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College of Engineering

Prediction of Cost and Delay of Construction Projects Using Artificial Intelligence Techniques

A Thesis Submitted to the Council of College of Engineering University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

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بِسْمِ ٱللَّهِ ٱلرَّحْمَـٰنِ ٱلرَّحِيمِ

﴿ هَـٰذَا بَيَانٌ لِّلنَّاسِ وَهُدًى وَمَوْعِظَةٌ لِّلْمُتَّقِينَ ﴾

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DEDICATION

I dedicate this thesis to;

My Dear Father

The man who did not know the taste of comfort in order to provide all the requirements of family life.

My Dear Mother

The tree that is fruitful in my life.

My Brothers and Sister

The courage and importance you bring to me when I leave the house each day are unparalleled.

My Dear wife

That was always supporting me up until this beautiful moment.

My best Friends

Those who leave us happy things that make me smile when life seems bleak.

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ABSTRACT

Artificial Intelligence as Smart Optimization Tool in Construction Projects Management

By

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The construction industry is subject to a high level of risks and uncertainties than any other industry. In reality, most participants experience risks in cost and time overruns and often fail to meet quality standards and operational requirements. In order to overcome these risks and make decisions with high accuracy, traditional and smart techniques have been applied to predict the cost and delay of construction projects with a high degree of accuracy and minimal errors.

This research aimed to investigate the accuracy of five Artificial Intelligent techniques (Artificial Neural Network, Support Vector Machine, Extreme Learning Machines, Artificial Neural Network-Particle Swarm Optimization, and the Adaptive Neuro-Fuzzy Inference System) to demonstrate the impact of risk factors on prediction the cost and delay of construction projects. These techniques were represented through a virtual graphical user interface allowing the user to ease and clarify use.

This study collected data from 47 construction projects from the AL-ZAWRAA state company in Baghdad city. Thus, the factors of risk were specified as well as analyzed employed Probability and Impact Analysis which were adopted as the inputs of the models. In contrast, the outputs of models were represented contractor's profit ratio to the costs of project and the delay in the construction project.

Root Mean Squared Error (RMSE), correlation coefficient (R), and the coefficient of determination (R^2) were utilized as the indices of performance of the models to evaluate the results accuracy.

The results showed that the optimal method based on root mean squared error, and enabling to predict the cost and delay of projects was (ELM) with percentage (0.003) while the optimal method based on correlation factor and coefficient of determination were (ANFIS and ELM) with percentage (0.999, 0.999) and (0.999, 0.999) respectively.

It was concluded that artificial intelligence techniques could be used as successful tools to solve essential problems in construction projects, especially in estimating the costs and delays. Besides, it supported construction companies in analyzing and evaluating risks affecting the management of new projects.

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List of Abbreviations

Abbreviations	Explanation
AI	Artificial intelligence
ANFIS	Adaptive neuro-fuzzy inference system
ANN	Artificial neural network
ANN-PSO	Artificial neural network- particle swarm optimization
CM	Construction management
CP	Contractor profit
DB	Design-build
DBB	Design-bid-build
DF	Delay factor
ELM	Extreme learning machines
FEM	Finite Element Method
FSM	Finite Strip Method
GA	Genetic algorithm
GFF	General feed forward
GUI	Graphical user interface
ML	Machine learning
MLP	Multilayer perceptron
MPC	Monthly Payment Certificates
PI	Performance indices
QR	Quoted Rates
R	Correlation coefficient
R^2	Coefficient of determination
RF	Risk factor
RMSE	Root mean square error
SM	Site Memorandums
SVM	Support Vector Machine
TD	Total delay
VO	Variation Orders

Chapter One
Introduction

1.1 General

The sector of construction has a vital part in enhaencing the developed states economics (Tiruneh et al., 2020). This success of sector is measured via the cost, time and the quality performance of the construction projects. The procedure of construction being exposed to numerous parameters as well as unforeseen variables that outcome from several sources. Such sources avert the projects completion within the identified time and cause a delay risk in the procedure of construction. The delay risk being regarded as a main challenge that is tackled via the firms of construction (Najafi et al., 2018) . The delay can be descibed as an event or action which prolongs the needed time for completing the project specified in a contract. (Cheng et al., 2020) .The delay of project possesses an inverse effect upon the performance of project, which results in the overruns of cost and the reduction of productivity. The influence of delay prolongs to comprise the contractor, owner and consultant in the argument, lawsuit and negotiation (Rahimian et al., 2020) and (Chou et al., 2013).

