International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 07 | July - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

AN EXAMINING ANALYSIS OF THE LINEAR CONSTRUCTION METHOD FOR ROADWORK'S

Mr.AKASH.T[1], Dr. SAMBHAJI PADWAL[2]
Scholar, Department of Civil Engineering, Sunrise University, Alwar, Rajasthan-301026, INDIA
Assistant Professor, Department of Civil Engineering, Sunrise University, Alwar, Rajasthan-301026, INDIA

CHAPTER 1

INTRODUCTION

The linear construction method is an essential and widely utilized approach in roadwork projects, known for its systematic and sequential execution. This method plays a critical role in the organized and efficient development of infrastructure, which is pivotal for economic growth and societal advancement. Roads are integral to the transportation network, and their construction requires meticulous planning and execution to ensure longevity, safety, and functionality. By adhering to a clear, phase-by-phase framework, the linear construction method provides a robust mechanism for project managers and engineers to plan, allocate resources, and implement roadwork projects effectively.

Sequential Approach to Road Construction

The linear construction method is defined by its sequential nature, where each stage of the project must be completed before the next begins. This structured approach minimizes confusion and overlap, ensuring that each phase of the construction process is executed with precision. The typical phases in the linear construction method include planning and design, site preparation, earthworks, pavement construction, and finishing touches. Each of these phases is critical to the overall success of the project and requires careful attention to detail.

Planning and Design Phase

The planning and design phase is the foundation of the linear construction method. This initial stage involves extensive research and analysis to develop a comprehensive plan that addresses all aspects of the road construction project. Route selection, environmental impact assessments, budgeting, and scheduling are key components of this phase. Accurate planning is crucial, as it sets the groundwork for all subsequent phases, ensuring that the project is feasible and sustainable. By thoroughly analyzing potential challenges and requirements during this phase, project managers can develop a detailed roadmap that guides the entire construction process.

GENERAL

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.

LINEAR PROJECTS

Construction projects consist of activities which have a discrete or continuous relationship between them. In other words the start or progress of an activity depends on the completion of a previous activity in discrete systems whereas progress of activities is simultaneous in continuous systems. The progress of both the discrete and continuous activities has no bearing on the location of the activity as far as the linearity of the project is confined to small distances. Linearity may either be vertical or horizontal. Typical examples of vertical linearity are high rise constructions like towers and skyscrapers and horizontal linearity are projects like roads, rails, pipelines etc.

CURRENT SCHEDULING TRENDS

In the subcontinent, it has been noted that the Gantt chart output using the MS Project software is the most widely adopted method for road project scheduling, which has wide range of facilities and functions. The start to start relationships, finish to start relationships of the activities in a roadproject are well depicted in the MS project outputs. These outputs are shown as bars horizontally against the duration and therefore the progress of work can be interpreted as percentage of the total quantity of work that needs to be completed. But, this chart fails to depict the actual location at which any activity is at any point of time and also cannot accurately show the exact critical path and floats due to the nature of relation ships of the linear activities

CHAPTER 2

REVIEW OF LITERATURE

OVERVIEW

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.

FUNDAMENTALS AND EXTENSIONS OF LINEAR SCHEDULING

The origins of linear scheduling methods may be accredited as a development over the bar charts in which the distance factor has been additionally included to exhibit the spatial relationship of activities, plotting distances covered on the horizontal axis and the duration on the vertical axis.

A new approach to determine activity production rate, activity interruption and restraint and activity interval in highway projects was developed by Johnston (1981). In that work, he presented a graph by considering time on x-axis and locations on y-axis to represent the nature of activities in linear projects. The method was called as linear scheduling method (LSM) and his work suggested that the method could be used in transportation construction projects and other types of repetitive projects. A procedure for cost duration analysis was also illustrated with an example.

Chrzanowski and Johnston (1986) represented repetitive activities as lines of constant or varying slopes on the two axes, distance against time. They suggested that discrete activities may be shown at their appropriate times and locations on the linear schedule itself and then referred to a network schedule for more details. An illustration was made by actually applying LSM to a road construction project consisting of upgradation of two roads. The entire project was broken down into five phases with necessary tasks planned to be completed in that phase. A CPM network was presented at first for the phases and later an LSM model was discussed for each phase with their components. The authors compared the bar chart progress schedule with the actual progress with the LSM and estimated a completion delay of one year for the project .The simplicity of the method and its advantages of application to such types of projects were revealed.

A study conducted by Handa and Barcia (1987) on linear scheduling using optimal control theory showed that a discrete optimal control framework was adequate for construction process. This new branch of optimisation presented by them made it possible to view the construction production process as a dynamic system that evolves over time. A hypothetical cut-and-fill job on a section of highway was presented by them by means of a continuous optimal control formulation.

Mattila and Park (2003) have compared the results of critical activities of basic linear scheduling elements determined with the help of the linear scheduling method and the repetitive scheduling method (RSM). Use of control points was proposed by them in the determination of critical paths with RSM whereas controlling links were used for the same purpose with LSM. The controlling paths for various types and relationship conditions of activities were studied both with LSM and CPM and found to be providing similar results for both methods.

A random linear project generator was developed to produce a group of twenty five random linear projects to analyse and compare their critical paths by Kallantzis et al (2007). They also compared the critical path of the kallantislambropoulos repetitive project model against the CPM network model.

A two state variable, N- stage dynamic programming formulation of the linear scheduling problem was presented by Russell and Caselton (1988) as an extension to linear scheduling optimisation. The problem was structured with the objective of minimizing the overall project duration as a conventional dynamic programming framework. The method suggested by them was able to treat a variety of work continuity constraints in repetitive construction. A sensitivity analysis procedure was also described which permitted the identification of near-optimal solution with schedule alternatives to suit undefined criteria in a better manner.

