AN ANALYTICAL STUDY ON HIGHWAY CONSTRUCTION PROJECTS IN INDIA FOR PROBABILITY FORMULATION DISTRIBUTION FUNCTIONS FOR DURATION AND COST

[1]Md. Ashfaque Alam, [2]Minakshi

[1]M.Tech. Scholar, [2]Assistant Professor
Civil Engineering Department
Transportation Engineering
CBS Group of Institutions

***Abstract*: The goal of the study was to create a simple tool for project managers to use in order to predict project duration, cost, and delay overruns in a straightforward manner. The project managers may use this decision support tool to assess the level of risk associated with the various site features that are present on the project's construction site. Only highway construction projects were investigated since the likelihood of mistake is greater and project management is critical to avoiding cost overruns and delays. The simulation models that have been developed to represent project duration, cost, and delay analysis are in turn controlled by the software tool that has been developed. In order to include the real-world characteristics and on-site conditions that will be important to the project, simulation models are developed. From the statistical analysis of activity cost data, it can be concluded that Exponential distribution function represents the probabilistic nature of the activity durations more accurately than any other distribution. Except for the activity 'site clearing' and 'laying of road base' all other nine activities followed Exponential distribution function. The activity 'site clearing' followed Triangular distribution and 'laying of road base' layer followed Beta distribution function.**

***Keywords*: Highway Construction, Formulation Distribution, Distribution Functions**

I. INTRODUCTION

In India, roads have been in use for over 5000 years. Roads were built by Ashoka and Chandragupta in the early phases of Indian history. "However, it was during the Mughal era that substantial development was realized.'' During the Sultanate and Mughal eras, a number of roads were built. The Mughal routes are followed by the majority of today's trunk lines. These roads were critical to the empire's strength and consolidation.

With a total length of 5.89 million kilometers, India boasts the world's second-largest road network (kms). This road network moves 64.5 percent of all commodities in India, while 90 percent of all passenger traffic in India travels by road. With improved connection between cities, towns, and villages around the nation, road traffic has progressively risen over time.

The sale of autos and the transit of freight by road in India is rapidly increasing. The Union Minister of State for Road, Transport, and Shipping indicated that the government seeks to increase corporate investment in the roads and shipping sectors, as well as implement business-friendly measures that balance profitability with project completion. Between April 2000 and December 2020, the construction development industry received US$ 25.93 billion in FDI inflow, according to statistics supplied by the Department for Promotion of Industry and Internal Trade Policy (DPIIT).

ROAD TRANSPORT SYSTEM IN INDIA SCENARIO

In India, the road transportation system provides a vital service to the general public in a variety of ways. In India, there are two types of road transport: traditional and mechanized. Bullock carts, thelas, rickshaws, and other non-mechanized modes of transportation are examples of traditional transportation. This ancient means of transportation carries over 25% of India's commerce and directly employs almost 2 crores of people. Furthermore, mechanised road transport encompasses all transportation services provided by motor vehicles, the number of which is rapidly expanding. From 0.3 million in 1950-51 to 89.61 million in 2005-2006, the total number of cars on the road has expanded dramatically. During the same time period, the total number of buses climbed from 34,000 to 9,92,000, while the total number of trucks climbed from 82,000 to 44,36,000. As a result, the yearly growth rate of this mode of transportation was 5.4 percent. There are now 66 State Road Transport Undertakings with a combined fleet of about 1.2 lakh buses, conveying 6.8 crore people daily as of March 1993. A Transport Development Council and an Inter-State Transport Commission were also formed to develop inter-state links. For a smooth flow of inter-State routes, a national permit system was also implemented.

