ISSN No:-2456-2165

Cost and Time Optimization of Highway (NH 24-B, Phase-I) Construction

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Abstract:- India is a growing country, and its progress mainly depends on the economy, Infrastructure and the living standards of the public in the country. India's infrastructure facilities including transport, electricity and sanitation are still estimated inadequate for its population and thereby presenting a challenge for sustainable progress. For completing a highway project in transportation with minimum time and cost is critical in a competitive situation. Time and cost are the main objective to be discussed in the present optimization study using Genetic Algorithm (GA) for highway project. For scheduling of project has been used which gives the correct and accurate schedule of the project while GA optimization solver in MATLAB are used to optimize time and cost of the project. The Performance of the solvers mainly depends upon the parameters of GA which are used according to target and actual duration of project. GA modeling is used to properly allocate the material that will result in lower computational cost and increased productivity. In this study the solution has been performed under different combination of GA parameters and after the analysis of result, best values of these parameters have been found for feasible solution. The results of GA technique could produce the most optimal solution for time cost optimization, especially when project is vast and complex.

Keywords:- *Time, Cost, Optimization and Genetic Algorithm.*

I. INTRODUCTION

Transportation plays a significant role in the socio-economic growth of a country. India's road infrastructure has seen consistent improvement in the last few years. Transport investments are generally long-term, costly and practically irreversible. They also have a tremendous impact on people's lives and the growth of regions and communities. Investment decisions are therefore, fine attention and different alternatives are carefully compared before making a final decision. Financing is the major problem faced by many developing countries to complete the huge project. Most of the projects are cancelled due to the lack of funds. Time and cost of each activity of project should be estimated to determine the total cost and duration of project for planning and completing the task. To obtain the best outcomes optimization is used and profit margins are achieved between them. Optimization technique is mostly used by project managers or contractors to complete the project in given schedule. In last numerous years' costs of construction resources have gradually rises. So effective planning, estimation of project time and cost is leading to a contracting organization. Zheng et al. (2002) applied Genetic Algorithm (GA) for optimization of time and cost of project. However (GA) shows better results compared with other techniques such as Critical Path Method (CPM), Linear Programming (LP) and Integer Programming (IP). Jang (2004) computed lower computational cost and increased productivity helps to properly allocate the space by Genetic Algorithm (GA) for construction space management. For highway projects Maji and Jha (2008) developed multi-objective highway alignment optimization for determination of construction, user cost while Cristobal (2009) modeled integer programming to minimize time meeting quality, to minimize cost subject to quality and to maximize quality subject to time and cost objectives. Setinc et al. (2013) proposed an optimization for highway project planning based on GA and computer modeling for cash flow simulation and Mendes (2015) presented a hybrid genetic algorithm for the time-cost optimization (TCO) problem.

Afterwards Ahamed et al. (2016) proposed to try to optimize the time and cost involved in a highway bridge construction and Sushma et al. (2017) used Planning, Scheduling and Resource Optimization for Road Construction Using Primavera. Recently Baviskar and Devalkar (2018) explained time cost optimization in the road construction.

This case study provides a review of construction scheduling and solving a Genetic Algorithm (GA) by optimization tool solver in MATLAB for cost and time optimization of highway project. This preferred tool gives a complete account about working hours, availability hours, and idle hours allowing infrastructure industry to decide about the consumption hours. It also enables them to decide the equipment and gives ideas about reducing the idle equipment, thereby reducing cost and maximizing profit respectively.

ISSN No:-2456-2165

II. STUDY AREA AND DATA ACQUISITION

The present study is focused on scheduling and time cost optimization of highway project by Genetic Algorithm. As a case study Rae Bareli Ring Road project of Phase I – Eastern side of Rae Bareli city is chosen. The Rae Bareli city located on the bank of SAI River and in south east of Lucknow district of Uttar Pradesh state in northern India.