Harmelink and Rowings (1998) developed the linear scheduling method to provide a level of analytical capability to the linear scheduling process. This paper documented a method by which a controlling activity path can be determined for linear projects similar to the critical path method. This fundamental ability helped in the identification of controlling and non- controlling segments and determination of floats and provided a means of updating linear schedules.

PRODUCTIVITY IN PROJECTS

Float characteristics of linear activities have been analysed using the linear scheduling method (Harmelink 2001). For linear construction , the concept of float is somewhat different from the traditional scheduling techniques. Rather than start time and duration being the main attributes of float, production rate is more fundamental attribute of a linear activity. This paper presented the term rate float and its impact as it applies to the controlling activity path defined by the linear scheduling method .As such, for float to be meaningful for a linear activity, it must be reflective of the activity's major characteristic. Rate float captures this characteristic and presents information to construction planners and managers in terms that are meaningful for linear projects.

A process model was developed for measuring and analyzing the overall project productivity (Hyun Lee 2003). The daily quantities of work and input resources were recorded and validated for two urban projects and one rural project with similar scope of work but located in different areas .A productivity process model was developed to combine simultaneous work activity productivity into a global productivity value for the project as a whole. Three factors affecting the overall project productivity such as the variation of daily project productivity, the degree of inefficiency of construction operations, disruptive events that contributed to loss in project productivity were the key considerations in his work. Project productivity was calculated by dividing the total daily equivalent work units by total daily man hours to produce these work units. Equivalent work unit factors were developed to covert daily amount of work with common units into an equivalent unit of work with a common unit.

Vaziri et al (2007) developed control policies in the form of planned resource allocation to tasks that capture the uncertainty of task durations and the impact of task durations on those resource allocations. They adopted resource multipliers and duration multipliers to study the effect of resources on durations. An algorithm in this context was developed adopting simulation methods to arrive at a nominal and an optimized crew size. The probability distribution of durations with a project of 21 activities was analysed based on their mean and standard deviation and the results obtained for varied crew allocations have been explained with respect to the variation in duration and cost.

SIMULATION TOOLS

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 (2003) for predicting road project durations. Their study was focused on eleven key activities in highway projects under various scenarios 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.

CHAPTER 3

OBJECTIVES AND METHODOLOGY

3.1 OBJECTIVE

1. To evaluate the time and cost efficiency of the linear construction method in roadwork projects compared to alternative methods.
2. To Challenge Identification Identify key challenges and limitations associated with implementing the linear construction method in roadwork.
3. To Quality Impact assess the impact of the linear construction method on the quality and durability of road infrastructure.
4. To Safety Evaluation: Evaluate the effectiveness of safety measures and protocols in the linear construction method for roadworks.
5. To analyse the environmental effects of the linear construction method, including sustainability and ecological impact.

METHODOLOGY

The methodology indicated in flowchart in Figure 3.1 for achieving the above objectives is planned to involve the following steps.

The detailed methodology involves the following tasks.

Task1 : Review of Scheduling Techniques

Literatures in the area of scheduling of road projects with tools and techniques adopted currently in practice were reviewed at first. The limitations of networking tools for scheduling of road projects have been understood clearly. Software tools being adopted in scheduling road projects by constructors have been studied and the gap in information required for efficient project planning and scheduling have been collected.

The requirement of a unique type of scheduling methodology for road projects has been identified as a potential area of research due to the peculiar nature of relationships, the number of activities in a road project, their method of execution and work environment. In this context, a number of road project schedules, specifications, contract documents, codes of design and construction practice, on site data etc have been examined.

Task 2 : Production Rate Approach through LSM

From the literature review on scheduling tools for road projects, the use of LSM was demonstrated with application to simple projects and comparisons with software schedules of road projects. In this process the basic parameters controlling linear activities have been arrived through hypothetical examples. The application of LSM was further studied by collecting data from a recently completed national highway project through the actual production rates of activities in the project. Generic equations have been developed to define criticality of activities of a road project by comparing the linear production rates of consecutive activities. A simple method of superimposition of critical segments of activities of various sections has been suggested for determination of overall project duration.

Task 3 : Probable Production Rates through Simulation

Having understood the need for production rates of activities, a simulation model was developed using the probability distribution of activity durations in road projects presented by Arun and Rao (2003) to arrive at probable production rates of activities in order to estimate road project durations.

An analysis has been made with the probable linear production rates obtained from the simulation model with the actual linear production rates of the KTRP and an investigation was carried out for the wide range in activity production rates obtained through simulation and data from various sites.

Figure 1.2 Project Site Map

Task 4 : Consensus of Activity Production Rates through Delphi

Due to wide range in the probable production rates of activities obtained through simulation, a consensus was reached in production rates for a specific type of project using the Delphi process. 12 predictable factors affecting project duration were considered for survey through 20 highway constructors. 5 major factors influencing project durations out of the 12 factors considered were used for the second round of the survey. Consensus on probable production rates was reached after the third round of survey through the Delphi with the help of three–time-estimate factors for activities in road projects.

