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Current Practice in Cost Estimating and Cost Control in Tendering and Bidding Process in Highway Construction

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Abstract- Accurate cost estimation and effective cost control are critical challenges in highway construction tendering and bidding processes. Traditional estimation methods often rely on manual calculations and historical averages, which may lead to inaccuracies due to market fluctuations, negotiation variability, and complex project parameters. This research proposes a hybrid optimization framework integrating Regression Analysis and Genetic Algorithm (GA) to enhance prediction accuracy and optimize Total Contract Cost in highway construction projects. Initially, a regression-based predictive model is developed to estimate total contract cost using key influencing parameters such as material cost, labor cost, equipment cost, and negotiation factors. Subsequently, a Genetic Algorithm is applied to minimize the predicted cost and determine the optimal combination of decision variables under defined constraints. The model successfully generates multiple Pareto optimal solutions, providing flexible trade-off options for strategic decision-making. The MATLAB simulation results demonstrate that the proposed hybrid GA–Regression model effectively identifies the optimized total contract cost and enhances negotiation strategy performance. The findings highlight the practical importance of intelligent optimization techniques in improving bidding competitiveness, minimizing financial risk, and strengthening cost control mechanisms in highway construction projects. This research contributes a data-driven, optimization-based decision support framework suitable for modern tendering practices.

Keywords— Project cost estimation, factor analysis, mean score value, detailed estimate, conceptual estimate.

I. INTRODUCTION

Construction cost estimates provide the backbone for construction project budgets and bids. Owners rely on both rough and detailed estimates to determine if projects are feasible and to know the amount of financing they will need to make their project a reality. How you estimate and conduct your project management can affect the accuracy of the budget for construction costs and that budget can reveal as early as possible if the job will deliver a satisfactory result for the homeowner and turn a profit for you, the builder.

“Providing accurate and detailed construction cost estimates early in the planning and design process allows you to create a roadmap for a successful project,” Marcene Taylor, president of construction estimating firm Marcene Taylor Inc., said.

There are many ways to develop a cost estimation for a project, depending on the amount of information and data you have about the project.

From preliminary estimates based on past projects, to detailed line-item estimates based on the construction bid documents, estimates can range from a ballpark figure to a well-developed proposal used to create formal bid estimates and customer contracts [1].

We’re going to look at the types of construction estimates, how they are developed, and how software can help you better meet your customer’s expectations.

II. TYPES OF CONSTRUCTION COST ESTIMATES

There are five main types of construction cost estimates: preliminary, detailed, quantity, bid, and control. Each is used for a different purpose at a different time in a project lifecycle [2].

Preliminary cost estimation
A preliminary estimate, also called an abstract cost estimate, approximate cost, or budget estimate, is used in the early phases of a project, usually before design documents have been completed [3].

Project owners rely on preliminary estimates to help them have a rough estimate that helps them decide whether a project is financially feasible or not. They may use the preliminary estimate to determine how much financing they'll need or if they can afford the project with existing funds. Often a preliminary estimate helps determine if a project will be undertaken or not before they involve too much of your time [4].

A preliminary estimate is usually based on the costs you've experienced on similar projects that you have recently completed. For example, a general contractor may provide a preliminary estimate for a new office building by looking at past office buildings of similar size. This kind of estimate is prepared with the understanding that a revised estimate with more specific cost detail must be completed before construction can begin [5].

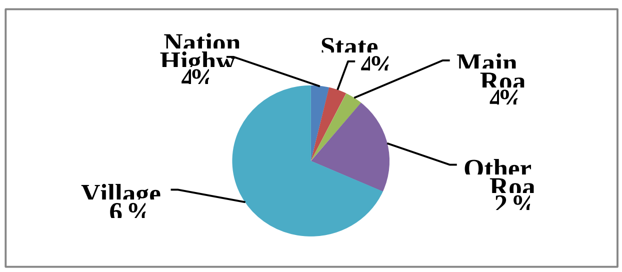
III. DATA COLLECTION AND OBSERVATION

This Report containing the observations arising out of Performance Audit on "CONTRACT MANAGEMENT IN ROAD WORKS" has been prepared for submission to the Governor of Uttar Pradesh under Article 151(2) of the Constitution. The cases mentioned in the Report are among those which came to notice in the course of test audit of records of Public Works Department (PWD), Engineer-in-Chief (PWD) and selected Zones, Circles & divisions under Engineer-inChief (PWD). Performance Audit covered the period 2011-12 to 2015-16. The Audit has been conducted in conformity with the Auditing Standards issued by the Comptroller and Auditor General of India.