CONSTRUCTION SECTOR IN INDIA

In India, construction industry is poorly organized consisting of unorganized players that work on subcontract basis. Due to the nature of the industry, it requires intensive capital, intense labor, and is risky, companies are trying to mechanize from few years onwards. As a result of mechanization, requirement of labors in FY 2004 decreases by 0.7% after four years. The industry plays vital role in economy, industrialization, urbanization of the country. It consists of 40%-50% of the country's capital expenditure to various projects like highways, roads, railways, airports, energy, irrigation, etc. and it is the second largest industry next to agriculture 11% of total GDP. In construction industry cost overruns are usual. In India, hardly few projects are completed on their original estimated costs. According to reports of the Statistics Minister on 31stMarch, 2012, out of 555 ongoing projects 179 of them had cost overruns by Rs.1.23 lakh crore. Their major causes were cost underestimation, change in foreign exchange rates and statutory duties, escalation in cost of land, high cost of environmental safeguards and rehabilitation measures, inflation and delay in projects. According to the reports, details of the cost overrun projects of railways was the first by Rs 69,551.81 crores, second by Rs 15,886.71 crores petroleum and third Rs 15,113.80 crores power sectors. The cost of projects escalated by Rs 6,187.54 crores, Rs 5,272.90 crores, 4,838 crores in steel, urban developments and atomic energy sectors respectively.

HIGHWAY CONSTRUCTION IN INDIA

Between FY16 and FY19, India's highway development rose at a 21.44 percent compound annual growth rate (CAGR). In FY19, 10,855 kilometers of highways were built, with the government aiming to build 12,000 kilometers of national roads in FY20. The foundation stone for nine National Highway projects in Tripura, totaling 262 kilometers and costing over Rs. 2752 crore (US$ 371.13 million), was laid in October 2020.

The National Investment and Infrastructure Fund (NIIF) is working to integrate its road and highway portfolio by October 2020. Essel Devanahalli Tollway and Essel Dichpally Tollway were purchased by the NIIF master fund. These road infrastructure projects will be backed by Athaang Infrastructure, NIIF's own road network, as well as a team of experienced individuals with a wide range of subject skills in the transportation area. For FY 2019-25, the Indian government has set out Rs. 111 lakh crores (US$ 1.4 trillion) for the National Infrastructure Pipeline. Over the next five years, the roads sector is expected to account for 18 percent of capital spending.

The National Highway Authority of India (NHAI) would be able to raise Rs. 1 lakh crore (US$ 14.30 billion) each year from tolls and other sources in the next five years. The government is working on strategies to encourage considerable investment interest via a number of initiatives. By 2022, 200,000 kilo-meters of national roads are projected to be finished.

The NHAI has gone 'Fully Digital', with the development of a unique cloud-based and Artificial Intelligence-powered Big Data Analytics platform – Data Lake and Project Management Software, as one of the most significant changes. NHAI's full project management work flow has been converted from manual to online portal-based, with all project execution procedures, such as workflow with time lines and alert mechanism, setup. The site is currently the exclusive source of project documents, contractual decisions, and approvals. The National Motorways Authority of India (NHAI) has taken up asset recycling for 100 highways using the toll-operate-transfer (ToT) model. The first two bundles of nine roads were each successfully monetized for a total investment of nearly $2 billion.

II. DATA COLLECTION

Construction industry can be broadly classified based on the type of project as building projects, highway projects, etc. Each type of project has its own characteristics and these govern the cost and duration of the project. Duration and cost of a project are dependent on various project parameters which are unique to the type of project. Even if there are similar tasks in different types of projects, cost and duration are likely to vary widely due to inherent characteristics of the activity involved in each type. For example, even though site clearing is one of the predominant activities common for both highway construction project as well as building construction project, it is evident that cost of site clearing in highway project will be different from that in building project because the particular activity is linear in highway project and discrete in building project.

In this investigation highway construction projects mainly National Highways and Expressways, were studied and data were collected from one hundred and forty different construction sites distributed all over India. These sites represented a broad spectrum of varied features like geographic, geological, political, social etc. that are likely to influence the project duration and cost. The data collected were both quantitative and qualitative.

