CHAPTER 4

LINEAR SCHEDULING METHOD (LSM) AND ITS APPLICATIONS

4.1 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 $D_p$ should have been equal to $D_{A1} + D_{A2} + D_{A3} + D_{A4}$, wherein $D_{A1}$ is the duration of activity A1, $D_{A2}$ is the duration of activity A2, $D_{A3}$ is the duration of the activity A3 and $D_{A4}$ 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 up to 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 $L/D_{A1}$ km/day to complete the activity A1 in time $D_{A1}$. Similarly activities A2, A3 and A4 should progress at rates respective to their durations so as to complete the project in the scheduled time $D_p$. Further, if the total time $D_p$ 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).

4.2 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:

a) Plotting the activity sequence list,

b) Determination of the least time interval and least distance intervals by upward pass method,

c) Determination of the critical and non-critical segments in activities by downward pass method,

d) 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 Upward Pass

Figure 4.6 Downward Pass

Determination of LDI and LTI with 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.

Figure 4.5 represents the origin and target activities and the least
time (LTI) and least distance (LDI) that are determined between consecutive
activities of the sample linear project. It is seen from Figure 4.5 that the least
time interval is the shortest duration between the consecutive activities which
can be connected vertically without crossing any other intermediate activity
and the least distance interval is the shortest distance between the consecutive
activities with respect to its least time interval. The lines representing the least
distance intervals are called as links and their intersection with
the activities forming vertices are called as critical vertices as indicated in
Figure 4.5.

**Downward Pass**

Once the least time, least distance intervals, links and critical
vertices are finalised, the critical and non-critical segments are identified. In
other words activities or segments of activities in linear projects having floats
or without floats are determined. In the downward pass of the LSM as per
backward pass of the CPM, a path is traced from the end of the last activity
back in time. This path may intersect a critical vertex or trace back to the start
point of the activity based on the nature of relationships between activities. If
the path happens to meet a critical vertex it then takes an horizontal direction
along the link to the end point or another critical vertex of the previous
activity and then is continued back in time once again. If the path does not intersect any critical vertex and instead continues upto the starting point of the activity the path is traced horizontally from this starting point until it meets the next activity at another critical vertex or the endpoint of the preceding activity back in time. In this case if the path traced does not meet any other critical vertex then the path is shifted to the end point of the preceding activity back in time and is traced down once again as mentioned above until it reaches the start point of the first activity. It is also possible that the path may also shift to the endpoint of the activity previous to the preceding activity when two or more activities end at the same point. Eventually, the longest path obtained connecting the start points, end points and critical vertices connected by the controlling links defines the critical path of the project in a linear schedule.

Figure 4.6 represents the downward pass which defines the critical and non-critical segments of the activities of the project. Following the procedure explained above, it is seen from Figure 4.6 that activity A4 is totally on the critical path from point 7 to point 8. A portion of the activity A3 between points 5 and 6 is on the critical activity path. Again, activity A2 is totally on the critical activity path between 3 and 4. A portion at the beginning of the activity A1 is also controlling between points 1 and 2. Thus the duration associated with these segments determines the optimal project duration with the assumed durations $D_{CA1}$, $D_{CA2}$, $D_{CA3}$ and $D_{CA4}$ as indicated in Figure 4.6.

**Float Calculation**

The determination of critical segments by the downward pass method enables us to understand that the progress rates of these segments cannot be altered if the project were to be completed in the scheduled time, as they are the activities or the portions of the activities without any float.
Having determined the critical segments that have no floats, it becomes important to quantify the progress rates of the non-critical segments. These can be determined as progress rates as per original schedule and the least possible progress rates based on the critical path.

4.2.1 Initial Non – Critical Segments and Floats

In order to determine the floats for activities which have the initial portions as non-critical, the planned start point, the critical vertex point at which the activity becomes critical and the earliest possible start point considering the available float of this activity are determined. The critical vertex points are already obtained as in the upward pass method and the earliest possible start point is determined by adding the starting duration of the preceding activity by the LTI between the activity in consideration and the preceding activity. In case of a continuous series of initial non-critical segments, increments are made from the preceding earliest possible start points and not from the start point of the preceding activity. The floats of initial non-critical segments which can have earlier starts are represented with a negative sign such as -A3 as shown in Figure 4.7.

