American Research Journal of Civil and Structural Engineering

Volume 4, Issue 1, 1-7
Research Article | Open Access
ISSN (Online)- 2577-5944

AMERICAN RESEARCH JOURNALS
An Academic Publishing House

Using linear Chouquet integral algorithm to design optimal time-cost model in large construction projects

Hamid Jafari Nia[1], Hamideza Babaali[1], Kaveh Ostad-Ali-Askari[*2]

[1]Department of Civil Engineering, Khorramabad Branch, Islamic Azad University, Khorramabad, Iran

[2*]Department of Water Engineering, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran

[*](Corresponding Author), kaveh.oaa2000@gmail.com

Abstract

Nowadays, the problem of scheduling and executing projects with the least cost and time has become one of the main concerns of project managers. In this regard, researchers have used different methods and patterns. One of these methods is to use concurrent engineering in projects. Simultaneous engineering means the creation of a project schedule for projects based on existing units and human resources so that a synchronous rule can be applied to the project so that the project can be completed in less time. Modeling time and cost in large-scale construction projects is actually complicated and complicated. These complexities actually increase the risk of time and cost in the project. In this research, a new method called Chouquet integral algorithm is used to analyze time and cost equations. The chouquet integral is a method used to analyze and linearize complex equations. The proposed method is implemented on an executable model in 2017 and analyzed and analyzed in MATLAB software. The results show that the error rate of time and cost in the construction model resulted in a reduction of 27% and 14%, respectively.

Keywords: *Construction Management, Chouquet Integral, Linear Analysis, Error*

Introduction

Given the evolving trend of different industries and the rise of new development plans and consequently the rise of various industrial and business projects, the innovation-driven economy, the development of skills and knowledge and the motivation of the workforce and the ability to intelligently respond to change An economy-driven environment must have the proper planning and management based on a systematic approach to the planning, control, and execution of projects in terms of time and cost [1]. Project management is the process by which the project should achieve the most appropriate and cost-effective way during its lifetime [2]. In other words, project planning and control is a process, in order to maintain the project's path to achieving a justified economic balance between the three factors of cost, time and quality during project implementation, which requires specific tools and techniques to achieve these goals. To be used. On the other hand, when departing from the program path, it is possible to return the project to its closest possible original path (2 and 3) by identifying the causes [2, 3].

Project planning and control can be effective when it comes to facilitating implementation when systematically implemented. In addition to overseeing the physical and financial progress of the project, project control can be managed by the manager in areas where problems such as excessive administrative costs, lack of resources and materials, failure to execute key project activities in due date, etc. can be addressed. Help the project identify the solution and control the adverse consequences of the problem [4]. In many cases, the problem can be rescheduled and rescheduled.

One of the issues related to implementing large-scale projects, especially in the field of construction, is to be able to execute several projects that form a sub-plan of a single large-scale project at the same time. The problem with concurrent execution is that projects can be timed to match. Failure to comply with the project concurrently causes financial losses and in fact leads to many problems. Therefore, a method needs to be developed that can produce reliable results for large projects [5].

To assess the impact of concurrency on EPC implementation, we first need to identify the workflow and information in these projects. A project is performed in four stages: product definition, design, preparation and sample testing, as well as reliability and quality testing [6]. Figure 1 shows the network structure of a project. This is an overview of the workflow and information in the project, and the communication displayed in this structure reflects the interactions that exist between the various stages of the project. Some of these interactions are:

a) Advancements in the job or information stage can be limited by the slow progress of the job and information stages. These streams are displayed in a line.

b) Tasks obtained by a single step in the provisioning process may require rework. Using the work requires a change in the receiving stage, and the work done in this step also needs to be changed and reworked.

c) Re-work requires the coordination between the re-diagnostic stage and the re-creation phase. This coordination must be done before resuming work.

In the model, each of these stages has a general structure, with elements similar to these structures being distinguished at different stages by phase indices. Activities performed may be incorrect or based on information or inaccuracies and may therefore require a radical change. We call the workaround to correct errors or respond to changes in the information on which the activity was based.

The physical and information linkage between the activities of the various stages of the project as well as the existence of these relationships between the activities of a single stage limit the processes at that stage. These constraints are often expressed in terms of the length of time that an activity is performed. They are therefore called prerequisite relationships. Management decisions, coordination mechanisms, the type of information that is exchanged between different stages of the project, and the amount, skill and experience of the staff involved, as well as the number of manpower in the project, can also influence project progress.