QUANTITATIVE DATA

Quantitative data consisted of duration and cost of the individual activities and also the duration and cost of the project. The data related to ongoing as well as completed projects were collected from various private firms, governmental organisation and project management consultancy firms, which adopted fully mechanized technology as per the norms laid down by the Government of India. Terminology of the activities used by various project planners varied from each other. Hence, it became essential to characterize the activities through a common terminology. After this exercise, the various main activities involved in highway construction were identified as site clearing, preparation of sub grade, capping layer, sub base course, road base course, base course, wearing course, foundation for cross drainage, substructure for cross drainage, super structure for cross drainage and drainage works

Preparation of Subgrade

Earthwork excavation and filling is carried out to level the ground for subgrade. The excavation is mainly carried out using construction equipment like Power shovel, Pock lines, Bulldozers and Scrappers. Dumping of earth at required places for filling up the depressions in the alignment is carried out using rear dump trucks of capacities 15 tonnes and more. All the operations are carried out under the supervision of expert survey team according to the specifications laid in the standards released by Ministry of Surface Transport (MOST).

The compaction of levelled earth is carried out in order to provide strong foundation for the pavement. Grading operations are carried out to provide a proper vertical profile to subgrade as per the designed grade and camber. This operation is carried out in several layers using sophisticated equipment like sheep foot rollers, pneumatic tyred rollers, smooth wheeler vibratory rollers, etc depending upon the characteristics of the soil. Compacting operation is earned out at optimum moisture content and addition of water required is carried out by spraying water over subgrade using calibrated water tankers.

Site Clearing

The site clearing activity involves the removal of vegetation as well as obstructions in the alignment of the highway such as built-up structures, trees, etc. After removal of obstacles, centre line of the highway is marked precisely on the ground. After fixing the alignment, boundaries of the right of way and carriage way which include the offset and elevation are fixed.

Subbase Course

The constituent of subbase course is a combination of crushed aggregates and we 11-graded sand with four to ten percent passing through 75 microns IS sieve Mixture with required grading is spread using full-length paver finisher and compacted using 8 tonne to 10 tonne smooth wheeled vibratory roller to a finished thickness of two hundred millimetres. Thickness of this course is checked at regular intervals along the centerline as well as along the edges of the carriageway. The field dry density of this layer is checked using nuclear density gauge.

Capping Layer

This is a non-bituminous layer provided as foundation for the highway for which constituents are natural gravel, crushed aggregates and sand with particle size less than three percent passing through seventy-five micron IS sieve. The combination of constituents depends on the grading required for the pavement. This mix is prepared at optimum moisture content and paved using hydraulic motor grader. Compaction is carried out by 8 tonnes to 10 tonne smooth wheeled vibratory roller to obtain a thickness of five hundred millimeters.

Base Course

Base Course (BC) is provided as a layer of dense bituminous course over a thin primer coat on the dry road base course. Primer coat is applied by pressure-spraying medium cured bitumen at forty to sixty degrees Celsius over the road base course Before the application of Dense Bituminous Macadam (DBM) layer, the surface treated with primer coat is sprinkled with water and cleaned with wire brooms to remove the dust particles from the surface. The coarse aggregates of required gradation for the dense bituminous macadam are heated at 150°C to 163°C in preheater plant and then mixed with paving bitumen of grade 60/70 in the hot mix plant. This mixture is discharged to the truck for transporting to the site at a temperature of 130°C to 160°C. This is laid on primed surface at a temperature ranging from 120°C to 135°C. The initial and final compaction is carried out using smooth wheeled vibratory roller and switching off the vibratory mechanism at temperature of 100°C.

Road Base Course

Road base course is mainly provided by one layer of Wet Mix Macadam (WMM). The aggregates of required grading are mixed with water at optimum moisture content with allowance to loss of water content due to evaporation during transportation, spreading and compaction. In aggregate mixing plant. Pug mill or Power Mixer of suitable capacity having provision for controlled addition of water is used. The spreading operation is carried out using paver finisher or hydraulic motor grader. The thickness is regulated such that the finished thickness is not less than three hundred millimetres. The alignment of centreline, width of the carriageway and longitudinal profile are checked at regular intervals.

