A FRAMEWORK OF ORGANIZATION PERFORMANCE ASSESSMENT IN THE CONSTRUCTION INDUSTRY USING FUZZY APPROACH

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Abstract: Organizations have been trying to increase their efficiency and improve their performance in order to achieve their goals. The organizational success is determined by various factors that impact organization's performance. The ability to predict construction organization performance will enable practitioners to identify the weak points and in searching solutions to improve, thus leading to better efficiency and increase profit. Previous research works have focused on measuring project success and in the process the importance and evaluation of organization's performance in non-financial aspects has received little attention. Uncertainty and uniqueness of projects are inherent characteristics of this industry. Hence, developing an effective construction performance assessment model has been very difficult. Therefore, the objective of the present research is to identify and study the success factors and to propose a performance prediction model(s) for construction organizations. The potential success factors are collected from literature and shortlisted based on construction expert's opinion. A questionnaire is prepared and sent to evaluate the effect of these potential success factors on organizational performance. The collected data will be analyzed using Fuzzy modelling approach to build a prediction model, which will show robust results when verified and tested. The proposed research/model will benefit both researcher and practitioners to predict accurate company performance.

1 INTRODUCTION

Construction is a diverse, project based industry (Ozorhon, 2012). The project-based nature of construction industry makes every project unique (Veshosky, 1998). The unique nature of concerns and challenges often render the generalizable decision rules and frameworks for organizational phenomena unusable (Pinto & Covin, 1989). Financial and tangible assets gained are often translated to organization success. In a review of project success factors conducted by Müller et al. 2012, it is has been noted that project success was considered only as a subject of implementation in the 1980s. The approach towards the subject has evolved over the years. It is now gradually extending from inception to closing out of a project. Today, the literature in this field spans the entire product life cycle from product success to business success. This change has led to shift in emphasis from project success to organization success. The need to examine A/E/C organizations and the factors that impact the performance of organizations is now necessary to compete in an ever-changing marketplace (Liu et. al., 2014).

2 BACKGROUND

A company is a complex structure, comprising of various interconnected components that influence its performance (Tang & Ogunlana, 2003). The existing literature shows that numerous models were developed to measure performance by using critical success factors, performance measures, and
indicators. However, they mostly address metric requirements for the manufacturing industries rather than construction. Studies conducted in the construction industry have laid more emphasis on the measurement of project performance rather than company performance (Isik, Arditi, Dikmen, & Birgonul, 2010). Bontis et al. 1999 proposed Balanced Scorecard (BSC). The framework laid emphasis on qualitative measure at organizational level and advocated the balance between measure of financial and non-financial success. Another example of performance measurement and management framework is Performance Prism. The first part of this framework encourages to assess stakeholder satisfaction, and assess the needs of stakeholder. The second part is to understand the needs of organization (i.e. reciprocal relationships) as well as on how to align strategies, processes and capabilities (Neely et. al., 2001). The prism focuses on significant measures and connects the performance practices within the organization. These frameworks are more than a decade old. Hence, in order to keep up with the ever changing markets, many new studies are being carried out.

Performance prediction of construction organizations enables identification of the weak points in order to improvise processes and to increase profits (Zayed et al. 2012). The attention of organizations is usually focused on improving the efficiency of its tangible assets as they can be measured and evaluated (Hauser & Katz, 1998). In the process, the organizations often do not consider the invisible and intangible assets that impact the overall performance. A good metric systems empowers organization (Hauser & Katz, 1998). In a recent study and analysis of a case study by Gustavsson et al., 2012, a need for new collaborative project practice development and organizational change has been discussed. Company performance can be assessed by evaluation of measurable characteristics of performance indicators (Bititci & Muir, 1997).

2.1 Critical Success Factors in construction organization

Organizations that focus on satisfying the customers with greater efficiency and effectiveness have an edge over their competitors (Neely et. al., 2005). Studies have shown that practitioners have been able to settle that improving communication has a major impact on construction practice. It allows better customer engagement, leading to better performance of organizations. Neely et al. 2005 stresses on importance of metrics associated with quality, time, cost and flexibility, thus relating performance of organizations with project success. Pinto and Covin (1989), Müller et al, 2012 have discussed that project success is dependent on the interaction of individuals, project teams and organizational success. Chinowsky et al. 2000 proposed the concept of seven guiding principles of strategic management for construction industry. These comprise of Vision, Mission, Goals, Core Competencies, and Knowledge resources, Education, Finance, Markets and Competition (Chinowsky & Meredith, 2000). Knowledge and information are now considered as critical factors that influence a company's life. They are rated higher than land, capital or labor (Bontis & Dragonetti, 1999). A good knowledge data base will allow organizations to leverage against their competitors in future and thus giving organizations a competitive edge (Arthur, 1994). Unfortunately, Knowledge being an intangible asset is difficult to measure and hence often forgotten in the process (Bontis & Dragonetti, 1999).

