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PROPOSING A NEURAL NETWORK MODEL TO PREDICT TIME AND COST CLAIMS IN CONSTRUCTION PROJECTS

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Abstract. Despite broad improvements in construction management, claims still are an inseparable part of many construction projects. Due to huge cases of claim in construction industry, this study argues that claim management is a significant factor in construction projects success. In this study, the most possible causes of these emerging claims are identified and statistically ranked by *Probability-Impact Matrix*. Subsequently, by classifying claims in different cases, the most important ones are ranked in order to achieve a better understanding of claim management in each project. In this regard, a new index is defined, being able to be applied in a variety of projects with different time and cost values, to calculate the amount of possible claims in each project along with related ratios with respect to the cost and time of each claim. This study introduces a new model to predict the frequency of claims in construction projects. By using the proposed model, the rate of possible claims in each project can be obtained. This model is validated by applying it into fitting case studies in Iran construction industry.

Keywords: claim management, risk management, artificial neural networks, construction industry, project management.

Introduction

During the implementation of construction projects due to complexities, uncertainties and challenges (Gardezi *et al.* 2013), claims are very likely to arise. According to Chan *et al.* (2004), the construction industry has an organic nature, which stems in the staggering uncertainties in technological processes, budgeting practices, and other similar issues. The presence of such uncertainties may cause some conflicts in projects (Li *et al.* 2015). Many of these construction problems are trivial matters in the beginning, but in case of not being addressed in a short period of time or not being swiftly referred to those responsible, they may become problematic (Acharya *et al.* 2006). According to Scott and Harris (2004), it is quiet natural in construction projects that major changes in contract terms become the potential grounds for claims. Verweij *et al.* (2015) conducted an empirical exploration to find the reasons that make contract changes. Based on Ho and Liu (2004), it is almost a fact that the number of construction claims and disputes are growing (Jiang *et al.* 2015), so that such cases have become an additional burden on overhead costs in the construction industry increasing the responsibility of project managers. For this reason, it is suggested that claim management should be considered seriously as an integrated and significantly important part of the construction process. Even in competitive tenders, it is likely that the contractors would participate in the bids with low suggestions with a hope to compensate the loss or low interest with the aid of future negotiations on claims. Therefore, special attention to claims management has become an imperative issue for the managers of construction projects.

In this regard, this study aims to delineate a framework to understand the main sources of claims in construction industry projects, and then provides a new model to predict the amount of claims in a construction project. In the following parts, first of all related literature about the main topic of research, i.e. claim management is discussed. In the next part the main sources of claims in the construction projects in Iran are identified by applying the probability–impact matrix shown in Table 1 in various sections. Then all 60 cases are put under an AHP ranking process by using senior experts in the field

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Table 1. Different causes of the claims in Iran construction projects

Area	Description of the Risks Leading to Claims	Impact	Probability	Weighted Average Index
Integration Management	Lack of integration between the plans of various parts of the project	48.21	49.11	30.3
	The work interventions that may occur between various contractors	46.88	54.02	32.5
	Late delivery of the operations and the working site by client or a contractor to the other contractors	66.96	70.09	38.5
	Lack of coordination between the design and construction operations	62.50	50.45	31.4
	Lack of coordination between the line and staff employees in each organization	46.43	38.39	26.8
Scope Management	Inaccurate estimation and setting the contract based on unrealistic values	69.64	73.21	39.2
	Accomplishment in excess of the contract's content and the contractor's obligations	53.57	54.46	33.8
	Subjecting to unforeseen conditions, which result in changes in the type, quantity and methods of the construction	52.68	30.80	29.3
	Failure to develop an accurate scope between the contractors	41.52	33.48	25.7
	Failure to supply the proper facilities that the client is obliged to provide to the contractor	51.34	37.05	26.1
	Inability of the consultants and lack of proper feasibility studies, and an appropriate selection of the project technology	46.43	32.14	29.1
	The contractor's negligence, failure to visit the project site, and also failure to review the documents prior of the bidding	66.95	46.43	29.6
	Lack of the proficiency and knowledge of the parties with regard to the legal affairs of the contracts and contractual negotiations	65.18	30.80	31.7
Time Management	Failure to timely notify the contractor about the contract, agenda, changes, approvals, and plans	62.07	64.73	36.3
	Failure to timely record the events and prepare various weekly and monthly reports	43.30	44.20	29
	Failure to timely deliver the site of construction to the contractor	50.89	55.80	33.5
	Poor knowledge in the planning and the project management	49.11	49.55	32.1
	Inability in determination of the authorized and unauthorized delays	52.68	50.89	32
Procurement Management	Ambiguous points in the contents of the contract (in both general and specific terms and conditions)	55.36	35.27	31.4
	Insufficient attention to the problems and obstacles facing the project, and failure to determine the side, which is responsible for resolutions in the contract	52.68	56.25	33.7
	Failure to specify the contract coefficients, the adjustment index and the price list in the contract	52.68	26.79	29.8
	Failure to release the contractor's warranties of doing obligations despite completion of the work	38.39	29.46	29.8
	Failure or delay in issuance of the draft or delivery of the materials required by the contractor	46.88	36.16	29.3
	Disagreement over the site layout and distances of the goods or materials locations	39.29	32.59	29.5
	Failure to approve the documents related to the technical specifications of the materials or equipment purchased	42.41	37.50	31.8
	Selection of the contractor only based on offering the lowest price regardless of technical ability	84.82	62.50	35.2
	Choosing an improper type of contract	55.36	37.95	27.8
	Disproportionate distribution of the risks, obligations and responsibilities in the contract and ignorance of the parties' abilities	54.02	45.98	30.1
	Absence of reliable suppliers of materials and equipment	45.09	42.41	29.3
Communication Management	Existence of excessive bureaucratic and administrative requirements to obtain inquiries, licenses, etc.	31.96	63.39	31.4
	Reliance on oral communications instead of written documents in the communications between the parties	43.30	48.21	32.1
	Failure to hold the ongoing meetings between the client, consultant, and the contractor	37.95	37.95	26.1
	Multiplicity of decision-makers on the project's issues and lack of transparency in mutual responsibilities	53.13	47.77	31.3
	Lack of written and timely notifications at milestones of the project	48.66	53.13	28.2
	Lack of project management office and Lack of documentation of the project's issues.	46.43	49.55	30.4