Task 5 : Analysis of Results
The results of the Delphi analysis have been validated with the overall production rates of activities of the KTRP and other similar projects. An analysis of progress of activities has been carried out considering work breaks and calendar days to arrive at a method for duration estimates of large highway projects.
Task 6 : Production Based Scheduling simple flowchart methodology in a LSM framework for scheduling road projects has been presented based on production rates and buffer distances between consecutive activities. A hypothetical 5 km two - lane carriageway construction has been illustrated with this approach with standard dimensions for gauging time estimates in single road stretches. However, the extent of application of LSM in large highway construction projects has been brought out by a production based scheduling model which can handle work progress simultaneously at various locations in large projects. The model developed was tested for sensitivity analysis for variation of production rates, buffer distances and time intervals A

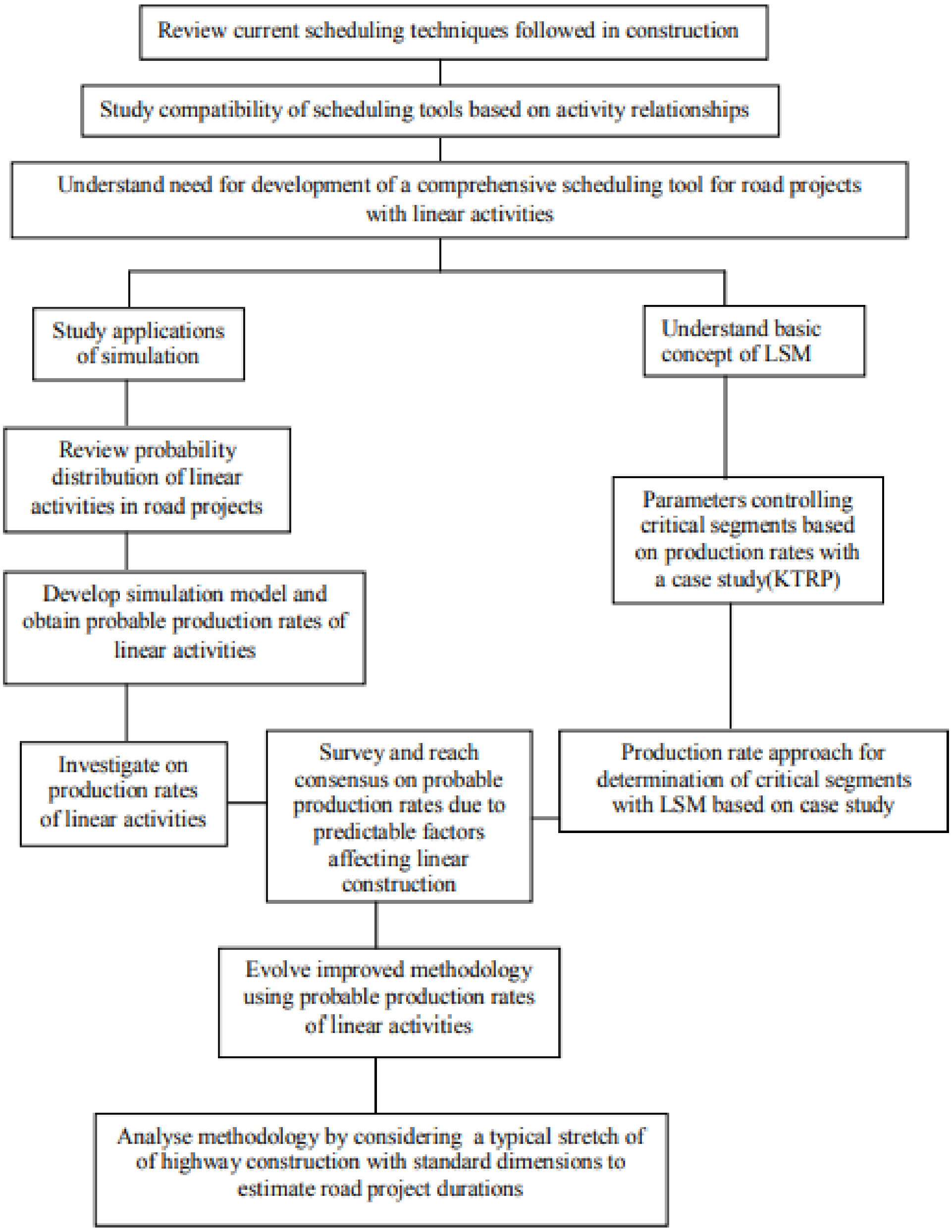


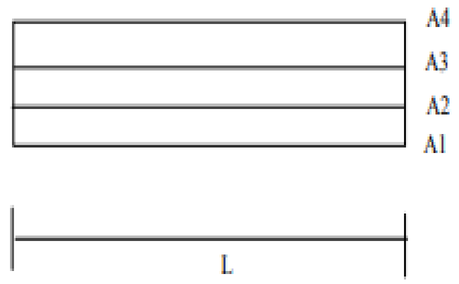
Figure 3.1 Flow Chart Indicating Research Methodology

