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Developing Risk Assessment Model For (FIDIC, NEC and Local contracts) in construction projects

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ملخص البحث:

تعتبر مشاريع البناء أكثر خطورة مقارنة بالمشاريع التقليدية. هذا يرجع إلى حقيقة أن صناعة البناء تحتوي على المزيد من المخاطر بسبب الميزات الفريدة لأنشطة البناء وكونها مشاريع طويلة الأجل بما في ذلك العمليات المعقدة. قد تحدث عدة أنواع من عوامل الخطر في وقت واحد وتؤثر هذه العوامل على تجاوز التكلفة والجدول الزمني. لذلك ، فإن الهدف الأساسي لمدير المشروع هو مراقبة المخاطر بعناية وإنجاز المهام المرتبطة بأي مشروع بدقة ويتم ذلك عن طريق التحقيق في عوامل الخطر وإدارتها قبل حدوثها. لذلك فإن أهداف البحث المقدمة في هذه الورقة هي دراسة وتحديد العوامل التي تؤثر على تكلفة و وقت و جودة مشاريع البناء في مصر مع الأخذ بعين الاعتبار تأثير فيروس كورونا وتحديد احتمالية حدوثها بالإضافة إلى تأثيرها على وقت وتكلفة المشروع ، وتقييم تأثير هذه العوامل ، ومن ثم تطوير نموذج لتقييم المخاطر عن طريق الشبكة العصبية الاصطناعية. تم عمل استبيان يتضمن عوامل الخطر ، وقمنا بجمع البيانات من مختلف المشاريع وشركات المقاولات في مصر. تم استخدام البيانات التي تم جمعها لتطوير نموذج تقييم المخاطر بواسطة الشبكة العصبية باستخدام IBM SPSS Statistics 26

Abstract:

Construction projects are more risky compared to traditional projects. This is due to the fact that the construction industry contains more risks due to the unique features of construction activities and being long-term projects including complex operations. Several types of risk factors may occur simultaneously and these factors affect cost overrun and schedule overrun. Therefore, the primary goal of the project leader is to carefully monitor risks and accomplish the tasks associated with any project accurately and this is done by investigating and managing risk factors before they occur.

Therefore, the objectives of the research presented in this paper are to study and determine the factors that affect the cost, time and quality of construction projects in Egypt, taking into account the impact of the Coronavirus (COVID-19), determine the likelihood of their

occurrence in addition to their impact on the time and cost of the project, evaluate the impact of these factors, and then develop a risk assessment model by artificial neural network. A questionnaire was conducted that includes the risk factors, and we collected data from various projects and contracting companies in Egypt. The collected data was used to develop a risk assessment model by the neural network using IBM SPSS Statistics 26.

1. Introduction:

The construction industry is dependent upon more risks because of the unique features of construction activities, for example being long period projects, including complicated processes, financial intensity, abominable environment and dynamic organizational structures (Taylan et al., 2014) , Therefore construction projects are more risky compared to traditional projects (Luo et al., 2015) and The success and strength of any construction company lies in the effective management of safety, quality, productivity, the environment and health, in addition to marketing and finance (Venkataraman, 2008) ,therefore The primary goal of a project leader is to monitor the risks carefully and successfully accomplish the tasks associated with any project which meticulously includes the controlling and performance of it (Cooke, 2013).

Risk is depicted as prospect problems and complications to finish all points accomplishments of project and depicted as mysterious event and have a positive or negative effect on a project's goals (Cooke, 2013). And considering the diversity of risks in construction projects, it is necessary to minimize the effects of negative risks on projects, and this is done through investigation and management of risk factors before they occur, but because of the interrelationships between risk factors, it is difficult to achieve and analyze the effects (Park et al., 2016).

Effective Risk Management (RM) is an important process for the success of any project and develops during the life cycle of the project until its completion (Perry & Hayes, 1985), Risk Management (RM) is divided into identification, evaluation, avoidance, mitigation, allocation, monitoring and manage risks (Patterson, 2009). Risk Management (RM) isn't a tool which insure success the project but rather a tool that helps to increase the probability of realization the success , RM is a proactive not a reactive. The contract is the main line of the project management and the legal ground for determining the rights, benefits and responsibility between the contractor and the owner (Zaghloul, 2005).There are many factors which influence the selection of the type of contract , the most important of this factors are risk sharing (Peckiene et al., 2013).

2. Literature review:

(Malik et al., 2019) Portrays risk as a flawed event or condition that, if it occurs, has a confirmed or negative effect on something close to one anticipate objective. Risk Management (RM) is an important technique that should be applied within construction projects, Risk management is a procedure which identifies the project risks, analyze them, and decide the actions to avert the threats on the project. All steps in the risk

management process ought to be included to deal with risks in order to implement the process of the project and because of the nature of construction projects, risk management is a significant procedure (Mhetre et al., 2016).

(Mhetre et al., 2016) said that Risk management process consists of (identification, assessment, response and review). according to (Eskander, 2018), The risk management process was classified to (Identification, Classification, Analysis and Response), however Response of risk was grouped to four behaviors (Reduction, Retention, Avoidance and Transfer). according to (Wang et al., 2018) the main processes of risk management has three parts: risk identification, risk analysis and evaluation, and risk control and treatment (Mhetre et al., 2016).

