# Evaluation of Critical Success Factors of Construction Projects Using Soft Computing Methods

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***Abstract*—Critical success factors of the project (CSFs) will help the employer, contractor and consultant and its users. Artificial neural networks are one of new methods which have been developed to estimate and predict parameters using the inherent relationship among data. In this research, through reviewing the key indicators of project success, CSFs factors among the main elements involved in the industry of macro-civil construction projects (employer, contractor and consultant) a model for determining with the success of the project, it has been tried to propose a model to determine the score of the project success using radial based neural networks. To achieve this goal based on conditions of the present research, firstly, ten CSFs key project success indicators, were recognized in five categories including financial, interaction processes, manpower, contract settings, and characteristic nature of the project. Then, by random sampling of projects operated during the last 5 years in the country's Ministry of Energy, project information was collected by managers of large projects. After training the designed neural network, the success model of the project was provided based on an assessment of project objectives, including factors of Scope, Time, Cost, and Quality of the projects, the applied equation of the model was also presented to facilitate use by other researchers. Outputs were calculated by the proposed model were in good agreement with the actual number of projects.**

***Index Terms*—Construction, critical success factor, project, soft computing.**

## I. Introduction

The success of a project is of the largest and most important objectives and concerns of managers and all those involved in a project which is somehow unifying the efforts of all team members of the project. Reviewing the success and failure factors of projects in construction projects is more sensitive due to the dynamic and changing nature of the construction industry in various stages of implementation of the project. But, determining the success factors of a project is a complex and relative concept, which due to their nature and execution system and natural characteristics, most of experts have proposed different and sometimes contradictory definitions. On the other hand, the volume of construction activities is of the essential development factors of a country. Annually, trillions of dollars of investments in the public and private sectors of various countries, either directly or indirectly are expended in civil and building infrastructure. A construction project is a combination of different events, planned or unplanned, during the life cycle of the project, and survives under the umbrella of the changes in their environment. Among them, there are factors that are more important in the success or failure of a project. These factors are known as project success factors. In a definition, success factors of the project are expressed as "a set of environmental factors, facts or influential factors that can affect the output of the projects. These are factors that can accelerate a project or make it difficult, can lead to the success or failure of the project, but cannot be the basis for project evaluation. (Udwadia and Trifunac, 1973 [1]; Lim and Mohammed, 1999 [2]).

Based on this, the PMBOK (Project Management Body of Knowledge) standard, a project is a unique effort to deliver a series of products (output) in the defined Scope, Time, Cost, and Quality. Projects include activities which should be carried out in the transparent scope and description of services, determined dates, with identified costs and determined quality, and voiding any of the four factors mentioned limits, can lead to an unsuccessful and uneconomical project.

The definition of a strategic framework that tactically examines the success of the project and identification of the critical success factors (CSFs), could be an important start point. As a result, the objectives of this assessment (1) are essential to identify the critical factors, which overall determine success of the project (2) define and identify key CSFs of construction projects from the perspectives of different participants of the project with different goals. According to the actors in civil and forming CSFs for the purposes of the project, such as scope, budget, schedule and quality, we can gain a better understanding of the success of the project. Management can take necessary steps to (1) avoid project failure (2) identify promising projects and keep track of them, and (3) identify the problematic areas of the project to undergo necessary corrective actions.

## II. Critical Success Factors

Research on the success of the project has attracted the interest of many researchers and specialists. In 1986, Tuman has defined success of the project as having anything that can be reason for hope, and predicting all project requirements and having sufficient resources to meet the requirements in the appropriate mode. In the same year, another definition was mentioned by De Wit. In the proposed definition, if a high level of satisfaction exists in terms of output and product of the project among key stakeholders, including the main organizations (mother), the project team and end users, has introduced as the overall success of the project.

In the following definition of project success, Ashley *et al.* (1987) [3] suggest success as a consequence of better results

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expected of the project (or normal level of project results), which is usually observed based on cost, schedule, quality, safety and satisfaction of participants. Since that time, safety is expressed a success factor. In 1996, Pocock *et al.* [4], explain legal claims of the project as another indicator of the success of the project. Wuellner in 1990 [5], has claimed that a project is successful when is performed on time and on budget with a reasonable profit margin. In addition, it should meet expects of customers and produce a high quality project or consulting services, while limiting the professional commitments of the company to an acceptable level. Summary of the definitions provided by different investigators about the success of the project is presented in the Table I.