Organizations are conceptualized as “the product of though and action of [their] members” (Gioia & Sims, 1986) or as Weick 1987 stated “the body of thought by organizational thinkers” (Nicolini & Meznar, 1995). Human elements are the assets of organizations that are capable of learning, evolving, innovating and creatively propelling the growth of organization, which is essential for long-run survival of the organization. It has been noted that majority of Human Resource Accounting (HRA) techniques have been designed for industries like accounting firms, banks, insurance companies and financial service firms, where human resources represent a substantial share of the organization value (Bontis & Dragonetti, 1999). However, construction organization lacks such initiatives that are designed to evaluate employee performance, satisfaction and compensation. Factors such as organization’s employee culture and engagement are important aspects for an organization. Other important factor is the feedback systems, as they are extremely crucial for implementation of metric system and evaluating performance of organization. Feedback evaluation is one of the critical success factors that aid in analyzing and improving organization performance (Hauser & Katz, 1998).
2.2 Previous studies

In a study conducted by Zayed et al. 2012 classified 18 Critical Success factors into four categories, i.e. (i) Administrative and legal factors, (ii) Technical factors, (iii) Management and (iv) Market and finance, as shown at Figure 1.

![Critical Success Factors Diagram]

The research work is in continuation to the study carried out by Elwakil et al. 2009. The previously published paper was an overview for an outline or a framework for performance assessment of organizations in construction industry. The procedure included a literature review and identification of 18 potential critical success factors. This was followed by preparation of questionnaire designed to assess the impact of these factors in construction industry. The questionnaire had two parts where Part I asked the experts from construction organizations to answer the questions, reflecting their experience and corporation information. Part II asked the experts to use a specified 5 point subjective scale to rate the impact of identified success factors on organization performance. Additionally, the decision-makers were asked to evaluate the overall success of his/her construction organization using a value out of 100. One hundred and fifty questionnaires were sent out to top and middle management decision makers in construction organizations across different countries, i.e., Canada, Egypt, France, Greece, Germany, USA, Saudi Arabia and United Arab Emirates. A total of Sixty three responses were received i.e. A response rate of 42%, which is considered good. A sample response from data is provided in Table 1 (Zayed et al., 2012).
Table 1: A sample of questionnaire

<table>
<thead>
<tr>
<th>Category</th>
<th>Success Factors</th>
<th>Responses (Scale: 1-5)</th>
<th>Sample #3</th>
<th>Sample #4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Competition Strategy</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Organizational Structure</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Political Conditions</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Number of Full Time employees</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Technical</td>
<td>6. Usage of International Aspects (ISO)</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. Availability of Knowledge</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8. Usage of IT</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9. Business Experience (no. of years)</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10. Product Maintenance</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td>11. Employee Culture Environment</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12. Employee compensation and Motivation</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13. Applying Total Quality Management</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14. Training</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Market and Finance</td>
<td>15. Quick Liquid Assets</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16. Feedback Evaluation</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17. Research and Development</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18. Market Conditions/ Customer Engagement</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Overall Company Performance (%) 70 75

* Data is shared by co-author

Since the responses from questionnaire dealt with 18 factors, it is very difficult to analyse the impact of all the factors. Hence, these factors were evaluated and allotted ranks using ANN training i.e. ranking the factors to determine the relative importance of each variable and the highest impact on the model. Analysis of weights of the trained neural network are used to derive the contribution percentages. The higher the value implies that the variable contribution to classification/prediction is also high. Based on the ANN rankings, 9 factors with highest contribution factor were shortlisted from the pool of 18 factors as shown at Figure 2.