![Figure 4.7 Initial Non-Critical Segments](image1)

![Figure 4.7 Terminal Non-Critical Segments](image2)
Thus in Figure 4.7, if \((L_{PS}, D_{PS}), (L_{PS}, D_{ES})\) and \((L_{IVC}, D_{IVC})\) are the coordinates of the planned starting, earliest possible starting and critical vertex of any activity, then the progress rates and the floats of the activity at the initial portions can be written in km/day as shown below in Equations (4.1), (4.2) and (4.3).

i) Planned progress rate \((PR_p) = \frac{L_{IVC} - L_{PS}}{D_{IVC} - D_{PS}}\) \hspace{1cm} (4.1)

ii) Least possible progress rate \((PR_l) = \frac{L_{IVC} - L_{PS}}{D_{IVC} - D_{ES}}\) \hspace{1cm} (4.2)

iii) Float rate \((FR) = PR_p - PR_l\) \hspace{1cm} (4.3)

Where, \(L_{PS}\) - The planned starting location of any activity
\(L_{IVC}\) - The location at critical vertex point of any initial non-critical segment
\(D_{ES}\) - The earliest possible starting duration of any activity
\(D_{PS}\) - The planned starting duration of any activity
\(D_{IVC}\) - The duration at critical vertex of any initial non-critical segment

Therefore float rates of activities in any initial non critical segment in general can be determined by the difference of planned progress rate of the activity to least possible progress rate of the activity.

4.2.2 Terminal Non-Critical Segments and Floats

In order to determine the floats for activities which have the terminal portions as non critical, the location and duration at planned completion, the critical vertex point at which the activity becomes non critical and the latest possible completion time of the activity are determined. The critical vertex points are already obtained as in the upward pass method and
the latest possible end point is determined by reducing the ending duration of the succeeding activity by least time interval between the activity in consideration and the succeeding activity. In case of a continuous series of terminal non critical segments deductions are made from the succeeding latest possible end points and not from the end point of the succeeding activity. The floats of terminal non-critical segments which can have later finish times are represented with a positive sign as +A1 and +A3 as shown in Figure 4.8.

Therefore in Figure 4.8, if \((L_{PC},D_{PC}), (L_{PC},D_{LC})\) and \((L_{TVC},D_{TVC})\) are the coordinates of the planned ending, possible ending and critical vertex of the activity, then the progress rates and floats of the activity can be written as in km/day as shown below in equations (4.4), (4.5) and (4.6).

i) Planned progress rate \((PR_p) = \frac{L_{PC} - L_{TVC}}{D_{PC} - D_{TVC}}\) \hspace{1cm} (4.4)

ii) Least possible progress rate \((PR_l) = \frac{L_{PC} - L_{TVC}}{D_{LC} - D_{TVC}}\) \hspace{1cm} (4.5)

iii) Float rate \((FR) = PR_p - PR_l\) \hspace{1cm} (4.6)

Where, \(L_{PC}\) - The ending location of any activity
\(L_{TVC}\) - The location at critical vertex point of any terminal non-critical segment
\(D_{LC}\) - The latest possible ending duration of any activity
\(D_{PC}\) - The ending duration of any activity
\(D_{TVC}\) - The duration at critical vertex of any terminal non critical segment

Therefore in general, float rates for any terminal non critical segment of activities is given by the difference of planned progress rate to least possible progress rate of the activity. It is once again to be noted from
the above paragraphs that activities in linear projects can be entirely critical, or only for portions at the start, end or at any intermediate segment of the activity based on the parameters controlling it.

4.3  ILLUSTRATION 1

A typical road project with 4 activities as shown in Table 4.1 has been considered and attempted to be scheduled using the bar charts, CPM network techniques at first and later by the LSM. The advantages and effectiveness of the LSM for road projects over the other scheduling techniques currently in practice is discussed in the next sections.