TABLE I: SUCCESS DEFINITIONS SUMMARY

| Reference | Definition of success |
|---|---|
| Tuman (1986) | All project requirements anticipated and needs met with sufficient resources, in a timely manner |
| De Wit (1986) | A project is considered an overall success if it:<br>Meets the technical performance specifications or mission to be performed<br>Results in high level of satisfaction concerning project outcome among:<br>Key people in parent organization<br>Key people on project team<br>Key users or clients of project effort |
| Ashley *et al.* (1987) | Results are better than expected or normally observed in terms of cost, schedule, quality, safety,<br>and participant satisfaction |
| Pinto and Slevin (1987) [13] | A successful project fulfills four criteria:<br>Completed on schedule (time)<br>Completed within budget (cost)<br>Achieved all goals originally set for it (effectiveness)<br>Accepted and used by clients for whom project is intended (client satisfaction) |
| Wuellner (1990) [5] | A successful project:<br>Completes on time, within budget, and with an acceptable profit margin<br>Satisfies client expectations<br>Produces a high-quality design or consulting services<br>Limits firm's professional liability to acceptable levels |
| Kerzner (1998) | The success of a project is defined in terms of five factors:<br>Completed on time<br>Completed within budget<br>Completed at desired level of quality<br>Accepted by customer<br>Customer agreeing to allow contractor to use customer as a reference |
| Low and Chuan (2006) | Insufficient focus on time, cost, and quality since such a definition entails a measurement of project success as too objective, difficult, and ambiguous due to disparity between project success and product success |

The term critical success factor (CSF), originally has been introduced by Rockart (1982) [6] to define the number of activities that favorable results of which are necessary to achieve the objectives of project management. In other words, critical success factors (CSFs) are factors which help to predict the success of the project in addition to its durability (Sanvido *et al.*, 1992 [7]; Ghosh *et al.*, 2001 [8]). A new definition by Ogunlana and Toor (2009) [9] explains that the critical success factor (CSF) means a specified element that helps considerably to the success of the project and is a very important component for success. Hence, to check and ensure the success of the project, one must first and foremost be able to identify the factors that affect the success and failure of the project. However, there is no general definition for the CSFs or its evaluation.

Regardless of theory and empirical studies, success factors may also be identified by examining the actual projects. By taking the neural network approach, Chua *et al.* (1997) [10] have identified CSFs critical success factors for performance of construction budget. They were limited to quantifiable aspects and details of completed projects in the United States. Also. Chua *et al.* (1999) [11], have identified 67 elements related to the success from a professional survey focused on the budget, schedule and qualitative objectives of the project.

It is reasonable to assume that the overall ranking of CSFs based on the involvement of participants of various projects will be different and hence it is considered as a study hypothesis. By forming CSFs for the purposes of the project (scope, budget, schedule and quality), the main players in construction projects, can achieve a better understanding of the success of the project. On the other hand, the lack of sufficient and inclusive knowledge of project success factors makes controlling, monitoring, and performance of the projects difficult. Therefore, identification of factors affecting the success or failure of projects, depending on the type of projects, could provide a suitable framework for evaluation of project outputs by managers and bosses and executives. Also, identification of factors in the success of the project can help to manage the appropriate allocation of resources over the life of the project (Ahadzie *et al.*, 2007 [12]).

## III. CSFs for Construction Projects

In 1990 Pinto and Mantel [14], has conducted his research on the causes of project failures of 97 projects identified as failed projects. In 1992 Sanvido *et al.*, has conducted a research to determine the CSFs for construction projects using data from interviews with employers, architects, engineers, contractors. Mohsini and Davidson in 1992 [15] investigated the effects of violations stimulating organizational variables on cost, time and quality of the project and identified the most important determinants among these variables. In another study in 1995, Ahmed and Kangari [16] reviewed factors which were understood as the most important factors by employers in contracting organizations. By survey on 280 construction projects, the relationship between the project performance and alternative approaches for managing the contractor- employer relationship was studied by Larson in 1995 [17]. In the case of contract investigation, By Alarcon and Ashley in 1996 [18], a method was proposed to model project performance. Also in 1997, prolongation of construction time in Hong Kong has been investigated by Chan and Kumaraswamy [19].