Continued Table 1

Area	Description of the Risks Leading to Claims	Impact	Probability	Weighted Average Index
Risk Management	Existence of some opponents for the land, which is to be handed over to the contractor	58.48	36.61	26.8
	Adverse weather conditions that lead to slowness or stoppage of the project or to taking specific measures	54.91	33.93	24
	Act of god such as earthquakes, floods, etc. leading to damages and destruction of facilities and equipment of the contractor	64.29	21.88	18.4
	Accidents resulting from the failure to comply the principles of safety	53.13	35.71	24.3
	Stopping the project's by the administrative, legal, and legislative entities and organizations outside the project	58.04	25.45	21.1
	Legal problems with the neighbors of the project	38.84	17.86	19.2
	Codification of the laws or instructions by the policy-setting organizations and entities outside the project	39.73	41.96	27.5
	Economic inflation and rises in the employees' wages and the prices of materials and equipment	86.16	79.91	42.6
	Political and economic sanctions and consequently, being unable to import the materials and equipment	82.14	70.54	39.1
	The problems resulting from failure to insure the project, which is considered as the client's obligation	41.07	30.36	23.5
	When the ethics and business characteristics of the contractor are based only on gaining more profit so that s/he is always about to raise claims	59.82	51.79	31.3
Human Resource Management	Failure to gain a full understanding of the technical and construction details of the project by the contractor as a result of the poor project management	45.98	46.43	29.1
	Disputes between the contractors and consultants, and lack of control by the client	53.57	46.88	29.5
	Presence of non-professional staffs and shortage of experts involved in the project	52.68	45.54	29.5
	Lack of sufficient motivation and productivity in manpower	41.52	48.66	31.5
	Inflexibility of the contractor or client in dealing with the occurred issues	40.18	47.32	29.1
Cost Management	Lack of proper budgeting at the beginning of the project and failure to provide the funds timely	75.45	75.45	40.7
	Absence of a cost control system	59.38	54.46	33.1
	Performing overtime work without the specified prices in the contract	73.66	56.70	32.6
	Changes in the foreign currency rates	56.25	70.54	38.4
	Increases of the costs by more than 25% of the contract	67.86	66.52	36.7
	The costs of the unemployed manpower and machinery due to cancellation or termination of the contract	45.98	47.77	31
Quality Management	Absence of a quality control (QC) system	57.59	45.09	28.2
	Lack of a quality assurance system	54.46	45.98	28.4
	Imprecise explanation of the expected quality in the contract, which consequently leads to behaving based on individual thoughts	50.00	48.21	30.3

of construction to select the top 10 priorities, shown in Table 2, the results are then tested by a sensitivity analysis, shown in Figure 1, to check the results exactness. Two new indexes named CCI and TCI are developed and then applied in Artificial Neural Networks to develop a new approach to predict claims amount, time and cost in construction projects, then in three case studies in Iran construction industry the model is tested and validated.

1. Literature review

According to the definition of the "Project Management Body of Knowledge Construction Extension", a claim is "a demand for something due or believed to be due" (PMI 2007). In construction projects, the word "something" is usually referred to an additional cost due to the surplus work more than the pre-outlined contract, or due to the extension of the project completion time, or both. In claims, unlike the changes, there is a factor of parties' disagreement over something, in which both parties consider the case as their own right. As soon as the agreement is reached, the claim will be disappeared and transformed into a change (or an amendment) in the contract terms. Otherwise, it would be still considered as a claim and will be entered into the processes of negotiation (which is always the preferred method for both clients and contractors) (Lu *et al.* 2014; San Cristóbal

Table 2. The overall priorities of the factors effective in the development of the cost and time claims

Factors	Overall priorities
Economic inflation and rises in the employees' wages and the prices of materials and equipment	0.244
Performing overtime work without the specified prices in the contract	0.194
Lack of proper budgeting at the beginning of the project and failure to provide the funds timely	0.151
Political and economic sanctions and consequently, being unable to import the materials and equipment	0.106
Inaccurate estimation and setting the contract based on unrealistic values	0.097
Increases of the costs by more than 25% of the contract	0.055
Late delivery of the operations and the working site by client or a contractor to the other contractors	0.047
Selection of the contractor only based on offering the lowest price regardless of technical ability	0.043
Failure to timely notify the contractor about the contract, agenda, changes, approvals, and plans	0.04
Changes in the foreign currency rates	0.023

2015), mediation, arbitration, and litigation to be finally resolved in the settlement (PMI 2007).