Table 4.1 Sample Road Project (km 10.00 – km 12.00)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Activity</th>
<th>Activity ID</th>
<th>Start date</th>
<th>End date</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Clearing and Grubbing</td>
<td>A</td>
<td>01.01.04</td>
<td>22.01.04</td>
<td>22</td>
</tr>
<tr>
<td>2.</td>
<td>Earthwork Excavation</td>
<td>B</td>
<td>07.01.04</td>
<td>12.02.04</td>
<td>37</td>
</tr>
<tr>
<td>3.</td>
<td>Embankment and Subgrade</td>
<td>C</td>
<td>31.01.04</td>
<td>21.02.04</td>
<td>22</td>
</tr>
<tr>
<td>4.</td>
<td>Granular Subbase</td>
<td>D</td>
<td>08.02.04</td>
<td>10.03.04</td>
<td>32</td>
</tr>
</tbody>
</table>

4.3.1 Bar Chart Scheduling

A Gantt or Bar chart schedule for the above project in Table 4.1 is presented in Figure 4.9. From this figure the following information about the activities can be obtained.
<table>
<thead>
<tr>
<th>S.No</th>
<th>Activity</th>
<th>Activity ID</th>
<th>January 2004</th>
<th>February 2004</th>
<th>March 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clearing and Grubbing</td>
<td>A</td>
<td>0</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>Earthwork Excavation</td>
<td>B</td>
<td>4</td>
<td>37</td>
<td>43</td>
</tr>
<tr>
<td>3</td>
<td>Embankment and Subgrade</td>
<td>C</td>
<td>31</td>
<td>29</td>
<td>52</td>
</tr>
<tr>
<td>4</td>
<td>Granular Sub-base</td>
<td>D</td>
<td>22</td>
<td>37</td>
<td>32</td>
</tr>
</tbody>
</table>

**Figure 4.9 Bar Chart Schedule of the Sample Road Project**  
(km 10.00 – km 12.00)

**Starting and ending durations of activities**: For example, it is seen that activity A (Clearing and Grubbing) can be started on the 1st day and completed on the 22nd day. Similar information can be gathered for the remaining activities and also about the total duration of the project.

**Time intervals between activities**: The figure indicates that activity B (Earthwork Excavation) can be started on the 6th day from the start of activity A (Clearing and Grubbing) and can be completed on the 43rd day which is 21 days from the completion of activity A. Therefore 6 days are available as lag time between the starts of activities A (Clearing and Grubbing) and B (Earthwork Excavation) and 21 days are available as lag time between their ends.

**Progress of activities**: The progress of activity A (Clearing and Grubbing) on the 11th day should be 50% of the total length or in other words activity A should have progressed up to Km 11.00 after 11 days. Similar progress measurements can be made in terms of the percentages of the total duration of any activity at any instant of time.
In addition to the above information, Figure 4.9 also expresses the spatial relationship between consecutive activities, i.e., the commencement of activity B (Earthwork Excavation) on the 7th day of the project when activity A (Clearing & Grubbing) is still in progress and has already covered a certain distance. Despite such useful information, this method still has the following shortcomings.

i) Only the duration aspect of the activities is being represented in Figure 4.9. The distances covered or the location of any activity at any point of time is not being shown in the above figure. Hence it lacks a comprehensive visual impact.

ii) Although Figure 4.9 gives information about the lag time available at the beginning and end of activities, the representation and computation of floats becomes a tedious process considering the rescheduling which is done in practical situations to balance the resources. This problem becomes all the more complicated when the number of activities and sections of the road project increases.

iii) Due to a large amount of uncertainties in resources and duration, the progress of some of the sections of the activities control the total duration of the entire project. These critical segments and progress rates of the activities at various sections of the project cannot be represented or computed from the above figure.

4.3.2 CPM- Network Scheduling

Due to these shortcomings with the bar chart method, an attempt has been made to schedule the same project with the CPM network method.
From the projected schedule and duration of activities of the sample project in Tables 4.1 and 4.2, an activity on arrow (AOA) network diagram trying to indicate the relationships of activities has been attempted in Figure 4.10.

