Evaluation of highway construction foreman’s competency based on support vector machine

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Abstract. The purpose of this study was to scientifically and quantitatively evaluate highway construction foreman’s competency. This article divided the foreman’s competency into four dimensions: knowledge dimension, personality dimension, ability dimension and development dimension, including 22 competency elements. The rationality of the competency model was tested by confirmatory factor analysis method and structural equation model. A support vector machine model was trained to evaluate the overall competency of highway construction foreman. The case study shows that the SVM evaluation model has high accuracy and can reliably identify the foreman with excellent competency.

1. Introduction
The highway construction industry is a project-based industry. The success or failure of the project not only affects the development of the enterprise, but also has obvious social effects. In the highway construction project, the foreman is the manager of the grassroots in the nearest position to the ordinary workers, and is the most important link between senior managers and workers [1]. The management system and management methods of the project require the foreman to lead the team to implement. Therefore, it is necessary to study the ability structure and evaluation methods of the foreman.

Competency model is an effective method to identify and evaluate people’s ability. Harvard psychologist R W White took the lead in proposing the concept of “competence” to characterize individual ability [2]. Inspired by the results of White, D C McClelland proposed a competency approach based on competence rather than talent [3]. R E Boyatzis extracted the basic competencies necessary for work: knowledge, motivation, traits, self-impression, social roles, skills, etc. [4]. Y F Wang proved that people with higher competency assessments can be more devoted to work and usually have better job performance and successful career [5].

Chinese scholars agree that due to differences in culture and social systems, the competency model in China should be combined with specific domestic research, and at the same time be in line with the international standard. H Z An pointed out that the competency model can be divided into model based on posts, model based on professional, model built according to the role of individual employees in the organization and model based on different strategies from the enterprise perspective [6-7]. J F Peng proposed that the competency model of frontline executives is usually divided into dimensions such as initiative level, intensity and completeness of action, and size of influence range [8]. Y H Jin et al. pointed out that the different dimensions of the competency model have different effects on job performance [9].
Through research, it can be found that the use of competency model can achieve a comprehensive evaluation of the capacity of the highway construction foreman. However, the specific content of the highway construction foreman’s competency model is still lack of targeted research. With the advancement of science and technology and the continuous development of highway construction, the original evaluation methods based on the independence and linear relationship between indicators cannot be well adapted to the nonlinear relationship among the elements in the competency model. Therefore, this paper firstly combined the work content of highway construction projects and built a competency model system for the highway construction foreman; then constructed an intelligent evaluation model capable of nonlinear relationship between independent learning indicators based on support vector machine; at last gave an enterprise’s final competency evaluation results.

2. Competency evaluation index

2.1 Index construction

This paper referred to the international and domestic requirements for the capacity of the highway construction foreman, and built the competency model based on the specific work content of the highway construction project. Combining the competency guidelines of project managers in the United States and the United Kingdom with the requirements of the foreman in China, it can be concluded that the foreman’s competency model should normally have the following dimensions:

Knowledge dimension. The foreman should be able to master certain project management knowledge and be able to handle relevant technical issues during the project construction process. Therefore, the foreman should have knowledge such as: construction process, construction safety, equipment operation, document writing, schedule control, cost control and personnel coordination.

Personality dimension. People’s personality characteristics and behavioral traits play an important role in the individual’s ability, so it is an indispensable dimension of the foreman’s competency. The American Project Management Association proposed the personality traits that construction personnel should have, including: executive power, cooperation, influence, cognition, and operational efficiency.

Ability dimension. The ability dimension refers to the ability of people to cope with complex environments and situations, and is one of the most important abilities of high-level talents. The UK International Project Management Association proposed the capabilities of project managers in a complex environment and context, including: project processing, team retention, health, safety and environment (HSE) support, financial capability and law capability.

Development dimension. Development and learning are the inevitable requirements of a learning society. The American Project Management Association proposed the project management personnel’s learning abilities, including: determining objectives, quantifying standards, assessing their own abilities, clarifying their own gaps, and progressing actions.

