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Significant Factors Causing Delay of Ethiopian Road Construction Projects performing by Foreign General Contactors

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Abstract:. Following the booming of the Ethiopian construction industry, a number of Foreign General Contractors (FGCs) are participating in the industry. The severity of the construction projects schedule delay, which is a worldwide problem also, affecting the FGCs participating in the Ethiopian road construction projects. Identifying the challenging factors affect the project performance was an important and initial stage for improving the project progress. This study identified the significant factors that cause the projects schedule delay systematically and objectively. After 30 factors were determined from literature and pilot survey, the final questionnaire survey of 235 domain experts was conducted to systematically select 20 factors. Based on the 20 selected factors, 81 historical data of road construction projects with schedule delay were collected; and the database was established. The artificial neural network (ANN) inference model was developed to train the database and predict the project schedule delay. Integrating it with the Garson algorithm (GA), the relative weights of challenging factors with rankings were calculated and identified. The top ten significant factors identified were Contractor's poor site management; Ineffective planning, scheduling, controlling and quality monitoring; Difficulty in Budget availability for the project; Delays in construction activities due to weather changes; late land acquisition; Shortage of materials; Financial problem of contractors; Poor supervision; Cash-flow problems (irregular payments), and Financial Capability of Client. This study uses as a significant reference for FGCs who are currently working in the Ethiopian Road construction projects for improving the projects schedule performance.

Keywords: Foreign general contractors, construction schedule delay, Ethiopian Road construction Projects, Relative Importance Index, artificial neural network, Garson algorithm

1. Introduction

One of the most common issues with construction industry is deviation from a predetermined time schedule, which affects both developed and developing nations (Kazaz, Ulubeyli and Tuncbilekli 2012). On-time project completion is a sign of efficiency, but the construction process is subject to a lot of uncertainties and unforeseen elements that come from a variety of sources (Assaf and Al-Hejji 2006). Perhaps more than any other sector, the construction industry has seen a variety of hazards that frequently lead to subpar performance, rising prices, schedule delays, and even project collapse (Zeng, An and Smith 2007). In addition to having an impact on the construction industry, cost overruns and schedule delays also have an impact on the general economy (El-Karim, Nawawy and Abdel-Alim 2017).

In Ethiopia, construction industry has significant contribution to GDP of the country and creates jobs for millions of the citizens (Cheng and Darsa 2021), which is struggling with the severity of schedule delay. Besides the local contractors, international contractors from China, India, South Korea, Saudi Arabia, Spain and other overseas countries are currently

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participating in the industry, and they are facing challenges and difficulties during construction stage that hinder better performance of the construction projects.

Identifying significant challenging factor is essential for a project manager to improve performance that could minimize the schedule delay. Subjective judgment is the most common techniques for identifying the factors affecting a construction project performances (R. F. Aziz 2013) (Aziz and Abdel-Hakam 2016) (El-Razek1, Bassioni and Mobarak 2008) (Gebrehiweta and Luob 2017) (Sambasivan and Soon 2007) (Sweis, et al. 2008). However, the subjective judgment is not consistent among the experts, for different experts the decisions on specific factor will also different. This cause in the same geographical area different studies can get different finds due to the inconsistent of the expert judgments that could makes confusion on a project manager on which factors needs to focus for improving the schedule performance.

Moreover, through the experts' subjective judgments, it difficult to consider the non-linear characters of the challenging factors. According to (Cheng and Darsa 2021) several researchers perceive the factors as linear and independent that could not consider the complexity and uncertainty of the problems. The interplay between the components is what ultimately results in the schedule delay. As a result, the research' ranking findings may not accurately reflect the presumption that the elements are linear and independent.

The primary focus will therefore be on discovering and taking into account the interacting relationships of the factors in the study for priority ranking in order to effectively and considerably reduce the schedule delay. The main purpose of this research is to identify the significant challenging factors objectively. Artificial neural network is the artificial intelligence technique that could determine the impact of the factors through input and output mapping relationship. This ANN was implemented in this research for identifying the significant challenging factors causing the schedule delay in construction projects run by foreign general contractors. The Garson algorithm was implemented to interpret the ANN 'black box' and used to rank the significant challenging factors.

2. Literature Review

2.1 Garson Algorism

This section introduces the Garson algorism to calculate the relative weights of the challenging factors by interpreting the 'black box' of ANN. Even though, the ANN is important for determining the mapping relationship among the challenging factors and the projects' schedule performance, computing the RWs of input variables is challenging because to a lack of understanding of the ANNs' 'black box,' as demonstrated by (Xu, Wong and Chin 2013). Then for solving this challenge, Garson algorism is introduced in this section in order to open the 'black box' of ANN (Garson 1991). Garson algorism employs the following formula to decode the ANN's 'black box':

$$\mathrm{RW_{ik}} = \frac{\sum_{j=1}^{p} \frac{|W_{ij}||W_{jk}|}{\sum_{i=1}^{N}|W_{ij}|}}{\sum_{i=1}^{N}\sum_{j=1}^{p} \frac{|W_{ij}||W_{jk}|}{\sum_{i=1}^{N}|W_{ij}|}} \tag{1}$$

where RW_{ik} denotes the relative weight of input factors x_i on the output y_k, W_{ij} denotes the connection weight between the *i*th input variable and the *j*th hidden neuron, and W_{jk} denotes the connection weight between the *j*th hidden neuron and the *k*th output variables (Xu, Wong and Chin 2013).