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Node</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 – 2</td>
<td>22</td>
</tr>
<tr>
<td>B</td>
<td>3 – 4</td>
<td>37</td>
</tr>
<tr>
<td>C</td>
<td>5 – 6</td>
<td>22</td>
</tr>
<tr>
<td>D</td>
<td>7 – 8</td>
<td>32</td>
</tr>
</tbody>
</table>

The AOA representation in Figure 4.10 does not comply with the rules of network scheduling and therefore applying CPM network scheduling to road projects becomes impossible and hence cannot provide realistic information about the activities in a road project.

![Figure 4.10 AOA Network Diagram](image-url)
The sample road project has also been attempted to be scheduled with CPM using the activity on node technique (AON) as shown in Figure 4.11.

### Figure 4.11 AON Network Diagram

The AON diagram enables us to indicate the earliest and latest times due to the advantage of representing the finish to start (FS) relationship between activities. Although the activity on node has the ability to represent all other activity relationships such as start to start (SS), start to finish (SF) and finish to finish (FF) relationships, it is noted that the earliest times and latest times are equal which infers that all activities are critical and the distance progress information is not available.

#### 4.3.3 Linear Scheduling

Having experienced the above mentioned drawbacks in the bar chart and CPM/PERT methods for scheduling linear projects, the sample project is now scheduled using the LSM involving the following steps.

#### 4.3.3.1 Activity Sequencing

- The activities of the projected schedule shown in Table 4.1 are listed sequentially.
- The sequential activities are drawn on the LSM schedule corresponding to their start and end dates and locations as per
the projected schedule by calculating the number of calendar days required for each activity and plotting them on the graph with locations (km) on the ‘x’ axis and duration (days) on the ‘y’ axis.

iii) Figure 4.12 shows the activity sequencing of the sample project marked with the start and end dates of all the activities and their locations.

4.3.3.2 Upward Pass

i) LTI is the shortest duration in between consecutive activities that is obtained by comparing their start and end times. LDI is the shortest distance between the consecutive activities with respect to the least time interval considered.

ii) From the least time and the least distance intervals, the critical vertices are calculated mathematically using slope equations and links are connected to these vertices.

iii) Figure 4.12 also shows the Upward Pass method for the sample project with the critical vertex coordinates marked on it.

4.3.3.3 Downward Pass

i) A path is traced from the end of the last activity back in time continuously connecting the critical vertices, start points and endpoints of the activities through the links as shown in Figure 4.4.
ii) The critical and non-critical segments are established upon completion of the downward pass.

iii) Figure 4.13 explains the downward pass method for the sample project thus identifying the critical segments as thick lines and non critical segments as ordinary lines. The durations and lengths for which each of the activity is critical is shown in Table 4.3.

**Table 4.3 Critical Activity Path (km 10.00 – km 12.00)**

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity</th>
<th>Duration (days)</th>
<th>Start (km)</th>
<th>End (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Clearing and grubbing</td>
<td>06</td>
<td>10.00</td>
<td>10.55</td>
</tr>
<tr>
<td>B</td>
<td>Earthwork Excavation</td>
<td>37</td>
<td>10.00</td>
<td>12.00</td>
</tr>
<tr>
<td>C</td>
<td>Embankment and Sub grade</td>
<td>05</td>
<td>10.70</td>
<td>11.20</td>
</tr>
<tr>
<td>D</td>
<td>Granular Sub base</td>
<td>32</td>
<td>10.00</td>
<td>12.00</td>
</tr>
</tbody>
</table>
4.3.3.4 Float Rates

The non-critical segments of activities may occur either at the initial portions of the activities or at the terminal portions of the activities as indicated in Figure 4.13. The floats of such non-critical segments can be determined as below.

a) Initial Non-Critical Segments and Floats

1) The planned rates, lowest rates and float rates for beginning non-critical segments as shown in Figure 4.14 has been presented in Table 4.4. In activity C, $L_{PS}$ is taken as 10 as it remains the location at planned start and $D_{ES}$ becomes 15 which is obtained by adding the LTI between activity B and C to $D_{PS}$ of B.