According to the study of Kassab *et al.* (2006), the claims that might occur after the completion of the projects should be considered from both viewpoints of the contractor and the client. From the contractor's viewpoint, these claims may arise due to the bad planning (as a consequence, the contractor has been urged to pay unnecessary costs, which rises the project costs). On the other side, from the client's perspective, these claims may arise because of the losses occurred in the contract as a result of the contractor's poor performance. Lu *et al.* (2016) investigate the influence of behavioral primers on subjective value in construction claim negotiations (Lu *et al.* 2016). It should be noticed that according to Sweet (2004), finding the guilty party or determining the one responsible for the claims is very difficult, because the claims parties involved in the project would try to incriminate each other and show themselves blameless. However, it should be remarked that even though it is the contractor who may have caused the delays, the responsible party might be the client. The main reason for occurring claims in the construction projects are the risks and uncertainties involved in the projects (Hanna *et al.* 2013). According to Hegab and Nassar (2005), all the activities in the life as well as in the projects are simply associated with various types of risks. Although the

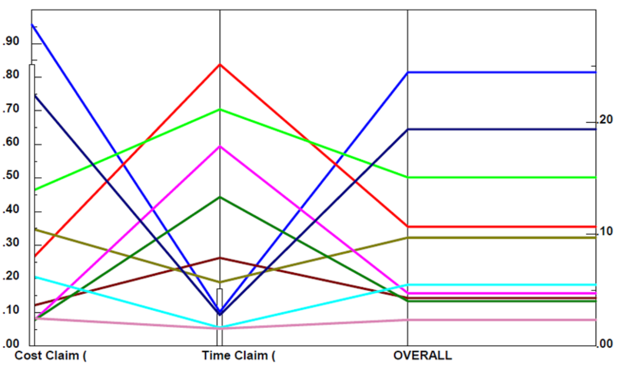

Fig. 1. The graph of sensitivity analysis for the causes of claim

risks in such activities are not completely avoidable, their effect can be moderated by making righteous decisions. According to Jannadi and Almishari (2003), a construction project would bear many risks that are highly correlated with scheduling delays and the issues emanating from the working times, since time is one of the basic parameters of each project (González *et al.* 2013). However, in defining the term delay, it should be considered that according to Arditi and Pattanakitchamroon (2008), the delays are occurred when the contractor's tasks are slowed down or some kind of ceasing is happened. According to Abdul-Rahman *et al.* (2006), a claim on delay is usually occurred when there is a difference between the actual announcement date of a contract and its completion date. The length of a delay is also the key element of the information needed to decide on the reasons producing that delay. It is exceptionally difficult to analyze a delay claim, since there are numerous factors and reasons causing that delay (Akinsiku, Akinsulire 2012), and as a result, such cases become incredibly complicated. This complication makes the claims arising from the delay more complex than expected. However, it should be considered that according to Lee *et al.* (2005), delay means the period exceeding the contract term or is a surplus from the time on which the contract parties have agreed for the delivery of the project, which in either way is costly. Thus, the delays not only can cause time claims, but may also be used as a cause for expense claims. Cost overruns have become a common part of infrastructure and building projects (Rosenfeld 2013). In the current study, it has been tried to address both aspects of time and cost claims.

Performing the researches like the present study and occurring claims in the projects have both drawn the attention of researchers to the management of such claims as well as identification of their causing factors. Some researchers cover the construction contractual claims through anatomy (Cheung, Pang 2012) and comprehensive ontology process (Niu, Issa 2012, 2013), and some researches cover the dynamic technical specification system for avoiding disputes (Erdis, Ozdemir 2013).

The claim management process has been divided into several components, such as understanding the claims, notification, investigation, documentation, declaration, and negotiation and afterwards, modeled by using the tools for prevention (Kululanga *et al.* 2001; Lo *et al.* 2006). Many studies have been conducted on the management of claims, particularly in the developing countries such as Iran. According to Long *et al.* (2004), the most common problems in the construction projects in developing countries are identified. In the study of Doloi *et al.* (2012), Vietnam and India had been reviewed as a case study. However, the claims management in the construction industry is not limited to the developing countries. For example, in the study conducted by Chan and Suen (2005), the major causes of disputes in China have been examined. According to the survey conducted by Chan and Suen (2005), it should be mentioned that as the projects increase in size and workload, their operations become more intensive and difficult to proceed as planned before. Consequently, the claims in the projects rise due to the increases in the parties' cooperation and interactions. This fact has led to an increase in claims of construction projects with great sizes, considerable workloads, and numerous interactions.