In summary, the competency model of the highway construction foreman has a total of four dimensions and 22 evaluation factors, as shown in table 1.

| Knowledge dimension | Personality dimension | Ability dimension | Development dimension |
|---------------------|----------------------|------------------|----------------------|
| A1 Construction process | B1 Executive power | C1 Project processing | D1 Determining objectives |
| A2 Construction safety | B2 Cooperation | C2 Team retention | D2 Quantifying standards |
| A3 Equipment operation | B3 Influence | C3 HSE support | D3 Assessing their own abilities |
| A4 Document writing | B4 Cognition | C4 Financial capability | D4 Clarifying their own gaps |
| A5 Schedule control | B5 Operational efficiency | C5 Law capability | D5 Progressing actions |
| A6 Cost control | | | |
| A7 Personnel coordination | | | |
2.2 Confirmatory factor analysis
In order to test the effectiveness of the above-mentioned competency model, we introduced the confirmatory factor analysis method. The 22 competency evaluation indicators were made into the assessment scale, and the Likert five-level scoring method was adopted. The assessors scored from 1 to 5 according to the importance of each index of competency. A total of 300 questionnaires were distributed and 297 valid questionnaires were returned. The structural equation model was built by AMOS software. The final results are shown in table 2:

Table 2. Results of CFA.

| Evaluation index | Fitting result | General requirements for fitting |
|------------------|----------------|---------------------------------|
| CMIN/DF          | 1.748          | <3.000                          |
| SRMR             | 0.046          | <0.050                          |
| GFI              | 0.900          | >0.900                          |
| CFI              | 0.958          | >0.900                          |
| RMESA            | 0.050          | <0.050                          |

It can be seen that the fitting indices of the confirmatory factor analysis are all in line with the requirements, and the normalized factor loads of the 22 indicators in the four dimensions are between 0.5 and 0.95, which are all significant at the 0.001 level, indicating that the model fits well.

3. Support vector machine evaluation method
The Support vector machine (SVM) is an algorithm proposed by C Cortes and V Vapnik based on statistical theory. It can effectively solve the classification problem of small sample datasets [10]. The idea of SVM is to find an optimal hyperplane that separates the different classes of samples, that is, the hyperplane farthest from the sample. First, the sample is mapped from the original space to the high-dimensional space. The model corresponding to the hyperplane in the feature space can be expressed as:

\[ f(x) = w^T \phi(x) + b \]  

(1)

In equation (1), \( w \) and \( b \) are hyperplane parameters. For the classification problem, the sum of the distances from the training sample points to the hyperplane is:

\[ \gamma = \frac{\gamma}{\|w\|} \]  

(2)

In equation (2), \( \gamma \) represents the number of intervals. SVM requires the hyperplane that is the farthest from the samples:

\[ \max_{w, b} \frac{\gamma}{\|w\|} \]  

s.t. \( y_i (w^T \phi(x_i) + b) \geq 1, i = 1, 2, \cdots m. \)  

(3)

In equation (3), \( y_i \) represents the corresponding classification. In order to maximize the interval, it only needs to maximize\( \|w\|^{-1} \), that is, to minimize\( \|w\|^{\frac{1}{2}} \). In the actual situation, it is difficult to have a hyperplane to completely separate the different types of samples, and in order to alleviate the over-fitting, we introduce a slack variable \( \xi_i \geq 0 \), then equation (3) can be rewritten as:
\[
\min_{\omega,b,\xi} \frac{1}{2} \|\omega\|^2 + C \sum_{i=1}^{m} \xi_i \\
\text{s.t.} \quad y_i (\omega^T \phi(x_i) + b) \geq 1 - \xi_i \\
\xi_i \geq 0, i = 1, 2, \ldots, m.
\] (4)

The dual problem of the above is:
\[
\max_{\alpha} \sum_{i=1}^{m} \alpha_i - \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \alpha_i \alpha_j y_i y_j \phi(x_i)^T \phi(x_j) \\
\text{s.t.} \quad \sum_{i=1}^{m} \alpha_i y_i = 0 \\
0 \leq \alpha_i \leq C, i = 1, 2, \ldots, m.
\] (5)

Set kernel function \(k(\cdot, \cdot)\)
\[
k(x_i, x_j) = \langle \phi(x_i), \phi(x_j) \rangle = \phi(x_i)^T \phi(x_j)
\] (6)

Then equation (5) can be rewritten as:
\[
\max_{\alpha} \sum_{i=1}^{m} \alpha_i - \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \alpha_i \alpha_j y_i y_j k(x_i, x_j) \\
\text{s.t.} \quad \sum_{i=1}^{m} \alpha_i y_i = 0 \\
0 \leq \alpha_i \leq C, i = 1, 2, \ldots, m.
\] (7)

After solving it can be obtained:
\[
f(x) = \omega^T \phi(x) + b = \sum_{i=1}^{m} \alpha_i y_i k(x, x_i) + b
\] (8)

4. Case study
We applied the competency model to a highway construction enterprise, and the sub-item and the overall score of the 22 competency indicators were collected. For the sub-item score, 1 was poor performance and 5 was excellent. For the overall competency indicators, according to high competency, medium competency and low competency, the scores were 3, 2, and 1. A total of 200 data were collected, and the proportion of high competency was 23%, the proportion of medium competency was 58%, and the proportion of low competency was 19%.