(Renuka et al., 2014) Explain that identifying the risks early in the construction project during the bidding stage will lead to a better estimate of the escalation of overtime and cost. (Khodeir & Mohamed, 2015) identified the latest major risk probabilities in construction projects according to economic and political variables. (Chapman, 2001) grouped risks into four subsets: project, client, industry and environment. (Shen et al., 2001) categorized risks according to the nature of them into six groups financial, management, legal, policy, market, and political. (Abd El-Karim et al., 2017) said that factors that influence schedule and cost overruns must be identified and discussed and the factors divided into four major criteria (Site conditions, Project parties, Resources, and Project features related factors).

(Taylan et al., 2014) explain that the objective of risk assessment is to use analytical tools that put risks in an appropriate category and forecast their level in advance so that strategies and coping with high risk factors can be developed. (Mahendra et al., 2013) Explain that if the risks are not analyzed well and effectively and the strategies are not trained to deal with them, then the project leads to failure, and said that Risk Assessment process can be done by the following methods: Quantitative methods and Qualitative method.

There are several techniques for assessing risks, for example: fuzzy AHP and fuzzy TOPSIS methodologies, Probability and Impact (P&I), Analytical Hierarchy process (AHP), Monte Carlo simulation (MCS), Likelihood occurrence of risk (LR), Bayesian belief Network (BBN) and Analytical neural network (ANN) (Aminbakhsh et al., 2013; Mohanty et al., 2012; Taylan et al., 2014). An artificial neural network consists of: a layer of inputs, a layer or two of hidden neurons, and a layer of outputs where the hidden layer is a layer of neurons that is not connected to the outside world but related to other layers (Tijanić et al., 2020). There are several types of Artificial Neural Networks software's (ANNs) like BIM SPSS, Neuron Solution, and MATLAB are used to predict the future values based on past data. IBM SPSS program is a statistical program that uses an artificial neural network to allow the user to model data and is characterized by simplicity and ease of use. It is also possible with Microsoft Excel to extract the database used in the program easily (Badawy, 2020).

3. **Research methodology**:

Figure 1 illustrates the detailed steps followed to perform the various activities of the present research. At the outset, the problem discussed by the research is identified and previous literature is reviewed. The risk factors that affect the cost and the timetable for violations are identified and discussed using the literature review and expert opinion in the field of construction industry. A questionnaire is designed to collect the probability of each factor occurring and its impact on the project cost and its duration. The data is collected by visiting construction project sites and by asking experts, the data collected through the questionnaires are analyzed, then building many models using different structures using IBM SPSS Statistics 26 and making a comparison between the results of these models and testing the best model.

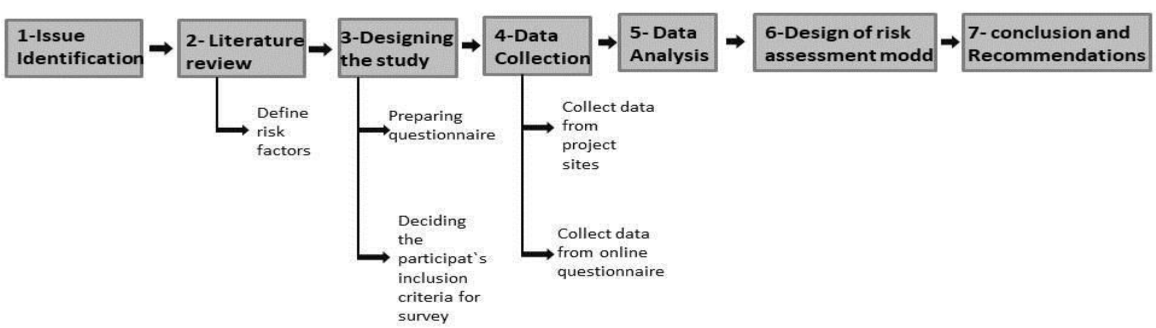

Figure 21 research methodology

Risk factors affecting schedule and cost overruns:

Based on the previous literature and opinion of experts and practitioners of the construction industry process, several inevitable risk factors affecting the cost and schedule of construction projects have been identified and studied and are divided into nine main criteria: (1) Physical, (2) Environmental, (3) Design, (4) Logistics, (5) Financial, (6) Legal, (7) Construction, (8) Political, and (9) Management. **Table 1** details these key criteria and the factors they contain.

Detailed risk factors / features related to each criterion are shown in **Table 1**. It is clear that the determining factors and standards contribute effectively to the uncertainty in construction project cost and scheduling, which in turn affects the assessment of schedule and cost overruns.