The objective of the current study is to review the claims management in construction projects. For this purpose, the management role is considered very important. According to Mahalingam and Levitt (2007), the senior management plays a much more critical role in creating and resolving the disputes than the other characteristics of the project. Poor project management is cited as one of the main causes of delays (AlSehaimi *et al.* 2012). And for this reason we can see relationship management affect the project performance (Meng 2012). Another study conducted by Al Qady and Kandil (2013) also implies that since the project managers are the primary commentators of the requirements of the contract documents and the first individuals who make judgments with regard to the acceptability of the work, therefore, the claims, disputes, and other matters related to the project claims, quantification, classification of the tasks, and also interpretation of the requirements of the contract documents for operating the project, all appear to be their responsibility. Finally, as pointed out by Caplicki (2006), although the project team members may pursue their own objectives and needs seeking to maximize their profit levels, there is an undeniable fact that in the construction projects, it is required to integrate and coordinate the efforts and operations of the project team in order to be able to organize different professional purposes of the project. Moreover, according to another survey conducted by Cheung *et al.* (2006), despite all the efforts done for controlling the risks in the projects, there are still alarming evidences and indications that cause the claims in the projects. As a result, it seems indispensable more than ever to develop a method for resolving the potential disputes occurring in the future and engage the people aware of how to resolve and address the claims in the projects. Hence, it has been tried in the present study to identify the most important sources of the emerging claims in the projects through appropriate grouping of such claims in order to provide the necessary grounds for participation of all the project team members in management of the claims (Hanna 2007).

2. Methodology

2.1. Identification of the main sources of claims

In this paper, the most important causes of disputes in the construction projects in Iran are primarily identified. Due to the large number of effective factors, the most critical factors required are recognized. For this purpose, by considering similarities between the risk management and claims management processes (PMI 2007), the probability–impact matrix is employed (PMI 2013). To this end, the occurrence probability levels in the project as well as its importance degree and impact on the incidence of claims are analyzed and established in the questionnaires. According to the obtained results and by using the risk theory, the weighted average index is also calculated for each case. In the following table, all the causes of the claims are provided, which have been categorized based on their managerial areas along with the impact average, occurrence probability average, and the average index. Given that no framework of the target population is present, Cochran sampling method is used to calculate the number of comments to provide the sample size (Cochran 2007). Considering the confidence level of 90% and the allowable error value of 0.1, the sample size is obtained as 43 subjects.

2.2. Ranking and sensitivity analysis of the causes of claims

At this stage, prior to prediction of the claims in the projects, it is needed to verify the above-mentioned ranking. It should be noticed that the performed statistical survey based on the probability–impact approach has been aimed at finding the most critical claims, which does not necessarily lead to the correct ranking. The "Analytical Hierarchy Process (AHP)" is utilized for ranking of these factors. The AHP has been widely employed as a result of its several advantageous facets, including the ease of use, simplicity, and great flexibility. Moreover, the AHP can be used in association with other methods such as mathematical programming, and also can be utilized to apply some restrictions similar to the real world (Nassar *et al.* 2003). Amongst the widespread usages of the AHP, its application in project and construction management can be mentioned, including the multi-criteria selection process of building components (Nassar *et al.* 2003), the decision-making support system for selecting an appropriate project delivery method by using the AHP (Mahdi, Alreshaid 2005), the traditional or advanced automation construction process (Hastak 1998), multi-criteria evaluation of the probability of winning in a competitive bidding process (Cagno *et al.* 2001), and application of AHP in project management (Al-Harbi 2001) and the contractor's pre-qualification process (El-Sawalhi *et al.* 2007). In the present study, it has been intended to use this method to rank the causes of disputes in the projects. Initially, the claims are classified in two following categories:

- Time claims: time claims are the claims in which the client or the contractor, depending on the situation s/he has faced, appeals to revise and extend the contract's period. These types of claims can be made by each party.
- Cost claims: cost claims are the claims in which the client or the contractor is subject to bear some losses due to the faulty performance of the other party or any other reason and as a result, it demands for compensation.

In order to rank the causes of claims, a correct hierarchy is firstly constructed. Afterwards, the paired-comparison is performed on these factors in the construction projects by considering their influence on the cost and time claims. For each series of the questionnaires, 91 paired-comparisons are made. It is worthwhile to express that this high number of comparisons might sometimes cause some inconsistencies among the comparisons made by the experts. After collecting the questionnaires, the consistency of comparisons within the questionnaires is examined, and the paired-comparison matrices related to the questionnaires with the inconsistency rate less than 0.1 are approved. Thus, the priorities of the factors contributing to the development of the cost and time claims are determined separately. Then, according to the relative importance of the cost and time claims for the construction projects in Iran in accordance with the experts' opinions, the final ranking of the factors effective in generating claims is acquired. The following table shows the ranking for the top 10 cases associated with their overall priorities.

The sensitivity analysis is carried on the ranking to have a more comprehensive examination and also to assess its applicability in other construction projects (with respect to the variations of the importance of the time and cost claims in different projects). The sensitivity analysis for the target indicates the sensitivity rate of the options by considering all the criteria. The Figure 1, which shows the sensitivity analysis of the claims, indicates the options' priorities relative to each other, with respect to each criterion and also on the whole. The right and left axes in the above figure show the options' scores and the importance of the criteria, respectively.

