CHAPTER 1

INTRODUCTION

1.1 GENERAL

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 the 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.

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.
1.2 HIGHWAYS IN INDIA

The history of roads in India dates back to 25 to 35 B.C. as revealed by the well-paved road networks of Mohenjadaro and Harappa civilizations. Literature regarding the design depth of the road pavement is available in the literary piece ‘Arthashastha’ by Kautilya. The highways connecting Northwest and Eastern frontiers through Gangetic plains interlinking coastal and central India were constructed during the Mughal period.

In British rule, roads connecting important military and business centres were constructed by military engineers. Later in 1865, the Public Works Department was established by Lord Dallhousie to undertake construction and maintenance of roads. After Second World War, the industrial revolution and innovation in automobile engineering made the roads inadequate to support the enormous increase in the civil and military vehicle population. Due to rapid increase in the number of vehicles and the deterioration of roads, various legislative measures like the Motor Vehicle Act, National Highways Act, etc were introduced and various research organisations like the Central Road Research Institute, Highways Research Board, etc were established. Apart from this, Twenty Year Road Development Plan was formulated in 1943 and the third Twenty Year Road Development Plan (1981-2001) classified the roads into three categories as given in Table1.1.
Table 1.1 Different systems of roads according to Third Twenty Year Road Development Plan (Source: MORTH website)

<table>
<thead>
<tr>
<th>System</th>
<th>Roads that the system comprise</th>
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<tbody>
<tr>
<td>Primary system</td>
<td>Expressways and National Highways</td>
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<tr>
<td>Secondary system</td>
<td>State Highways and Major district Roads</td>
</tr>
<tr>
<td>Tertiary system</td>
<td>Other District Roads and Village Roads</td>
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Apart from this, the tenth five year plan provides an outlay of one lakh sixty five thousand crore Indian Rupees for removing the deficiency on existing National Highways and for the construction of Expressways. The Golden Quadrilateral Expressway project connecting Chennai, Mumbai, Delhi and Kolkata is proposed to cover a total distance of 5846 kilometres, is scheduled to complete by December 2003, is expected to save an average of Eight Thousand Crore Indian Rupees annually as vehicle maintenance cost and fuel cost. The expressway named North-South, East -West corridor connecting Srinagar and Kanyakumari and Probandar and Silchar respectively is having a total of 7300 kilometers and is expected to complete by 2007. The entire expressway project envisages a total cost of five thousand four hundred crores of Indian Rupees in 2003.

1.3 CONSTRUCTION SCHEDULING

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.

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. 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.

In all the systems of scheduling the main input is the durations of the activities associated with the project. This input has to be provided by the user. Activity duration is mainly dependent on site conditions, which may not be east to predict during the planning stage of the project. Hence, activities are delayed behind the schedule. In certain cases activity duration may be overestimated leading to a situation where the activity is likely to be completed ahead of the schedule. Therefore continuous site monitoring and updating of
the schedule is necessary throughout the project to keep the duration and cost of
the project under control

During continuous monitoring of highway construction projects, 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. 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.

Some of the important activities involved in highway construction are
presented in Figures 1.1 to 1.8. Most of these are complex in nature and the cost
of each of these activities has a direct component as well as indirect component. The direct cost is dependent on the labour conditions, use of machineries, material availability, technology adopted, etc. The indirect cost of the activity is mainly affected by the time delay in completion. Since the indirect cost is related to the duration of the activity, it is essential to analyse the duration and cost of the activities simultaneously. The stochastic behaviour of duration and cost of the activity is used to formulate a three dimensional probability model for activity cost and duration.

Figure 1.1  Earthworks for Subgrade for Highway Construction
Figure 1.2  Laying of Capping layer

Figure 1.3  Laying of SubBase Course
Figure 1.4 Laying of Road Base Course

Figure 1.5 Laying of Base Course
Figure 1.6 Laying of Wearing Course

Figure 1.7 Construction of Cross Drainage works
1.4 DELAY AND COST OVERRUN

The delay, which occurs in any of the construction projects, may be caused by one or more reasons. The influence of each of the causes may vary from activity to activity depending on the nature of the cause and the corrective action taken by the project personnel.

Whenever delay occurs in a construction project, it is likely to affect the resources, which in turn affects the cost associated with it. The delay in completion is likely to increase the project cost by unproductive manpower charges, unproductive equipment rents, cost of additional resources for corrective actions, etc. Hence the cost overrun associated with the activity is directly related to the time overrun in the activity. Since the time and cost
overrun are interrelated, the analysis of cost overrun is inevitable in delay analysis.