Table 9 Factors affecting schedule and cost overrun

Criteria	Risk factor		Risk Probability				Cost Risk Impact				Schedule Risk Impact			
			Not happen	Low	Medium	High	Not happe	Low	Medium	High	Not happen	Low	Medium	High
			0	1	2	3	0	1	2	3	0	1	2	3
1. Physical	R01	accidents because of poor safety procedures												
	R02	Supplies of defective materials												
	R03	Variation of labor and equipment productivity												
2. Environmental	R04	Natural Disasters (floods, earthquakes,..., etc.)												
	R05	Difficulty to access the site												
	R06	Adverse weather conditions												
3. Design	R07	Defective design (incorrect)												
	R08	Not coordinated design (structural, mechanical, electrical, etc.)												
	R09	Lack of consistency between bill of quantities, drawings and specifications												
	R010	Awarding the design to unqualified designers												
4. Logistics	R011	Unavailable labor, materials and equipment												
	R012	Poor materials storage												
5. Financial	R013	Delayed payments on contract												
	R014	Financial failure of the contractor												
	R015	Monopolizing of materials due to unexpected political conditions												
	R016	acceleration in the cost of raw materials												
	R017	Exchange rate fluctuations												
	R018	Increase in Unit Labor Cost												
	R019	Oil prices spike												
	R020	Tax Reform Impact												
6. Legal	R021	Difficulty to get permits												
	R022	legal disputes among the parties of the contract												
	R023	Delayed disputes settlement												
7. Construction	R024	Gaps between the execution and the specifications												
	R025	Errors on surveying works												
	R026	Undocumented change orders												
	R027	Lower work quality in presence of time constraints												
	R028	Actual quantities differ from the contract quantities												
	R029	Use of defective material												
	R030	structural damage												
8. Political	R031	New governmental acts or legislations												
	R032	Civil disorder												
9. Management	R033	Uncertainty planning due to Inadequate specification												
	R034	lack of resources management												
	R035	Poor communication between involved parties												

4. Data collection

A single questionnaire is administered to collect data through structured interviews to collect information on case study projects. A survey is conducted in the form of a questionnaire to identify the probability of occurrence of each risk factor for each project in addition to its impact on the project cost and schedule. The questionnaire was designed using important risk factors that were identified through previous literature and experts, as they were 35 factors divided into nine main criteria as shown in **Table 1**. The questionnaire consists of three parts: The first part includes the respondent's general personal information, which is name, job title, academic degree and years of experience, the second part includes the general information of the project, which is the name of the project, the type of contract used and the total cost of the project. The third part includes risk factors, occurrence, their impact on cost and schedule, and finally the overall risk. In order to facilitate the reviewers' answers, a scale from 0 to 3 is used (with 0 representing non-occurrence, 1 representing low incidence, 2 representing medium incidence and finally 3 representing high incidence).

5. Data analysis :

Interviews were conducted in person and by telephone with many construction experts and engineers working on a variety of construction projects located in Egypt. 200 answered questionnaires were received, a total of 200 real life construction projects had been collected and gathered in Microsoft excel , part of them were received before the Corona pandemic(before cov-19) , and their number was 133 projects , and the other part after the Corona pandemic (after cov-19) , and their number was 87 projects as it is in **Figure 2.**

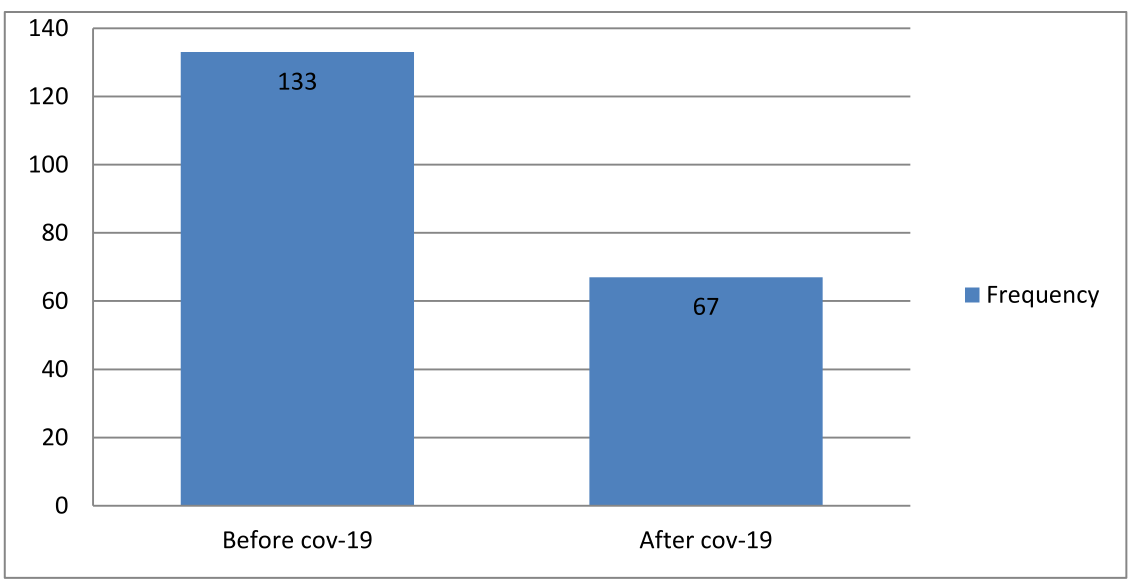

Figure 22 Time distribution

The questionnaire was also answered by engineers and experts whose years of experience ranged from 5 to 26 years, as shown in **figure 3**, and their job title differs as shown in **Figure 4**.