Figure 2: Factors shortlisted using ANN ranking method
2.3 Previous modelling techniques

The previously published paper guides the researchers to the starting point of a detailed research in the field. The previous paper discussed the overall impact of the factors. The selected nine CSFs were used to develop prediction models for performance of construction organization using Artificial Neural Network (ANN) model and regression. Neuroshell software package was used to develop and train the ANN model. Similarly, MINITAB software is used to build a regression model for construction organizations’ performance using the selected CSFs (Zayed et al., 2012).

One of the many advantages of theoretic properties of ANN is the ability to distinguish unspecified relations such as nonlinear effects and/or interactions. However, this advantage comes at the cost of minimized interpretability of the model output. The “black box” quality of an ANN model makes it next to impossible to gain insight into a problem based on an ANN model. Regression technique allows the user to sequentially remove possible explanatory variables that do not contribute to the fit of the model (Sargent, 2001). Regression techniques permit hypothesis testing concerning both the univariate and multivariate association amongst each explanatory variable and the outcome of interest. However, it fails to recognize or identify the highly nonlinear factors, or correlation among variables (Sargent, 2001). Human reasoning being more approximate than precise in nature often makes it difficult to measure and determine the measure of factors affecting a particular cause. Introduced by Zadeh (1965), Fuzzy logic can be used as a tool to understand imprecision and qualitative aspects of natural language and imprecise cognitive reasoning. Fuzzy logic-based systems are used to analyze and process linguistic inputs to derive outputs or decisions, refer Figure 1 (Senouchi et al. 2014).

The background shows a lack of a model that considers the qualitative factors and the expert opinions. The objectives of this paper will be: identify and study the success factors and to develop performance prediction model(s) for construction organizations.

![Figure 3: Fuzzy expert system (FES) (Senouci et. al. 2012)](image)

3 Research Methodology

The methodology of this research is presented in the schematic diagram (figure 4). The steps are summarized as following:

1. Conduct a literature review to identify the success factors that can impact performance of construction organization. Data collected from questionnaire in the previous study conducted by Zayed et al. 2012 will be studied and analyzed.
2. Model the impact of individual factors and establish correlation between factors. It is proposed to develop a performance assessment model for construction organization using Fuzzy Expert System. The model will focus on analyzing the impact of preselected 9 CSFs on the performance assessment model.
3. The model will be tested and validated by results of ANN and regression analysis in order to determine their accuracy in assessing the performance of construction organization.

![Flowchart](Figure 4: Analysis framework)

3.1 Development of Fuzzy Logic-based performance assessment model

Factors that have an impact on an organization’s performance are the inputs for the fuzzy model. The selected CSFs have been identified and classified into 4 categories ie. 1. Administrative and Legal, 2. Technical, 3. Management and 4. Market and finance. The output will be the performance of construction organization. The methodology used to build the model using fuzzy expert system is shown in figure 5.
3.2 Values of Fuzzy Input and Output Linguistic Variables

The previous research paper included identification of potential success factors that impact an organization’s performance. These factors were compiled from various literature and expert professionals. A questionnaire was prepared to evaluate the impact of each factor on performance. (Zayed et al 2014). The values of linguistic input variables under the four categories (i.e. Administrative & legal, Technical, Management and Market & Finance) are allotted on a scale of one to five as they don’t have a tangible mean of measure. For example, an input value for a variable such as importance of factor of Clear vision, mission and goals cannot be given any crisp value. Such a factor can only be given rating on a subjective scale. The same concept applies to other variables as shown in Table 2. Miller et. 1956 suggested that maximum number of pieces of information should be seven, plus or minus two.

3.3 Fuzzy Member Function, Inference, Composition and Defuzzification

Inferencing is the process wherein specific values are applied to the input variables to calculate the values of the output variables. In FES, the inference process comprises of four subprocesses: fuzzification, inference, composition, and defuzzification. Inference is a step that involves computation of true value for the range of each fuzzy rule and then applying it to conclusion of each. The next step is called Composition where in fuzzy subsets are assigned to each output variable and then combined together to form a single fuzzy subset for each output variable; and followed by Defuzzification, where the fuzzy output set is assigned a crisp number. (Horstkotte, 2002)

3.3.1 Fuzzy Decision Rules

A FES computes the task formulated as a collection of fuzzy if/then rules. These are rules are formulated by combining certain scenarios and the corresponding output. These rules are represented in the form of linguistic if-then statement. They are describes as: IF precondition 1 exits AND precondition 2 exits AND precondition 3 exits AND: THEN consequence 1 AND consequence 2 will be the output (Chao & Skibniewski, 1998). For instance,