Assessing the costs of project are crucial to the success of project right from the project conceptual phases to its accomplishment. Whereas, the assessment of conceptual cost makes a benchmark for the whole other decisions of project, and the main variations in the thorough project assessments through the construction (also named the overruns of cost) can be harmful to the project accomplishment and success. The cost assessment of construction is the best instance of knowledge-intensive engineering functions. The exactness and completeness in the assessment of cost are subtle topics and can be simply influenced via numerous varios factors. Such cost effective factors can be widely categorized into: (a) the estimator-

specific factors and (b) the design-specific factors (Lu et al., 2017) . Where the first type can be govrned by the assistance of the appropriate decision support tools and computer-based algorithms, the second type is highly indirect and more reliant upon the project-specific parameters.

The construction costs analysis for supporting the estimator-specific parameters can be widely categrized into two types of techniques: (a) statistical and model analysis techniques and (b) artificial intelligence techniques.The first type comprises analysis of the costs that utilize the conventional statistical approaches, like via computing the mean, median, variance, standard deviation and so on. Also, this type involves the intricate analysis of multi-variate project circumstances employing the methods of the linear and multiple regression analysis. The second type includes, namely the techniques of Artificial Neural Networks, case-based reasoning, and machine learning (Elfaki et al., 2014). Therefore the author of the current research focused on optimizing the cost and delay using the artificial intelligence (AI) models.

1.2 Research Problems and Justifications

Research problems and justifications are addressed below accordingly:

1. The Ministry of Construction and Housing in Iraq addressed the truth that the majority of construction projects surpassed their prearranged time and being delayed. The delay means loss of productivity and incomes, because the contractor cannot get concerned in the else projects. Therefore, the profit of contractor is equivalent to the chance cost of the projects that the contractor loses. The efficient bidding system condition that a contractor with the minimum price of tender gains the project; this is an important reason that results in a deprived performance as well as delays in the public construction projects.
2. Because of the feeble performance of the present projects in Bagdad (for various sectors), the projects being entirely very frequently possible for

stumbling, it has often become alike to a phenomenon, making seminars and conferences for discussing such dilemma and trying to arise with recommendations and solutions for treating it.Certain pertinent authorities issued papers warning about the government projects' status from time to time.The existing cost and delay optimization practices are fragile or independable.Therefore, a need for a new technique for optimizing the cost delay in Iraq has become an urgent need.

3. Develop a smart tool using the artificial intelligence techniques to optimize the cost and delay in Baghdad's construction industry can sustain engineers and contractors in planning and optimizing engineers and contractors in a rapid, accurate, and easy procedure.

1.3 Research Aims and Objectives

Development mathematical smart optimization models using five techniques such as artificial neural networks (ANN), support vector machine (SVM), Extreme Learning Machines (E.L.M), artificial neural networks-Particle Swarm Optimization (A.N.N.-P.S.O), and the adaptive neuro-fuzzy inference system (A.N.F.I.S) to estimate the final cost of construction project and risk of delay of items at tendering prepare stage and made comparing between the models in term of accuracy in estimation.

The current aim, there are some objectives must be obtained as follows:

1. Investigation and identification of cost risks in construction projects.
2. Examining the uses of the five techniques in the field of project management.
3. Analyzing the cost risks in the construction projects and this done by adopting quality risk management techniques.
4. Analyzing the delay risks in the construction projects and this done by adopting quality risk management techniques.

5. Building and validation the mathematical smart optimization models equations to compute the budget of the construction and cost indices for items of the project.
6. Representing artificial intelligence predictive techniques with a graphical user interface to allow the user to easily use these techniques.

1.4 Research Scope and Limitations

This study was carried out in a public sector of construction projects in the Baghdad governorate, including the tendering preparation phase. Many building projects implemented in 2020 were collected, so it could apply this kind of risk management process that manages the cost risks generated from risk responses in construction projects without affecting the project's budget preparation.

1.5 Research Methodology

The steps below summarize the methodology that used to achieve the objectives of the study :

1. Literature review

The literature review includes a collection of references related to the research topic such as thesis, papers, books, and website sources, particularly related to artificial intelligence and its application to the cost and delay.