The Relation Works

Many studies have been carried out on the old project cost-relationship relationships in the EVM method and other studies that have used the parameters of the method in constructing a model and a new forecasting relationship as well as many research studies. In the context of project cost estimation, construction projects have been investigated using non-EVM methods. Based on studies of the use of forecasting methods to estimate project time and cost, it is concluded that the present value management approach is also an effective and effective way of predicting completion time and cost. The project is considered and research on the use of this method in cost estimation is ongoing. Also, by reviewing the research done, it has been concluded that the models and methods presented so far have some features such as complexity, need for programming to build them, dependency on project type, dependency on Countries' currency or time dependence, inability to make predictions at any given time in the project, and inaccurate estimates.

Christensen (1993) has done extensive research on project cost estimation using the resulting value management approach and has obtained results by examining the results of other researchers [7]. Some of the results are: 1) Research shows that it is not possible to say that a relationship is best in all situations, 2) accuracy of performance indicator models is a function of system, stage and phase of the project, Cost, CPI is more important than Schedule Performance Index (SPI), 4- In the early stages of the project, relationships based on the Scheduled Cost Index (SCI) and in the final stages of the project, relationships. Based on CPI, they are better predictors. 5. Among the weighted predictor relationships, the relationships in which the SPI index is 0.2 weighted have the best performance.

Nagrica (2002) also investigated the accuracy of cost-predictive relationships during a study. He concludes that the CPI index is a good factor in predicting the cost of completing a project [8].

Cheng et al. (2010) used a fast turbulence genetic algorithm and a support vector machine to construct a model called the evolved support vector machine (ESIM) model. This model is able to estimate the cost of completing construction projects with greater accuracy than EVM relationships. The authors used 10 parameters affecting the cost of construction projects that 5 parameters out of 10 parameters are the main parameters and performance indicators of EVM relationships as input variables of the model. This paper uses information from two reinforced concrete construction projects to train and test the model, respectively. Information from all 13 projects was also used to compare the 8 relationships of the predictive relationships of the EVM method with the proposed model. The comparison results show that the prediction error of the

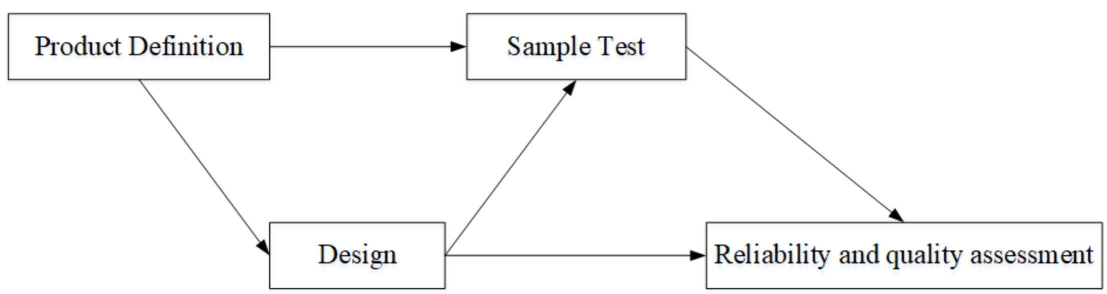

Figure 1: *network structure of a design project*

ESIM model is less than the prediction error of the EVM relationships [9].

Cheng et al (2012) in addition to genetic algorithms with fast perturbation and support vector machine. Have used fuzzy logic in constructing another model called Evolutionary Model of Fuzzy Backup Vector Machine (EFSIM) to predict the cost of completing construction projects. . The results of comparing the EFSIM model with the ESIM model and the eight relationships of the predictive relationships of the EVM method show that the prediction error of the EFSIM model is the least and this model is able to estimate the cost with very little error [10].

Narbio and Di Marco (2014) propose a new approach by integrating a progressive model and acquired scheduling method (ES) to improve the predictive accuracy of the cost-predictive relationships of completion of construction projects in the value-added method. Have. In this paper, the first four progressive models of Logistic, Gompertz, Bass and Weibull are compared in estimating the cost of 9 construction projects. Comparative results show the superiority of the Gompertz model in cost estimation [11].

Cheng et al (2015) of four methods based on artificial intelligence (artificial neural network, high-order neural network, fuzzy logic and genetic algorithm) in the development of a model called fuzzy neural network (EFHNN) for estimation. The costs of construction projects have been used. In this paper, 10 qualitative and quantitative variables affecting the cost of construction projects are considered as input variables of the model. The model output variable is the final cost of the project. Model results show that the model error in cost estimation is on average 10% which indicates high accuracy of EFHNN model [12].