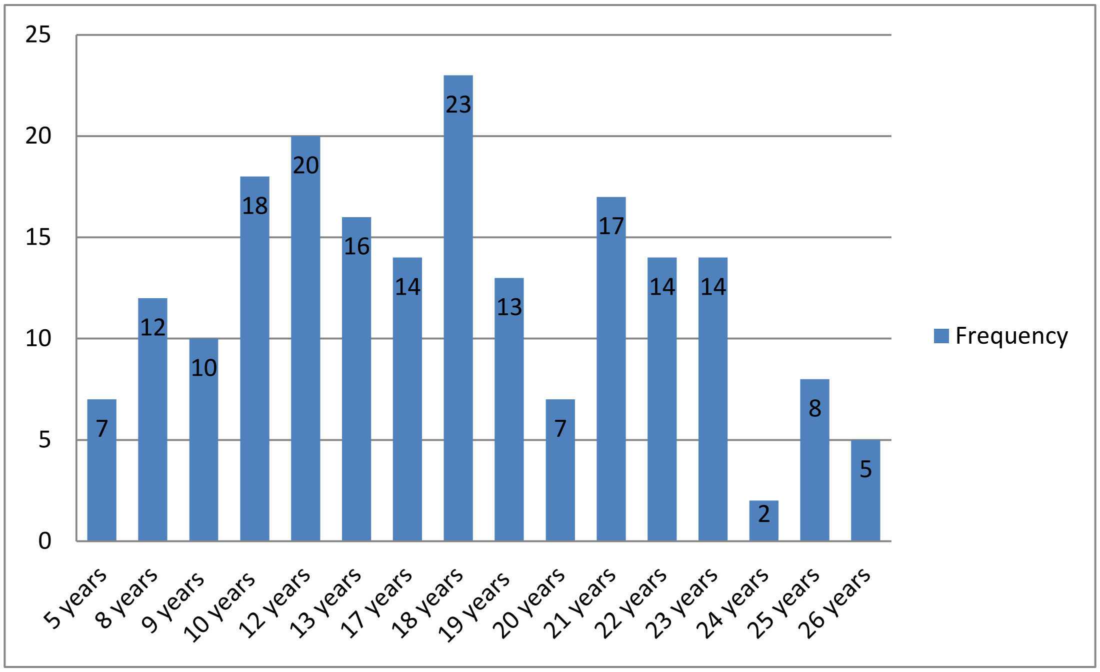

Figure 23 Experience distribution

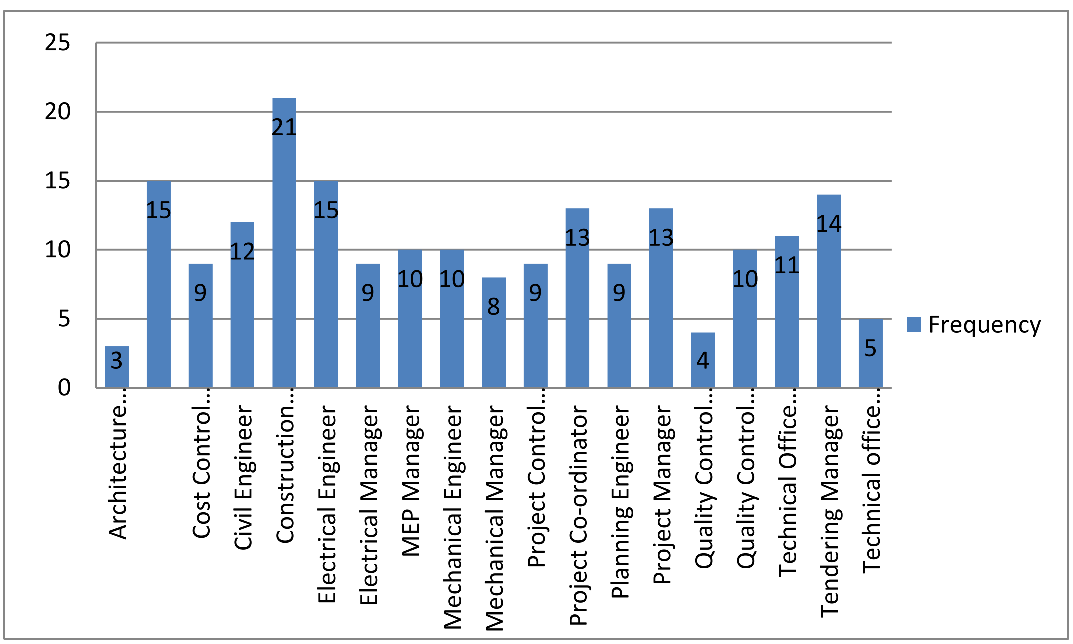

Figure 24 Job title distributions

6. Model development :

6.1 Model Design:

There are several types of Artificial Neural Networks software's (ANNs) like SPSS, Neuron Solution, and MATLAB.... ect are used to predict the future values based on past data .