In 2005, a research has been conducted by Iyer and Jha [20], to identify critical success factors CSFs affecting the cost performance of the construction projects in India. They reported coordination among project participants as the most

important success factor for cost performance. Lam *et al*. [21] in 2008 investigated Critical Success Factors CSFs for construction projects by design and build mehod. They identified nature of projects, effective project management practices and adoption of new management approaches as critical success factors CSFs for design and construction projects. Based on the results of another study in 2012 by Pakseresht and Asgari [22], identification and ranking of the important factors of success in construction projects of Pars Garma Company, was carried out using a questionnaire survey among the 58 members of the management staff, project managers and technical experts. In the same year, with the aim of identifying critical success factors in public housing projects in Ghana and using the experiences of 13 specialists in the field of these projects, a study was conducted by Adinyira *et al.*

In another study by Kog and loh in 2012 [23], identification of critical success factors (CSFs) has been conducted from the perspective of different specialists namely, civil and construction engineers, mechanical and electrical engineering, architects and monitoring devices. After collecting expertise comments from 27 building industry specialists, based on the analytic hierarchy process (AHP), 10 superior and important factors for project success of CSFs were identified. Also in 2013, in the research conducted by Hong and Lim [24], has been discussed to identify the critical success factors of construction projects in Singapore, with the distribution of prepared questionnaire of 32 important factors in the success of the project, among 12 specialists with at least 10 years of experience as representatives of employers, contractors and consultants. Factors affecting the success of construction projects in Malaysia by 48 experts from contractors, consultants and developer companies, were examined by Yong and Mustaffa in 2013 [25], and issues of the project manpower, commitment and communication of executive elements and management and control of project administrative process, were identified as the main topics contributing to success.

## IV. Artificial Neural Networks

Machine learning involves adaptive mechanisms that enable computers to learn from experience, learn by example and learn by analogy. Learning capabilities can improve the performance of an intelligent system over time. The most popular approaches to machine learning are artificial neural networks and genetic algorithms.

A neural network can be defined as a model of reasoning based on the human brain. The brain consists of a densely interconnected set of nerve cells, or basic information-processing units, called neurons. The human brain incorporates nearly 10 billion neurons and 60 trillion connections, *synapses*, between them. By using multiple neurons simultaneously, the brain can perform its functions much faster than the fastest computers in existence today. Each neuron has a very simple structure, but an army of such elements constitutes a tremendous processing power.

Our brain can be considered as a highly complex, non-linear and parallel information-processing system. Information is stored and processed in a neural network simultaneously throughout the whole network, rather than at specific locations. In other words, in neural networks, both data and its processing are global rather than local. Learning is a fundamental and essential characteristic of biological neural networks. The ease with which they can learn led to attempts to emulate a biological neural network in a computer.

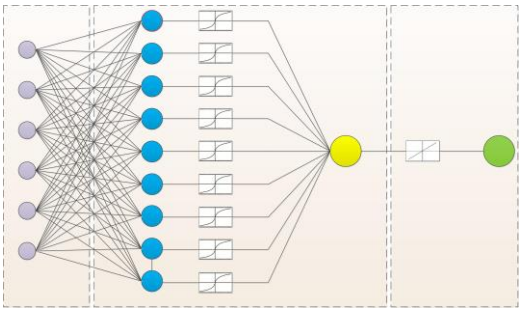

Fig. 1. Architecture of a typical artificial neural network.

## V. Data Gathering

As mentioned in the previous section, factors associated with success used in the study, are mainly extracted from the results obtained by chua *et al*. (1999). This may be explained as, by removing the potential discrepancies in terms of social, cultural, political or other differences which may cause abnormal results, these results has been used in construction projects. In the research carried out, rather than covering all project participants, this study has focused only on the main actors of the project, namely the employers, contractors and consultants and due to relatively lower influence of subcontractors, suppliers and manufacturers on the success of the project on all construction projects, these actors have been removed. To collect comments data, a semi-structured questionnaire was prepared interviewing with experts and scholars in the construction industry of development projects, by choosing 41 indicators affecting the success of the project, in 5 components as Table II.

Due to the sensitivity and importance of the study, the questionnaire was distributed among experts and prominent executives and government officials and investors of macro projects which have the sufficient experience, expertise and knowledge in the management of construction projects. A total of 175 questionnaires were collected and after analyzing the data and eliminating invalid questionnaires, 137 questionnaires were finally studied and analyzed. The effective factor of success of the project was evaluated based on Friedman test. The results of this line of research, were calculated to examine the efficacy of the top 10 indicators among the 41 identified indicators in this study, and were compared with previous studies in different countries. Critical factors of success in the country along with comparison of CSFs identified in this study with previous studies are shown in Table III. Based on the results of this section, factors of "Insertion of realistic commitments and description of services and purposes specified in the contract" and "professional competence of project manager client" are as factors selected in the previous researches among experts in different countries (Ashley *et al*., 1987, chue *et al.*, 1999, Kog

and loh, 2012, and Hong and Lim, 2013). Also, due to much agreement between nature of the the two countries of Iran and Malaysia in terms of developing situation of the two countries and shared spaces in construction projects in these countries, five indicators among the 10 key factors of the success of the project are in compliance. This compliance could be due to the developing situation in the two countries, and sharing in the space of construction projects between the two countries.