Table 4.4 Initial Non-Critical Segments and Floats

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>($L_{PS}$, $D_{PS}$)</th>
<th>($L_{IVC}$, $D_{IVC}$)</th>
<th>($L_{PS}$, $D_{ES}$)</th>
<th>Planned Rate km/day</th>
<th>Lowest Rate km/day</th>
<th>Float Rate km/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>(10,30)</td>
<td>(10.72,38)</td>
<td>(10,15)</td>
<td>0.09</td>
<td>0.03</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Figure 4.14 Initial Non-Critical Segments

Figure 4.15 Terminal Non-Critical Segments
b) **Terminal Non-Critical Segments and Floats**

i) The planned rates, lowest rates and float rates for ending non-critical segments as shown in Figure 4.15 has been presented in Table 4.5. For instance in activity A, \( L_{PC} \) is taken as 12 as it remains the location at planned completion and \( D_{LC} \) becomes 37 which is obtained by subtracting the LTI between activity A and B from \( D_{PC} \) of B.

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>((L_{TVC}, D_{TVC}))</th>
<th>((L_{PC}, D_{PC}))</th>
<th>((L_{PC}, D_{LC}))</th>
<th>Planned Rate km/day</th>
<th>Lowest Rate km/day</th>
<th>Float Rate km/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(10.55, 6)</td>
<td>(12, 22)</td>
<td>(12, 37)</td>
<td>0.09</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>C</td>
<td>(11.20, 43)</td>
<td>(12, 52)</td>
<td>(12, 62)</td>
<td>0.09</td>
<td>0.04</td>
<td>0.05</td>
</tr>
</tbody>
</table>

**4.4 ILLUSTRATION 2 - COMPARISON OF LSM WITH A GANTT CHART OUTPUT**

The method of scheduling road projects currently in India has been the use of MSProject software for generating the desired reports. A typical report of a section of a road scheduled with this software as shown in Appendix 1 has been compared with a linear schedule for the same inputs.

The Gantt chart output for the activity durations and other constraints keyed in for a typical road project obtained from a leading constructor using the MS Project software has been shown in Appendix 1. The first section of the road between km 273.5 km 277.50 shall be discussed in this work as other sections are typical. From Figure 4.16, it is seen that each activity is given an ID, a start time, an end time keeping in view its predecessor relationships with other activities. For instance activity 9 (Earthwork) has been scheduled to start on 01/05/04 and end on 08/06/04 keeping in view its predecessor relationship with activity 10 (granular sub-
Figure 4.16 LSM Schedule (km 273.50 – km 277.50)

base) whose scheduled start is 14/05/04 and scheduled completion is 11/06/04. Thus the predecessor relationship of activity 9 has been shown as 10FF - 3 days which means that it has a finish to finish relationship with activity 10 and has to be completed 3 days before the completion activity 10, considering all constraints. The predecessor relationship for activity 10 has been indicated as 11SS - 3 days which implies that this activity in turn has a
start to start relationship with activity 11(dry lean concrete) and thus the earliest start time possible is 14\textsuperscript{th} of April 2004. Thus an intense road schedule is prepared considering the predecessor relationships and progresses required for all the activities.