In this research the developed model based on used BIM SPSS Statistics 26. This application was chosen because its simplicity, easy of learning and good result. In addition, by this application we can control a neural network type, activation function, learning rate, number of hidden neurons/ layers and extract graphical interpretation of the results.

The steps used for designing the neural network model in BIM SPSS Statistics 26 application are:

1-Data Organization:

After obtaining the responses to the questionnaires, an Excel sheet is organized, so that the sheet is divided into 3 parts: The first part is basic information about the respondent, which are the years of experience and employment in addition to the time of responding to the questionnaire (Before cov-19 or After cov-19). The second part contains 35 risk factors. The third part is the output which contains overall risk of project.

2-Data entering and coding:

After the completion of placing and arranging the data in the Excel sheet, we can import the data into BIM SPSS Statistics 26 application and then begin to code the data.

3-Remove outliers:

Perform removal of outliers by using a Mahalanobis distance that uses estimates of the location and scatter to identify values that are far away from the main distribution of data. Data were collected for 200 construction projects, then when using a Mahalanobis distance to remove outliers , 11 projects were excluded, where the probability was < 0.001, so the final number of construction projects became 189 projects divided into 122 projects that were before Cov-19 and 67 projects after Cov-19.

4-Data setup:

The data is divided into three sets namely: training set, validation set and test set. In the present study the, the total data is 189 projects that were divided into three sets with the following ratio:

- Training set : includes 132 exemplars = 69.8 %
- Validation set (called holdout) : includes 31 exemplars = 16.4 %
- Test set : includes 26 exemplars = 13.8 %

5- Building Network:

After all data were prepared the second step is to create the initial network by selecting the (network type, number of hidden nodes/layers, activation function, learning rule and number of runs and epochs. five models were created as follows:

1- Neural network of multilayer (MLP) that consists of: one layer with a Hyperbolic function.
2- Neural network of multilayer (MLP) that consists of: two layers with a Hyperbolic function.
3- Neural network of multilayer (MLP) that consists of: one layer with a Sigmoid function.
4- Neural network of multilayer (MLP) that consists of: two layers with a Sigmoid function.
5- Neural network with a radial base function.

6.2 Models Results:

In the first stage of analyzing ANN the network parameters must be specified. It is possible to create a network model by ANN module of SPSS and it can also test the model with different parameters. The data set is analyzed using different network parameters to obtain the best parameters with fewer errors.

Table 2 shows the error values in the network architectures. Obviously, the best result is obtained through a Multilayer Neural Network (MLP) that consists of one hidden Layer with Sigmoid Function.

Table 10 the error values of the network models by SPSS

Analysis no	Model type	Transfer function	No of hidden layer	No of hidden units	Total squared error	
					Traning data	Testing data
1	(ANN) Multilayer Preceptron	Hyperbolic Tangent	1	3	3.278	1.687
2	(ANN) Multilayer Preceptron	Hyperbolic Tangent	2	5	0.038	0.012
3	(ANN) Multilayer Preceptron	Sigmoid	1	3	0.037	0.008
4	(ANN) Multilayer Preceptron	Sigmoid	2	5	0.035	0.012
5	Radial Basis Function	Softmax	1	10	6.738	1.111

6.3 Model Analysis:

The best model provided a more accurate estimate of the overall risk of a project was structured of Multilayer Neural Network (MLP) includes one input layer with 37 input units and one hidden layer with 3 hidden units and finally one output layer with 3 output units (Overall Risk). Table 3 provides information on the data sets used to construct the

ANN model.

Table 11 Case Processing Summary

Case Processing Summary			
		N	Percent
Sample	Training	132	69.8%
	Testing	26	13.8%
	Holdout	31	16.4%
Valid		189	100.0%
Excluded		0	
Total		189	

According to **table 4** which provides information regarding training, test and holdout sample results .the percentage of incorrect predictions based on training, testing and holdout sample respectively are 0.0%, 0.0% and 3.2% .These small values indicate the strength of the model in predicting overall project risk.

Table 12 Model Summary

Model Summary		
Training	Sum of Squares Error	0.037
	Percent Incorrect Predictions	0.0%
	Stopping Rule Used	Training error ratio criterion (.001) achieved
	Training Time	0:00:00.04
Testing	Sum of Squares Error	0.008
	Percent Incorrect Predictions	0.0%
Holdout	Percent Incorrect Predictions	3.2%
Dependent Variable: Overall Risk		

Table 5 displays a classification table (i.e. confusion matrix) of the impact of risk factors on the overall risk of the project; the MLP network correctly classified 132 projects out of 132 in the training sample and 26 out of 26in testing sample. Overall 100% of the training cases were correctly classified. In the holdout sample, the accuracy of the model was 96.8%. The MLP network model misclassified only one

Table 5 Confusion matrix

Sample	observed	Predicted			
		low	medium	high	percent correct
Training	low	36	0	0	100.0%
	medium	0	77	0	100.0%
	high	0	0	19	100.0%
	Overall	27.3%	58.3%	14.4%	100.0%
Testing	low	8	0	0	100.0%
	medium	0	18	0	100.0%
	high	0	0	0	0.0%
	Overall	30.8%	69.2%	0.0%	100.0%
Holdout	low	7	0	0	100.0%
	medium	1	15	0	93.8%
	high	0	0	8	100.0%
	Overall Percent	25.8%	48.4%	25.8%	96.8%
Dependent Variable: Overall Risk					

project.