TABLE II: SELECTED SUCCESS-RELATED FACTORS CONSIDERED IN THE STUDY

| Project aspect | Success-related factor |
|---|---|
| Financial (8 Factors) | (1) adequacy of funding; (2) economic risks; (3) owner team turnover rate; (4) contractor team turnover rate; (5) consultant team turnover rate; (6) owner top management support; (7) contractor top management support; (8) consultant top management support |
| Interactive Processes (10 Factors) | (9) design complete at construction start; (10) constructability program; (11) report updates; (12) budget updates; (13) schedule updates; (14) design control meetings; (15) construction control meetings; (16) site inspections; (17) relationships; (18) common goal |
| Human Resource (8 Factors) | (19) project manager competency; (20) project manager authority; (21) project manager commitment and involvement; (22) capability of owner key personnel; (23) capability of contractor key personnel; (24) competency of contractor proposed team; (25) capability of consultant key personnel; (26) competency of consultant proposed team |
| Contractual Arrangements (5 Factors) | (27) realistic obligations/clear objectives; (28) motivation/incentives; (29) risk identification and allocation; (30) formal dispute resolution process; (31) adequacy of plans and specifications |
| Project Characteristics (10 Factors) | (32) impact on public; (33) constructability; (34) project size; (35) site limitation and location; (36) owner track record; (37) owner level of service;(38) contractor track record; (39) contractor level of service; (30) consultant track record; (41) consultant level of service; |

After identifying the 10 critical factors of success of the project, with the aim of finding predictive model of success of the project in Iran using the radial basis neural network, we proceeded to design a new questionnaire to gather the actual information on the success of the finished project in Iran. In this questionnaire, the information was designed in two parts, Part I: model input based on prediction of achieving percentage of 10 critical factors of success of the project in five categories of financial, human resources, interactive processes, features of nature, and the contract items and the second part: the purpose of the model based on evaluation of the realization of the Scope, Time, Cost, and Quality of the project with preliminary estimates at the beginning of the project based on definition of the success of the project in the standard PMBOK (Project Management Body of Knowledge), (Project Management Institute, 2012). Since the accuracy of a model depends on the input data accuracy for network training, the information needed to build the model, information of the construction projects of Ministry of Energy of Iran, completed over 5 years, was received from the ministry. Raw data of 80 projects were evaluated, and after removing the incomplete information, information of 56 projects were selected to build the model.

TABLE III: COMPARISON OF CSFS IN DIFFERENT STUDIES

| CSFs | This study (2016) | Hong & Lim (2013) | Yong & Mustaffa (2012) | Kog & loh (2012) |
|---|---|---|---|---|
| political risks | | | * | |
| adequacy of funding; | * | * | | |
| site limitation and location | | | | * |
| constructability | | | * | * |
| realistic obligations/clear objectives | * | | * | * |
| risk identification and allocation | | | * | |
| adequacy of plans and specifications | | * | * | * |
| motivation/incentives | | | * | * |
| project manager competency | * | * | | * |
| project manager commitment and involvement | | | | * |
| owner team turnover rate | * | | | |
| owner top management support | * | * | | |
| owner level of service | | | | |
| capability of contractor key personnel | * | * | | |
| competency of contractor proposed team | * | * | | |
| contractor track record | * | | | |
| contractor level of service | * | | | |
| capability of consultant key personnel | | * | | |
| schedule updates | | | * | |
| design control meetings | | | * | |
| construction control meetings | | | * | |
| site inspections | | * | * | |
| common goal | | | | |
| relationships | * | | | |

In this study, to simulate the structure of the artificial neural network and relating coding, the software MATLAB was used. In order to reach the success of the project using RBF neural network, the information of 56 development projects collected in the country of Iran, have been used for training and testing the network. Based on the information collected and the above description, 5 inputs of neural networks including scoring financial items, human resources, interactive processes, features of nature, and the contract items of each project, and the achievement level of each of the objectives of a project including scope, time, cost, and quality of the project with the estimation conducted at the time of the project start, were considered as 4 outputs of the neural network.