2.3. The index of cost and time claims

Different kinds of claims may usually occur in different projects with different construction costs and times. Sometimes the claims that are raised in a particular project, despite their high amount of costs and extremely long time, are still compatible and acceptable considering the project's special conditions. The reason is that the mere comparison between the numerical values of the time and cost claims in different projects is not a viable and appropriate criterion (due to their different time and cost values). Therefore, it is required to define an index that in addition to considering the cost and time claims, could also address the special requirements and conditions in each project in terms of time and cost. Thus, with calculation of such an index in different projects and comparing the obtained values, more reliable and analyzable results with regard to the special conditions of the projects' claims can be perceived.

For this purpose, two different indices are defined for the cost and time claims. These two indices and their calculation formulas are given below:

$$\text{Cost Claim Index (CCI)} = \frac{\text{The excess claimed cost in the project}}{\text{Total cost of the project}};$$

$$\text{Time Claim Index (TCI)} = \frac{\text{The excess claimed time of the project (in months)}}{\text{Total project time (in months)}}.$$

Hence, by comparing these two indices in different projects, a comprehensive and analyzable picture of their situation in terms of the claims can be achieved. In addition, the success rate of every project manager in the management of his/her claims can be scrutinized to find the reasons for gaining success in future projects.

2.4. Predicting the claims by Artificial Neural Networks

The main objective of this research is to find a method to predict the occurrence of possible future claims as well as the frequency and level of such claims. By recognizing, classifying, and comparing the claims, the causes of their emergence can be discovered. Moreover, each cause can be allocated to a specific field of management with a more influence to control it. Having found the most important and critical causes, more focused attention and energy can be made on such causes. By providing a model for predicting the rate of possible claims in the future, the approximate rate of these claims can be known before their occurrence. Moreover, in case this rate is excessive and unacceptable, it can be tried to improve the current conditions prior to its occurrence so that the extent of these claims would reach to an acceptable level.

For this purpose, the multilayer perceptron (MLP) neural network has been applied. In this type of network, the nodes' activation function or the neurons located within each layer are similar to each other. However, the activation functions of different layers can be considered different from each other. The type and coefficients of the activation functions of layers are determined depending on the type of problem and the network's application. The layer on the left is called the input layer. The coefficients, called weights, are written on the lines between the layers. The weight on each line may differ from the weight on the other line. The number of nodes in the input and output layers of the network is related to the problem's known and unknown facts, but the number of nodes in the middle layers is determined according to the previous experiences as well as the problem's need (Haykin 2009). In order to train the applied artificial neural network, due to a number of advantages such as having a mathematical basis, high simplicity, and high efficiency, the back-propagation method has been chosen. Different probable situations that may happen are defined for the selected most important causes of claims and are organized in some questionnaires and distributed amongst a number of experts. These experts provided us the inlets in specific projects for each of these cases, and expressed the claims occurred in the projects as the time and cost indicators. It is advantageous to use this index, because while it is easily comparable between different projects, it is also beneficial to increase the neural network learning capability. For instance, it might happen that in a specific project, the worst managerial conditions lead to a cost claim and due to the small size of the project, the claimed cost and claimed implementation time become slightly more appropriate than a large project with the proper claims management (and vice versa). Thus, with the mere comparison of the values of these claims, the neural networks would not be able to find the optimal relationships. On the other hand, after training the network, by inserting the entry conditions of each project, the rate of probable claims can be received as an index, which helps maintaining the network capability for different projects with different working volumes.

In this neural network, the objective after training is that the network could predict the values of the cost and time claims' indices in that project through obtaining the specific conditions for each case of the claims on the project. Each of the causes of claims is given as an input to the neural network. Then, it goes to the first intermediate layer with 40 nodes, and subsequently, it enters the second intermediate layer with 40 nodes. Finally, their values are given to the output layer with 2 nodes. These two nodes represent the values of the cost claim index (CCI) and the time claim index (TCI). For network training, at first, the initial weights need to be randomly defined to establish the connection between the adjacent layers' nodes in such a way that the input layer would be connected to the first intermediate layer, the first intermediate layer to the second intermediate layer, and at the end, the second intermediate layer to the output layer. For this purpose, the rand function has been employed. The training rate is chosen as 0.1 by trial and error. For training, the patterns should be trained to the network multiple times. Each series of training is called an "epoch". For a better training of the network, the sequence of the patterns' training in each epoch is different from the other epochs. To perform this procedure, the *randperm* function has been used. The number of epochs depends on the network error value, which is calculated in each epoch as the sum of errors obtained from the patterns. The network error function is given in Equation (9). To initiate the process of network training, the entire operation is placed in a general loop, where the loop represents the number of epochs. In the general loop, firstly, an output is taken from the network by random weights (Appendix, Table 1A and Fig. 1A), and through calculating the error value between the existing output and the optimal output, the weights are corrected according to the following formula:

$$\varepsilon = \frac{1}{2}\sum_{k=1}^{n}\left(Y_{dk} - Y_k\right)^2 = \frac{1}{2}\sum_{k=1}^{n}\left(Y_{dk} - f_{1(y_k)}\right)^2, \quad (1)$$

where f_1 is the activation function of the output layer, and

$$\frac{1}{2}\sum_{k=1}^{n} = \left(Y_{dk} - f_1\left(\sum_{j=1}^{m} T_{jk}.H_j\right)\right)^2, \quad (2)$$

