMEs, need to implement HR validation mechanisms in order to prevent the outflow of funds, knowledge, and time on staff education and training. This study provides a practical tool with strong predictive power in the form of the BP neural network for examining the suitability of MAs.

3. Our results show that working attitude and interpersonal skills were better indicators of MA retention than that of the profession. It seems that effective interpersonal relationships are the key for the training of new MAs. They allow a smooth transition to a new corporate culture and facilitate a win-win relationship between employer and employee. In addition to emphasize the idea of the staff functioning as the ‘family’ of the firm when training new employees, management must be aware of newcomers who fail to integrate into the internal culture of the firm. Prompt decisions may allow managers to avoid unnecessary losses.

This study only focused on the intentions of MAs during the probationary period, which meant the sample primarily comprised job seekers in entry-level positions who possessed little work experience. Possible directions for future research include targeting recently recruited senior managers. Although examination of trends of these employees during the probationary period might not produce dramatic results, it is reasonable to assume that the results would present more meaningful implications.

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