The alignment of the ring road has been studied keeping NH-24B as center of the proposed ring road. The length of phase I is 17.927 Kms. The terrain of proposed alignment is completely plain. The initial information collected from Ministry of Road Transport & Highway, Office- Rae Bareli (U.P.) The detailed information of the case study is shown in *Table 1.*

Activity No.	Nom.	Activity Name	Duration	Predecessors	Successors	Direct Cost(Cr.)
1	A	Clearing & grubbing	40	-	2, 13	1112522
2	B	Excavation in Ordinary Soil & Rock	80	1	3	32015946.56
3	C	Earthwork in Embankment (Filling)	180	2	4	185312621
4	D	Subgrade preparation	156	3	5	68173316
5	E	Geo Textile below GSB	110	4	6	53012540.06
6	F	Granular Sub Base	110	5	7	167012432.5
7	G	Wet Mix Macadam	140	6	8	173309062.4
8	H	Prime coat	40	7	9	9156876
9	I	Tack coat	90	8	10	6198949
10	J	DBM	90	9	11	228965248
11	K	Tack Coat Bituminous Concrete	75	10	12	4123658
12	L	Bituminous Concrete	75	11	22	139544320
13	M	Excavation & Piling Foundation	60	1	15, 14	7015698.52
14	N	ROB with RE wall	140	13	-	528019238
15	O	1 HYSD Reinforcement & Structure Concrete M35	105	13	16	99584136
16	P	2 Reinforcement & Structure Concrete M40	100	15	17	95704291
17	Q	Pedestral and Bearing	25	16	18	18886192
18	R	Girder Launching	40	17	19	85556098
19	S	3 HYSD Reinforcement & Concrete M45	90	18	20	112563498
20	T	Expansion Joint & Wearing Coarse	50	19	21	17460410
21	U	Misc Activity for Structure	40	20	-	8955750
22	V	Crash Barriers	40	12	23, 27	92864710
23	W	Paver Block	40	22	24, 28	49826549.36
24	X	Turfing of Embankment Slope	70	23	25	983526.56
25	Y	Lane Marking & Traffic Signage	73	24	26	15036989
26	Z	KM. Stones/Road furniture	73	25	27	992914
27	Z1	Guide posts,Light and Utility poles	60	22, 26	28	30033183
28	Z2	Tree Plantation	60	23, 27	-	3385488

Table 1:- Details of the Construction Activity of Highway Project

III. METHODOLOGY

There are various techniques used for optimization of resources in construction projects. All techniques have their own advantage and drawback. The literature contains a wide range of techniques, tools and optimization techniques that support the decision-making process in the maintenance and construction of road networks. Out of these techniques, Genetic Algorithm is considered as optimization technique for the present case study. This technique is applied for multimodal function problems, with a frequent change in nature, the Genetic Algorithm are the best choice for optimization. This technique may be slow but strong in nature and confirm produce the possible best solution for optimization. When the best optimum solution is obtained the Program gets terminated. This solution is the final output. Otherwise next generation is

developed by doing the similar process of crossover and mutation. The best optimum solution is considered.

A. *Problem Formulation*

The case in view is an optimization problem whose objective is to minimize the cost and time of project by Genatic Algorithm (GA) for highway project.

$$\text{Minimize } Z = \sum_{i=1}^{n} \{ Y_1 - K * T_t + T_a(K + Y_2) \} \quad (1)$$

Subject to

$$K_p = (Tt - Ta) < 0; \quad (2)$$

$$K_i = (Tt - Ta) > 0; \quad (3)$$

Where,

Z = Project total cost
Y_1 = Actual direct cost of activity 'i'
Y_2 = Project daily indirect cost
T_t = Target duration
T_a = Project actual duration
K = Sharing ratio
Kp = Penalty ratio
Ki = Incentive ratio

The optimization goal is to minimize the objective function 'Z' by optimizing the values of its parameters. The duration of each activity is the time taken to finish the activity if the highway construction on site is running well according to schedule.