Cross Drainage Works

The Cross Drainage works (CD) include the construction of box culverts, pipe culverts, underpasses, cattle passes and bridges. In the case of box culverts, pipe culverts and underpasses the cost and time involved in construction are less when compared to the construction of bridges across rivers that cross the alignment. In this study, box culverts, under passes and cattle passes are considered as minor cross drainage works. The duration and cost of these works are taken into account in the activity 'substructure for cross drainage works. However, in the case of bridges, the foundation, substructure and super structure are considered as separate entities and the data obtained for bridges are divided into foundation, substructure and super structure for cross drainage. The foundation for cross drainage includes the piling work and construction of pile caps for the erection of piers. The substructure for cross drainage comprises of the construction of piers, construction of pier caps, and fixing the bearings for the girder. The super structure for cross drainage includes the construction and launching of pre-stressed girder, construction of deck slab, construction of barricades or side walls and pavement finishing.

Drainage and Miscellaneous Works

Drainage works include the construction of horizontal drains along the sides of the highway for easy passage of storm water and sewage water wherever necessary. The tasks involved are levelling and marking of the drainage line, excavation, laying of Plain Cement Concrete (PCC) along the excavation, construction of side retaining walls in random rubble masonry or in Reinforced Cement Concrete (RCC). The miscellaneous works include the construction of barricades, informative and cautionary signboards, construction of kerb walls, planting of trees, etc.

Wearing Course

Wearing Course (WC) is provided by a layer of bituminous concrete. The aggregates used are the same as those of dense bituminous macadam but tested for stone polishing value as per BS 812 Part 3. The mixture prepared is tested for water absorption test and the maximum water absorption value is limited to one and a half percent by weight. The coarse aggregate is preheated along with the fine aggregates to a temperature 155°C to 163°C. This mixture is mixed with bitumen at the hot mix plant at a temperature of 150°C to 163°C with a maximum temperature difference of 140C. This mixture is discharged from the mixing plant to the dump truck at temperature 130°C to 160°C and is laid using the grader paver at 120°C to 160°C. This mixture is rolled using smooth wheeled steel roller at a temperature of 80°C. Cost and duration for each activity obtained is normalised for unit kilometre length so that comparison amongst various projects in the country becomes rational. Data pertaining to the same project at different instants of time show that due to certain site conditions and uncertainties, actual activity duration is found to differ from the planned duration. This leads to delay and the associated cost overrun of the project.

III. ANALYSIS AND INTERPRETATIONS

The data collected from various highway construction projects were analyzed to determine the stochastic nature of the collected data. All data pertaining to activity duration, cost, duration overrun and cost overrun were found to vary widely with time, nature of the project, location of the site, characteristic features of the site viz, the type of soil, water table, availability of materials, etc. The wide variations in data necessitated the characterization of probability distribution function for each activity parameter like duration, cost and their overruns. The data analysis was carried out separately for quantitative data as well as qualitative data.

QUANTITATIVE DATA ANALYSIS

The quantitative data collected were in the form of planning sheets, project cost estimation sheet and site update reports. The activities in the planning sheet were characterized to standard activities for uniformity as given in Section 3.2 of Chapter 3. Activity duration and cost of each activity and the length of the highway constructed with this duration and cost were obtained from the planning sheet and the cost estimation report respectively. The quantitative analysis was carried out in two stages

- Activity cost analysis
- Activity duration analysis

Activity Duration Analysis

The probability model developed for activity durations of highway projects are based on the actual duration of the activities on the project site. From the data collected eleven major activities associated with highway construction has already been mentioned in Section 3.2 were identified for detailed study. Duration of these activities in a project varies with length of the highway to be constructed during a certain period. This was based on the assumption that site factors which affect the activity duration in one stretch would influence the activity throughout the length of the project. The adequacy of size of the data collected is tested using T test {Beeston (1983)} for which the test statistic is given by equation 4.1.

$$n = \left(\frac{1.25\ T\sigma}{0.3\ M}\right)^2$$

Were
n is the sample size
M is the median of the sample
o is the standard deviation of the sample.
T value for 90% confidence limit and corresponding degree of freedom
The sample size required at 90 percent confidence level has been determined. It was found from the analysis that the size of the data obtained for each activity at this confidence level is far higher than the required sample size at 90% level of confidence. The minimum sample size required and the sizes of the data collected for each activity are given in Table 1.