CHAPTER 4

LINEAR SCHEDULING METHOD (LSM) AND ITS APPLICATIONS

BASICS OF LINEAR SCHEDULING

The LSM is a graphical technique in which the locations or the length of the linear project is indicated on the horizontal axis and durations of activities of the project is represented on the vertical axis. This method of representing linear schedule is also termed as distance – time scheduling. Each activity is plotted one after the other based on the order of activities in the section of the project sequentially on this graph. The starting time and location of the activity is shown as the start point of the activity on the graph and the ending time and location of the activity is shown as the end point in the linear schedule graph. In short activities are represented as sloping lines based on the start coordinate and the end coordinate. The basics of LSM can be understood by taking the activities of a typical section of a road as mentioned in section 1.3. Let us assume that the road section comprises of four activities namely the subgrade represented A1,subbase represented by A2, base course represented by A3 and surface course represented by A4 as shown in Figure 4.1 which span the entire length of the project. Complying with the rules of networking, the CPM would have represented them as activities following one after the other as shown in Figure 4.2. The LSM representation following the same relationship between activities shall be as per Figure 4.3. In this figure each successive activity has been considered to begin only after the completion of the previous activity. Hence the total project completion time DP should have been equal to DA1 + DA2 + DA3+ DA4, wherein DA1 is the duration of activity A1, DA2 is the duration of activity A2 , DA3 is the duration of the activity A3 and DA4 being the duration of activity A4. But in reality succeeding activities of a linear project do not wait until the completion of the previous activity but start after a minimum buffer time and distance is allowed to satisfy the job requirements. This relationship between activities is represented in Figure 4.4, which cannot be represented by a network diagram. Now considering the project time as per Figure 4.4, the total duration of the project shall be from the start of the first activity upto the end of the last activity. This duration shall be much smaller compared to the earlier computation as per the CPM schedule. As activities are related in terms of distances covered with time taken, the progress rates of activities can be determined by the ratio of length to time. For instance, in the linear scheduling plot shown in Figure 4.4, it is observed that the progress rate of the activity A1 should be L/DA1 km/day to complete the activity A1 in time DA1. Similarly activities A2,A3 and A4 should progress at rates respective to their durations so as to complete the project in the scheduled time DP. Further, if the total time DP is to be optimised as per the constraints experienced in the project, linear scheduling has the flexibility to do so by increasing or decreasing the progress rate of each activity and the buffer distance between activities. These changes can be depicted on the LSM to arrive at the total project time.



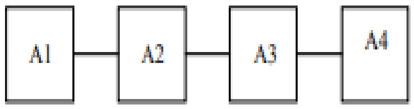
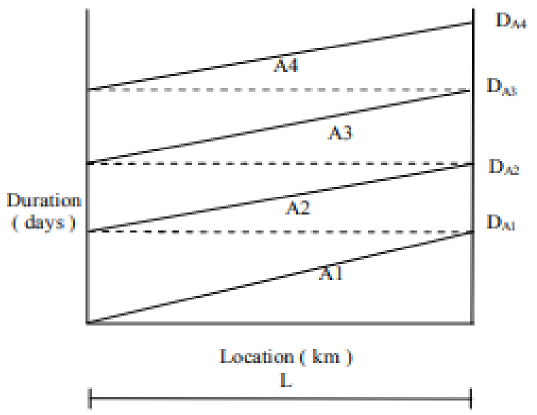


Figure 4.1 Sections of a Road Figure 4.2 Network Diagram

Having understood the fundamentals of LSM, and as per assumptions in the CPM that resources are unlimited, an algorithmic approach to determine critical paths and floats shall be as explained in the next sections (Harmelink 1998).



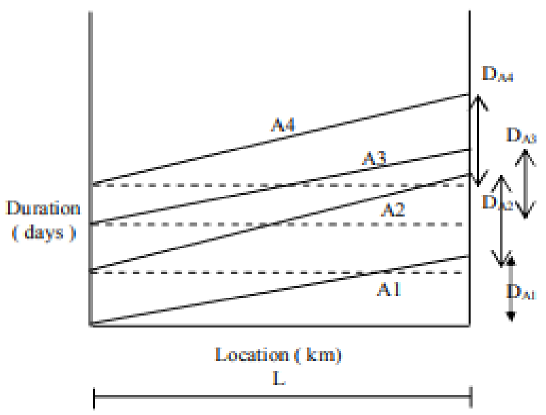


Figure 4.3 Duration Plot as per CPMFigure 4.4 Distance – Duration Plot as per LSM

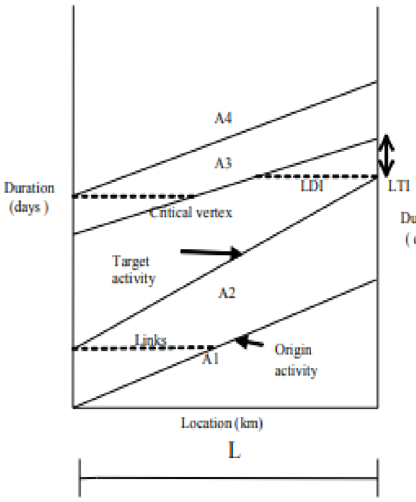
SCHEDULING WITH LSM

The methodology to plot the linear schedule as per the actual nature of relationship between activities and to determine the critical activity path and floats in a linear project comprises of the following steps:

1. Plotting the activity sequence list,
2. Determination of the least time interval and least distance intervals by upward pass method,
3. Determination of the critical and non-critical segments in activities by downward pass method,
4. Determination of floats available in activities.

ACTIVITY SEQUENCE PLOT

Let us consider the project explained in Figure 4.1, with four activities A1,A2,A3 and A4. The start and end time of all these activities are plotted on the linear schedule as indicated in Figure 4.5.Once the activities are plotted sequentially as per their order, the least time interval (LTI) and the least distance interval (LDI) is automatically exposed as indicated in Figure 4.5. This is the greatest advantage when applied to linear projects.



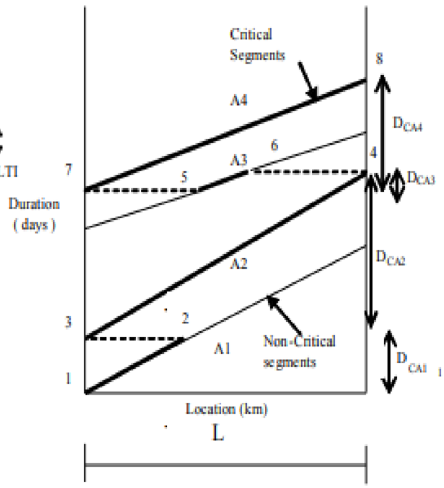


Figure 4.5 Activity Sequence and Determination of LDI and LTI with Upward Pass

Figure 4.6 Downward Pass Upward Pass

Having drawn the activity sequence list on the linear schedule, the LTI and the LDI between consecutive activities are determined to find out the critical and non critical activities of the project. In the activity sequence list plotted in Figure 4.5, the first activity is taken as the origin activity and the succeeding activity as the target activity. The criticality of the activities is determined by starting with the first activity designating that as the origin activity and the immediate succeeding activity as the target activity. The LTI and LDI between the origin activity and the target activity considered are determined. Similarly in the next stage, the target activity previously considered becomes the origin activity and the next immediate succeeding activity becomes the target activity. The LTI and LDI for the fresh set of activities are determined once again. Like wise the LTI and LDI are determined for all set of activities until the last activity is reached. It is to be noted in a linear schedule that not only the entire activity can be critical but also portions of activities can be critical as the activities are progressing continuously and spanning the entire length of the project.