IF C is $c_n$,
AND S is $s_n$,
AND O is $o_n$,
AND P is $p_n$,
AND K is $k_n$,
AND N is $n_n$,
AND E is $e_n$,
AND F is $f_n$,
AND R is $r_n$,
THEN OP is $op_n$
Where C= Clear Vision, Mission, and Goals; S= Competition Strategy; O= Organizational Structure, P= Political Conditions, K= Availability of Knowledge, N= Business Experience (no. of years), E= Employee Culture Environment, F= Feedback Evaluation, R= Research and Development and OP = Overall Performance. For example:

IF Clear Vision, Mission, and Goals is 4,
AND Competition Strategy is 4,
AND Organizational Structure is 4,
AND Political Conditions is 4,
AND Availability of Knowledge is 5,
AND Business Experience (no. of years) is 5,
AND Employee Culture Environment is 4,
AND Feedback Evaluation is 4,
AND Research and Development is 4,
THEN Overall Performance is 70

Table 2: Input and Output Linguistic Variables and Fuzzy/Crisp Value

<table>
<thead>
<tr>
<th>Input / Output</th>
<th>Linguistic Variable</th>
<th>Crisp/fuzzy value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative and</td>
<td>Clear Vision, Mission, and Goals</td>
<td>1-5</td>
</tr>
<tr>
<td>legal</td>
<td>Competition Strategy</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td>Organizational Structure</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td>Political Conditions</td>
<td>1-5</td>
</tr>
<tr>
<td>Technical</td>
<td>Availability of Knowledge</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td>Business Experience (no. of years)</td>
<td>1-5</td>
</tr>
<tr>
<td>Management</td>
<td>Employee Culture Environment</td>
<td>1-5</td>
</tr>
<tr>
<td>Market and Finance</td>
<td>Feedback Evaluation</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td>Research and Development</td>
<td>1-5</td>
</tr>
<tr>
<td>Overall Performance</td>
<td></td>
<td>0-100%</td>
</tr>
</tbody>
</table>

3.4 Model Implementation

It is proposed to utilize the software Matlab R2014b Fuzzy Logic Tool Box to process fuzzy logic inference. The input of the linguistic variables are fuzzified using the membership functions. One by one the strength of variable is determined and its impact on the output value. The minimum operator is used to calculate the firing strength of each fuzzy rule. The firing strength is directly proportional to the impact on the output. Output membership function maps the height corresponding to the firing strength of rules (Chao & Skibniewski, 1998).

$$F_i = \min(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9)$$

where $F_i$ is the firing strength of rule and $x_1, x_2, x_3, x_4, x_5,\ldots$ are the parameters representing membership of linguistic variables (Chao & Skibniewski, 1998).

After all the rules are evaluated, union member function is used to combine the consequences of all the rules to form an overall membership function. This function is then converted into crisp value using defuzzification method.
3.5 Model Validation

The purpose of this step is to check the accuracy of results provided by the model. It is proposed to set aside 20% i.e. 13 responses out of 63 responses from questionnaire for validation purposes. In order to predict error and validate the model, it is proposed to use average validity/invalidity percentages (AIP and AVP), followed by Root Mean Square error (RSME).

In addition to the mathematical validation, the results from previous study by Zayed et al., 2012 will also be used to determine the soundness of model. The models developed in previous study to assess the performance of organization used ANN modelling technique and Regression analysis.

4 CONCLUSION

The present study includes a literature survey to validate the importance of critical success factors identified in previous studies. This paper represents development of framework to assess the performance of construction organizations based on nine CSFs using fuzzy approach. These nine critical success factors (i.e. Clear Vision, Mission, and Goals, Competition Strategy, Organizational Structure, Political Conditions, Availability of Knowledge, Business Experience (no. of years), Employee Culture Environment, Feedback Evaluation, Research and Development) were selected in the previous study using ANN ranking system. In order to assess the impact of individual factors on the overall organization performance, they have been modelled using FES. Fuzzy input and outputs and the rules governing them are designed in order to cover maximum possible cases. The study will be a step towards understanding a detailed analysis of factors that may impact the overall performance. The study shows a need for further investigation on critical success factor to select the optimum number and nature for modeling the organizations’s performance. The developed research/model benefits both researcher and practitioners to predict accurate company performance.

References