where T is the weight connecting the second intermediate layer to the output layer, and H is the output of the second intermediate layer:

$$\frac{1}{2}\sum_{k=1}^{n}\left(Y_{dk} - f_1\left(\sum_{j=1}^{m} T_{jk}.f_2\left(h_j\right)^2\right)\right)^2, \quad (3)$$

where f_2 is the activation function of the second intermediate layer:

$$\frac{1}{2}\sum_{k=1}^{n}\left(Y_{dk} - f_1\left(\sum_{j=1}^{m} T_{jk}.f_2\left(\sum_{i=1}^{l} W_{ij}.G_j\right)\right)\right)^2, \quad (4)$$

where W is the weight connecting the first intermediate layer to the second intermediate layer, and G is the output of the first intermediate layer:

$$\frac{1}{2}\sum_{k=1}^{n}\left(Y_{dk} - f_1\left(\sum_{j=1}^{m} T_{jk}.f_2\left(\sum_{i=1}^{l} W_{ij}.f_3(g)\right)\right)\right)^2, \quad (5)$$

where f_3 is the first intermediate layer's activation function, and

$$\frac{1}{2}\sum_{k=1}^{n}\left(Y_{dk} - f_1\left(\sum_{j=1}^{m} T_{jk}.f_2\left(\sum_{i=1}^{l} W_{ij}.f_3(V_{oi}.X_o)\right)\right)\right)^2, \quad (6)$$

where V is the weight connecting the input layer to the first intermediate layer, and X represents the input values to the network. Now, for changing the values of weights connecting the layers, the process is as follows:

$$T_{jk}^{new} = T_{jk}^{old} + \Delta T_{jk}; \quad (7)$$

$$\Delta T_{jk} = -\eta\frac{\partial\varepsilon}{\partial T_{jk}} = \eta\left(Y_{dk} - Y_k\right).\frac{\partial Y_k}{\partial T_{jk}} =$$

$$\eta\left(Y_{dk} - Y_k\right).\frac{\partial f_1(y_k)}{\partial y_k}.\frac{\partial y_k}{\partial T_{jk}} =$$

$$\Delta T_{jk} = \eta\left(Y_{dk} - Y_k\right).\frac{\partial f_1(y_k)}{\partial y_k}.H_j,$$

where the weight between the second intermediate layer and the output layer is modified. Then, to correct the weight between the first and second intermediate layers, the following steps should be taken:

$$W_{jk}^{new} = W_{ij}^{old} + \Delta W_{ij}; \quad (8)$$

$$\Delta W_{ij} = -\eta \frac{\partial \varepsilon}{\partial W_{ij}} = \eta \sum_{k=1}^{n} (Y_{dk} - Y_k) . \frac{\partial Y_k}{\partial W_{ij}};$$

$$\Delta W_{ij} = \eta \sum_{k=1}^{n} (Y_{dk} - Y_k) . \frac{\partial f_1(y_k)}{\partial y_k};$$

$$T_{jk} . \frac{\partial f_2(h_j)}{\partial h_j} . G_i .$$

Finally, according to the following method, the weights between the first intermediate layer and the input layer are corrected:

$$V_{oi}^{new} = V_{oi}^{old} + \Delta V_{oi}; \quad (9)$$

$$\Delta V_{oi} = -\eta \frac{\partial \varepsilon}{\partial V_{oi}} = \eta \sum_{n=1}^{k} (Y_{dk} - Y_k) . \frac{\partial Y_k}{\partial V_{oi}};$$

$$T_{jk} . \frac{\partial f_2(h_j)}{\partial h_j} \quad \frac{\partial h_j}{\partial V_{oi}} =$$

$$\eta \sum_{n=1}^{k} (Y_{dk} - Y_k) . \frac{\partial f_1(y_k)}{\partial y_k} . \quad \frac{\partial Y_k}{\partial V_{oi}};$$

$$\Delta V_{oi} = \eta \sum_{n=1}^{k} (Y_{dk} - Y_k) . \frac{\partial f_1(y_k)}{\partial y_k} . T_{jk} . \frac{\partial f_2(h_j)}{\partial h_j} . W_{ij} . \frac{\partial f_3(g_i)}{\partial g_i} . X_0 .$$

At the end of the overall loop, the error value of each output related to each pattern is measured according to Eqn (9). Their values are added up and then, the total value of all errors is obtained from the sum of errors of all patterns in each epoch. The graph of error reduction during the network training is elaborated in the following Figure 2.

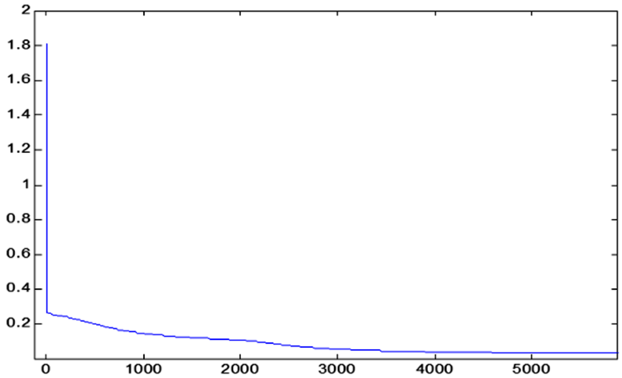

Fig. 2. The error reduction graph during training the neural network

The final value of error has reached 0.2%. Ultimately, with respect to the number of patterns in each epoch and the number of outputs in each pattern and also for more assurance, the smallest value of the outputs computing error equal to 1.25% is considered acceptable.