Table 1: Sample size required and available for activity duration

Activity	Available sample size	Sample size required
Drainage	90	4
CD Super structure	74	3
CD Substructure	74	4
CD Foundation	74	4
Wearing Course	94	40
Base Course	94	12
Road Base	94	12
Sub base	80	12
Capping Layer	74	4
Sub grade	94	4
Clearing	94	8

The data collected were analysed for fitting probability distribution function using Best Fit software developed by Palisade Inc. This software fits the data for each activity with sixteen standard probability distribution functions and tests for Goodness of Fit (GOF) using Kolmogrov-Smimov (KS), Anderson Darling (AD), Chi-square (y2) criteria as given by the Equations 4.2, 4.4 and 4.6 respectively. The software also fits the probability distribution function and arrives at the parameters for the distribution obtained by Moment Matching Method.

$$\boldsymbol{D_n = sup[|F_n(x) - F(x)|]}$$

Where,
$\boldsymbol{D_n}$ is the K.S test statistic
sup of a set of numbers is the smallest value that is greater than or equal to all the elements in the set
n is the total number of data points.
$\boldsymbol{F_n(x)}$ is fitted cumulative distribution function.

$$\boldsymbol{F(x) = \frac{N}{n}}$$

$\boldsymbol{N_x}$ x is number of X_j s less than x.

$$A_n^2 = n \int_{-f}^{+f} [F_n(x) - F(X)]^2 \psi(x) \hat{f}(x) dx$$

Where,
A_n^2 is defined as the AD test statistic

$$\psi(x) = \frac{1}{F(x)[1 - F(x)]}$$

n is total number of data points,
$\hat{f}(x)$ is hypothesised density function,
F(x) is hypothesised cumulative distribution function

$$F(x) = \frac{N}{n}$$

N_x is number of X, s less than x.

$$\chi^2 = \sum_{-f}^{k} \frac{(O - E_i)^2}{E_i}$$

Where
χ^2 is the Chi square test statistic
i is the number of bins,
O_i is the observed number of samples in the bin
E_i is the expected number of samples in the bin
Sixteen standard distribution functions were then formulated for each of the activities under each GOF criteria and were ranked based on the Root Mean Square Error (RMSE) between the probability obtained from the fitted distribution function and the actual probability value, which were calculated using the following formula

$$RMSE = \sqrt{\frac{1}{n}[\Sigma f(x_j) - y_i]^2}$$

Where
$f(x_i)$is the probability of x, from the probability function
y_i is the probability of x, from the observed data
n is the number of x_j
All the major activities involved in highway construction project were analyzed using BestFit by varying the sample size. The sample size was varied randomly from thirty to the maximum available with increments of ten samples taken uniformly throughout the population. The study was carried out for AD test and KS test and the variation in the probability distribution function was analyzed. From this analysis it was found that samples showed variation in distribution function when the sample size was less than forty in KS test and all the activities except one followed log-log distribution when the sample size was more than fifty. When the same activities were analyzed using AD criteria, five activities converged to Log logistic distribution while two converged to Inverse Gauss, two converged to Exponential and one followed Extreme value distribution, χ2 test was not taken into account due to the inherent disadvantage of the test that the distribution function is likely to vary with the size and number of class intervals used in the analysis.

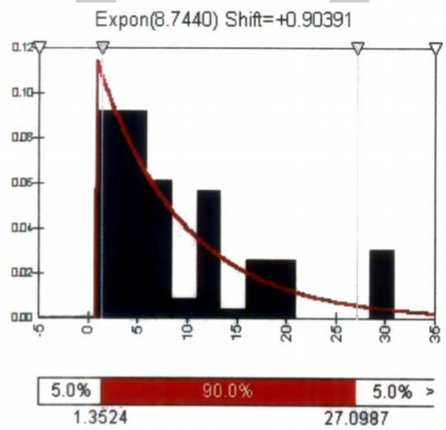

Figure 1: Probability Distribution for Duration of Activity –Clearing

IV. CONCLUSION

The following conclusions that are drawn from this study.

- The durations of the above activities, as analyzed from on-site data, are observed to be highly random in nature. India is a vast country with large variations in geographical, linguistic, political and social features. The highways run through various states with vastly dissimilar conditions. All these conditions have predominant effect on the progress of the project, unlike in many developed countries. The acute randomness observed in the activity completion times as reflected by the data collected could be attributed to the above factors.

