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A Review of Structural Decision Models for Highway Construction Projects Management

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ABSTRACT

The construction project management process begins with identification of the user requirement, project constraints, resource needs, and establishment of realistic objectives to meet the strategic goals. The vital role played by Indian National Highways on India's economy and security. Thus the Indian government designed different programmes for the development of National Highways that run throughout the length and breadth of the country. Construction of National Highways in India poses a major challenge as they have to traverse through varied geographic conditions with wide variety of geological, climatic and sociological complexities. These complexities necessitate need for proper management of men, material and machineries for the construction. Such complexities can be addressed by proper scheduling of construction projects. It is noticed that project schedules prepared by conventional techniques are not accurate and require lot of updating and rescheduling. In this research work we attempt to present effective solution for the highway construction management based on novel structural decision model in order optimize cost efficiency, safety, and durability parameters. In this paper we have presented the study on highway construction projects management using design of structural decision model. It focusses the importance of traffic construction project management and the review of existing models for construction management.

KEYWORDS: *Construction, Project Management, Risk Assesment, Highway Construction and Structural Decision Models.*

1. INTRODUCTION

A country's economy is mainly governed by the industrial and infrastructure development The development of highways is one of the main contributing factors for infrastructure development, since highways act as the arteries of national development. Distribution plays an important role in production-distribution-consumption chain of goods. Increased productivity alone cannot guarantee increased per capita consumption unless effective distribution is available. Efficient transportation is the key for effective distribution and roads and highways are the arteries of distribution [1].

Out of the various existing modes of transport, road transport is the only mode which could provide maximum service to all and it is the only mode which offers maximum flexibility to the users. A well-planned road network not only provides a feeder system for other modes of transport, but also provides an independent facility for travel throughout the country. The inherent characteristics of roads that facilitate efficient transportation are their accessibility to various types of vehicles, their lower cost of maintenance compared to other modes of transport and the ease of networking [2].

Highway construction is one of the most complex and complicated projects amongst construction projects because of its necessity for proper coordination of men, material and machinery. The complexity is attributed due to the uncertainties in the terrain, weather, and labour factors, etc. These uncertainties cannot be predicted accurately in all the situations due to high degree of anomalies in the geographical, geological and human factors.

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The project scheduling for any highway construction project is normally carried out using Critical Path Method (C.P.M.) or Project Evaluation And Review Technique (P.E.R.T.) with the aid of sophisticated software like MS
Project, Primavera Project Planner, etc [3]. This commercial software adopt the Precedence Diagram Method as the back end process to represent the various relationships between the activities for time scheduling. This facilitates easy computation using the computer for time scheduling as well as resource scheduling. However, the time schedule output of all commercial software normally provided in the form of bar charts, as it is easy for the user to interpret and understand.

During continuous monitoring of highway construction project, it has been observed that duration for each activity varies with project characteristics, and hence the activity duration can be represented easily and accurately using probability distribution functions. The distribution function selected to represent the activity duration should precisely represent the variation in scenarios of construction industry. For a more reliable formulation of statistical model, various site parameters and the influence on activities that are likely to happen in site have to be studied [4]. The P.E.R.T. model assumes Beta distribution function for the activity durations. However, high level of uncertainties associated with the construction activities in India and other developing countries requires verification of suitability of Beta distribution model. This is essentially requires to categorisation and verification whether the activity duration in actuality follow Beta distribution in all projects. In fact various researches have expressed the need for more flexible distribution function for representing the activity duration than Beta distribution.

The cost associated with an activity is another main concern in scheduling any project. The cost associated with the activities in a project are mainly dependent on various parameters like the climate, labour availability, use of machinery, social conditions, etc. Hence, the cost of the activities associated with the construction project is not deterministic in nature. The cost of the activities is mainly depends on the activity duration. Statistical analysis of cost and their relation to duration is not adequately researched into in Indian context [5].

Any developing country should aim for providing required infrastructure for public use together with meeting other necessary developments in agriculture and industrial sectors [6]. To name some of the infrastructure facilities to be provided by the government for public use are facilities such as (i) highways connecting important cities, towns and villages that may include express highway, national highway, state highway and rural roads, (ii) bridges and flyovers, (iii) recreational and zoological parks, (iv) water storing and channeling facilities such as dams, reservoirs, irrigational canals etc. It is diverted at this point to looking into the requirement of sustainable development in order to preserve nature for our future generations. According to the United Nations (UN) facts and Figures, it is estimated that by 2030, nearly 60 per cent of world's population will live in urban cities. It is reported that the cities in the world occupy only 3 per cent of the Earth's land, nevertheless it accounts for 60-80 per cent of energy consumption and 75 per cent of carbon emissions (URL-1). Increase in urbanization exerts pressure on fresh water supplies, sewage, the living environment, and health of the public. Increasing the density of cities is expected to bring efficiency gains and technological innovation at the same time reducing valuable natural resource and resulting in excess energy consumption.