It is obvious that ANN is associated by connection weights from input to hidden and from hidden to output layer. The input factor with high influence on output has greater weight than those have low influences. The hidden-output connection weights of each hidden neuron are divided into components related to each input neuron by Garson algorithm in order to calculate the RWs of independent factors (Gevrey, Dimopoulos and Lek 2003). To calculate the RWs of the input variables, Garson algorithm uses a trained ANN with three input neurons, four hidden neurons, and one output neuron as an example. In Table 1, the connection weights of the ANN architecture's hidden layers are displayed. The following are the Garson algorithm computation methods:

Table 1 - ANN architecture's connection weights

Hidden Neurons	Weights			
	Input 1	**Input 2**	**Input 3**	**Output**
Hidden 1	−1.67624	3.29022	1.32466	4.57857
Hidden 2	−0.51874	−0.22921	−0.25526	−0.48815
Hidden 3	−4.01764	2.12486	−0.08168	−5.73901
Hidden 4	−1.75691	−1.44702	0.58286	−2.65221

For each hidden neuron i, multiply the absolute value of the hidden-output layer connection weight by the absolute value of the hidden-input layer connection weight for each input variable j, as presented in Table 2;

Table 2 - Product of the absolute values of the hidden-output and hidden-input layer connection weights (P_{ij})

	Input 1	Input 2	Input 3
Hidden 1	P_{11} = 1.67624 × 4.57857	P_{12} = 3.29022 × 4.57857	P_{13} = 1.32466 × 4.57857
Hidden 2	P_{21} = 0.51874 × 0.48815	P_{22} = 0.22921 × 0.48815	P_{23} = 0.25526 × 0.48815
Hidden 3	P_{31} = 4.01764 × 5.73901	P_{32} = 2.12486 × 5.73901	P_{33} = 0.08168 × 5.73901
Hidden 4	P_{41} = 1.75691 × 2.65221	P_{42} = 1.44702 × 2.65221	P_{43} = 0.58286 × 2.65221

For each hidden neuron, divide p_{ij} by the sum of all the input variables to obtainQ_{ij}. For example, for hidden neuron 1, $Q_{11} = p_{11}/(p_{11} + p_{12} + p_{13}) = 0.266445$ (see Table 3);

Table 3 - Division of the product connection weight (P_{ij}) by the sum of all the input variables to obtain (Q_{ij})

	Input 1	Input 2	Input 3
Hidden 1	Q_{11} = 0.266445	Q_{12} = 0.522994	Q_{13} = 0.210560
Hidden 2	Q_{21} = 0.517081	Q_{22} = 0.228478	Q_{23} = 0.254441
Hidden 3	Q_{31} = 0.645489	Q_{32} = 0.341388	Q_{33} = 0.013123
Hidden 4	Q_{41} = 0.463958	Q_{42} = 0.382123	Q_{43} = 0.153919
Sum	S_1 = 1.892973	S_2 = 1.474983	S_3 = 0.632044

For each input neuron, add all the products S_j formed from the previous computations of Q_{ij}. For example, $S_1 = Q_{11} + Q_{21} + Q_{31} + Q_{41} = 1.892973$ (see Table 3);

Divide S_j by the sum of all the input variables. The RW of an input variable is obtained as a percentage by multiplying the resulting value after the aforementioned division by 100. For example, the relative importance of input neuron 1 or input factor 1 is $(S_1 * 100)/(S_1 + S_2 + S_3) = 47.3\%$ (see Table 4).

Table 4 - Relative weights of input variables

	Input 1	Input 2	Input 3
Relative weight (%)	47.3	36.9	15.8

2.2 Determining the Challenging Factors that Cause Schedule Delay

Several researchers identified factors causes the schedule delay across the globe and in literature, the identified factors were inconsistent among the studies. This may be due to variety in geographical location and the subjective judgment as the main tools for identification. By nature the subjective judgment, it is inconsistent among the experts which may have the significant role for factors variety among researchers. This inconsistence of the identified factors from one literature to another is causing confusion on project manager to which factors need more focus to improve the schedule performances. Before conducting the final survey, it is better to determine the challenging factors relevant to the study area. For this research, the relevance of the factors to the study area is tested and the factors were systematically selected, after go through different stages. In the first stage the factors that frequently happened in the literature reviewed were determined and the summary was shown in Table 5. Then the pilot questionnaire survey was conducted to test whether the factors determined from different literature were relevant to the study area. The final questionnaire survey was developed based on the factors determined from the literature review and the decisions of the experts through the pilot survey.

Finally, the 20 top ranked challenging factors by using RII were selected to identify the significant factors causing the construction projects schedule delay. In this research the RII was used for factors selection only, rather than for identifying challenging factors. Through this RII the experts' decision on the factors were considered and the artificial intelligence technique (ANN) was used for final challenging factors identification. This ANN was implemented for identifying the factors objectively without incorporating the subjective judgments, since the subjective judgment is inconsistent among the experts and their results may cause confusion on the project managers. The very important in this research is the factors were identified through objective technique by also incorporating the experts' idea on the challenging factors during the factors selections.