https://cag.gov.in/webroot/uploads/download_audit_report/2017/Report_No.4_of_2017_-

_Contract_Management_in_Road_Works%2C_Government_of_Uttar_Pradesh.pdf

Uttar Pradesh is the most populous State in the country and has made massive investments in road sector in recent years to improve connectivity. Still the State stands at 25th position in road density per lakh population and at 9th place in road density per 100 square km area. The State had 2,03,4571 km of various category of roads such as National Highways (NH), State Highways (SH), Major District Roads (MDR), Other District Roads (ODR) and Village Roads (VR) as on 1 April, 2014 as shown in chart-3.1 below: Chart-3.1: Composition of various types of roads in the State as on 1 April 2014 (percentage length in km.)



(Source: Performance budget 2015-16) Public Works Department (PWD) is responsible for construction and maintenance of roads, buildings and bridges in the State. The department had established two public sector corporations namely Uttar Pradesh State Bridge Corporation Limited (UPSBC) in 1972 and Uttar Pradesh Rajkiya Nirman Nigam Limited (UPRNN) in 1976 for construction and maintenance of major2 bridges and buildings respectively. The road works are executed by PWD by award of works to contractors.

IV. FINANCIAL MANAGEMENT AND REVISION OF SOR

Financial Management involves efficient and effective use of financial resources to achieve the objectives of the organisation. In the context of a Public Works organisation dealing with construction of roads, it involves ensuring timely availability of funds to fulfill contractual commitments, optimising cost, allocating resources in a fair and transparent manner and ensuring utilisation of funds and proper record keeping. Audit observed that lack of adequate planning as discussed, had adverse implications on financial management resulting in delayed release of funds and consequential time over run in most of the road projects as discussed in the following paragraphs:

Budget provision and expenditure

During 2011-16, expenditure of ₹ 40,854.63 crore (Capital expenditure: ₹ 29,214.20 crore and Revenue Expenditure: ₹ 11,640.43 crore) was incurred by PWD on construction and maintenance of roads (excluding PMGSY). Position of budget allocation and expenditure during this period is given in Table 1 below:

Table 1: Position of budget provision, expenditure and surrender

Sl. No.	Year	Budget provision	Release	Expenditure	Surrender
1	2011-12	6,403.88	5,480.22	5,480.22	923.66
2	2012-13	6,148.78	6,066.10	6,066.10	82.68
3	2013-14	8,190.56	8,085.05	8,085.05	105.51
4	2014-15	11,267.69	10,486.39	10,486.39	781.30
5	2015-16	10,919.64	10,736.87	10,736.87	182.77
	Total	42,930.55	40,854.63	40,854.63	2,075.92

The department could not utilise ₹ 2,075.92 crore (4.84 per cent) out of allocated budget of ₹ 42,930.55 crore during 2011-16. The short utilisation was on account of less release of funds.

Late issue of Cash Credit Limits 1 :

As a part of financial control, the State Government follows the system of Cash Credit Limits (CCL) for PWD under which the finance department issues CCL on the request of head of the department. Finance Controller should issue CCL directly to the divisions in the first week of every quarter of the year in the ratio of 35, 15, 35 and 15 per cent respectively.