Lee et al. (2012) propose two models to predict the cost of asphalt resurfacing projects using artificial neural networks. In this study, a model is constructed for each of the two contract pricing methods (unit price method and cut price method). For the construction and testing of two models of unit cost and cross-section pricing methods, data from 103 and 68 asphalt resurfacing projects were used, respectively. The results show that the prediction accuracy of the two models of unit cost and cross-sectional price methods are in good and medium order, respectively [13].

Material and Methods

In studies using multiple criteria decision-making methods, the scores obtained for each option are examined according to the effect of each criterion, but the interaction between the criteria is not considered. Criteria affect each other and the sum of these effects must be examined. Therefore, the model used to aggregate the criterion effect should be able to consider these relationships. Since linear models do not have this capability, the choke integral is used for integration. Choke integrals are one of the best aggregation methods that can be used if the criteria are dependent. Validation is computed using Chouquet integrals taking into account the interaction between criteria. The use of the Chouquet integral method has been considered for a robust model in which the metrics work together and has been used in various cases [14].

In this method, the weighted vector of the weighted sum method is replaced by a uniform set function called capacity (μ). The Chouquet integral with respect to the capacitance (μ) on the X vector is defined as follows:

$$C\mu(x) = \Sigma x(i)[\mu\big(A(i)\big)n_i = 1 - \mu(A(i+1))] = \Sigma\mu(A(i))[x(i)n_i = 1 - x(i-1))]$$

μ(S) indicates the importance or weight of the set S of the criteria.

Given that the importance of each subset of criteria is not necessarily equal to the sum of its members, the interaction of criteria is taken into account in the calculation of the final score. Given the above relation, for each subset S of factors must be determined μ(S), so it increases exponentially with increasing number of elements.

In the multi-criteria decision-making discussions, the above interaction is ignored and limited to the interactions between the two criteria. Therefore, the simplified case of the quadratic integral is called the integral quadratic integral. In this case, the integral formula of the Chouquet will be as follows:

$$x = \sum v_i x_i - \sum \{i,j\} \subseteq N, \frac{I_{ij}}{2} |x_i - x_j|$$

In the above relation, x_i indicates the advantage that an option has been obtained in factor i. v_i is the significance factor of each factor and I_ij is the interaction factor of two factors. The model coefficients (coefficients of significance and coefficients of interaction of criteria) must be determined for the use of the chouquet integral. In large-scale problems where there are complex relationships between criteria, the decision maker cannot directly determine the coefficients, in which case learning methods are used to determine the coefficients. The decision maker is then asked to make a paired comparisons that he or she is certain of the number of alternatives he / she is considering; the reference or selected A⊆A ^ ‘alternatives. This preference information is used as learning data to discover the intellectual form of decision making. After determining the coefficients that are consistent with the decision maker’s preference information, they can be used to score and rank other options. This way the decision maker does not have to determine the coefficients in advance. Because of their high flexibility, these models can be very effective in determining choke integral coefficients.

The mathematical relation of the continuous chouquet integral between the two variables is obtained as follows:

$$\int_c hog = C_g(n) = \sum_{i=1}^{n} h(x_{\pi_i})[g(A_i) - g(A_{i-1})]$$

In this equation $h_{(x\pi i)}$ is the query supporting the hth information source. Also $g(A_i)$ is the value of combining resources to the ith source and $g(A_{i-1})$ is the value of combining (i-1)th resources. The expression $[g(A_i)-g(A_{i-1})]$ also indicates the value that π_i is the trusted source of information in answering questions.

In the chouquet integral method, mathematical operators are used to increase the effectiveness of the method. One of these mathematical operators is Einstein's operation. Einstein's operations are effective cumulative operators based on algebraic softwares, which include Einstein's multiplication of $\otimes_E$ and Einstein's sum of $\otimes_E$. For each $(a,b)\epsilon[0,1]^2$ we will have the following equations:

$$a \otimes_E b = \frac{ab}{1 + (1-a)(1-b)}$$

$$a \oplus_E b = \frac{a+b}{1+ab}$$

Suppose Ω is a set of triangular intuitive numbers . $\tilde{a}_j =< (\underline{a}_j, a_j, \bar{a}_j; u_{a_i}, v_{a_i} >, (j = 1,2,\dots,n)$ The triangular intuitive fuzzy Einstein (TIFEWG) dimension n is as follows:

TIFEWG: $\Omega^n \rightarrow \Omega$

So:

$$TIFEWG(\tilde{a}_1, \tilde{a}_2, \dots, \tilde{a}_n) = (\oplus_{j=1}^{n})_E a_j^{\omega}$$

In the above relation ω=(ω_1,ω_2,…,ω_n)^T is the weighted vector a_j and $\sum_{j=1}^{n} \omega_j = 1$

If $\tilde{a}_j =< (\underline{a}_j, a_j, \bar{a}_j; u_{a_i}, v_{a_i} >, (j = 1,2,\dots,n)$ is a set of triangular intuitive numbers, then the sum of the values is subtracted The TIFEWG operator is also a triangular intuition and is obtained by the following relation:

$$TIFEWG(\tilde{a}_1, \tilde{a}_2, \dots, \tilde{a}_n) = (\oplus_{j=1}^{n})_E a_j^{\omega} =< \left(\prod_{j=1}^{n} \underline{a}_j^{\omega_i}, \prod_{j=1}^{n} a_j^{\omega_i}, \prod_{j=1}^{n} \bar{a}_j^{\omega_i}\right);$$
$$= (\frac{2\prod_{j=1}^{n} u_{a_i}^{\omega_i}}{\prod_{j=1}^{n} (2 - u_{\bar{a}_i})^{\omega_i} + \prod_{j=1}^{n} u_{\bar{a}_i}^{\omega_i}}, \frac{\prod_{j=1}^{n}(1 + v_{a_i}^{\omega_i}) - \prod_{j=1}^{n}(1 - v_{a_i}^{\omega_i})}{\prod_{j=1}^{n}(1 + v_{a_i}^{\omega_i}) + \prod_{j=1}^{n}(1 - v_{a_i}^{\omega_i})})$$

Where ω=(ω_1,ω_2,…,ω_n)^T is the weighted vector $\sum_{i=1}^{n} \omega_j = 1)$.

If f is a positive real function on X={x_1,x_2,…,x_n} and μ is a fuzzy measure on X, then the discrete chouquet integral f with respect to μ is defined as the following relation.

$$C_\mu(f) = \sum_{i=1}^{n} f_{(i)}[\mu(A_{(i)}) - \mu(A_{(i+1)})]$$

Where $A_{(i)} = \{x_{(i)}, \dots, x_{(n)}\}$ and $A_{(n+a)} = \emptyset$ such that $f_{(1)} \leq f_{(2)} \leq \dots \leq f_{(n)}$.

Proposed Method

The basis of the new forecasting method is based on the use of the Chouquet integral method to solve the problem of time and cost management in large-scale construction projects. As explained, this method follows the linear equations of the nonlinear model prediction of time and cost. In the previous section, the theory of the Chouquet integral method was expressed. In this section, we present a linear prediction model by Chouquet integral.

In nonlinear models of time and cost prediction, the obvious factor is the maximization of the forecast error, the complexity of the time and cost model. The cost objective function is defined as follows:

$$\sum_{t=1}^{T} \rho_t L_t log(\frac{C(t)}{L(t)})$$

The cost model includes equations for describing technology, subtractive and diffusion characteristics. Impurities. The output cost is as follows:

$$Q_t = a_t L_t^{1-\gamma} k_t^{\gamma}$$

Where

Q_t is the output cost impurity, a_t the degree of overall factor of production, k_t^{γ} cost savings over period t, and γ the amount of savings. The subtraction attribute is defined as follows:

$$A_t = b_1 Y_t^{b_2}$$

Where A_t is the degree of cost reduction in period t and Y_t^{b2} time control in period t.

On the other hand we have:

$$Y_t = 1 - \frac{E_t}{\sigma_t Q_t}$$

Where E_t is the time error rate in the period of t and σ_t of the recovery factor. The net performance based on the cost of implementation is as follows:

$$\Gamma_t = Q_t - A_t Q_t - D_t Y_t$$

We use the Chouquet integral to solve the time and cost prediction problem. If we define X as the vector of the cost variable that is x_{ij}, Ω represents part of the prediction model for the constraints expressed that is satisfying in period t. We define the expected function cost function w_t as follows:

$$w_t = \sum_i E\{c_{it} g_{it}\}$$

$$min \sum_t \sum_i c_{it}(1 - x_{it}) + \sum_t \min \{w_t | (costraints)\}$$

The prediction constraints are as follows:

$$x_{it} = 1 \quad for \quad t \le e_i \quad or \quad t \ge l_i + d_i$$

$$x_{it} = 0 \quad for \quad e_i \le t \le s_i + d_i$$

$$x_{it} = 0 \ or \ 1 \quad for \quad e_i \le t \le l_i$$

These include distribution constraints, seasonal constraints, available resources, and optimal scheduling. If t is below the problem of a linear program, it can be replaced by the binary given in the chouquet. Douglas Lagrange's problem for the following t is as follows:

$$L_t = \max_{k,\pi,y,\zeta,\mu}\{L_t(k,\pi,y,\zeta,\mu)\}$$

Where L_t (k,π,y,ζ,μ) is a Lagrangian function and (k, π, y, ζ, μ) are the constraint coefficients.