The acquired data from Rae Bareli Ring Road project of Phase I – Eastern side, Rae Bareli is used in this study and further worked in Primavera (P6) software, as this study focuses on the construction of the highway project. Each activity has been transformed into work breakdown structure (WBS). The details of each activity in terms of duration are required to analyze the risks of highway construction schedule. The duration for each activity is the time taken to complete the activity if the highway progress on site is running smoothly according to schedule. To determine the completion time of the project using PERT analysis, the three estimates of all activities must be considered. The expected duration and variance for each activity should be calculated. After the completion of the tool further calculation is done in MATLAB, using Genetic Algorithm and by this cost and time is identified.

B. *Genetic Algorithm for Optimization Problem*

In a GA, a population of candidate solutions to an optimization problem is resulting in the direction of superior solutions. Each candidate solution has a set of properties which can be mutated, in binary as 0 and 1 and other are also possible. The GA usually runs from a population of randomly generated individuals and is an iterative process in each iteration called a generation. In each generation, the fitness of every individual in the population is evaluated as the fitness of objective function in the optimization problem being solved. The more fit individuals are selected from the current population, and each individual's is modified (recombined and possibly randomly mutated) to form a new generation. The new generation of candidate solutions is then used in the next iteration of the GA. Essential steps of GA as shown in *Figure 1.*

C. *Steps of Genetic Algorithm (GA) Optimization Tool in MATLAB Software*

Firstly, we will choose optimization tool in which GA solver is opened then generate a MATLAB code for input as objective function and constraints as shown in Equation (1) , Equation (2) and Equation (3). Then, Fitness function, number of variables, lower and upper bounds are chosen. After that following options are selected.

- Solver: Genetic Algorithm (GA) tool
- Fitness Function:
- Number of Variables: 3
- Bounds: upper and lower bounds
- Population type: double vector
- Population Size: 200
- Creation Function: feasible population
- Fitness Scaling: scaling function-proportional
- Selection: selection function- stochastic uniform
- Reproduction: crossoverfraction-0.60
- Mutation: Mutation function- Adaptive feasible
- Crossover: Crossoverfunction-Intermediate-0.70
- Migration-Direction-forward-0.45
- Constraint Parameters: Nonlinear constraint algorithm-Augmented Lagrangian
- Stopping Criteria- Generation: 200 and Stall Generations: 200
- Plot function-

  - Best Fitness
  - Distance
  - Range

- Display to command window-iterative
- User Function evaluation: in serial.

After entering all these values optimization starts and we get the result for the minimization of objective function. Lastly GA solver generate final results as Generation Vs Fitness value, Generation Vs Average distance b/w individuals and Generation Vs Best, worst and mean scores.

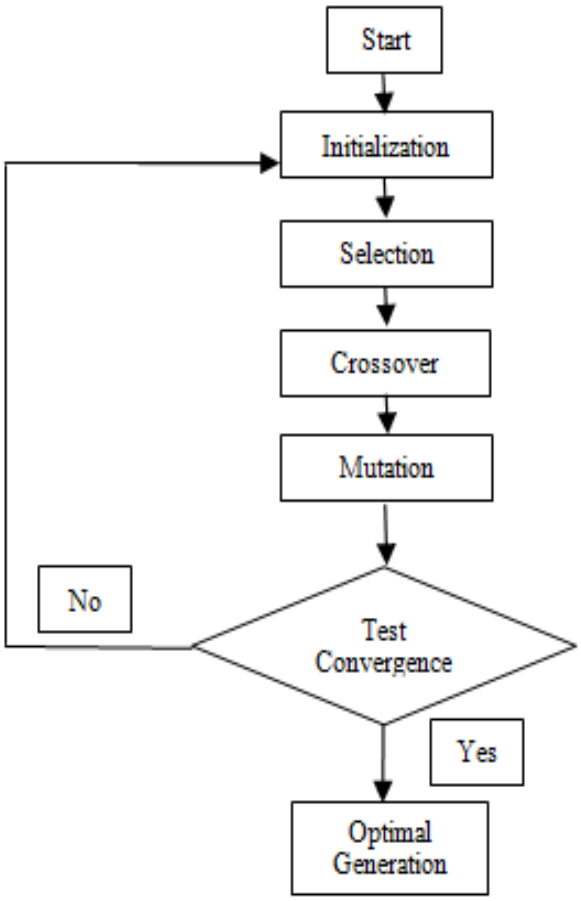

Fig 1:- General Flowchart of Genetic Algorithm (GA)