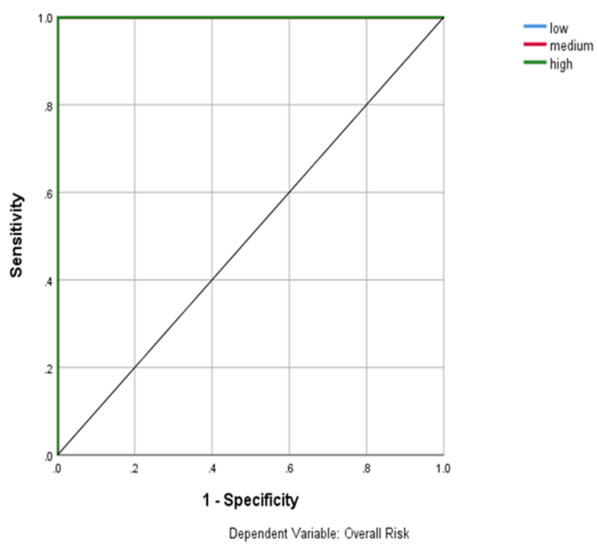

Figure 26 Area under the curve

Area Under the Curve		
		Area
Overall Risk	low	1.000
	medium	1.000
	high	1.000

Figure 25 ROC curve

Figure 5 gives a ROC curve which is a schematic diagram of sensitivity versus specificity based on the combined training and test samples. The 45° line from the upper right corner of the chart to the lower left represents the random guessing scenario of overall risk. The farther the curve moves away from the baseline of 45°, the more accurate the classification is. **Figure 6** gives the area under the ROC curve. The area value (1.00) shows that the strength of the model for classifying the overall risks of the project is excellent and represents 100%.