Table 5 - Relative weights of input variables

Sn	Factors	Literature										
		(El-Razek1, Bassioni and Mobarak 2008)	(Akomah and Jackson 2016)	(Sambasivan and Soon 2007)	(Aziz and Abdel-Hakam 2016)	(Sweis, et al. 2008)	(Cheng and Darsa 2021)	(Doloi, et al. 2012)	(R. F. Aziz 2013)	(Gebrehiweta and Luob 2017)	(Khair, et al. 2018)	(Antoniou 2021)
1	Contractor's poor site management			√	√			√	√	√	√	
2	Shortage of materials			√	√					√		
3	Late land acquisition				√						√	
4	Delays in construction activities due to weather changes		√									√
5	A shortage of manpower					√						√
6	Financial problem of contractors	√				√					√	
7	Non-payment or delay of completed works	√		√			√		√		√	
8	Cash-flow problems (irregular payments)	√			√							
9	Low skilled manpower				√	√			√		√	
10	Poor contract management	√						√			√	
11	Ineffective planning, scheduling, controlling and quality monitoring			√		√		√	√	√	√	
12	Difficulties in project financing (no sufficient funds) by client			√	√						√	
13	Inflation effect on materials purchasing								√	√	√	
14	Drawing changes	√			√							
15	Unforeseen ground conditions		√		√							
16	Poor Political situation and security				√							
17	Poor supervision								√			
18	Poor communication			√				√				
19	Inadequate contractor experience			√	√				√			
20	Too many change orders by clients	√		√	√	√	√		√			√
21	Bribery and corruption						√		√	√		
22	Changes in site conditions							√				√
23	Control sub-contractors through poor contract terms			√	√							

3. Research Methodology

The study mainly assessed the main causes of the schedule delay for the construction projects run by foreign general contractors in Ethiopia. To accomplish this research, the frequently happened challenging factors in the review literature were determined, then for testing whether the determined factors were relevant to the study area, pilot survey was conducted. The final questionnaire survey was developed based on the recommendation from the experts. In the final questionnaire survey 235 experts were contacted. The foreign general contractor experts; contract administrator, project follow up and coordinators, supervision, claims experts and Employer (Ethiopian Road Administration) project Engineers and also team leaders were the target group. The experts' judgment under the final questionnaire survey was conducted for selecting the most important factors and to collect the historical cases of construction projects to identify the significant challenging factors objectively.

3.1 Data Collections and Challenging Factors Selection

Data collections have three phases and two stages. In the first phase, the factors frequently happened in the reviewed literature were determined and the pilot questionnaire survey was performed for testing of the relevant factors in the study area. Then the structured questionnaire survey was developed by incorporating the determined factors and experts recommendation. In this stage the irrelevant factors were removed from determined factors from literature and added the factors that not included in the list. To facilitate this data collection, the questionnaires were filled in both online and offline. From 245 responses recorded only 235 respondents fill the questionnaires survey according to the instruction and the remaining 10 respondent's data didn't consider in data analysis because of invalid/void filling. The participant includes of 14 diploma holders, 164 BSc, 53 MSc and 4 PhD as of their educational statuses and it is illustrated in Table 6.

Table 6 - Year of experience and educational status of the respondents

Year of experience (in range)	Number	Educational level	Number
0 to 5	61	Diploma holders	14
5 to 10	100	BSc holders	164
10 to 15	46	MSc holders	53
More than 15	28	PhD holders	4
Total	235		235

Based on their year of experience in the industry: 61 experts have the year of experience range between 0-5; 100 participants have 5 to 10; 46 have 10-15 and 28 of them have more than 15 years of experience in the industry.

The final questionnaire survey has two major parts. Part (I): General information of the respondents (e.g. Type of organization employed, education level and construction year of experience). Part (II): A close ended/fixed alternative of five-point Likert scale ranging from 1 (very low) to 5 (very high) were used to determine the impact of the challenge factors over the projects' progress. To provide a degree of importance for each factor, relative importance index was used and determined as the following Equation 2 (Doloi, et al. 2012).

$$\boldsymbol{RII = \frac{\sum_{i=1}^{5} W}{A * N}} \qquad (2)$$

Where, W is the weight given to each factor; A is the largest scale available and N is the number of respondent answered the question.

Including the RII results, the factors selection was accomplished following three phases. That is literature review, pilot survey, and RII results computed from structural questionnaire survey. This means before establishing the database, several stages were undertaken to systematically select the influencing factors. In the first phase 23 factors were determined from the reviewed literature from the top causes reported by researchers. In the second step pilot questionnaire survey was commence for adding and removing the factors based on the recommendation from the experts. Based on the recommendation 30 factors were decided for developing the final questionnaire survey conducting, and RII results were computed. The RII results were used to select the most important factors to collect the historical data of the construction projects (second round data collection) and establishing the database to train ANN for commencing the schedule delay prediction.

ANN was implemented to identify the significant factors objectively based on the systematically selected factors. This approach was conducted because the factors identified by subjective judgments are inconsistent among the research finding even on the same geographical location. Moreover, there is no any way to justify the factors are the right factors causing the schedule delay on the study area. This could cause confusion on the project managers on which factors needs more focus for improving the projects' performances. Then this AI technique was chose for identifying the significant factors to minimize this confusion, furthermore to identify the challenging factors objectively.

3.2 Historical Data collection and Establishment of the Database

The collected historical data was used to establish the database. To collect the historical data, the questionnaire was prepared based on the factors selected using RII. The stakeholders were asked whether the factors are affecting their project or not. The format of the question was prepared as "do you think the following factors affecting the progress of your construction project?" and they could answer by saying 'Yes' if the factors are affecting their projects and 'No' if it does not affect the project. The respondents give the answer either 'Yes' if the factors affecting their projects or 'No' if the selected factors were not affecting their projects. The information collected from the experts was used to establish the database after converting to the binary system. This means, in the database binary system were used for the input values. This means, Yes or No answer was converted to the binary form in the database by replacing 'Yes = 1' and 'No = 0' to insert the values of input factors. A total of 81 road construction projects that administered by Ethiopian roads Administration (ERA) with schedule performance report has been asked the experts of each project whether the selected factors were affecting their projects or not. The percentage of the schedule performance, which the stakeholders were reported to the government office were used as the output value in the database.

All collected construction projects have different percentage of the schedule performance and also the challenging factors are different among different projects. May be only some of the selected factors affect a project or may be all the selected factors being able to affect a project progresses. The database containing selected input factors, one output factor (percentage of the progress schedule) and collected historical cases of the road construction projects.