IV. RESULTS AND DISCUSSION

This paper only concentrates on the cost time optimization hereby the project must be finished within the target duration. The parameters set for this study are as follows:

➢ *Solution:-1*

- Target duration: T_t = 630 days
- Actual duration: T_a =550 to 630 days
- Daily Indirect cost: Y_2= 336356/day
- Incentive cost: [(T_t - T_a) > 0]:K_i = 893922/day

➢ *Solution: -2*

- Project target (deadline) duration: Tt = 630 days
- Project actual duration: Ta =600 to 630 days
- Daily Indirect cost: Y_2= 336356/day
- Incentive cost: [(T_t - T_a) >0]:K_i = 893922/day,

➢ *Solution: -3*

- Project target (deadline) duration: T_t = 630 days
- Project actual duration: T_a =630 to 700 days
- Daily Indirect cost: Y_2= 336356/day
- Penalty cost: [(T_t - T_a) < 0]:K_p = 1117403/day

➢ *Solution:-4*

- Project target (deadline) duration: Tt = 630 days
- Project actual duration: Ta =640 to 740 days
- Daily Indirect cost: Y_2= 336356/day
- Penalty cost :[(Tt - T_a) < 0]:K_p = 1117403/day

➢ *Solution: -5*

- Project target (deadline) duration: Tt = 630 days
- Project actual duration: Ta =800 to 840 days
- Daily Indirect cost: Y_2= 336356/day
- Penalty cost: [(T_t - T_a) < 0]:K_p = 1117403/day

For Solution-1 to Solution-5; Y_1= Direct cost of activity 'i'as shown in *Table-1*.

S.No.	Description	No. of Solutions				
		Solution-1	***Solution-2***	***Solution-3***	***Solution-4***	***Solution-5***
1	Population size	200	200	200	200	200
2	No. of generation	200	200	200	200	200
3	Selection factor	0.60	0.70	0.85	0.90	0.90
4	Crossover factor	0.70	0.80	0.75	0.70	0.70
5	Mutation factor	0.45	0.50	0.30	0.55	0.65
6	Total target duration (Tt) days	630	630	630	630	630
7	Total actual duration (Ta) days	550-630	600-630	630-700	640-740	800-840
8	Total project cost (Z) in Crores	246.348	252.5.	256.19.	257.72	302.90

Table 2:- Result S Based on Genetic Algorithm

The present study shows five solutions with different inputs and outputs as shown in *Table-2*. For the first solution when selection, crossover and mutation factor is 0.60, 0.70, 0.45 respectively and no. of generations=200, if project is completed within target duration T_t=630 days i.e. (range of actual duration of project as T_a=550-630 days), we get the incentive and project cost becomes as 246.348 Crores from the performance of GA solver as shown in *Figure-2*. While for the second solution when we increase the value of selection, crossover and mutation factor as 0.70, 0.80 and 0.50 respectively with same population size and no. of generation we get the project cost 252.50 Crores i.e.(range of T_a = 600-630 days closer to T_t=630 days) from the performance of GA solver as shown in *Figure-3*. Afterwards for the solution-3, solution-4 and solution-5 when we increase the value of selection, crossover and

mutation factor respectively with same population size and no. of generation, we get penalty cost because T_a exceeds then T_t and project cost increases as 256.19, 257.72 and 302.90 Crores as shown in *Figure-4, Figure-5 and Figure-6* respectively.