2. Collecting the data

Historical cost data and delay of the project, Project assignment year, and detailed quantities of these projects were gathered.

3. Building the models

This stage involves choosing the software program, selecting the kind of models, and developing models. Furthermore, to execute the models and do training several times and validate the models. Additionally, this stage contains testing the models and discussing the findings carefully.

4. Validating the models

Finally, the models developed by the artificial neural network (A.N.N), Support Vector Machine (S.V.M), Extreme Learning Machines (E.L.M), artificial neural network-Particle Swarm Optimization (A.N.N.-P.S.O), and the adaptive neuro-fuzzy inference system (A.N.F.I.S) which validated at this stage, when the best model is found. It Can be summarized the research methodology, as shown in Figure (1.1).

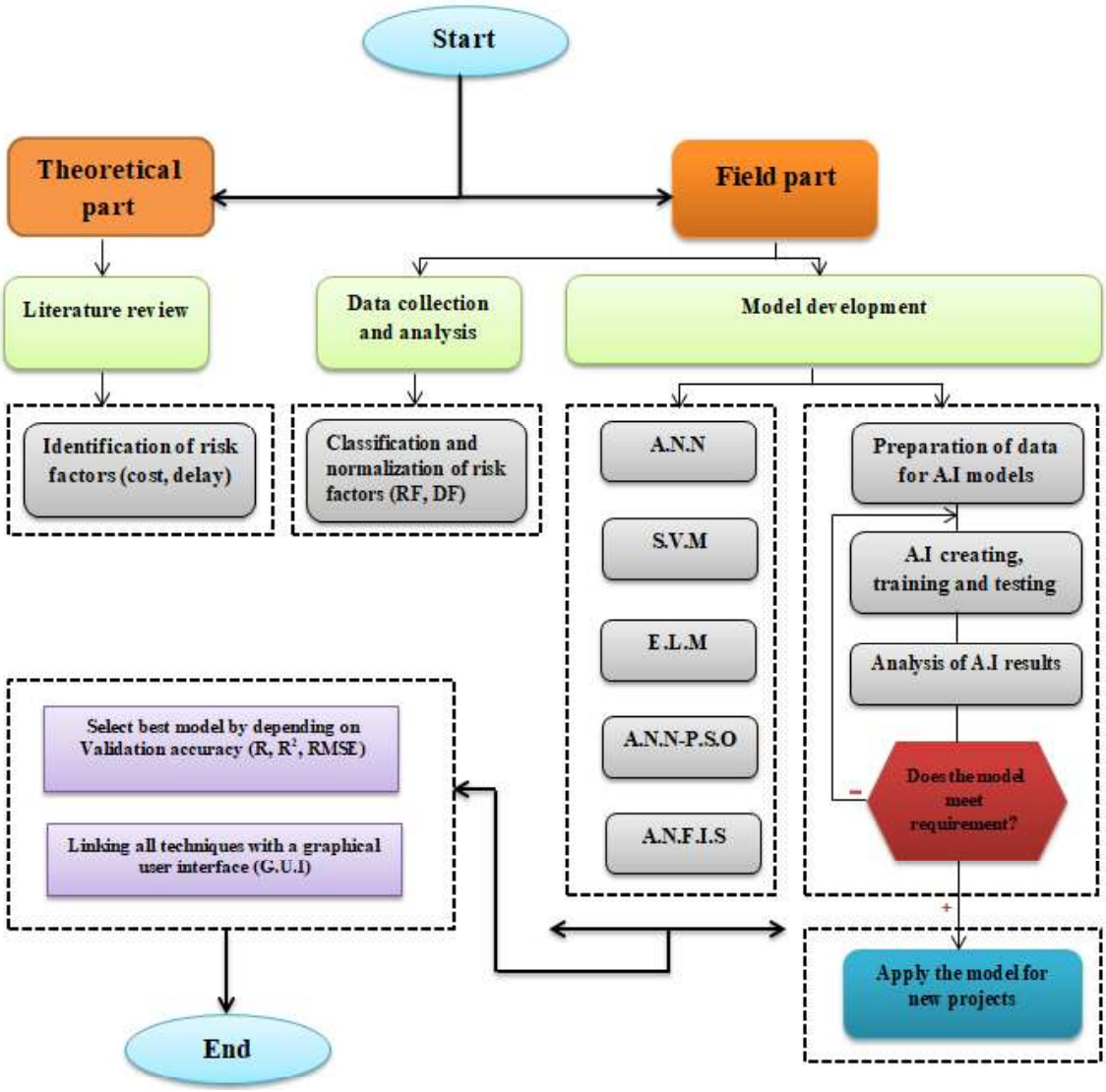

Figure (1.1): The Research Methodology .