3. Case study

Now, the trained network must be tested with some new data to validate its capability to be used in different projects. To do this, by using the modified weights, new input values are given to the network and their output values are extracted. Afterwards, the results are compared with the real output. For this purpose, three construction projects in the construction industry have been selected. The first project is an 80 million dollar project with the duration of 37 months. The main reasons for the claims are due to "inflation", "inaccurate estimation", "failures to timely notify the contractor about the contract", and the "sanctions". However, the project has been benefited from the possibility of purchasing the materials and equipment from intermediaries at higher prices. The expense claims occurred in this project accounted for 10 million dollars and the final completion time is 49 months. Thus, the indices for cost claims (CCI) and time claims (TCI) are obtained as 0.125 and 0.324, respectively. The neural network predicted the values of 0.122 and 0.321 for this project respectively for the CCI and TCI.

The second project is a project with the contract amount of 215 million dollars and the run time of 38 months. The contract of this project is of EPC and the major causes of claims included the following items: "very high inflation", "political and economic sanctions", "lack of proper budgeting", "inaccurate estimation ", "lack of timely notification", and "performing overtime work without the specified prices in the contract". However, it is worth to add that a transparent method of pricing has been utilized in this project. The amount of cost claims occurred in this project accounted for 40 million dollars and the final time of accomplishment lasted in 58 months. The indices related to this project are: 0.186 for the cost claims and 0.526 for the time claims. Moreover, the neural network had predicted the values of 0.196 and 0.508 for the cost and time claims, respectively.

The third project, which is amongst the best types of contracts in terms of the claims management, has been constructed as lump-sum, with the contract value of 23 million dollars and the construction time of 12 months. The cost claims of the project amounted as 300 thousand dollars with 45 days delay in delivery. The cost and time claims indices are 0.013 and 0.125, which have been predicted by the neural network as 0.027 and 0.1177, respectively.

By using this prediction method, an estimation of the contingent claims rate in the future projects can be achieved. Furthermore, having all the causes leading to claims and considering the most important ones (according to the importance rate of each of the time and cost claims and with respect to their sensitivity analysis), the energy and time would be spent for the most important and effective causes of the claims with more critical influence on the project.

Conclusions

Appropriate management of claims plays a crucial role in the ultimate success of construction projects. The importance of claim management in this industry which is attributed to high uncertainties, long durations, and high costs, stands among on the top. In the present study, firstly, the causes of disputes in the construction projects in Iran construction industry are identified and then grouped to 9 different sections based on their nature. Base on this grouping, In case of the occurrence in a project, each case can be referred to the corresponding professional management team based on proposed grouping. This significantly helps to manage the claims more effectively. By using the perspective of probability-impact and the weighted average index, the most important factors are chosen. Afterwards, based on different importance of time and cost claims, the causes of claims are ranked based on AHP results. This ranking, in addition to prioritizing the main factors, specifies the percentage of the overall priority for each item (which represents its relative weight in contrast to other factors). In various cases of claims, different indices are required to be able to scrutinize each case. In other words, in different projects, due to different amounts of contracts and completion times, managers are not simply able to compare them with each other. As a result, the claims raised in a case are incomparable in terms of the costs claimed or the number of additional days claimed. For this reason, two indices of the time and cost claims are defined in this study. Then, the artificial neural network approach is employed to predict the rates of probable time and cost claims in the projects. Therefore, for each of the main causes of disputes selected in this study, different circumstances of these factors are considered to enable the project managers and experts to predict the rates of time and cost claims by taking the special case of their projects. Consequently, they can have an approximate estimation of the various cost and time claims that may occur in their projects. In addition, since the answers of this network have been introduced as an index, each project manager can estimate the probable cost claims and probable time claims (months), according to the obtained number from this model and also the overall cost and time of the studied project. Therefore, if the probable cost and time claims are not optimal, there will still exist a good chance of changing the causes of the occurrence. Even with small changes in the causes of claims, the changes in the results can be apparently witnessed, and by considering the results, the best, simplest, least expensive, and the most effective situation for the project claims management can be selected.