$$L_t(k,\pi,y,\zeta,\mu) = \min_{g\ge 0}\{\mathrm{w}_t$$
$$+\sum_i k((\sum_k s_{ik}f_{kt}) + g_{it} + r_{it} - d_{it})$$
$$+\sum_i \pi_{it}(g_{it} - \bar{g}_{it}x) + \sum_i y_{it}(r_{it} - d_{it}) + \sum_k g(|f_{kt}| - \bar{f}_k) + \bar{\mu}_t((\sum_i r_{it}) - \varepsilon)\}$$

The T subdomain is then replaced by L_t:

$$min \sum_t \sum_i C_{it}(1 - x_{it}) + L_t$$

The following Tth problem is possible if and only if the following optimal values for the problem are less than 2:

$$\min \ E\{\sum_i r_{it}\}$$

$$S.T.Sf + g + r = d \qquad g \le g(\varphi)X \qquad r \le d$$

$$|f| \le \bar{f}(\varphi)$$

Dugan Lagrange is as follows:

$$max_{\vartheta,\lambda,\tau,\eta}U_t(\vartheta,\lambda,\tau,\eta)$$

Where U_t (ϑ,λ,τ,η) are the Lagrangian function and ϑ, λ, τ, are the constraint coefficients.

$$U_t(\vartheta,\lambda,\tau,\eta) = \min_{g\ge 0}\{\sum_i r_{it}$$
$$+\sum_i v_{it}((\sum_i\sum_t s_{it}f_{it}) + g_{it} + r_{it} - d_{it})$$
$$+\sum_i \lambda_{it}(g_{it} - \bar{g}_i x_{it}) + \sum_i \tau_{it}(r_{it} - d_{it}) + \sum_k \eta_{kt}(|f_{kt}| - \bar{f}_k)\}$$

We then go into the general problem of analyzing the chouquet:

$$Min\ z$$

$$S.T.z \ge \sum_t\sum_i C_{it}(1 - x_{it}) + \sum_t L_t\,(k,\pi,y,\zeta,\mu) \quad for \quad k,\pi,y,\zeta,\mu \ge 0$$

$$\sum_t v_t(\vartheta,\lambda,\tau,\eta) \le \epsilon \quad for \quad \vartheta,\lambda,\tau,\eta \ge 0$$

The main problem is a numerical programming problem that is solved using trial and error method for predictive decision variables. This is part of the main issue that only includes some of the restrictions. Once x_it is fixed, it makes the sub-problem independent of the other sub-problems. In each iteration, solving the dual coefficients produced by the sub-problem, the cost and the ability to determine the cost vary. These double multipliers are repeated in the form of one or more of the constraints added to the problem below.

Finally the linear prediction problem must follow the following optimal pattern:

$$\min z$$

$$z \ge \sum_t\sum_i \{c_{it}\tilde{g}_i(1 - x_{it})\}$$

If the following are probable issues, the cost for the period t, w_t, depends on the use of units to satisfy the constraints of each time period, with the aim of maintaining high capability. ε(φ) is the degree of capability. Therefore, the cost in period t can be expressed as follows:

$$w_t = \min E\{\sum_t c_{it}g_{it}x_{it}^n\}$$

$$S.T.Sf + g + r = d(\varphi)$$

$$g \le \bar{g}(\varphi)x^n \qquad r \le d(\varphi) \qquad |f| \le \bar{f}(\varphi)$$

$$\sum_i r_{it} \le \varepsilon(\varphi)$$

Solving subsystems is not complicated, since project data is available during the t period and allows us to minimize performance costs. The final cost rate is as follows:

$$z \ge \sum_t (w_t^n + \sum_i (c_{it}\tilde{g}_i(1 - x_{it}^n) + \pi_{it}^n\tilde{g}_i(x_{it}^n - x_{it})))$$

Where w_t^n is the expected output for period t for nth solution. The coefficient below the problem may not have any solution due to the fact that the output produced cannot be exceeded desirable. If a sub-issue is impossible, the cut is impossible. For each impossible sub-problem the result of the nth problem-solving method, the following is impossible to cut:

$$E\{\sum_i r_{it}^n\} + \sum_i \lambda_{it}^n\tilde{g}_i(x_{it}^n - x_{it}) \le \varepsilon$$

The coefficient λ_{it}^n is interpreted as the boundary decrease in the output produced.