3.3 ANN Training, Testing and Validation

After the preprocessing of the database was finalized, ANN was applied to train and predict the schedule delay. ANN is an artificial intelligence technique, which a powerful to determine the mapping relationship among the input factors with the output variable. Before implementing the prediction of the schedule performance, in this study, the accuracy of the data also tested and the results are also validated. 10-fold cross validation technique is used for validating the accuracy and RMSE of the training and testing results also measured to determine the level of accuracy for the data sources. Finally, after the results are believed to be satisfied, the Garson algorithm was employed to compute the relative weights of the selected factors from the whole trained data. The relative weights of the factors also sorted used to identify the significant challenging factors that facing the foreign general contractors practicing in the Ethiopian road construction projects.

3.4 Computing the RWs of Challenging Factors Using Garson Algorithm

After training was completed, Garson algorithm was used to determine the RWs of the challenging factors by partitioning the connection weights of the trained ANN to rank the factors according to the following procedure:

a) Determine p_{ij} of the selected risk factors by multiplying the absolute values of the hidden-output layer connection weights by hidden-input layer connection weights.

b) Then the Q_{ij} of the selected factors were computed by dividing p_{ij} by the sum of all the input factors; for input factor 1, Q_{11} is calculated as follows:

$$Q_{11} = p_{11}/(p_{11} + p_{12} + p_{13} + p_{14} + p_{15} + p_{16} + p_{17} + p_{18} + p_{19} + p_{110} + p_{111} + p_{112} + p_{113} + p_{114} + p_{115} + p_{116} + p_{117} + p_{118} + p_{119} + p_{120}) \quad (3)$$

c) The s_1 of the risk factor is computed with the following formula, which is calculated from the previous computations of Q_{ij}.

$$S_1 = Q_{11} + Q_{21} + Q_{31} + Q_{41} + Q_{51} + Q_{61} + Q_{71} + Q_{81} + Q_{91} + Q_{101} \quad (4)$$

Finally, the input neuron 1 (F1), which is expressed as a percentage, is computed as follows:

$$F_1 = (S_1 * 100)/(S_1 + S_2 + S_3 + S_4 + S_5 + S_6 + S_7 + S_8 + S_9 + S_{10} + S_{11} + S_{12} + S_{13} + S_{14} + S_{15} + S_{16} + S_{17} + S_{18} + S_{19} + S_{20}) \quad (5)$$

4. Data Analysis

4.1 Introduction

In the phase I factors that affect foreign contractor's project progress in construction projects were determined from reviewed literatures. A total of 23 delay factors have been determined, and sent as pilot questionnaire survey to check whether the factors are relevant or not to the study area. Then based on the recommendation of the experts, the questionnaire survey was developed and data collection was commenced. The Likert scale containing [(very low), (low), (moderate), (high) & (very high)] were prepared for respondents for filling.

A total of 245 respondents have been participated in filling the questionnaires which 72.05% from proposed sample size of 340. From those 245 respondents 235 respondents fill the questionnaires according to the instruction and remaining 10 respondent's data not used in data analysis because of incomplete information. The RII approach was used to synthesize the experts' decision on importance of the factors. Based on the results, 20 top ranked factors that have value of Relative Importance Index (RII) >0.8, from a total 30 delay factors were selected. Then the final data collection/third phase was commenced depending on the selected factors. Moreover, 81 road construction projects with percentage of the schedule performance report were collected. For each project the selected factors also asked whether they are affecting their projects or not. Binary system was used to insert the input values during development of the database. The input value of 1 implies presence of the factor and 0 implies absence of the factors in a project. This information is used to establish the database to predict the schedule delay using ANN. Finally, Garson algorithm was employed to calculate the relative weights of the risk factors with ranking. The factors that have maximum relative weights indicate the most important factors causing the schedule delay in the industry.

4.2 Selecting the Factors Using the Relative Importance Index (RII)

The RII is the common technique that researchers are used to identify the factors causing construction projects' schedule delay. It is based on the experts' decision in the construction industry to identify the important factors. In this study, the RII technique was implemented for factors selection only. Since this RII is depend on the subjective judgments the final results of the study could not only based on this technique, and it is believed that the objective analysis technique would be another option for identification of significant challenging factors. The computed RII results of selected factors were summarized in the Table 7.

Table 7 - RII results of the selected challenging factors with ranking

S.N	Project progress Delay Factors	RII	Rank
1	*Shortage of materials*	*0.92*	*1*
2	*Inflation effect on materials purchasing*	*0.91*	*2*
3	*Late land acquisition*	*0.91*	*2*
4	*Delay or non-payment of completed works*	*0.91*	*2*
5	*Cash- flow problems (irregular payments)*	*0.90*	*5*
6	*Theft Activities*	*0.87*	*6*
7	*In sufficient funds for project financing*	*0.87*	*6*
8	*Control sub-contractors through poor contract terms*	*0.87*	*6*
9	*Difficulty in Budget availability for the project*	*0.87*	*6*
10	*Ineffective planning, scheduling, controlling and quality monitoring*	*0.86*	*10*
11	*Bribery and corruption*	*0.85*	*11*
12	*Financial Capability of Client*	*0.84*	*12*
13	*Poor supervision*	*0.83*	*13*
14	*Unforeseen ground conditions*	*0.83*	*13*
15	*Financial problem of contractors*	*0.83*	*13*
16	*Contractor's poor site management*	*0.83*	*13*
17	*Capacity of Supervision by Consultants*	*0.83*	*13*
18	*Delays in construction activities due to weather changes*	*0.82*	*18*
19	*Political and security problem*	*0.82*	*18*
20	*Poor contract management*	*0.81*	*20*

Then based on these RII results, 20 factors were selected as the important factors for historical data collection. The historical data of completed construction projects were collected in the second rounds based on the analysis results of the RII results. The collected data was used to establish the database for ANN training and testing.