CHAPTER 5

THE LINEAR PRODUCTION RATE ALGORITHM FOR DETERMINATION OF CRITICAL PATHS

KRISHNAGIRI THOPURGHAT ROAD PROJECT (KTRP)

The KrishnagiriThopurghat Road Project (KTRP) is a recently completed road project in Tamilnadu, India in which widening of the existing carriage way and construction of new carriageway with other improvements have been undertaken. The project was started in September 2005 and completed in January 2009 with various setbacks suffered during its execution. The total project was divided and executed in three stretches as shown in the section details in Figure 5.1. Each stretch of the road was subdivided into further sections and subsections based on the constraints faced by the constructor and job logic. The actual schedule followed by the constructor during its execution for the new carriageway in Section A between km 94.00 and km113.00 has been presented in Tables 5.1, 5.2 and 5.3 and the subsections for this stretch has been indicated in Figure 5.2. The overall MSProject schedule has been presented in Appendix 2. Section A has been critically analysed using the LSM and an algorithm has been presented to study the duration of the section and the lengths and durations of critical segments using the actual linear production rates of activities.

From the actual schedule followed by the constructor, the production rates of each of the activity has been indicated in the last column of Tables 5.1,5.2 and 5.3 based on the duration taken for execution of the activity and the length of the sub section and expressed in days/km.

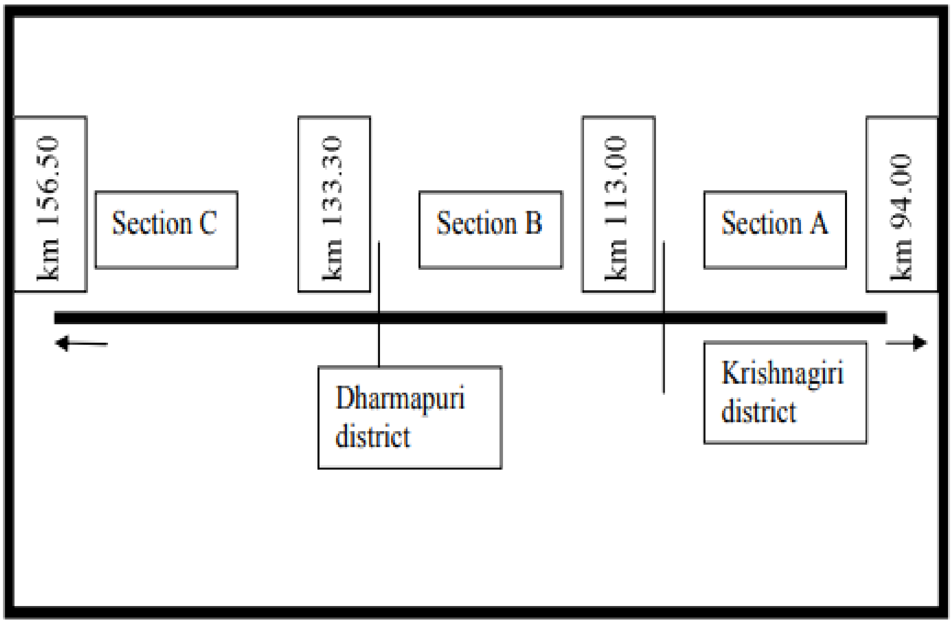


Figure 5.1 KTRP Sections (km 94.00 – km 156.50)

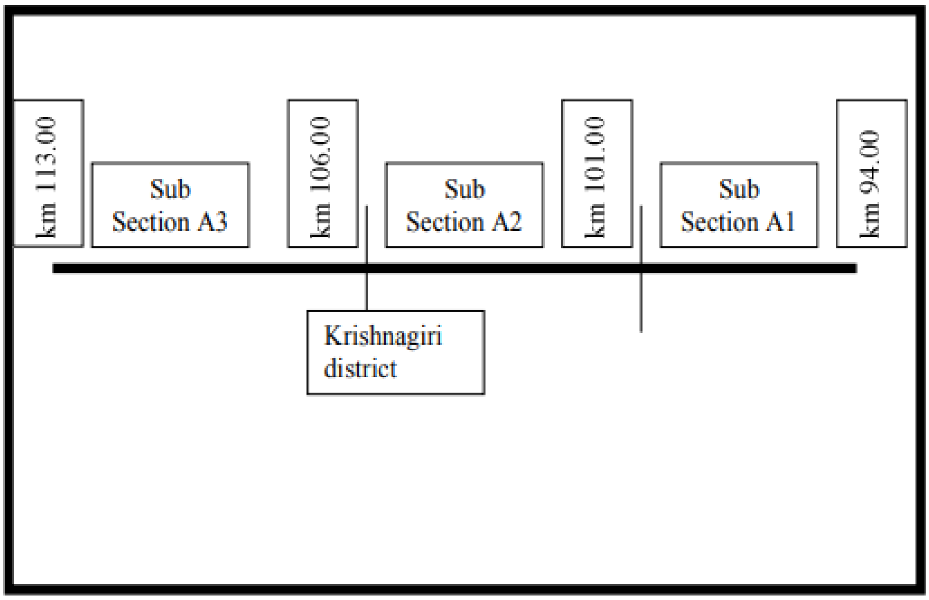


Figure 5.2 Section A - Subsections (km 94.00 – km 113.00)