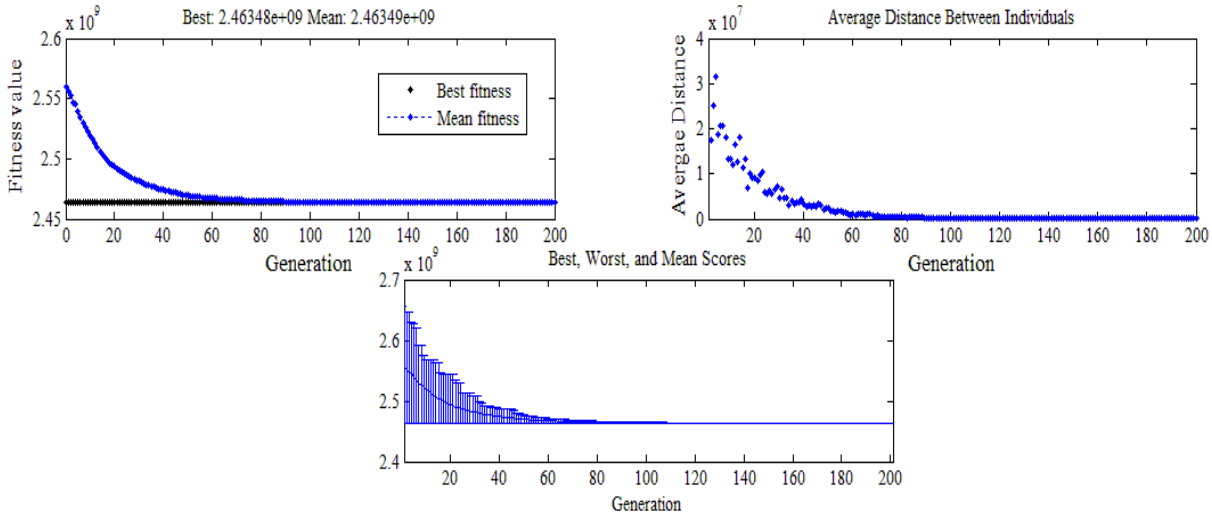

Fig 2:- GA Tool Generated Result for Solution-1

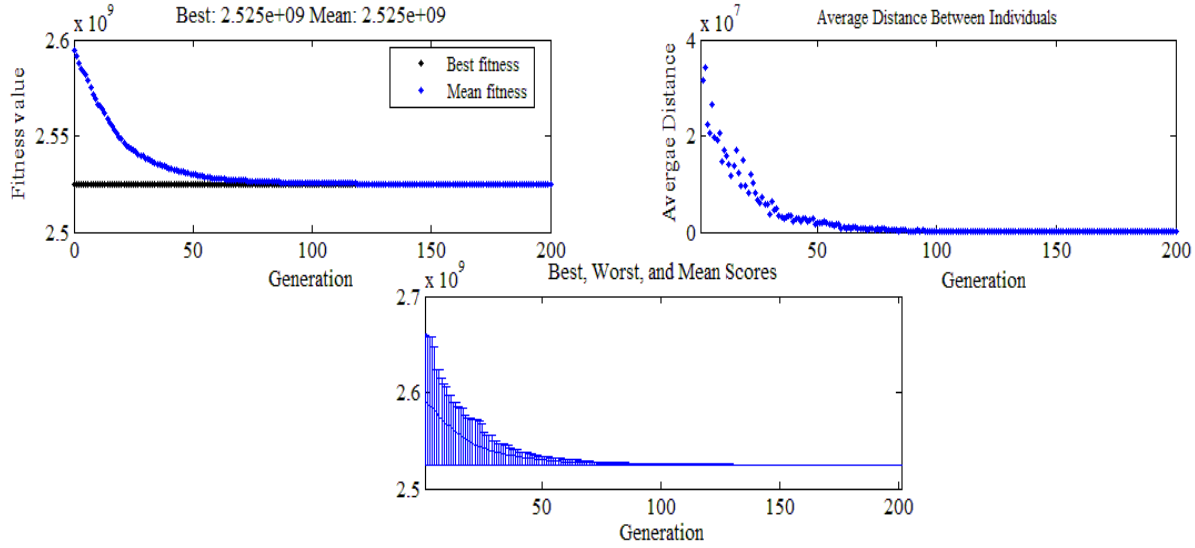

Fig 3:- GA Tool Generated Result for Solution-2

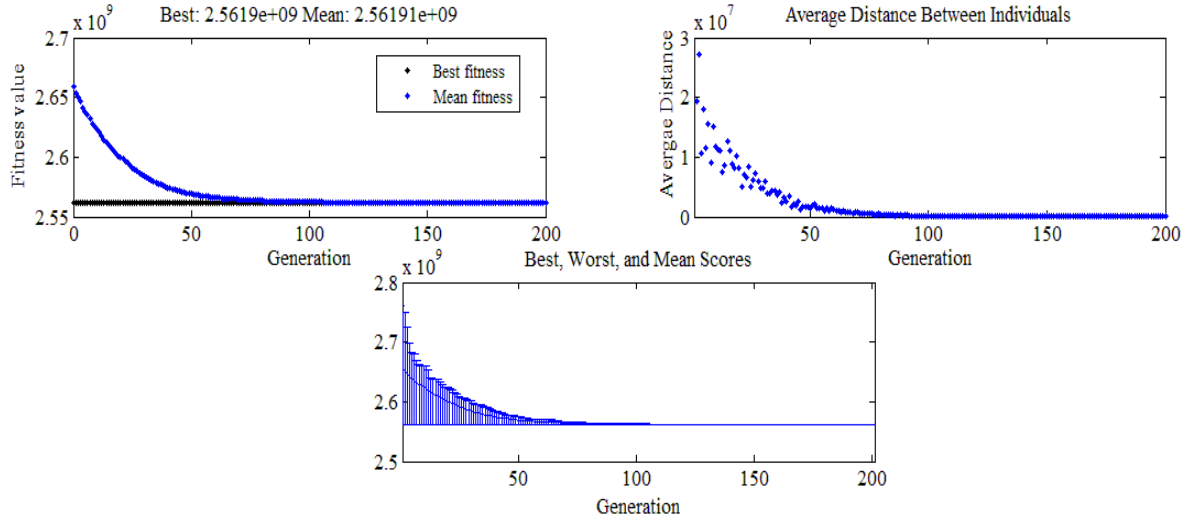

Fig 4 GA Tool Generated Result for Solution-3

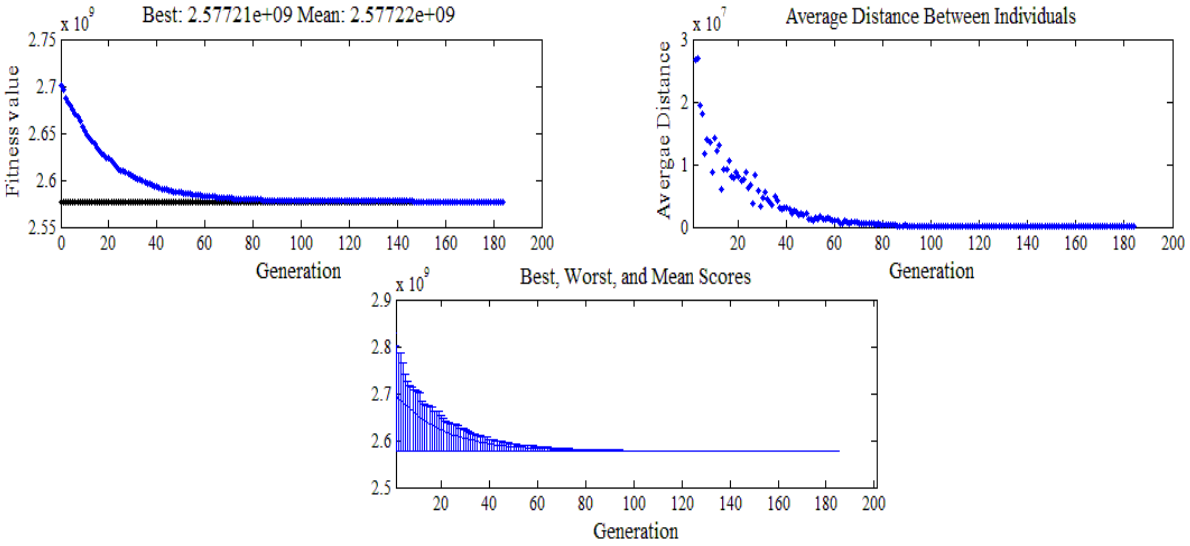

Fig 5:- GA Tool Generated Result for Solution-4

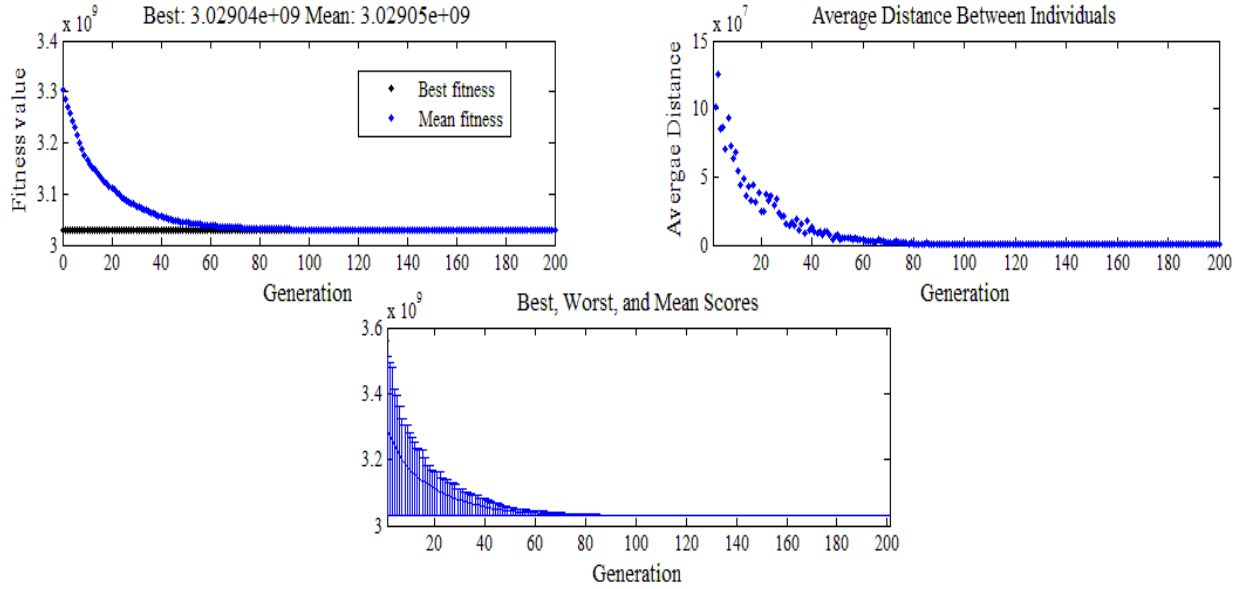

Fig 6:- GA Tool Generated Result for Solution-5

V. CONCLUSIONS

The present case study shows that GA can be applied in establishing an optimal cost-time balance for highway projects. By considering incentive and penalty costs into the consideration, the cost-time relationship would become more dependent and complex on data. However, GAs show better results in solving this type of problem in small and huge construction projects.

From the present study following conclusions are made.

- Genetic Algorithm (GA) guarantied the global searching from a population of solutions.
- Performance of Genetic Algorithm (GA) optimization tool well with a given set of GA parameters.
- The minimization of objective function for different solution with respect to GA parameters is achieved successfully and avoids complex formulation of mathematical models.
- From present study stopping criteria of GA optimization solver is achieved successfully.
- With the help of GA optimization solver, we get the best, worst and mean scores of generations.
- From the present study it is cleared that if the project is completed within a target duration we get the incentive cost but if it is not completed or actual duration of project is more than the target duration, project cost increases due to penalty cost.
- GAs show faster and efficient results in achieving time cost optimization with given population and generation.

More research efforts appear wanted to validate this initial finding and ensure continuous improvement in the field of construction industry.

ACKNOWLEDGMENT

The authors would like to express sincere thanks to Mr. Krishna Kumar Tripathi (Quantity Surveyor), for their valuable support in present study. The authors are also thankful to Friscmann prabhu pvt. ltd (Authority Engineer).

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