- The various activities involved in highway construction can be grouped into eleven major heads.
- The overruns in duration and cost of the activities as well as the projects showed wide variation indicating the need for detailed probabilistic analysis. These overruns are influenced by the nature of the delays. The delays can be classified as controllable and uncontrollable.
- Similar conclusions can be drawn with respect to the activity list as well as total project cost.
- From the statistical analysis of activity data, duration data, it can be concluded that Loglogistic distribution function represents the probabilistic nature of the activity durations more accurately than any other distribution. Except for the activity ‘site clearing’ and ‘laying of capping layer’ all other nine activities followed Loglogistic distribution function. The activity ‘site clearing’ followed Exponential distribution and ‘laying of capping layer’ followed lognormal distribution function. This conclusion is contrary to what much of the literature reported. It has become traditional to accept Beta distribution to represent activity durations. The above contradiction can be attributed to the extreme diversity of factors, existing in developing countries like India, that influence the progress of the activities.

V. FUTURE SCOPE

The whole study can be extended to other sectors of construction like building construction, construction of offshore structures, laying of pipelines, etc. Even though the parameters that influence the project may differ with the type of project, similar study will provide a more realistic tool to predict the cost and duration of the project. In the current investigation the effect of interaction of the delays on the project estimates is not considered. Studies can be carried out by taking into account the interaction between the various delays that may influence the project. The Decision Support Tool can be remodeled so as to focus at the activity level in addition to the project completion level as it is designed now.

REFERENCES

[1] Abbas, M. I. (2006) Causes and effect of delays in the Achele construction industry.

[2] Abdullah Alhomidan. (2013). Factors Affecting Cost Overrun in Road Construction Projects in Saudi Arabia. Journal of Management in Engineering J. Manage. Eng.,32(1), 04015032.

[3] Acebes F, Pajares J, Gala´n J M and Lo´pez-Paredes A 2014 A new approach for project control under uncertainty. Going back to the basics. Int. J. Proj. Manag. 32: 423–434

[4] Ahuja H N and Nandakumar V 1985 Simulation model to forecast project completion time. J. Construct. Eng. Manag. 111(4): 325–342

[5] Alhomidan, A. (2013). Factors Affecting Cost Overrun in Road Construction Projects in Saudi Arabia. International Journal of Civil & Environmental Engineering, 13 (3): 1-4.

[6] Ansah, R.; Sorooshian, S. Effect of lean tools to control external environment risks of construction projects. Sustain. Cities Soc. 2017, 32, 48–356.

[7] Ashem Emmanuel Egila, Oluwaseun Abdulakeem Balogun and Saheed Olanrewaji Yusuf (2020) Assessment of Delay and Cost-Overrun in Federal Road Construction Project in Abuja INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P). v. 11, n. 4. ISSN: 2236-269X DOI: 10.14807/ijmp.v11i4.1065

[8] Baker S, Ponniah D and Smith S 1999 Risk response techniques employed currently for major projects. Construct. Manag. Econ. 17: 205–213

[9] Ben-David I and Raz T 2001 An integrated approach for risk response development in project planning. J. Oper. Res. Soc. 52: 14–25

[10] Braimah, N. (2008) An investigation into the use of construction delay and disruption analysis methodologies. Ph.D. Thesis, University of Wolverhampton.

[11] Chang C W 2014 Develop a ranking algorithm for the green building project. Qual. Quant. 48: 911–921

[12] Chong, W.K., Lee, S.H. and O’Connor, J.T. (2011). Estimating highway construction production rates during design: Elements of a useful estimation tool. Leader ship and Management in Engineering, 11: 258-266.

[13] Cooper D F 2005 Project risk management guidelines: managing risk in large projects and complex procurements. London: Wiley.

[14] David Arditi, Shruti Nayak and Atilla Damci (2017) Effect of organizational culture on delay in construction International Journal of Project Management 35(2):136-147. DOI:10.1016/j.ijproman.2016.10.018

[15] Dawood N 1998 Estimating project and activity duration: a risk management approach using network analysis. Construvt. Manag. Econ. 16: 41–48