Figure 27 Importance of variables

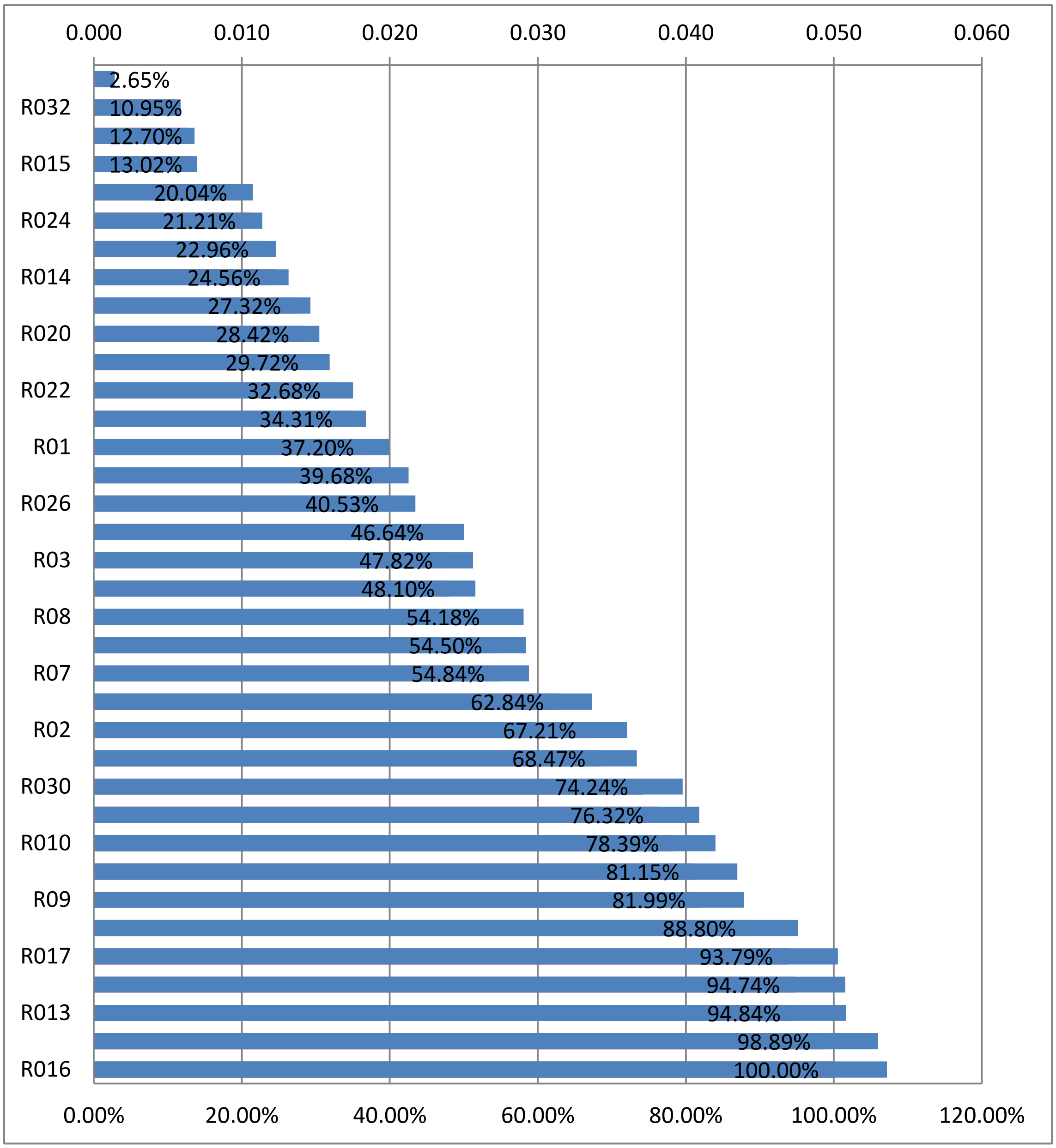

Figure 7 shows the effect of each independent variable in the ANN model in terms of normalized and relative importance. It shows the importance of the variables, i.e. how sensitive the model is to changing each input variable.

The chart also shows that the most important factors that have the greatest impact on the overall risk of the project are: (R016: acceleration in the cost of raw materials, R012: Poor materials storage, R013: Delayed payments on contract, R035: Poor communication between involved parties, and R017: Exchange rate fluctuations). And the factors that have the least impact are: (R031: New governmental acts or legislations, R032: Civil disorder and R029: Use of defective material). Also, the existence of the Corona pandemic (COV-19) affected the overall risk of the project by 34.31%.

7. Conclusion :

The aim of this research was to study and determine the factors that affect the cost, time and quality of construction projects in Egypt, taking into account the impact of the Coronavirus, then developing a risk assessment model through the artificial neural network and determining the effectiveness in predicting the overall risk of the project, based on the data collected from Construction projects through a questionnaire. A review of previous literature indicated that neural networks are characterized by accurate prediction. A layered neural network was trained using IBM SPSS Statistics 26 to predict the effect of risk factors on overall project risk.

The IBM SPSS program was chosen due to its ease of use, efficiency and ability to illustrate results through graphs. Data were collected from 200 construction projects, then using the Mahalanobis distance, the abnormal projects were excluded, and there were 11 projects, in order to obtain a more accurate model. The remaining 189 projects were divided into three groups. By changing the number of layers and the activation function of the hidden layer, the best ANN model providing results close to the overall risk of the project was determined. The best ANN model was a Multilayer Neural Network (MLP) that consists of one hidden Layer with Sigmoid Function.

It turns out that the accuracy rate of the overall project risk classification into low, medium and high categories is very excellent. The results also showed that the most important predictors of overall project risk were (acceleration in the cost of raw materials, Poor materials storage, Delayed payments on contract, Poor communication between involved parties, and Exchange rate fluctuations). And the factors that have the least impact are: (New governmental acts or legislations, civil disorder, and Use of defective material). Also, the existence of the Corona pandemic (COV-19) affected the overall risk of the project by 34.31%.

8. References :

Abd El-Karim, M. S. B. A., Mosa El Nawawy, O. A., & Abdel-Alim, A. M. (2017). Identification and assessment of risk factors affecting construction projects. HBRC Journal, 13(2), 202–216. https://doi.org/10.1016/j.hbrcj.2015.05.001

Abdelalim, A. M., Nawawy, O. A. El, & Bassiony, M. S. (2016). Decision Supporting System for Risk Assessment in Construction Projects : AHP-Simulation Based Technique. 4(5), 22–36.

Abrantes, R., & Figueiredo, J. (2015). ScienceDirect Resource management process framework for dynamic NPD portfolios. JPMA. https://doi.org/10.1016/j.ijproman.2015.03.012

Alexopoulos, E. C., Kavadi, Z., Bakoyannis, G., & Papantonopoulos, S. (2009). Subjective Risk Assessment and Perception in the Greek and English Bakery Industries. Journal of Environmental and Public Health. https://doi.org/10.1155/2009/891754

Aminbakhsh, S., Gunduz, M., & Sonmez, R. (2013). Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects. Journal of Safety Research, 46, 99–105.

Badawy, M. (2020). A hybrid approach for a cost estimate of residential buildings in Egypt at the early stage. Asian Journal of Civil Engineering, 21(5), 763–774. https://doi.org/10.1007/s42107-020-00237-z

Barrett, & Hine. (2001). Managing Risk. Australian CPA.

Besaiso, H., Fenn, P., Emsley, M., & Wright, D. (2018). A comparison of the suitability of FIDIC and NEC conditions of contract in Palestine. Engineering, Construction and Architectural Management.

Chan, A. P. C., Chan, D. W. M., & Yeung, J. F. Y. (2009). Overview of the application of “fuzzy techniques” in construction management research. Journal of Construction Engineering and Management, 135(11), 1241–1252.

Chapman, R. J. (2001). The controlling influences on effective risk identification and assessment for construction design management. International Journal of Project Management, 19(3), 147–160.

Cooke, T. (2013). Can knowledge sharing mitigate the effect of construction project complexity? Construction Innovation, 13(1), 5–9. https://doi.org/10.1108/14714171311296093

Cheung, S. O., & Pang, K. H. Y. (2013). Anatomy of construction disputes. Journal of Construction Engineering and Management, 139(1), 15–23.