Since the input values of the neural network have been scattered, and the possibility of lack of achieving the desired model due to scattering between the input data was expected, we limited input values in the range between zero and one through normalization by division of all components of the input by their maximum. In the hidden layers of networks, different number of neurons has been used and their optimal

value has been determined to minimize error. Under the programming conducted, the number of hidden layers is begun with 1 and adding additional hidden layers continues until the increase in hidden layers does not affect the improvement of the error rate.

## VI. Results

With the aim to build a prediction model for the success of the project in Iran, by radial basis neural network, it was proceeded to conduct the coding and analysis of data collected. In the program written for production of neural networks, 4 outputs of scope, time, cost, and quality of the project were calculated with 4 distinct networks based on 5 parameters. The results of implementing the program on 56 projects, including correlation coefficient gained by comparing the calculated outputs with actual value outputs and the error rate calculated by Mean Square Error MSE, are given in Table IV.

Fig. 2 to 5 present the regression and performance of the neural networks.

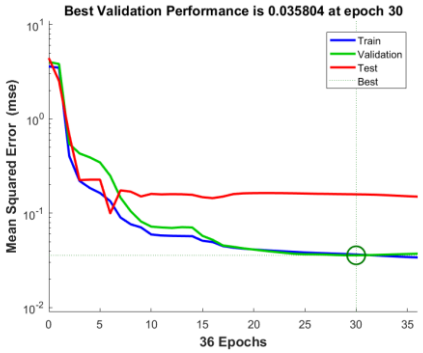


Fig. 2. Mean squared errors for different sets of data.

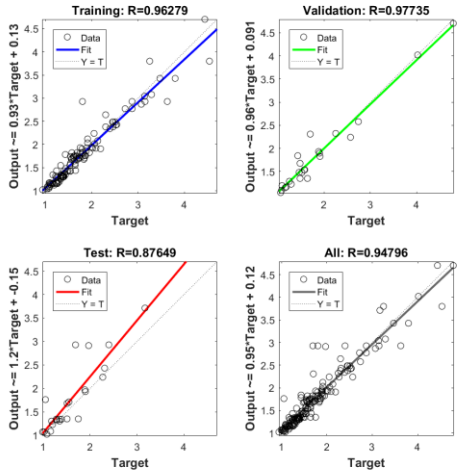


Fig. 3. Regression values for training, validation and test data.

TABLE IV: Regression Results and the Calculated Error

| | | |
|---|---|---|
| Each Regression | scope | 0.83 |
| | time | 0.87 |
| | cost | 0.79 |
| | quality | 0.92 |
| Total Regression | | 0.94 |

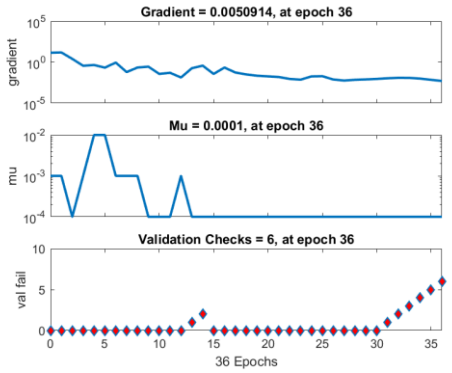


Fig. 4. Performance of idealized network.

## VII. Conclusion

This study was conducted to present a model to predict the success score of the project. To achieve this goal, using artificial neural networks and based on studies and researches conducted in two stages including identification of factors relating to success of the project and gathering the data of the exploited projects, the proposed model has been designed and presented. As in the first phase, studies conducted to identify the success factors of the project, despite the general agreement on critical success factors CSFs of the project, but due to geographical conditions of each region and conditions governing the space of the construction projects, there are no single factors among different countries. In this regard, and according to the project implementation status, 10 critical success factors of the project were recognized and selected among the 41 factors in previous studies based on researches conducted and performing semi-structured interviews with experts and top specialists in the construction industry, from the view of employers, consultants and contractors, in 5 categories of financial, interactive processes, human resources contract settlement, and characteristics of the nature of the projects. In the second stage of the investigation, information on the development projects exploited by project managers was collected through the Department of Energy. After reviewing the information and using the neural network, the model to determine the success of the project was designed and after assessment of the model on three other projects, and good compliance of the output values calculated by the model with actual values of the project, the applied equation for use by other researchers was presented.

This research can create practical applications for project leaders, which can exploit the results as guidelines for the formation of CSFs, according to the order and specifications according to the customer desires for building projects. They can also compare the success factors identified in this study with real success factors in projects conducted in the past.

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