4.3 ANN Training, Testing and Validation Using the Selected Factors

The 20 selected factors were used to commence second round historical data collection and for establishing the database. 81 completed construction project cases with the progress report were collected. The progress report indicates the percentage of the projects' performed from their plan. Then the database containing 20 input factors, 1 output factor and 81 historical cases was established as shown in Table 8 below, and then ANN was used for training and testing the database.

Table 8 - Established historical cases of the construction projects

Proj #	Input Factors																				Output
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F6	F17	F18	F19	F20	Delay%
1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1	1	1	1	0	16.642
2	1	1	1	1	0	1	1	0	1	1	1	0	0	1	0	1	1	1	1	1	77.912
3	0	1	1	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	87.500
4	1	1	1	0	0	0	1	1	1	1	0	1	1	1	0	0	1	1	1	1	37.447
5	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	29.024
6	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	19.167
7	1	1	0	0	1	1	0	0	0	0	0	1	1	0	0	1	1	1	1	1	72.857
8	0	0	0	1	0	0	1	0	0	1	1	0	1	0	0	1	1	1	1	1	92.870
9	0	1	1	1	0	1	1	1	0	0	0	1	0	1	1	1	1	0	1	1	70.810
10	1	1	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	93.040
11	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	89.121
12	1	1	0	1	1	0	0	0	0	1	0	0	1	1	1	0	0	1	1	1	88.462
13	1	0	0	1	0	1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	89.61
14	1	1	0	0	0	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	97.300
15	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	94.118
⋮																					
78	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	90.909
79	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	23.188
80	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61.441
81	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	89.888

An important factor in the training of ANN models is the number of neurons. An increase in the quantity of hidden neurons may accompany the over fitting. In the training stage, this phenomena lowers the RMSE, but not in the validation stage. Therefore, it is necessary to make try and errors in order to figure out the optimal amount of hidden neurons (Cheng and Darsa 2021). The RMSEs of training and validation in this study were at their lowest when there were 10 hidden neurons. Consequently, the ANN architecture consisting of 20 input neurons, which stood for the 20 challenging variables, 10 hidden neurons, and 1 output neuron, was adopted (Figure 1). A 10-fold cross-validation approach was used during the training and validation processes.

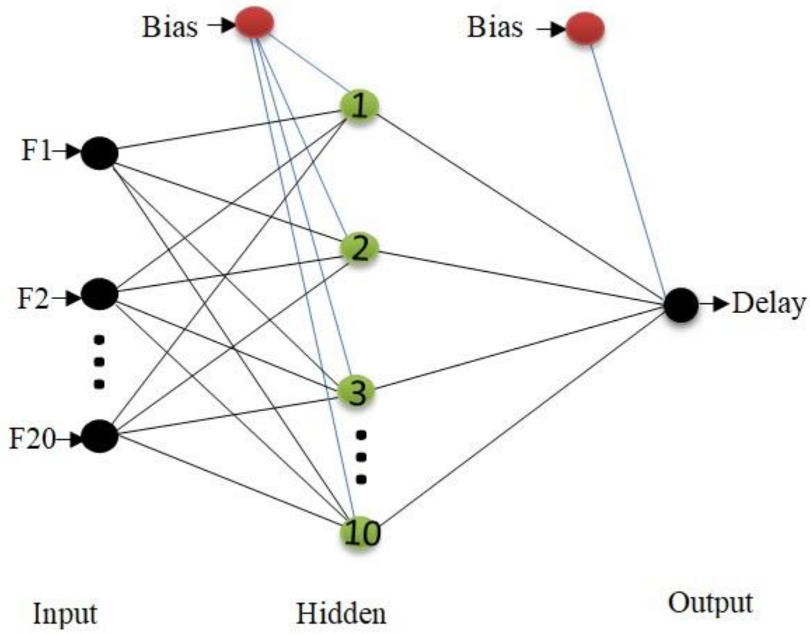

Fig. 1 - ANN architecture used in this study

4.4 Computations of the RWs of the Selected Factors Using the Garson Algorithm

Following the completion of data training, RWs were determined using the Garson algorithm by splitting the ANN's connection weight in order to rank the factors. This means, after ANN training, testing and validation were accepted; the Garson algorithm was used to ascertain the RWs of the 20 selected challenging factors and sorted based on their RWs. The greater the influence of a risk factor on schedule delay, the higher its RW. To determine the RWs of the selected factors, the procedure is illustrated as follow:

a) The absolute values of connection weights for all selected factors are presented in Table 9, for P_{11} computational procedure is also illustrated as follow:

$P_{11} = 0.294 * 0.905 = 0.266$ $\quad P_{12} = 0.556 * 0.905 = 0.503$

The results for computed P_{ij} are presented using Table 10.