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Appendix

Table 1A. The weights used in the first and second intermediate layers based on epochs Conditions and Randperm function

1	–0.15	–0.16	–0.15	–0.15	–0.16	–0.17	–0.14	–0.39	–0.15	–0.16	–0.15	–0.22	–0.2	–0.15	–0.16	–0.15	–0.15	–0.16	–0.15	–0.16
2	–0.14	–0.16	–0.15	–0.15	–0.16	–0.16	–0.08	0.366	–0.15	–0.15	–0.14	0.231	0.222	–0.13	–0.16	–0.13	–0.15	–0.15	–0.15	–0.16
3	–0.13	–0.15	–0.13	–0.13	–0.14	–0.16	–0.09	0.15	–0.13	–0.13	–0.12	0.072	0.061	–0.12	–0.17	–0.12	–0.13	–0.15	–0.14	–0.14
4	–0.07	–0.05	–0.06	–0.06	–0.05	–0.04	–0.09	0.206	–0.06	–0.06	–0.07	–0.15	–0.04	–0.07	–0.04	–0.07	–0.06	–0.05	–0.06	–0.06
5	–0.09	–0.13	–0.11	–0.09	–0.11	–0.12	–0.05	0.103	–0.1	–0.11	–0.09	0.067	0.083	–0.09	–0.13	–0.09	–0.1	–0.11	–0.11	–0.11
6	–0.02	–0.05	–0.04	–0.02	–0.04	–0.04	0.047	0.039	–0.02	–0.03	–0.02	0.178	0.144	–0.01	–0.05	–0.01	–0.02	–0.03	–0.04	–0.04
7	–0.16	–0.26	–0.21	–0.17	–0.22	–0.25	–0.11	0.578	–0.18	–0.19	–0.15	–0.1	–0.02	–0.14	–0.31	–0.15	–0.18	–0.21	–0.21	–0.21
8	–0.04	–0.02	–0.03	–0.04	–0.03	–0.02	–0.05	0.261	–0.04	–0.03	–0.04	–0.02	0.048	–0.05	–0.02	–0.04	–0.04	–0.03	–0.03	–0.03
9	–0.12	–0.03	–0.08	–0.11	–0.06	–0.04	–0.2	–0.49	–0.11	–0.09	–0.13	–0.39	–0.36	–0.14	0.012	–0.13	–0.1	–0.08	–0.08	–0.07
10	-0.01	0.027	0.013	-0.01	0.013	0.029	–0.011	–0.2	0.006	0.007	0.002	–0.06	–0.07	–0.01	0.042	–0.01	0.005	0.014	0.009	0.009
1	–0.15	–0.16	–0.16	–0.16	–0.17	–0.17	–0.15	–0.14	–0.15	–0.17	–0.21	–0.15	–0.16	–0.17	–0.16	–0.15	–0.16	–0.15	–0.16	–0.15
2	–0.13	–0.16	–0.16	–0.16	–0.16	–0.16	–0.15	–0.11	–0.12	–0.16	0.23	–0.15	–0.16	–0.15	–0.15	–0.14	–0.16	–0.16	–0.15	–0.15
3	–0.13	–0.14	–0.14	–0.16	–0.16	–0.17	–0.13	–0.11	–0.12	–0.16	0.071	–0.13	–0.14	–0.15	–0.14	–0.13	–0.15	–0.16	–0.14	–0.13
4	–0.07	–0.05	–0.05	–0.04	–0.05	–0.04	–0.06	–0.08	–0.08	–0.04	–0.1	–0.06	–0.05	–0.05	–0.06	–0.07	–0.05	–0.04	–0.05	–0.06
5	–0.09	–0.12	–0.11	–0.12	–0.12	–0.12	–0.1	–0.07	–0.08	–0.12	0.069	–0.1	–0.11	–0.12	–0.11	–0.1	–0.13	–0.13	–0.1	–0.09
6	–0.01	–0.04	–0.03	–0.04	–0.05	–0.04	–0.02	0.027	0.003	–0.04	0.156	–0.02	–0.04	–0.05	–0.04	–0.02	–0.05	–0.05	–0.02	–0.02
7	–0.15	–0.22	–0.21	–0.26	–0.25	–0.29	–0.18	–0.12	–0.14	–0.27	–0.07	–0.18	–0.22	–0.22	–0.19	–0.17	–0.26	–0.32	–0.19	–0.18
8	–0.04	–0.03	–0.03	–0.02	–0.02	–0.02	–0.04	–0.05	–0.04	–0.02	0.011	–0.04	–0.02	–0.03	–0.03	–0.04	–0.02	–0.02	–0.04	–0.04
9	–0.13	–0.07	–0.08	–0.04	–0.04	–0.02	–0.11	–0.18	–0.15	–0.03	–0.38	–0.11	–0.07	–0.06	–0.08	–0.11	–0.03	0.008	–0.11	–0.11
10	–0.01	0.012	0.009	0.028	0.023	0.036	0.005	0.001	–0.01	0.025	–0.07	0.007	0.015	0.023	0.012	–0.01	0.027	0.042	0.012	–0.01

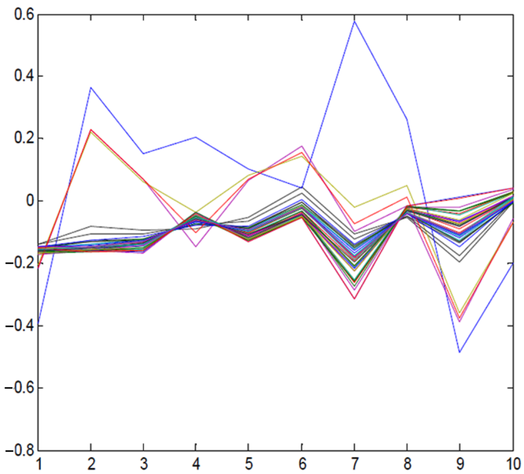

Fig. 1A. Changing of weights in neural network