Table 5.1 Constructor's Schedule for Sub section A1 (km 94.00km 101.00) Length - 7 km

Activity	Activity ID	Start Date	Completion Date	Start Day	Completion Day	Actual Duration (days)	Linear Production Rate (days/km)
Clearing and Grubbing	AA1	05/10/07	27/02/08	185	350	165	23.57
Embankment and Subgrade	BA1	10/10/07	03/03/08	190	355	165	23.57
Granular Subbase	CA1	17/10/07	10/03/08	198	363	165	23.57
Wet Mix Macadam	DA1	08/11/07	27/03/08	223	383	160	22.86
Kerb Laying	EA1	08/11/07	27/03/08	223	383	160	22.86
Bituminous Macadam	FA1	15/12/07	29/03/08	266	386	120	17.14
Dense Bituminous Macadam	GA1	17/12/07	31/03/08	268	388	120	17.14
Bituminous Concrete	HA1	18/06/08	23/06/08	478	483	05	0.714

Table 5.2 Constructor's Schedule for Sub section A2 (km 101.00km 106.00) Length - 5 km

Activity	Activity ID	Start Date	Completion Date	Start Day	Completion Day	Actual Duration (days)	Linear Production Rate (days/km)
Clearing and Grubbing	AA2	17/03/07	23/05/07	0	50	50	10.00
Embankment and Subgrade	BA2	12/04/07	12/01/08	20	264	244	48.80
Granular Subbase	CA2	27/05/07	19/01/08	53	273	220	44.00
Wet Mix Macadam	DA2	20/08/07	10/04/08	132	397	265	53.00
Kerb Laying	EA2	09/02/08	10/04/08	330	400	70	14.00
Bituminous Macadam	FA2	20/03/8	10/04/08	375	400	25	5.00
Dense Bituminous Macadam	GA2	21/03/08	12/04/08	377	402	25	5.00
Bituminous Concrete	HA2	12/04/08	26/05/08	402	452	50	10.00

Table 5.3 Constructor's Schedule for Sub section A3(km 106.00-km 113.00) Length - 7 km

Activity	Activity ID	Start Date	Completion Date	Start Day	Completion Day	Actual Duration (days)	Linear Production Rate (days/km)
Clearing and Grubbing	AA3	17/05/07	02/08/07	46	112	66	9.43
Embankment and Subgrade	BA3	05/06/07	13/10/07	60	160	100	14.29
Granular Subbase	CA3	17/06/07	26/11/07	69	244	175	25.00
Wet Mix Macadam	DA3	29/08/07	15/12/07	142	267	125	17.86
Kerb laying	EA3	19/09/07	29/12/07	166	281	115	16.43
Bituminous macadam	FA3	01/12/07	09/02/08	250	331	81	11.57
Dense Bituminous macadam	GA3	10/12/07	13/02/08	260	335	75	10.71
Bituminous concrete	HA3	23/06/08	27/06/08	484	490	6	0.86

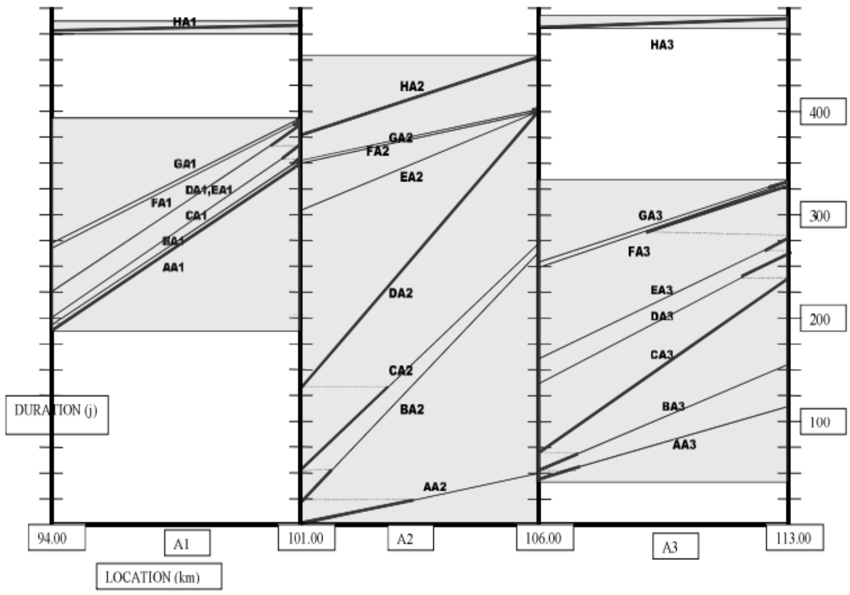


Figure 5.3 Linear Schedule - Section ALINEAR PRODUCTION RATE PARAMETERS CONTROLLING CRITICAL SEGMENTS

These linear production rates have been adopted in the schedule in Figure 5.3. Also the start day of clearing and grubbing for section A2 has been taken as the first day for count as this is the first activity that was started in the section as per the actual schedule. All other start days and completion days in the schedule have been determined considering the start day of activity clearing and grubbing of A2 as reference. The actual duration of an activity has been computed from the difference between the start and completion day for each activity and indicated in the tables 5.1 to 5.3. Further, the critical segments of all these activities shown as thick lines in Figure 5.3 have been calculated based on the production rate algorithm.