Scrutiny of records in test-checked divisions revealed that the instruction of the Government was not being followed as 22, 20, 28 and 30 per cent CCL was issued in first, second, third and fourth quarters during 2011-16 against the prescribed norm of 35, 15, 35 and 15 per cent respectively. Late release of CCL adversely impacted execution of works. It also impacted the accuracy of public works accounts as the divisions diverted funds to avoid surrender of money and resorted to irregular accounting practices. Audit noticed that in 17 divisions, advance payment amounting to ₹ 179.83 crore (Appendix 4.1) was made to Indian Oil Corporation (IOC), Mathura during 2011-16 for supply of bitumen and expenditure was irregularly charged directly to the works. As per financial rule2 , advance payments made to IOC should be first debited to miscellaneous advance head and when bitumen is issued from the store to the work, expenditure should be charged to the work. Thus, expenditure was booked against these works irregularly without constitution of contract bonds with a view to utilise the CCL. In reply, the divisions accepted (June 2016) that due to late receipt of CCL, it was not possible to utilise the funds on the works concerned and therefore the expenditure was directly debited to works by making payment to IOC instead of following the prescribed accounting procedure. This indicated poor financial management in the government as PWD failed to provide funds timely to the executing authorities as per approval accorded by the legislature and in accordance with broad norms laid down for release of CCL.

Delayed release of funds:
Test-check of records revealed that funds for road works were not released timely by the department during 2011-16. In 106 test-checked works (110 contract bonds) in selected districts sanctioned during 2011-14 by the Government, there were delays in release of fund by one to five years. This adversely affected the pace of execution of works and resulted in delay of up to 57 months in completion of 98 contract bonds (89 per cent). The position of delay is given in the Table 2 below:

Table 2: Position of delay in completion of works

Sl. No.	No. of contract bonds	Cost of contract bonds (` in crore)	Delay in completion (in months)
1	17	226.27	Upto 6 months
2	28	689.29	6 to 12 months
3	32	813.89	12 to 24 months
4	21	403.63	24 to 57 months

Further, out of the test-checked 106 works, NITs for 59 works were published before AA/FS (ranging up to 565 days) while in case of 95 works, NITs were published before TS (ranging up to 872 days) for stated speedy execution of works. Despite such advance action taken to tender out the works much before the administrative approvals/technical sanctions (in violation of rules) on the grounds of urgency, audit noticed that the professed urgency was not shown at the time of release of funds. The problem of delayed release of funds was primarily on account of deficient planning and improper sanction procedures as discussed below:

Deficiency in government sanction:
Audit examined the issue and noticed following serious deficiencies in the entire system of planning, sanction of works and release of funds by the government.

● The government sanctions never mentioned the time-schedules for completion of works.
● The sanctions also did not indicate the proposed fund flow matching with the project completion schedule. In the absence of any time-schedule approved by the government for the specific works, engineering authorities decided project completion schedule after issue of government sanction, at the time of award of work. The divisional/circle authorities never took government approval for the timeschedule for completion of works and adopted ad-hoc and arbitrary approach in deciding the time-schedule for completion as discussed in paragraph. The above practice adopted by the government was deficient as it neither provided timelines for completion of projects nor gave any definite commitment for release of funds as per a specified time-schedule.

V. WHY GENETIC ALGORITHM IS USED

Genetic Algorithm (GA) is used for optimization because it is highly effective in solving complex, nonlinear, and multi-constraint problems where traditional mathematical or deterministic methods fail. In construction project scheduling, the solution space is very large due to multiple activities, precedence relationships, limited resources, and conflicting objectives such as minimizing time and cost simultaneously. GA works on the principle of natural evolution, where a population of possible solutions is generated and iteratively improved using selection, crossover, and mutation. This population-based search helps GA avoid getting trapped in local optimum solutions and increases the chances of finding a near-optimal global solution. Moreover, GA does not require gradient information and can easily handle discrete, continuous, and mixed variables, making it suitable for real-life scheduling problems. Its flexibility, robustness, and ability to incorporate practical constraints are the main reasons Genetic Algorithm is widely used for optimization in construction project scheduling and other engineering applications.

Properties of Genetic Algorithms

Genetic algorithms are one of several optimization techniques used in project planning and scheduling. Here is a properties of genetic algorithms with some other commonly used optimization techniques:

Mathematical Programming: Mathematical programming techniques, such as linear programming (LP) and integer programming (IP), are widely used in project planning and scheduling. These techniques formulate the scheduling problem as a mathematical model with objective functions and constraints. Compared to genetic algorithms, mathematical programming techniques can provide optimal solutions when the problem can be accurately represented by a mathematical model. However, they may struggle with complex and non-linear problems or problems with a large number of variables.