Table 9 - Absolute values of the connection weights

	Weights																				
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	Output
Hidden 1	0.294	0.556	0.520	0.241	0.599	0.979	0.204	0.347	0.750	1.282	1.069	0.383	0.171	0.699	0.481	0.755	0.030	0.406	0.636	0.867	1.246
Hidden 2	0.618	0.029	1.088	0.133	0.283	0.547	0.300	0.181	0.593	0.392	0.137	0.780	0.500	0.046	0.661	0.347	0.414	0.804	0.240	0.104	1.230
Hidden 3	0.739	0.219	0.023	0.335	0.149	0.029	0.185	0.239	0.418	0.105	0.052	0.192	0.160	0.035	0.347	1.027	0.117	0.224	0.315	0.143	1.807
Hidden 4	0.311	0.947	0.798	0.435	1.398	0.314	0.139	0.063	0.427	0.697	0.142	0.207	1.384	0.520	1.563	0.762	0.167	0.217	0.378	0.537	1.749
Hidden 5	1.004	0.429	0.892	1.989	0.364	2.518	1.119	0.661	1.869	0.352	0.416	1.420	0.598	0.252	0.295	1.694	0.872	0.020	0.783	1.196	1.145
Hidden 6	0.600	0.226	0.187	0.037	1.638	0.412	0.320	2.001	0.220	1.833	2.094	0.446	0.768	1.212	0.325	0.530	0.214	2.039	1.605	1.419	1.739
Hidden 7	0.490	0.160	0.060	0.156	0.207	0.033	0.185	0.229	0.530	0.269	0.002	0.066	0.288	0.153	0.520	0.733	0.243	0.455	0.266	0.169	1.668
Hidden 8	0.569	0.154	1.112	0.131	1.272	0.321	0.403	0.402	0.253	0.585	0.037	0.538	0.577	1.134	0.918	0.317	1.054	1.724	0.197	0.125	2.088
Hidden 9	1.379	0.216	1.169	1.084	0.403	0.975	0.106	0.470	0.781	3.349	0.518	2.213	2.265	0.099	0.259	0.704	0.676	0.370	0.375	0.189	0.064
Hidden 10	0.155	0.177	1.259	0.149	0.166	0.160	0.165	0.037	1.010	0.311	0.202	0.465	0.108	0.101	0.024	1.199	0.160	0.717	0.367	0.457	1.017

Table 10 - Product of the absolute values of hidden-output and absolute values of hidden-input layers connection weights (pij)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
Hidden 1	0.266	0.503	0.470	0.218	0.542	0.886	0.185	0.314	0.679	1.160	0.968	0.347	0.155	0.633	0.435	0.683	0.027	0.367	0.575	0.785
Hidden 2	0.389	0.018	0.684	0.084	0.178	0.344	0.189	0.114	0.373	0.247	0.086	0.491	0.315	0.029	0.415	0.218	0.260	0.505	0.151	0.065
Hidden 3	0.118	0.035	0.004	0.054	0.024	0.005	0.030	0.038	0.067	0.017	0.008	0.031	0.026	0.006	0.056	0.164	0.019	0.036	0.050	0.023
Hidden 4	0.209	0.637	0.537	0.292	0.940	0.211	0.094	0.042	0.287	0.468	0.096	0.139	0.931	0.350	1.051	0.512	0.112	0.146	0.254	0.361
Hidden 5	1.047	0.447	0.930	2.074	0.379	2.626	1.167	0.689	1.949	0.367	0.433	1.481	0.623	0.263	0.308	1.767	0.909	0.021	0.816	1.248
Hidden 6	0.878	0.331	0.273	0.055	2.395	0.602	0.468	2.925	0.321	2.679	3.061	0.652	1.123	1.772	0.474	0.775	0.313	2.981	2.346	2.075
Hidden 7	0.119	0.039	0.015	0.038	0.050	0.008	0.045	0.056	0.129	0.065	0.000	0.016	0.070	0.037	0.127	0.179	0.059	0.111	0.065	0.041
Hidden 8	0.591	0.160	1.155	0.136	1.321	0.334	0.419	0.417	0.262	0.608	0.038	0.559	0.600	1.179	0.954	0.330	1.095	1.791	0.204	0.13
Hidden 9	1.432	0.224	1.214	1.126	0.419	1.013	0.110	0.488	0.812	3.479	0.538	2.299	2.352	0.103	0.269	0.731	0.702	0.385	0.390	0.197
Hidden 10	0.093	0.106	0.754	0.089	0.100	0.096	0.099	0.022	0.605	0.186	0.121	0.279	0.065	0.061	0.014	0.718	0.096	0.429	0.22	0.274

Table 11 - Product connection weight (pij) divided by the sum of all input variables to obtain (Q_{ij})

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
Hidden 1	0.026	0.049	0.046	0.021	0.053	0.087	0.018	0.031	0.067	0.114	0.095	0.034	0.015	0.062	0.043	0.067	0.003	0.036	0.056	0.077
Hidden 2	0.075	0.004	0.133	0.016	0.035	0.067	0.037	0.022	0.072	0.048	0.017	0.095	0.061	0.006	0.081	0.042	0.050	0.098	0.029	0.013
Hidden 3	0.146	0.043	0.005	0.066	0.030	0.006	0.037	0.047	0.083	0.021	0.010	0.038	0.032	0.007	0.069	0.203	0.023	0.044	0.062	0.028
Hidden 4	0.027	0.083	0.070	0.038	0.123	0.028	0.012	0.005	0.037	0.061	0.012	0.018	0.121	0.046	0.137	0.067	0.015	0.019	0.033	0.047
Hidden 5	0.054	0.023	0.048	0.106	0.019	0.134	0.060	0.035	0.100	0.019	0.022	0.076	0.032	0.013	0.016	0.090	0.047	0.001	0.042	0.064
Hidden 6	0.033	0.012	0.01	0.002	0.090	0.023	0.018	0.110	0.012	0.101	0.116	0.025	0.042	0.067	0.018	0.029	0.012	0.112	0.089	0.078
Hidden 7	0.094	0.031	0.011	0.030	0.040	0.006	0.036	0.044	0.102	0.052	0.000	0.013	0.055	0.029	0.100	0.141	0.047	0.087	0.051	0.032
Hidden 8	0.048	0.013	0.094	0.011	0.108	0.027	0.034	0.034	0.021	0.049	0.003	0.045	0.049	0.096	0.078	0.027	0.089	0.146	0.017	0.011
Hidden 9	0.078	0.012	0.066	0.062	0.023	0.055	0.006	0.027	0.044	0.190	0.029	0.126	0.129	0.006	0.015	0.040	0.038	0.021	0.021	0.011
Hidden 10	0.021	0.024	0.170	0.020	0.023	0.022	0.022	0.005	0.137	0.042	0.027	0.063	0.015	0.014	0.003	0.162	0.022	0.097	0.050	0.062
Sum (S)	0.603	0.295	0.654	0.373	0.542	0.455	0.279	0.361	0.675	0.697	0.332	0.532	0.551	0.345	0.558	0.868	0.345	0.662	0.450	0.423