It is known that industries generate large quantity of by-products and wastes together at the end or in the process of manufacturing. These byproducts and wastes are usually dumped into vacant lands or some per cent of them recycled or re-used. Nevertheless, a large portion of them is being disposed of. Researches have been carried out to determine the feasibility of using these by-products and wastes as alternate materials. This is primarily to avoid land-dumping that causes environmental hazards.

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Planning and Scheduling of construction projects has always been a significant factor determining the successful completion of a project due to competition, time, space and resource constraints, penalties and incentives that are predominant in this sector. A well-planned and meticulously scheduled project invariably becomes a successful project and contributes directly or indirectly to the development of any nation. Planning and scheduling of construction projects are being carried out with bar charts, milestone charts and network techniques and software packages based on these techniques. The use of scheduling tools helps the project manager to determine the slack times available between activities and critical paths for decision making during the course of the project. Based on this information, the scheduler (project manager) further manipulates and reschedules the activities in a project so as to complete the project optimally. The most important criteria in predicting the completion or duration of a project is by defining the probable production rates of activities involved in order to provide resources appropriately to these activities. The allocation of duration for each activity is based on the production rate of a crew that is employed to carry out the activity keeping in mind the total project time. Standard data books for analysis of rates of activities in construction projects provides us with guidelines which can be used to determine production rates for various activities of a project.

Road structure cross section normally composes of the following layers and can be represented in a simple form. The thickness of these layers, pavement composition and other specifications such as materials etc are provided as per standard codes of practice [7].

i. Subgrade layer

ii. Subbase layer

iii. Base course

iv. Surface course/Wearing course

Although a pavement's wearing course is most prominent, it is the subgrade which decides the life of the pavement. The subgrade can be composed of a wide range of materials and its performance in a great way depends on its load bearing capacity, moisture content and shrinkage or swelling characteristics. Capping layers are provided only on weak subgrades so to improve their strength. It is usually a granular type of material laid to provide a working platform on which the subbase layers can be constructed [8].

The subbase is a layer of granular material provided above the subgrade generally with natural gravel. It should be clean and free from organic matter and should be able to be compacted by a roller. The material should conform to stipulated standards. It enables traffic stresses to be reduced to acceptable levels in the subgrade. It acts as a drainage layer between subgrade and road base and also intercepts upward movement of water by capillary action [9]. The road base and base course are layers immediately below the wearing course which are subjected to severe loading conditions. They are constructed with superior quality materials as per codal recommendations.

2. LITERATURE REVIEW

Efficient project management is a combination of various components and factors like understanding the objectives, knowledge of the activities, experience in economic usage of resources, suitability of tools used, proficiency in the handling of tools, awareness of planned time-cost relationship and the commitment of the firm to achieve the objectives [10]. The common planning techniques used for scheduling engineering project are

i. Bar charts

ii. Closely resembling network analysis like

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iii. Precedence Diagram Method

iv. Critical Path Method

v. Project Evaluation and Review Technique

vi. Line of Balance Method

The essential rule of lean management is to lessen the wastage of resources by asking whether the task in hand or process adds any worth to the assignment. Supply chain associated jobs and assignments are seen from a project project-driven point of view as opposed to a general or normalized viewpoint, making it simpler for project managers to concentrate on the specific project expectations and one of a kind client requirement [11]. The lean methodology distinguishes seven types of wastages incorporate all types of over-production, over-processing, delays, excess inventories and motions, failures, and defects [12]. Thus, when discussing waste management in construction projects, the lean methodology doesn't label waste as material waste alone, but any waste of time, resources, and motion. Roads, though, are construction projects, have a very different outlook and design flow as several other construction projects [13].

Wei C'hih Wang [14] formulated utility theory for determining project ceiling price based on utility theory and facilitated by cost simulation approach. Utility theory was applied to reflect owner's perspective regarding price determination criteria while simulation approach was used to generate a more objective approach to support execution of utility theory. In this study, simulation model is used to generate project cost and associated probability. The cumulative probability distribution function was formulated using output of the simulation model. This was used to determine the utility values for the various project costs. The highest utility value was provided for the project cost with highest probability and the lowest utility for the cost with probability zero. The threshold criteria were determined as the cost that the contractor may have fifty percent chance of cost overrun or underrun. Depending on the value of maximum price, minimum price and threshold price, ceiling price function was developed based on owner's perception. Based on these and the project criteria utility value, the corresponding probability of each cost was computed. The ceiling price for a project was found using the cumulative probability distribution. In this approach, the option for user's preferences regarding selection of probability distribution for simulated cost and the normalisation approach for the cost created a more realistic method of determining the project ceiling price.