Monitoring of a project is carried out by comparing progress of individual activities and achievements of milestones with the actual schedules. It is essential for project management team to predict the cost overrun depending on the various technical and non-technical problems associated with the activities. The cost estimates provide the base line for the assessment of financial performance and the cost overrun analysis gives an indication of the actual scenario. Project control procedures are mainly intended to identify the deviations from the project plans rather than suggest possible cost savings. The deviations in plan are likely to cause delay which in turn result in cost overrun.

1.5 SIMULATION MODELS

According to Geoffrey Gorden (1999) “to simulate means to try to duplicate the features, appearance and characteristics of a real system. The word ‘simulation’ means ‘imitation of operations of the real world process or system over time’”. The history of simulation goes back five thousand years to Chinese war game Weich’i and continues to recent days for testing war strategies under various environments. The idea of using a simulation model is to imitate the real world situation with a mathematical model that does not affect the operations. Simulation is one of the commonly employed quantitative tools for solving quantitative problems for decisions making. Simulation is employed when situations to be experimented are so complex to prohibit the use of mathematical models and there is high risk and cost involved to experiment with the actual prototype. Another major advantage of simulation is time
compression, which allows the managers to study the affect of long run situations on a system within a short period of time. Due to these inherent advantages and with the developments in software and hardware technology, simulation can easily be employed to represent complicated and hazardous exercises like inventory decision making, emergency vehicle despatching, financial planning, nuclear fusion experiment, project management etc.

In highway construction the complexity associated with each activity is enormous due to the uncertainties associated with it. Hence, scheduling of activities in accordance with the real time site scenario is extremely difficult and cumbersome. Scheduling tools like PERT or CPM may be successfully used for projects where the uncertainty associated with the activity duration is limited. However, when these uncertainties are highly random as in developing countries like India, scheduling by these traditional methods may result in deviation from the actual construction performance leading to delay in the project. The cost overrun associated with the delay is also likely to further influence the project completion time and the budgeted cost. The simulation model becomes handy in such situations to represent the various scenarios of delay that are likely to affect the activities and the subsequent cost overrun. Simulation analysis will yield a better result than any mathematical scheduling method provided accurate stochastic input regarding the activity duration, cost, delay and cost overrun is provided to the model. This model can thus be used by the project managers to predict the cost and duration of the project depending on the delay and cost overrun associated with the activities.

The major disadvantage of any simulation model is that the conditions and constraints have to be provided by the user and the model does not produce
any result by itself. Moreover, the model does not produce any unique solution and the decision maker has to interpret judiciously the solution provided by the model depending on the situations. Hence, a Decision Support Tool has to be available along with the results of simulation runs of duration-cost and delay-cost overrun models for arriving at more reliable time and cost schedule of the construction projects.

1.6 DECISION SUPPORT TOOLS

Decision Support Tool (DST) is a computer code which provides guidance to arrive at reaching the right decision from an analysis of specialised knowledge and information available related to a problem having multiple solutions. This system may completely fulfil the function that normally requires human expertise or it may play the role of an assistant to human decision maker.

The main characteristics of DST are

- It performs reasoning over representation of knowledge in addition to doing numerical calculations and data retrieval;
- It solves problems by heuristics which unlike algorithmic solutions are not guaranteed to succeed and
- It deals with subject matter of realistic complexities that normally require considerable amount of human expertise.

Predicting the influence of several parameters on the outcome of a construction project is a rigorous process. Highway construction project is mostly influenced by more than one external parameter that can cause delay and
cost overrun to the project. It is very tedious for the user to correlate the various results from a simulation experiment to predict the cost and duration and hence predict the likely delay and cost overrun of the project. Hence, a DST has been developed to predict and provide the result in a more realistic sense, which is relevant to the real world scenario representing the actual conditions prevailing at the site. The DST will provide the probable duration and cost and the degree of confidence that can be associated with them and thence the likely delay and cost overrun that may occur due to the site parameter which was earlier unpredictable at the planning stage.

1.7 SUMMARY

The DST is devised here to analyse the results obtained from the simulation analysis. This system is used to obtain the result required by the user to facilitate decision making from out of the various results obtained from simulation runs. The results of simulation model act as the knowledge base for the expert system developed herein.

The simulation models are formulated for the cost duration analysis and for delay-cost overrun analysis for a highway of unit kilometre length. These models are backed by probability distribution functions for each activity in the highway construction project. The probability distribution functions that act as the backbone of this study are formed based on the data collected from several National Highway construction projects located in different parts of India. The two dimensional distribution functions formulated for individual parameters are used to formulate three dimensional activity cost probability distribution function and overrun model for controllable and uncontrollable delays. The simulation analysis is employed to characterise the interaction of the cost and duration for each activity in terms of specified confidence levels.