Numerical Results

As illustrated in this paper, the Chuquet integral method is used to manage time and cost in large-scale construction projects. In the previous section, the proposed method and the mathematical theory of this method are presented. In this section, the numerical results of this method are evaluated. MATLAB software was used to evaluate and present numerical results on a construction model.

- **Data Collection**

This paper uses information from 21 actual projects completed with a total duration of 719 months to build and test the time and cost forecasting model of construction projects. It should be noted that all projects have been implemented in Iran. The model building uses information from 17 projects with a total duration of 541 months and the model data from 4 projects with a total time of 178 months. Projects are very diverse in terms of type. As a result of a variety of civil engineering projects including two complementary dams, road projects such as freeway and road construction, construction projects, water and wastewater projects such as construction of pipelines, canals and tunnels. Construction of a new city irrigation and drainage and sewage system, preparation and landscaping projects of a new city and projects of industrial structures such as silos have been used in the evaluation.-

Compare the results of the model with the results of the EVM relationships

The model error value and the optimal relationship error value of the EVM method in predicting the cost of completing each project of the 21 projects used in model building and testing are shown in Table 1. It should be noted that opt. Is the one that has the least error. The value of the second optimal relationship error for the projects that have the best performance of the EVM method relative to the model is shown in Table 2. It can be seen in Table 1 that the Chouquet integral model estimates and reduces the cost of completing 16 of the 21 projects most accurately to the optimal relationship of the EVM method. Table 2 also shows that the proposed model estimates the cost of completing the other 5 projects more accurately than the second optimal relationship. Therefore, it can be said that the proposed model has a better overall performance in reducing project costs.

Conclusion

This paper presents an optimal way to manage time and cost and reduce it in large construction projects. The proposed

***Table 1:** Estimating time and cost in the proposed model*

Project / Variable	1	2	3	4	5	6	7	8	9	10	11
Output Variable	1.444	1.722	1.094	1.364	1.782	1.167	1.677	1.739	1.215	1.119	1.064
Real Time	30	18	13	60	40	23	52	41	8	26	16
Error	0.00289	0.01005	0.00119	0.00600	0.00507	0.00411	0.00521	0.00576	0.06710	0.00125	0.00084
Error redution	17	14.5	12.1	9.37	12.54	16.39	10.25	11.45	12.86	10.65	13.35
Cost redution	19.1	12.18	16.30	15.41	13.54	16.63	15.27	18.34	15.72	14.45	13.90
Project / Variable	12	13	14	15	16	17	Test 1	Test 2	Test 3	Test 4	
Output Variable	1.000	1.222	1.047	1.082	1.082	2.104	1.494	1.250	1.678	1.159	
Real Time	54	20	14	20	20	86	31	9	96	42	
Error	0.00130	0.01037	0.04080	0.00484	0.00103	0.01100	0.00978	0.00557	0.02400	0.01167	
Error reduc-tion	15.13	9.25	12.45	9.33	11.47	10.55	16.48	14.20	17.96	10.14	
Cost reduc-tion	11.33	14.49	15.40	12.53	16.92	15.43	13.61	11.35	13.67	15.84	

***Table 2:** Model error estimation*

Project/Variable	9	11	13	14	15
Output Variable	1.215	1.064	1.000	1.222	1.047
Real Time	8	16	20	14	20
Error	0.06710	0.00361	0.01037	0.04080	0.00484

method is based on the application of the chouquet integral. This method was used to break down time and cost equations into linear and simple equations. The proposed method has shown that the use of the chouquet integral can significantly reduce the time and cost model error when faced with a large and complex model. It also enables parallel analysis for simultaneous projects. The method used can also be used to predict time and cost models in large construction projects.

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Citation: Hamid Jafari Nia, Hamideza Babaali, Kaveh Ostad-Ali-Askari, "Using linear Chouquet integral algorithm to design optimal time-cost model in large construction projects". American Research Journal of Civil and Structural Engineering, vol 4, no. 1, 2020, pp. 1-7.