b) Q_{11} is calculated using Equation (3), and Table 11 presents the results of Q_{ij} for all selected challenging factors.

$$Q_{11} = 0.266/(0.266 + 0.503 + 0.470 + 0.218 + 0.542 + 0.886 + 0.185 + 0.314 + 0.679 + 1.160 + 0.968 + 0.347 + 0.155 + 0.633 + 0.435 + 0.683 + 0.027 + 0.367 + 0.575 + 0.785) = 0.026$$

c) S_1 is calculated using Equation (4), and Table 11 presents the results computed for S_i.

$$S_1 = 0.026 + 0.075 + 0.146 + 0.027 + 0.054 + 0.033 + 0.094 + 0.048 + 0.078 + 0.021 = 0.603$$

For input neuron 1 (F1), the RW is 6.03%, as per Equation (5).

$$F_1 = (0.603 * 100)/ (0.603 + 0.295 + 0.654 + 0.373 + 0.542 + 0.455 + 0.279 + 0.361 + 0.675 + 0.697 + 0.332 + 0.532 + 0.551 + 0.345 + 0.558 + 0.868 + 0.345 + 0.662 + 0.450 + 0.423) = 6.03\%$$

The RWs of 20 selected factors are shown in Table 12, which were obtained in the same manner.

Table 12 - Relative Weights of the selected challenging factors

Symbol	Challenging Factors	Relative Weights
F1	Shortage of materials	6.03%
F2	Inflation effect on materials purchasing	2.95%
F3	Late land acquisition	6.54%
F4	Delay or non-payment of completed works	3.73%
F5	Cash- flow problems (irregular payments)	5.42%
F6	Theft Activities	4.55%
F7	In sufficient funds for project financing	2.79%
F8	Control sub-contractors through poor contract terms	3.61%
F9	Difficulty in Budget availability for the project	6.75%
F10	Ineffective planning, scheduling, controlling and quality monitoring	6.97%
F11	Bribery and corruption	3.32%
F12	Financial Capability of Client	5.32%
F13	Poor supervision	5.51%
F14	Unforeseen ground conditions	3.45%
F15	Financial problem of contractors	5.58%
F16	Contractor's poor site management	8.68%
F17	Capacity of Supervision by Consultants	3.45%
F18	Delays in construction activities due to weather changes	6.62%
F19	Political and security problem	4.50%
F20	Poor contract management	4.23%

The results of Garson algorithm indicate that Contractor's poor site management; Ineffective planning, scheduling, controlling and quality monitoring; Difficulty in Budget availability for the project; Delays in construction activities due to weather changes; late land acquisition; Shortage of materials; Financial problem of contractors; Poor supervision; Cash-flow problems (irregular payments), and Financial Capability of Client are the top 10 challenging factors causing the schedule delay for road construction projects practiced by foreign general contractors (Table 12 and Figure 2).

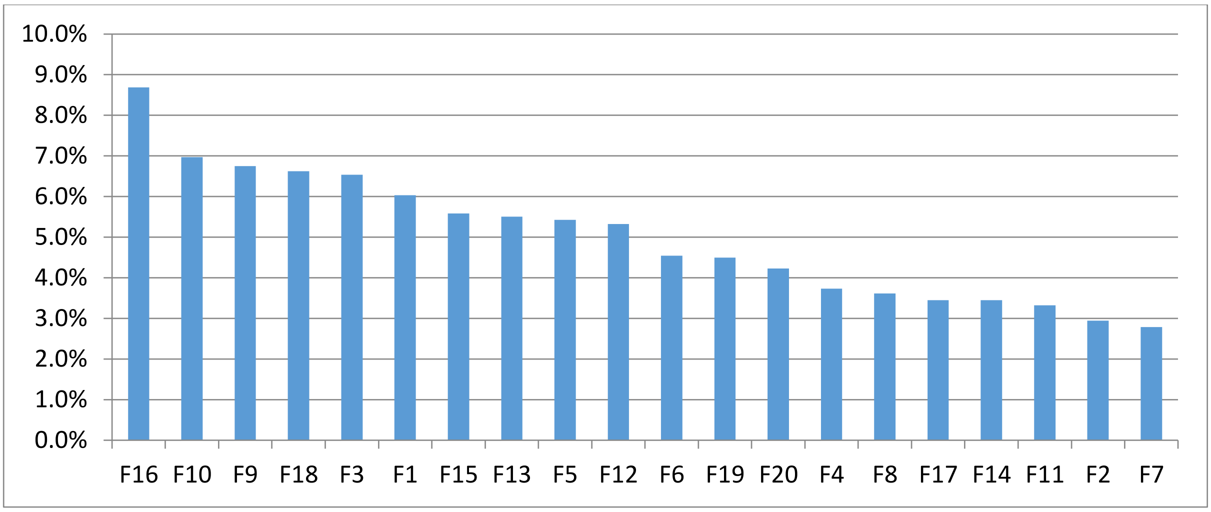

Fig. 2 - RWs of the selected factors calculated using the GA

5. Discussion of Results

This section discusses the results obtained through Garson algorithm. The RII result in this study is used for only selecting the most important challenging factors for further analysis. Based on the RII results, 20 most important factors were selected from 30 factors, and the Garson algorithm's analysis is based on the selected factors the significant challenging factors were identified.