Simulation is one of the sophisticated tools available for modelling complex situations. In construction projects, activity cost and duration are highly unpredictable and uncertain which lead to over estimation or under estimation of the project cost and duration. This results n continuous rescheduling of the construction project depending on the site conditions. Even though PERT takes into account uncertainties in durations to some extent, it is found to be inadequate to account for variation in cost and duration due to variation in the critical path resulting out of combining activity durations with different probabilities. Also this analysis may be cumbersome. Simulation approach for project scheduling involves determination of probability distribution function for activity duration and cost and then, simulating the network for various scenarios. In all the research models provided, activity cost and duration are not jointly analysed. Observation from various construction sites indicated that cost variation and delay are having close relationship.

Probabilistic optimal cost scheduling put forward by Leroy J Isidore and Back [15] used discrete system simulation to simultaneously perform range estimation and probabilistic scheduling. The result obtained was analysed statistically to arrive at a compressed schedule and obtain a minimised cost estimate. Activity cost and duration were assumed to follow uniform probability distribution function, based on

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assumption that both cost and duration are likely to take any value between the extremes with equal probability. ABCsim Software simulated projects for both activity cost and duration and it was found that even though there was not much significant difference between project durations obtained by least cost method and probabilistic optimal cost scheduling technique, there existed a wide variation in minimum cost of the project obtained by the above methods. Moreover, this methodology provided a range of cost associated with each project completion duration, thus allowing the decision maker a more user friendly tool for predicting the project cost and duration. This model did not specify the type of probability distribution function followed by the cost and duration of the activities and the interaction between them. Moreover, the variation in critical path for cost and duration estimates was not considered

Chua and Li [16] formulated resource integrated simulation modelling for construction, which was used for project scheduling at two abstraction levels, process level and resource level. At resource level, it conceived the project as a collection of resources involved and their interaction. Logic of operations was represented as internal resource flow between complex resources. Process level provided logic necessary and process duration was based on the attribute value. Interaction between resource and process was achieved by four kinds of mechanisms

i. Simple resource flow;
ii. Internal complex resource flow;
iii. Common process and;
iv. Interactive signals

The classification of resources varied with operations depending on number of attributes of each resource used.
Ming Lu [17] in his research on enhancing Project Evaluation and Review Technique simulation through artificial neural network based input modelling has proposed an artificial neural network (ANN) model to estimate errors in calculating statistical parameters for Beta distribution. In this model, distribution defined is by minimum, maximum values and values along the upper and lower quartiles and the range of distribution parameters are obtained by observing their effect on the final distribution curve. The various criteria that are taken into account for training ANN in characterising the distribution function are

i. Distribution should be continuous, non negative and finite between the lower and upper bound
ii. Distribution should have unique mode and most likely value and should be able to accommodate various degrees of skewness.

Sen & Mishra [18] reviewed the possibilities of using industrial wastes and by-products such as fly ash, blast furnace slag, cement kiln dust, waste foundry sand, phospogypsum, waste plastic bags and colliery sand for the construction of village roads. The authors report that use of these materials improves the engineering properties of the soil and hence suitable to be used for village road construction.

Swamy & Das [19] have explored the possibility of using industrial wastes such as fly ash, waste glass, construction demolishes, colliery spoil, slag, foundry sand and kiln dust. They conclude that there is ample scope for using these materials for road construction but with the caution to ensure that the use of industrial wastes and by-products does not produce health hazards.

Dhawan et al. [20] showed that fly ash can be used as sub-base and sub-grade material. They carried out experiments to determine the properties of coal ash and soil combinations that could be used for road

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construction. Laboratory studies were carried out to determine the strength parameter of the combinations that were considered. The selected soils belonged to the groups such as CL, ML and CH as per Indian Soil Classification System. Test results indicated that the soils that were mixed with the bottom ash were stronger than those mixed with fly ash it is suggested that the soils that are relatively poor in strength might mixed with coal ashes to get improved strength and bottom ash may be used as sub-base material in road construction.

From the literature survey it is clear that there is a wide scope for using the industrial wastes and by-products in highway construction. Waste foundry sand, fly ash and red mud are reported to improve the engineering properties of the soil and hence might form suitable alternative materials to virgin materials. Some of the researchers have also noted that use of stabilizing materials such as lime or cement is necessary for achieving better geotechnical strength parameters.

The research studies also report that the industrial by-products and wastes if used do not contaminate the water that seep into the ground and percolate through the ground water. In general it is very clear that the industrial by-products and wastes such as waste foundry sand, fly ash and red mud may be considered as a material to be used for construction. With respect to our country India, there is a lot more is needed for new construction of highways and repairing of existing damaged highways. And hence, use of industrial by-products and wastes for construction of highways may thus form an excellent space for utilizing them without being dumped or disposed on the vacant land thereby polluting the environment. Thus use of industrial by-products and wastes will lead to achieve sustainable development.