1.6 Review of Previous Studies

Table (1.1) summarizes the previous studies based on two issues. The first issue is the intelligent technique used in a proposal. The second issue is the type of validation that is used to prove the applicability of the proposal. Table (1.2) shows the result of surveyed proposals based on risk factors that affect on construction project management. The symbol "✓" means that this factor has been considered in this proposal, while the symbol "-" means that this factor has not been considered.

Table (1.1): The Reviews of Previous Studies

NO.	Researcher	Technique	Validation
Previous Studies on Causes of Delay in Construction projects			
1	S. Kouhestani et al.2020	Build process models to describe the as happened process and make the diagnosis to discover potential reasons for failure and delays. machine-learning (ML) system.	Process discovery and diagnose .
2	Burkina Faso,2020	Retrieve the most frequent command sequences for productivity monitoring and evaluation, hybrid systems (HS).	Pattern extraction.
3	Pan, Y., Zhang,2020.	Discover social networks in the design process to increase collaboration opportunities,(ANN).	Social network analysis.
4	Zhang,2018.	Make intelligent design command predictions towards	Time-series analysis.

		automation and intelligence of the design process,(AI) system.	
AI Applications Concerning Project Duration			
5	Elfaki, A. O., Alatawi, S., & Abushandi, E. (2014).	AI, machine-learning (ML), rule-based systems (RBS), evolutionary systems (ES), agent-based system (ABS), and hybrid systems (HS).	The methodology has been proposed as a standard benchmark for construction cost estimation proposals.
6	Marinelli, M., Petroutsatou, K., Fragkakis, N., & Lambropoulos, S. (2018).	Machine-learning (ML), ANN.	The critical role of the implementation of appropriate tools and informed decision-making in design and construction and present alternative solutions of enhanced cost efficiency for the required value for money to be achieved in each of the above projects.
7	Wauters, M., & Vanhoucke, M. (2017).	Forecasting with Artificial Intelligence.	The technique is employed as a predictor and to hybridize existing methods and The performance of both Nearest Neighbour purposes is assessed.
8	Hashemi, S. T., Ebadati, O. M., & Kaur, H. (2020).	Machine learning techniques. SN Applied Sciences.	By result with previous conceptual cost estimation studies.
9	Ji S-H et al (2019).	Cost Model CBR.	It relates to provide a modified parameter-making process to enhance reliability of a cost estimation.
Previous Studies on Cost Risks in Construction projects			
10	Yuan, T., Xiang, P., Li, H., & Zhang, L. (2020).	A Monte Carlo simulation.	To achieve sustainable cost control, decision-makers should pay more attention to the effects of cost-estimating risks.
11	Rostami, A., &		The investigation of risk

	Oduoza, C. F. (2017).	ANN.	factors in construction projects in Italy from contractors' perspective.
12	Liu, J., Zhao, X., & Yan, P. (2016).	Structural equation modeling technique.	The identification of risk path scenarios enables practitioners to gain a better understanding of the sources and impact areas of risks, and to better deal with the risks, thereby contributing to the practice.
13	Aminbakhsh, S., Gunduz, M., & Sonmez, R. (2013).	Analytic hierarchy process (AHP).	Adequate prioritization of safety risks during risk assessment is crucial for planning, budgeting, and management of safety.
14	Hwang, B. G., Zhao, X., & Toh, L. P. (2014).	Low level of Risk management (RM).	It can provide an in-depth understanding of RM in small projects in Singapore as well as create the advantages of (RM) satisfactory to the members of small projects.
AI Applications Concerning Project Cost			
15	Sharma, et al., (2021).	Artificial Intelligence for Pre-Parametric and in Internet of things (IoT).	It greatly assists the civil engineers in efficiently using the capabilities of AI for solving complex and risk-sensitive tasks, and it can also be used in Internet of things (IoT) environments for automated applications such as smart structural health-monitoring systems.
16	Le Hong Haa, Le Hunga, Le Quang Trunga, 2018.	Artificial Neural Network (ANN).	It suggests a risk evaluation framework utilizing the artificial neural network (ANN) for supporting the company of construction in evaluating the risk and assessing their influence upon the profit of project for fresh projects.
17	Zhou, et al.,	Support vector	Training and test stages of