Darnall, R., & Preston, J. (2010). Project management from simple to complex.

El-sayegh, S. M. (2008). Risk assessment and allocation in the UAE construction industry. 26, 431–438. https://doi.org/10.1016/j.ijproman.2007.07.004

Eskander, R. F. A. (2018). Risk assessment influencing factors for Arabian construction projects using analytic hierarchy process. Alexandria Engineering Journal, 57(4), 4207–

4218. https://doi.org/10.1016/j.aej.2018.10.018

Hwang, B., Zhao, X., & Toh, L. P. (2014). ScienceDirect Risk management in small construction projects in Singapore : Status , barriers and impact. JPMA, 32(1), 116–124. https://doi.org/10.1016/j.ijproman.2013.01.007

Khodeir, L. M., & Mohamed, A. H. M. (2015). Identifying the latest risk probabilities affecting construction projects in Egypt according to political and economic variables. From January 2011 to January 2013. HBRC Journal, 11(1), 129–135. https://doi.org/10.1016/j.hbrcj.2014.03.007

Luo, L. Z., Mao, C., Shen, L. Y., & Li, Z. D. (2015). Risk factors affecting practitioners' attitudes toward the implementation of an industrialized building system a case study from China. Engineering, Construction and Architectural Management, 22(6), 622–643. https://doi.org/10.1108/ECAM-04-2014-0048

Mahendra, P. A., Pitroda, J. R., & Bhavsar, J. J. (2013). A Study of Risk Management Techniques for Construction Projects in Developing Countries. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 3, 139.

Malik, S., Fatima, F., Imran, A., Chuah, L. F., Klemeš, J. J., Khaliq, I. H., Asif, S., Aslam, M., Jamil, F., Durrani, A. K., Akbar, M. M., Shahbaz, M., Usman, M., Atabani, A. E., Naqvi, S. R., Yusup, S., & Bokhari, A. (2019). Improved project control for sustainable development of construction sector to reduce environment risks. Journal of Cleaner Production, 240. https://doi.org/10.1016/j.jclepro.2019.118214

Mhetre, K., Konnur, B. A., & Landage, A. B. (2016). Risk Management in Construction Industry. International Journal of Engineering Research, 1(5), 153–155. https://doi.org/10.17950/ijer/v5i1/035

Mohanty, R. P., Sahoo, G., & Dasgupta, J. (2012). Identification of Risk Factors in Globally Outsourced Software Projects using Logistic Regression and ANN. International Journal of Sup. Chain. Mgt, 1, 2–11.

Park, J., Park, B., Cha, Y., & Hyun, C. (2016). Risk Factors Assessment Considering Change Degree for Mega-projects. Procedia - Social and Behavioral Sciences, 218, 50–55. https://doi.org/10.1016/j.sbspro.2016.04.009

Patterson, R. (2009). Using NEC contracts to manage risk and avoid disputes. Proceedings of Institution of Civil Engineers: Management, Procurement and Law, 162(4), 157–167. https://doi.org/10.1680/mpal.2009.162.4.157

Peckiene, A., Komarovska, A., & Ustinovicius, L. (2013). Overview of risk allocation between construction parties. Procedia Engineering, 57, 889–894. https://doi.org/10.1016/j.proeng.2013.04.113

Perry, J. G., & Hayes, R. W. (1985). RISK AND ITS MANAGEMENT IN CONSTRUCTION PROJECTS. Proceedings of the Institution of Civil Engineers (London), 78(pt 1), 499–521. https://doi.org/10.1680/iicep.1985.859

Renuka, S. M., Umarani, C., & Kamal, S. (2014). A Review on Critical Risk Factors in the

Life Cycle of Construction Projects. Journal of Civil Engineering Research, 4(2A), 31–36. https://doi.org/10.5923/c.jce.201401.07

Shen, L. Y., Wu, G. W. C., & Ng, C. S. K. (2001). Risk assessment for construction joint ventures in China. Journal of Construction Engineering and Management, 127(1), 76–81.

Taylan, O., Bafail, A. O., Abdulaal, R. M. S., & Kabli, M. R. (2014). Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies. Applied Soft Computing Journal, 17, 105–116. https://doi.org/10.1016/j.asoc.2014.01.003

Tijanić, K., Car-Pušić, D., & Šperac, M. (2020). Cost estimation in road construction using artificial neural network. Neural Computing and Applications, 32(13), 9343–9355. https://doi.org/10.1007/s00521-019-04443-y

Venkataraman, N. (2008). Safety performance factor. International Journal of Occupational Safety and Ergonomics, 14(3), 327–331. https://doi.org/10.1080/10803548.2008.11076772

Wang, T., Gao, S., Li, X., & Ning, X. (2018). A meta-network-based risk evaluation and control method for industrialized building construction projects. Journal of Cleaner Production, 205, 552–564. https://doi.org/10.1016/j.jclepro.2018.09.127

Zaghloul, R. S. (2005). Risk Allocation in Contracts - How to Improve the Process.