Efficient project management is a result of continuous focus on the project objectives, knowledge of the nature of activities, experience in optimal usage of resources, suitability of project management tools used, proficiency in the handling of these tools, awareness of time-cost relationship of activities and the commitment to achieve the objectives. The common scheduling techniques used for engineering projects are bar charts and network methods.
The CPM, PERT and precedence diagram method have been the most popular methods based on the networks. Developments in the network based methods have been incorporated into various types of software tailored for this purpose. However, the requirement of the type of scheduling tool that is to be adopted demands that it becomes the most versatile tool for a particular project and should be based on the nature of activities of the project. In construction projects, duration of various activities associated with the project always exhibit major uncertainties. Estimation of activity time is based on previous experience or from theoretical computations based on productivity. The performance of the project is based on the actual productivity of these activities which exhibit variation based on site conditions. The activity durations are fixed with some discrete values considering the total project duration and available resources. But in the construction sector the assumed duration is only a probability and hence the actual durations followed seldom meets the scheduled program. Therefore the reality is that durations of activities follow a distribution unique to that particular activity based on factors such as availability of resources, social, political, environmental factors etc. Focusing on linear projects, these aspects influence highway construction projects more so because highways run across the length and breadth of the country traversing varied geographic and geological conditions. Since these aspects influence completion of highway construction projects considerably, it becomes essential to develop new techniques for accurate prediction of duration of the different activities as the existing approaches disregard these factors.

A study on the probability distribution of actual durations of activities collected from around 120 road projects located geographically all over India was made by Arun and Rao [21] for predicting road project durations. Their study was focused on eleven key activities in highway projects under various scenarios

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of uncertainty such as location factors and site specific factors. The stochastic analysis of the data collected from these projects showed that the durations of activities in highway projects in India invariably followed a log-logistic distribution. They suggested that these distributions can be attributed to the high uncertainty of durations in developing countries. They concluded that the probability distribution incorporated in a simulation model can provide a realistic estimate of project duration at a desired confidence level.

Many of the researches in simulation in construction were carried out for improvement or modification of additions to the simulation languages. The employment of simulation languages for construction management is evident with the introduction of simulation languages like Cyclone, Stroboscope, etc. These simulation languages have been used as decision support tools in construction process engineering. In general development of decision support tools involving simulation studies have been limited mostly to industrial engineering and process engineering. Simulation languages for construction process include the integration of artificial intelligence in scheduling of construction projects.

Computer simulation approach for management of national highway network was proposed by considering a case study of widening a two lane highway into a four lane highway (Singh [22]). A network consisting of ninety five activities composing of all the activities in a typical highway work was listed. Adopting a computer simulation approach by allocating durations at random to all the activities, the criticality indices of activities was arrived at. The project time was computed for each run of the simulation. The number of occurrences in one thousand trials for a particular range of project duration was tabulated with this model to understand the distribution of project completion time. Activities with maximum critical index values were identified as activities mostly falling in the critical path. The probability of completing the project was estimated at 1225 to 1230 days as it had the highest number of repetitions in the distribution table.

3. SIGNIFICANCE AND SCOPE

The term and content of highway construction project management are explained in this paper. The fundamental issues of construction management are identified and possibilities to solve them are examined. The model for decision making in construction management by utilizing multi-criteria techniques were made and applied to real case studies. AHP method and “Expert Choice” computer programs were utilized for computations. The majority of construction management issues are MCDM problems. Countering complexity of an issue to be resolved in 4 optimization techniques can be utilized: multi-criteria, oriented cost, mono objective, multi objective. Elimination, optimization and probabilistic methods can be adopted by project managers to make a critical decision. Multi-criteria aspect is critical while a making construction management decision. The 9-stage model used to solve the decision making problems in construction has been suggested. Based on the literature review and expert’s opinion, a set of criteria was determined: i) technical experience ii) performance recourses iii) financial stability iv) management’s performance v) employee’s qualification vi) capacity vii) safety record viii) operations and ix) equipments.

4. CONCLUSION

The study was carried out with an objective to devise a user-friendly tool for project managers to predict the total project duration, cost and delay associated overruns. The study concentrated only on highway construction projects because the randomness associated with them is high and requires thorough project control measures to tide over the overruns. This decision support tool can be used as a schedule risk analysis tool for the project managers to predict the risk involved in the various site parameters of the

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project. 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. This paper introduces a structural approach for the decision-making process, which can consider conflicting criteria simultaneously. It aims to be used in all the phases of the life cycle irrespective of the project goals. Future development of it could include automation or embedding assistive tools in the general framework.

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