Activities in road projects can be classified as start activities, intermediate activities and end activities. Start activities are the first activities in road projects such as clearing, earthwork etc, intermediate activities are subbase, base courses etc and end activities are final activities such as surface finishes.

From the above data and after careful analysis of the parameters controlling the critical activities in linear projects, the following general equations have been written taking the production rate of activities as a key controller of project duration in roads. These equations can be used to identify the criticality of the activities in linear projects with continuous full span activities. The lists of symbols and notations in equations (5.1) to (5.24) have been abbreviated in the report.

a) The last or ending activities in linear projects become totally critical for Lc(ae)- Ls(ae)km and for a duration Tc(ae)-Ts(ae) days when;

1) ae starts on or after completion of ae-1 (5.1) or

Pe< Pe-1 (5.2)

b) Ending activities become critical at its end for a distance Lc(ae)- Ldc(ae) km for a duration Tc(ae)-Tdc(ae) days when

Pe> Pe-1 (5.3)

or

Pe = Pe-1 (5.4)

c) Intermediate activities become critical entirely for Lc(am)-Ls am) km for a duration Tc(am)- Ts(am) days when;

Pm = Pm+1 and am starts on or after completion of am-1(5.5)

CHAPTER 6

SIMULATION MODEL FOR INVESTIGATION OF PROBABLE ACTIVITY PRODUCTION RATES

SIMULATION FUNDAMENTALS

Simulation is the imitation of a real phenomenon by developing a model and conducting operations on it. The system comprises of variables and constants associated with it, that are copied into the model to investigate on the behaviour of the system. Physical models comprises of three-dimensional duplication of the system whereas schematic models are two-dimensional model of the system in the form of charts, diagrams, etc. Symbolic models can be deterministic or stochastic in nature and are normally in the form of mathematical models.

The simulation process comprises of four major phases;

- Definition of the problem and statement of objectives,
- Construction of an appropriate model,
- Experimentation with the model constructed and
- Evaluation of the results of simulation.

Each of this phase involves a number of tasks and the size of the model depends on the real world system. The major tasks involved in this process are the collection of data and selection of a suitable method in which the simulation activity would replicate the real the random behaviour of the real system. Simulation models are dynamic and stochastic in nature and belong to the class of symbolic models. Simulation models are considered superior to mathematical models due to its versatility to analyse complex processes without requiring major computing provisions. Discrete event simulation is a method of simulation that involves modelling of a system over time by a representation in which status of the variables change instantaneously at separate points in time.

CHAPTER 7

DETERMINATION OF ROAD PROJECT DURATIONS

PRODUCTIVITY BASED SCHEDULING

Productivity of activities can be affected by both predictable and unpredictable factors in large projects and unless a specific study is carried out based on the former, the role of constructors on the production rate variability cannot be quantified. Other factors which are out of the scope of these agencies have not been considered in this work so as to narrow down on the range of probable production rates for a more realistic time frame in field execution.

In order to arrive at probable durations of activities in road projects, it becomes necessary to understand the standard productivity measures adopted at project sites. The components of a road project fundamentally comprise of activities spanning along a certain length progressing depending on the quantity of work in each activity and the crew allocation based on the target date of completion. From the above discussions, it is clear that estimating road project durations requires a comprehensive approach which can handle productivity based scheduling and incorporate the risk of delays.

DURATION ANALYSIS BY DELPHI PROCESS

Having obtained planned linear productivity of activities in a road project, it becomes imperative to have knowledge on predictable durations so as to arrive at probable durations of activities. The Delphi method has been adopted to reach consensus on production rates in construction of highway projects. Delphi is seen as a structured process within which one uses qualitative, quantitative or mixed research methods. For a homogeneous group, a sample of between ten to fifteen people is stated to yield sufficient results. Literature indicates that only three participants have been used for consensus. Also for homogeneous groups, fewer than three rounds may be sufficient to reach consensus. Thus, methodological rigor can contribute to a successful Delphi. Further, a statistical analysis of the Delphi results with real time data can provide us with a reliable approach in scheduling. Factors influencing delays in highway projects have been analyzed to enhance project management in highway construction (Sharma 2004).

CHAPTER 8

RESULTS AND CONCLUSIONS

FINDINGS

Road projects are unique and need to be scheduled with a different approach due to the method of execution and nature of activities. From the above study involving probable production rates of linear activities, the following conclusions are drawn;

I. The parameters controlling critical segments of linear activities in road projects provide the basic information about the behaviour of critical paths in road projects based on various activity relationships. They are also instrumental in identifying the nature of critical segments based on the production rates of activities. From Figure 5.3 and Table 5.4, it is seen that activity bituminous concrete is totally critical between km 101 and km 106 of KTRP for 50 days satisfying equation 4.2. All other ending, start or intermediate linear activities in the LSM comply with the equation relevant to its status. However, when the number of sections and subsections are increased as in large highway projects, interpretation of information and monitoring progress becomes more complex.

II. A simulation model developed based on the probability distribution helps us to understand the activity durations in a road project and provides us with a range of probable production rates of linear activities. For instance, the production rates obtained for clearing and grubbing from the model indicates a value of 1.3 days/km to 26.90 days/km. The wide range in production rates shows indefinite delays that occur due to certain factors such as land acquisition, shifting of utilities etc. Likewise the production rates of all the activities from the simulation model exhibit wide variations in production as the probability distribution is based on durations of activities in various types of road projects with no clarity with respect to dimensions, crews and reasons for delay.

In short, simulation model can be used for determining probable production rates only if probability distributions are specific to the type of project in hand.