Data collected from 200 questionnaires were randomly sorted, the first 100 sets of data were used as training data, and the last 100 sets of samples were used as test data. The SVM model was implemented by Libsvm, and the radial basis function (RBF) was selected as the kernel function. The optimal penalty parameter \(C\) and kernel function parameter \(g\) of SVM were determined by grid search. Finally, it was found that when \(C=8.0, g=0.0078125\), the error was the smallest, and the SVM model at this time was the optimal model. The parameter selection diagram of the SVM model is shown in figure 1:
Figure 1. Support vector machine model parameter selection diagram.

The untrained post-100 data was putted into the SVM model for testing, and the accuracy was 91%, indicating that the model performed well. The error of the test set was analyzed, and the error analysis matrix is shown in table 3 below.

Table 3. SVM model error analysis matrix.

| Predictive value | True value | 1 | 2 | 3 |
|------------------|-----------|---|---|---|
|                  | 1         | 17| 0 | 0 |
|                  | 2         | 0 | 54| 2 |
|                  | 3         | 0 | 7 | 20|

As can be seen from the above table, among the 9 data of the model prediction error, 2 of the data with a true value of 2 are predicted to be 3, and 7 of the data with a true value of 3 are predicted to be 2, indicating that the model tends to predict the high competency foreman to medium competency, that means the model prediction is conservative. At the same time, the model predictions of the data with a true value of 1 are all correct, indicating that the model is accurate for the foreman with low competency.

5. Conclusion

This paper referred to the international and domestic requirements for the capacity of the highway construction foreman and combined the specific work content of the highway construction project to construct the competency model. Through CFA, the rationality of the indicator was verified. Through SVM, the evaluation method of the foreman’s competency was constructed. The reliability and accuracy of the evaluation method were shown by the case verification.

Compared with other evaluation methods, the advantages of competency evaluation based on SVM method are as follows: compared with the human evaluation, the SVM model evaluated competency...
automatically by computer, which can minimize the impact of human scale. Compared with the evaluation methods such as analytic hierarchy process, fuzzy comprehensive evaluation method and factor analysis method, the SVM evaluation method can learn the nonlinear correlation between indicators so it is closer to the actual situation. Compared with artificial intelligence methods such as the neural network, the SVM has better performance in the case of small sample datasets. It is less over-fitting with strong generalization ability.

The highway construction foreman’s competency model is a relatively conservative model. The foreman selected under this model can ensure the completion of the highway construction project, and the model is more in line with the actual needs of the highway construction project. At the same time, the model is accurate for the foreman with low competency, so it can reliably select and exclude the incompetent foreman.

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References
[1] Wang, H.P., Lian, S. (2015) Analysis of the position and behaviour of the team leader in the organization network. China Youth Study, 10: 5-11.
[2] White, R.W. (1959) Motivation reconsidered: the concept of competence. Psychological Review, 66: 297-333.
[3] McClelland, D.C. (1973) Testing for competence rather than for “intelligence”. American Psychologist, 28: 1-14.
[4] Boyatzis, R.E. (1982) The Competent Manager: A Model for Effective Performance. John Wiley & Sons, Inc., Hoboken.
[5] Wang, Y.F. (2013) Constructing career competency model of hospitality industry employees for career success. International Journal of Contemporary Hospitality Management, 25: 994-1016.
[6] An, H.Z. (2003) Construction and perfection of characteristic model of being-competent-at-jobs. Research on Economics and Management, 4: 42-45.
[7] An, H.Z., Wu, M.J. (2003) Competency model. Career, 3: 15-17.
[8] Peng, J.F., Jing, X.J. (2003) Employee Quality Model Design. People’s University Publication House, Beijing.
[9] Jin, Y.H., Chen, W.Q., Wang C.M. (2004) The relationship between managerial competency and job performance. Psychological Science, 27: 1349-1351.
[10] Cortes, C., Vapnik, V. (1995) Support-vector networks. Machine Learning, 20: 273-297.