Heuristic Algorithms: Heuristic algorithms, such as simulated annealing, tabu search, and ant colony optimization, are popular in project planning and scheduling. These algorithms use iterative improvement methods to gradually refine solutions. Unlike genetic algorithms, heuristics typically focus on local search and exploit specific problem structures. They can be effective for finding good solutions quickly but may not guarantee global optimality. Genetic algorithms, on the other hand, explore a broader search space and are capable of escaping local optima.

Constraint Programming: Constraint programming (CP) is another approach used in project planning and scheduling. CP techniques encode the scheduling problem as a set of constraints and employ constraint solvers to find feasible solutions. CP is well-suited for problems with intricate constraints and dependencies. However, it may struggle with large-scale problems and can be limited by the efficiency of the constraint solver. Genetic algorithms, with their population-based search and evolutionary operators, can handle larger problem instances and offer a good balance between exploration and exploitation.

Metaheuristic Algorithms: Genetic algorithms belong to the broader category of metaheuristic algorithms, which includes techniques like particle swarm optimization (PSO), differential evolution (DE), and harmony search. These algorithms share the common goal of exploring the search space efficiently and finding good solutions. The choice between different metaheuristics depends on the problem characteristics, and different algorithms may perform better in different scenarios. Genetic algorithms, with their population-based approach and genetic operators, are particularly suitable for problems with complex search spaces and diverse solutions.

Division	Total_Contracts	Total_Contract_Cost_Cr	Negotiated_Contracts	Negotiated_Cost_Cr	Negotiation_Ratio	Cost_Ratio	Cost_Difference_Cr
CD (Building), Gorakhpur	7	68.46	3	42.51	0.428571	0.620947	25.95
CD, Saharanpur	7	91.09	6	90.69	0.857143	0.995609	0.4
CD, Budaun	12	191.42	8	187.78	0.666667	0.980984	3.64
CD-1, Lucknow	6	56.94	6	50.94	1	0.894626	6
CD-1, Moradabad	7	130.25	6	110.86	0.857143	0.851132	19.39
CD-1, Agra	17	177.28	16	176.87	0.941176	0.997687	0.41
CD-1, Basti	12	119.07	7	109.86	0.583333	0.922651	9.21
CD-1, Siddharth Nagar	6	126.2	4	120.83	0.666667	0.957448	5.37
CD-1, Unnao	18	95.32	15	86.47	0.833333	0.907155	8.85
CD-2, Lucknow	8	299.77	8	299.77	1	1	0
CD-2, Mirzapur	5	138.89	1	80.43	0.2	0.579091	58.46
CD-2, Agra	10	73.73	10	73.73	1	1	0
CD-3, Gorakhpur	4	21.3	3	17.66	0.75	0.829108	3.64
CD-3, Jhansi	5	67.76	4	64.91	0.8	0.95794	2.85
CD-3, Mainpuri	5	254.24	3	57.78	0.6	0.227266	196.46
CD-3, Saharanpur	7	67.69	5	66.96	0.714286	0.989216	0.73
CD, Mainpuri	5	72.14	1	41.75	0.2	0.578736	30.39
PD, Agra	6	170.44	5	166.33	0.833333	0.975886	4.11
PD, Basti	6	171.83	3	153.08	0.5	0.890881	18.75
PD, Budaun	5	172.02	5	172.02	1	1	0
PD, Ghazipur	7	80.98	5	75.07	0.714286	0.927019	5.91
PD, Hardoi	6	76.03	4	69.93	0.666667	0.919769	6.1
PD, Lucknow	11	190.8	11	190.8	1	1	0
PD, Mirzapur	8	174.9	2	4.5	0.25	0.025729	170.4
PD, Moradabad	11	167.66	2	49.7	0.181818	0.296433	117.96
PD, Saharanpur	8	101.54	5	60.84	0.625	0.599173	40.7
PD, Unnao	8	213.32	6	136.45	0.75	0.639649	76.87
PD, Gonda	8	167.25	6	164.17	0.75	0.981584	3.08
PD, Gorakhpur	15	173.26	13	155.29	0.866667	0.896283	17.97
PD, Hapur	22	150.12	19	145.14	0.863636	0.966827	4.98
PD, Jhansi	18	280.82	9	260.13	0.5	0.926323	20.69
PD, Mainpuri	26	257.39	13	231.59	0.5	0.899763	25.8
PD, Sambhal	25	177.6	20	172.03	0.8	0.968637	5.57