	2021.	machine (SVM), gray Wolf optimization (GWO), moth flame optimization (MFO).	the MFO-SVM model confirmed that this hybrid SVM model is a powerful and applicable technique addressing problems related to TBM Performance with a high level of accuracy.
18	He, X, et al., 2021.	It identifies the key tasks of implementing conceptual cost estimation models.	The current conceptual cost estimation studies, from the perspective of data modeling process for the first time.
19	Jin, X., Liu, Q., & Long, H. (2021).	Fuzzy optimal back propagation neural network (BPNN).	BPNN can be used to calculate the cost and benefit and predict the financial benefit of investment projects.

Table (1.2) : Result of the proposals based on risk factors that affect the construction project management

Researcher	**Owner risk**	**Contractor risk**	**Consultant risk**	**Organization risk**	**Resources of Project Risk**	**Natural risks**	**Political and environmental risk**	**Financial & Economic risk**	**Design risk**	**Management and contract risk**
S. Kouhestani et al.2020.	✓	✓	-	✓	-	✓	✓	-	✓	✓
Burkina Faso,2020.	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
Pan and Zhang,2020.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zhang, 2018.	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
Elfaki et al., 2014.	✓	-	✓	✓	✓	✓	✓	✓	✓	✓
Marinelli et al., 2018.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wauters et al., 2017.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hashemi et al.,2020.	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
Ji et al., 2019.	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
Yuan, et al., 2020.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rostami, et al., 2017.	✓	✓	✓	✓	✓	✓	✓	-	✓	✓
Liu, et al., 2016.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Aminbakhsh, et al., 2013.	✓	-	✓	✓	-	✓	✓	✓	✓	✓

Hwang, et al., 2014.	✓	✓	✓	-	✓	✓	✓	✓	-	✓
Sharma, et al., 2021.	✓	✓	✓	-	✓	✓	✓	✓	✓	✓
Le Hong Haa, Le Hunga, Le Quang Trunga, 2018.	-	-	-	-	-	✓	✓	✓	✓	✓
Zhou, et al., 2021.	✓	✓	✓	-	✓	✓	✓	-	✓	✓
He, X, et al., 2021.	✓	-	✓	-	✓	✓	✓	✓	✓	✓
Jin, X., Liu, Q., & Long, H. (2021).	-	✓	✓	-	✓	-	-	✓	✓	✓

1.7 The Structure of the Thesis

The structure of the research involves the following :

Chapter One: Introduction

This chapter provides an overview of the research topic and the justification of research, hypothesis, aim and objectives, research methodology, as well as research structure.

Chapter Two: Literature review

Chapter two includes an explanation of cost management and cost estimation methods. It also includes an explanation of the delay in construction projects and their types and clarifying the risk factors that affect the management of the construction project.

Chapter Three: Artificial intelligent techniques

This chapter offers a complete explanation of the research techniques regarding their kinds, classifications models, taxonomies, architecture, and models' evolution.

Chapter Four: The framework for identifying the project risks and performance of the AI models

This chapter includes clarifying the structure of the research and identifying risk factors in construction projects, and clarifying performance indicators for artificial intelligent techniques.

Chapter Five: Results and discussions

This chapter attempts to develop and evaluate the construction cost and delay models using smart optimization artificial technique to offer an instrument to help guess the costs and delays of construction through several stages.

Chapter Six: Conclusions and Recommendations

In this chapter, some recommendations and conclusions are presented, and some suggestions for future studies that may be undertaken for developing smart prediction models in the area of managing construction project risk factors.

1.8 Summary

This chapter demonstrates a brief introduction for using Artificial intelligent techniques in optimizing the cost and delay in construction project management . The description of a research problem and Justifications, explanation research aim and objectives, research scope andlimitations, brief research methodology, the structure of the thesis, andreview of previous studies.