III. The Delphi process has led to the benchmarking of the optimistic, most likely and the pessimistic time estimates of linear activities for five major factors influencing project durations based on predictable delays. The simulation results for maximum durations indicate a value of 26.90 days/km for clearing and grubbing whereas Delphi survey indicates a maximum of only 3.00 days/km. Similar comparisons indicate a large difference between the values which is due to the fact that the simulation model caters to all types of factors and a wide range of road projects whereas the Delphi process deals with predictable factors and fixed crew size indicating that specific study is required for the type of project in hand. The results from the Delphi process have been compared with the productivity guidelines as per standard databook and also the actual production at sites. Although the schedules reflect a slower production when considered section wise, the actual overall production considering the entire project falls within the estimates of the Delphi analysis.

IV. A generalised method of scheduling road projects and estimating durations with the production based LSM has been suggested with a flow chart. The ideal time for completing a continuous stretch of a two-lane carriageway for 5km considering 7 activities for pavement formation with a given set of inputs should take 53 days. If the same project is affected by all factors, it should take 75 days. It is to note here that apart from the probable production rates in activities, the buffer distances play a key role in arriving at these durations. In other words if the buffer distance and the buffer time interval between activities are increased, then the project durations may increase irrespective of high production rates and relatively small time overruns. This has been shown with the sensitivity analysis in Table 7.25.

V. For large highway projects consisting of various developments such as new carriageways, bypasses, service roads etc., the PBSM considering total volume of work against time of activities in the project shall be a practical approach to constructors. Durations of projects can be estimated provided work breaks and progress phases are planned and scheduled adopting probable production rates. This has been illustrated with the production and progress analysis of the KTRP which has taken about 733 calendar days for completion of all the activities. The model also helps constructors in deciding overtime working hours for ensuring targeted production as planned between two calendar dates. The duration of the project needs to be attributed to the quantity of work involved with little relevance to the length of the project. Therefore based on this study, the model incorporating production rates through Delphi provides for a flexible and improved method of scheduling in road projects based on productivity, site practices and conditions, crews and work quantities.

Distance-time linear scheduling becomes complex for large highway projects as works are carried out in parallel at the same time in various locations. Therefore, production based scheduling based on quantity of work is recommended for such large projects due to its versatility in handling varying production and work breaks. However the use of LSM for different stretches separately can only provide additional information which can help in the effective utilisation of resources and enhance overall production.

From the three time estimates of durations obtained in this work, the project completion can be forecasted for various combinations of factors as done for the hypothetical cases considered. Scheduling road projects considering probable durations due to a particular factor or a combination of factors shall be the best approach. The significance of buffer distance intervals has been discussed by sensitivity analysis which shows that apart from concentrating on the production rates of activities the constructor should also plan based on the buffer distances and time intervals between activities for arriving at a more efficient schedule. This approach not only provides alternative schedules but paves a way for working out costs based on occurrence of various types of risks and time durations

LIMITATIONS OF THE STUDY

The production rate approach of scheduling linear construction incorporating time estimate factors provides a basic platform in predicting road project durations. The study deals with a continuous stretch of dual carriageway construction for given dimensions under normal weather and topographic conditions.

The study has been limited to project durations only and does not consider financial factors of production.

SCOPE FOR FURTHER STUDY

Apart from the study in normal topography and weather conditions, road construction projects are taken up in various locations and scenarios. Therefore, the work may be extended for various categories of road construction with production rates defined for specific types of projects. Also, further study on the effect of variation in production on cost for each category of work shall be useful in balancing work progress with economic aspects of construction in road projects.

CONCLUSION

In conclusion, the linear construction method for roadwork proves to be an effective and efficient approach, offering significant benefits in terms of time management, resource allocation, and project coordination. This method streamlines the construction process by allowing for continuous work flow along the project length, thereby reducing idle times and enhancing productivity. Furthermore, its structured approach facilitates better planning and control, leading to improved quality and safety standards. Overall, adopting the linear construction method can result in substantial cost savings and timely project completion, making it a preferred choice for large-scale roadwork projects.

CHAPTER 9

REFERENCES

[1] Podolski, Michał & Sroka, Bartłomiej. (2018). Cost optimization of multiunit construction projects using linear programming and metaheuristic-based simulated annealing algorithm. JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT. 25. 848-857. 10.3846/jcem.2019.11308.

[2] Yogesh, G & Chappidi, Hanumantharao. (2018). A study on linear scheduling methods in road construction projects. Materials Today: Proceedings. 47. 10.1016/j.matpr.2021.07.393.

[3] Dinh, Trong & Trung Hieu, Dinh & Götze, Uwe. (2018). Roadworks design: study on selection of construction materials in the preliminary design phase based on economic performance. International Journal of Construction Management. 24. 1-9. 10.1080/15623599.2023.2179603.

[4] Trunzo, Giampiero & Moretti, Laura. (2019). Life Cycle Analysis of Road Construction and Use. Sustainability. 11. 377. 10.3390/su11020377

[5] Kassem, Mohamad. (2013). Road construction projects: an integrated and interactive visual tool for planning earthwork operations.

[6] Gara, Jawa & Zakaria, Rozana & Aminudin, Eeydzah & Adzar, Jeffryl & Yousif, Omar. (2013). The Development of Real-Time Integrated Dashboard: An Overview for Road Construction Work Progress Monitoring. Hunan Daxue Xuebao/Journal of Hunan University Natural Sciences. 48. 128.

[7] Chou, Jui-Sheng. (2009). Generalized linear model-based expert system for estimating the cost of transportation projects. Expert Systems with Applications. 4253-4267. 10.1016/j.eswa.2008.03.017.

[8] Liu, Shu-Shun & Wang, Chang-Jung. (2007). Optimization model for resource assignment problems of linear construction projects. Automation in Construction. 16. 460-473. 10.1016/j.autcon.2006.08.004.