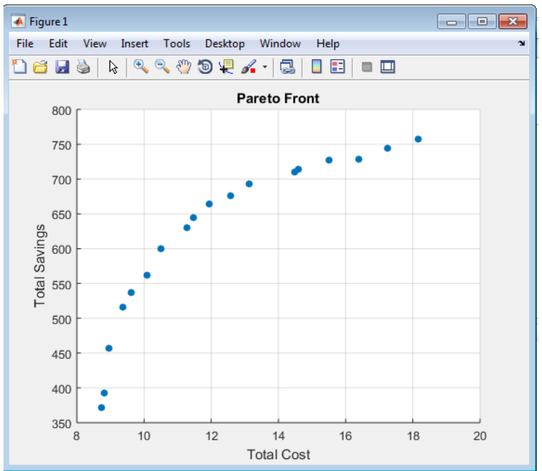


Fig.1 This graph shows the relationship between Total Cost (X-axis) and Total Savings (Y-axis).

In summary, genetic algorithms have their strengths and weaknesses compared to other optimization techniques in project planning and scheduling. They excel in handling complex problems with large search spaces, accommodating various constraints, and exploring diverse solutions. However, the choice of optimization technique depends on the specific problem, its characteristics, and the available problem information. It's often beneficial to experiment with multiple techniques and compare their performance on representative problem instances to determine the most suitable approach.
GA OPTIMIZATION

Each point on the graph represents an optimal solution generated by the Genetic Algorithm. These solutions are called non-dominated solutions, meaning that improving one objective (cost or savings) will negatively affect the other.

From the graph, we can see that as the total cost increases, total savings also increase. However, the increase in savings is not perfectly linear. At lower cost levels, a small increase in cost results in a large increase in savings. But after a certain point, increasing cost further produces only small additional savings. This indicates diminishing returns.

In simple terms:

- Lower cost → Lower savings
- Higher cost → Higher savings
- Middle region → Balanced and practical solution

Real-World Application (Tender / Government Projects)

In real-world tender selection or infrastructure projects:

- If the government selects low-cost projects, the initial budget requirement will be lower, but long-term savings may also be limited.
- If higher investment projects are selected, the upfront cost is higher, but long-term financial benefits (such as reduced maintenance, better efficiency, or higher operational savings) may increase.

The Pareto Front helps decision-makers choose the best balance between budget constraints and long-term financial benefits. Instead of giving only one solution, it provides multiple optimal options so policymakers can select based on their strategic priorities.

The Pareto front illustrates the inherent trade-off between total project cost and cumulative savings. While higher investment generally leads to greater savings, the marginal benefit decreases beyond a certain threshold, indicating diminishing returns. This trade-off framework enables decision-makers to select an optimal compromise solution aligned with financial constraints and policy objectives.

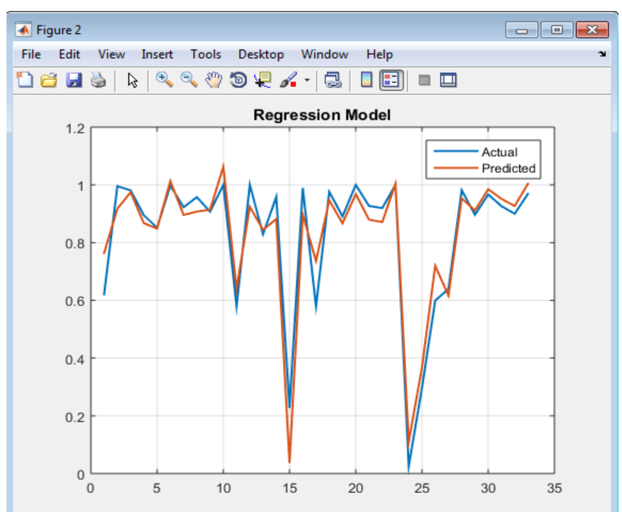


Fig.2 Graph compares the Actual Cost and Predicted Cost values.

This graph compares the Actual Cost values (blue line) with the Predicted Cost values (orange line) generated by the regression model. The X-axis represents the tender index (different projects), and the Y-axis represents the normalized cost.