The ten significant challenging factors identified by Garson algorithm as shown in Table 12 were: (1) Contractor's poor site management (8.68%), (2) Ineffective planning, scheduling, controlling and quality monitoring (6.97%), (3) Difficulty in Budget availability for the project (6.75%), (4) Delays in construction activities due to weather changes (6.62%), (5) late land acquisition (6.54%), (6) Shortage of materials (6.03%), (7) Financial problem of contractors (5.58%), (8) Poor supervision (5.51%), (9) Cash-flow problems (irregular payments) (5.42%), and (10) Financial Capability of Client (5.32%).

Among these top 10 challenging factors Contractor's poor site management; Ineffective planning, scheduling, controlling and quality monitoring; Financial problem of contractors, and Poor supervision is fundamentally related to the contractors problem and needs to focus on their organization to minimize them. If a contractor precisely planned for each activity, better control will follow. The poor site management also will be due to the improper planning and scheduling. You manage what you plan, fail in planning soon follow for poor management, due to unclear planning and scheduling.

However, difficulty in budget availability for the project; delays in construction activities due to weather changes; late land acquisition; shortage of materials; cash- flow problems (irregular payments), and financial capability of client would be out of their control and needs to improve by the support of the client organization.

Generally the top 10 significant challenging factors facing the foreign general contractors could be categorized into the factors related to contractors (Contractor's poor site management; Ineffective planning, scheduling, controlling and quality monitoring, and Financial problem of contractors) and client (Difficulty in Budget availability for the project; Shortage of materials; Poor supervision; cash-flow problems (irregular payments), and Financial Capability of Client). These means from the stockholder the client has significant role to minimize these problem.

Some of the challenging factors identified in this research are also similar with finding reported by (Gebrehiweta and Luob 2017). Their study identified poor site management, Ineffective planning, scheduling, and financial problem are among the top 10 affecting the project progress. These poor site management; Ineffective planning, scheduling, and financial problem are not only concerned for Ethiopian construction industry, but also for Malaysian construction industry (Sambasivan and Soon 2007), they are the top challenging factors affecting the project progress.

The results indicate the projects performance is affected due to the failure of the general contractors and they have significant contribution to overcome the problems. Moreover, the client organizations have also similar role for improving the schedule performance by minimizing or eliminating the significant factors. As the results indicate the significant problem is from the contractors' organization itself. The foreign contractors needs to modify their techniques of management for sub-contractors, site management and also needs to find the optional source of their financial capabilities. This source of finance could be from financial institutions in the country or abroad. To solve the financial problems of the contractors may need to work with financial institutions that could overcome the problem.

6. Conclusion

In this study, the significant factors that affecting the Ethiopian road construction projects that undertaking by foreign general contractors were identified through systematically and objectively. Before final analysis of identifying the factors, several stages were undertaken to systematically select the factors. In the first stage 23 factors were determined from different published literature and sent to the domain experts as pilot questionnaire survey to decide whether the factors are relevant to the study area and to add non included factors. Based on the recommendations of the experts, 30 relevant factors were decided and survey having 235 participants was conducted to determine the importance of the factors. For the final selection of the factors, RII was implemented and ranked the factors. The top 20 factors that have maximum RII values were selected. Depending on the RII results, historical data of 81 construction projects were also collected.

The collected historical data was used to establish the database and ANN was implemented to train the database. ANN is an artificial intelligence technique that can used to determine the input-output mapping relationship of variables. This ANN was used to determine the relationship among the input factors causing the project schedule delay with the percentage of progress report for each project. This is important to rank the factors by considering the non-linearity of the factors which cannot handled through subjective judgment and ranked using RII which several researchers are considering as the factors are linearly interrelated, but actually not. The GA was also important to interpret the ‘black box’ of ANN and can determine the weights of input factors to rank the factors based on the values of their weights.

Then GA indicated that the significant factors facing the road project schedule delay in Ethiopian construction industry which is practiced by foreign general contractors were: Contractor's poor site management; Ineffective planning, scheduling, controlling and quality monitoring; Difficulty in Budget availability for the project; Delays in construction activities due to weather changes; late land acquisition; Shortage of materials; Financial problem of contractors; Poor supervision; Cash- flow problems (irregular payments), and Financial Capability of Client. Therefore the identified challenging factors are considered as the top 10 significant factors causing the schedule delay for road construction projects practiced by foreign general contractors. As an important contribution we identified the factors systematically and objectively by commencing data collections in different stages for foreign general contractors. This technique could also minimize the confusion on project managers caused due to inconsistent of subjective judgments among experts. Moreover, the challenging factors are also systematically selected following differ steps. Non-linear relationship among the challenging factors also maintained in this study, which lack attention among many researchers during identifying the challenging factors.

The construction schedule delay is the substantial problem in Ethiopian construction industry. The problem could be sever for foreign general contractors entering or plan to enter the industry due to lack of information about the significant factors causing the schedule delay. However, this study brings important information for them and they could apply risk management principle on identified significant factors to minimize the schedule delay and improve the schedule performance. Therefore, foreign contractors shall strictly focus on control mechanism of the significant factors for effective project progress.

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