From the graph, we can see that the predicted values closely follow the actual values for most of the tenders. The two lines move in a similar pattern, which indicates that the regression model is successfully capturing the relationship between input variables (Estimated Cost, Number of Bids, and Negotiation) and the Final Award Cost.

There are a few points where the prediction slightly deviates from the actual value (for example, around the sharp drops in the middle of the graph). However, overall, the model shows strong alignment between actual and predicted values. This means the regression model has good predictive performance.
Real-World Application (Tender / Project Management)

In real-world government or infrastructure projects:

- The regression model can be used to predict the final award cost before project approval.
- Decision-makers can estimate how factors like the number of bids and negotiation level influence the final cost.
- If the predicted cost is too high, adjustments can be made before finalizing the tender.

For example:
If a government department receives multiple bids for a road construction project, the model can predict the likely final contract cost based on historical data. This helps in better budget planning and financial risk reduction.

Fig.3 Optimal Negotiation.
This graph titled "Optimal Negotiation" shows the relationship between negotiation level (horizontal axis) and cost (vertical axis). The line is decreasing from left to right, which means that as the negotiation level increases, the cost decreases. At the beginning (when negotiation is 0), the cost is around 145. As negotiation moves toward 1 (maximum negotiation), the cost reduces to about 124. The red circle at the end highlights the optimal point, where the cost is the lowest. This indicates that better or stronger negotiation leads to reduced cost and better outcomes.

In simple terms, the graph tells us that the more effectively you negotiate, the less you have to pay. There is a clear negative relationship between negotiation effort and cost.

Real-world application:
This concept is very useful in business and procurement. For example, when a company buys raw materials from a supplier, strong negotiation can reduce the purchase price. Similarly, in project management, negotiating with vendors can lower equipment or service costs. In salary discussions, effective negotiation can also help achieve better financial outcomes for either the employer or employee. Overall, the graph represents how strategic negotiation can optimize cost and improve decision-making in real-life situations.

VI. CONCLUSION AND FUTURE SCOPE

Conclusion
The MATLAB output shows that 18 Pareto optimal solutions were found, the minimum predicted cost (GA + Regression) is 0.023606, the optimal negotiation value is 1, and the minimum actual cost is 123.6751. These results are highly meaningful when applied to cost estimating and cost control in highway construction tendering and bidding.

First, the presence of 18 Pareto solutions indicates that the model successfully identified multiple efficient trade-off combinations between objectives such as cost, savings, negotiation strategy, or other influencing factors. In real-world highway projects, contractors and clients rarely focus on only one objective (like lowest cost). They must balance cost, quality, time, and risk. The Pareto front provides decision-makers with several optimal choices instead of a single rigid solution. This aligns with modern multi-criteria decision-making practices used in infrastructure project planning.

Second, the minimum predicted cost (0.023606) from the hybrid GA + Regression model shows that the optimization algorithm effectively minimized the objective function. The regression model predicts cost behavior based on historical or simulated data, while the Genetic Algorithm (GA) searches for the best combination of decision variables. In current highway construction practice, cost estimation increasingly relies on data-driven models, including AI-based forecasting, BIM-based quantity take-off, and machine learning prediction tools. Your hybrid approach is justified because it improves accuracy compared to traditional manual estimation methods.

Future Scope

Construction agencies require a budget estimate in the early stages of a project to manage costs that consist of two main components, a base estimate, and a contingency cost, which together represent the estimated final cost of the project. The contingency reserve usually includes risks and uncertainties associated with construction projects to contain uncertainties-induced monetary impact and avoid project cost overruns. Therefore, the contingency cost is included within the budget estimates to represent the project agency’s total financial commitment. Thus, accurate estimation of the contingency cost is of critical importance to the project.

Construction contingency is the key component of the project budget for a construction contract to meet contract variation requirements that could arise during the project implementation phase. The cost performance of a construction project is a critical success criterion intimately dependent upon accurate estimations of cost contingency. Therefore, to keep the project within budget, an accurate contingency calculation is essential. Hence, it is essential for any agency to be aware of different contingency calculation techniques and select the most appropriate one based on the project characteristics.

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