**Table 4.6 Projected Schedule (km 273.50 – km 277.50)**

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity</th>
<th>Start Date</th>
<th>End date</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Diversion @ 276.00</td>
<td>31/03/04</td>
<td>31/03/04</td>
</tr>
<tr>
<td>7</td>
<td>Diversion @ 275.34</td>
<td>31/03/04</td>
<td>31/03/04</td>
</tr>
<tr>
<td>9</td>
<td>Earthwork</td>
<td>01/05/04</td>
<td>08/06/04</td>
</tr>
<tr>
<td>10</td>
<td>Granular Subbase</td>
<td>14/05/04</td>
<td>11/06/04</td>
</tr>
<tr>
<td>11</td>
<td>Dry lean concrete</td>
<td>18/05/04</td>
<td>15/06/04</td>
</tr>
<tr>
<td>12</td>
<td>Pavement quality concrete</td>
<td>29/05/04</td>
<td>16/10/04</td>
</tr>
<tr>
<td>13</td>
<td>Widening and sealing of transverse joints</td>
<td>15/06/04</td>
<td>02/11/04</td>
</tr>
<tr>
<td>14</td>
<td>Widening and sealing of longitudinal joints</td>
<td>15/06/04</td>
<td>02/11/04</td>
</tr>
<tr>
<td>15</td>
<td>Kerb casting</td>
<td>23/10/04</td>
<td>15/11/04</td>
</tr>
<tr>
<td>16</td>
<td>Granular shoulder</td>
<td>23/10/04</td>
<td>15/11/04</td>
</tr>
<tr>
<td>17</td>
<td>Opening to traffic</td>
<td>18/11/04</td>
<td>18/11/04</td>
</tr>
<tr>
<td>19</td>
<td>Pipe culvert at 274.39</td>
<td>13/04/04</td>
<td>11/05/04</td>
</tr>
<tr>
<td>20</td>
<td>Pipe culvert at 274.42</td>
<td>13/04/04</td>
<td>11/05/04</td>
</tr>
<tr>
<td>21</td>
<td>Pipe culvert at 274.54</td>
<td>13/04/04</td>
<td>11/05/04</td>
</tr>
<tr>
<td>22</td>
<td>Pipe culvert at 274.78</td>
<td>13/04/04</td>
<td>11/05/04</td>
</tr>
<tr>
<td>23</td>
<td>Pipe culvert at 275.21</td>
<td>24/04/04</td>
<td>22/05/04</td>
</tr>
<tr>
<td>24</td>
<td>Pipe culvert at 276.66</td>
<td>24/04/04</td>
<td>22/05/04</td>
</tr>
<tr>
<td>25</td>
<td>Pipe culvert at 277.11</td>
<td>24/04/04</td>
<td>22/05/04</td>
</tr>
</tbody>
</table>

**4.4.1 Linear Schedule with LSM (km 273.50 – km 277.50)**

The projected schedule of the section of the road between km 273.50 and 277.50, taken from the gantt chart in Appendix 1 has been
indicated in Table 4.6. This projected schedule has now been scheduled by the linear scheduling method and shown in Figure 4.16. It can be observed that activities can be shown in the LSM as points, bars, lines and blocks depending on the nature of the activity, its location and time consumption and relationship with other activities. For instance activity 6 is shown only as a point as it is scheduled only for one day on March 31 and at location 276 as per the schedule. Similarly activity 19, pipe culvert is shown as a bar (vertical line) at location at 274,391 for a duration of 28 days as per the schedule. Activities 9 to 17 are shown as sloping lines for the entire length of the section of the project with their start and end time as per the schedule. Also, the monsoon period is indicated as a block activity wherein no activity is scheduled.

4.4.2 Analysis of Outputs

From the above schedules a comparison can be drawn between the MS project schedule and the LSM schedule.

Although MS project allows the scheduler to program the section of a road considering all constraints and available resources, it is limited to the following information for road projects.

- Starting and ending time of all activities assumed by the scheduler depending on the length and activities in the section of the road project and resources consumed.

- The predecessor/successor relationships with all other activities respecting job logic such as start to start finish to start relationships as programmed by the scheduler.
• Total project completion time or the duration of completion of a particular section of the road as scheduled by the planner.

Based on the above schedule the constructor proceeds further with allocation of resources and monitors the progress of the project. Now from the LSM schedule in Figure 4.16, the following information can be obtained.

• The start and end durations of all activities can be indicated as dates and also as the day on which activity starts or ends on the vertical axis.

• The progress of each activity from the start duration up to the end duration is indicated as sloping lines, vertical lines or points based on the location traversed by the activity and the duration for which it extends on the XY plane.

• The critical path or the critical segments of the set of activities is indicated by thicker lines and the other segments of the activities with lines of normal thickness.

• Also, the floats available for the portions or segments of activities that are not critical in a road project are shown as hidden lines.

Comparing the Gantt chart and linear scheduling outputs, the LSM schedule provides us with better information due to its graphical representation of its 2 main attributes namely the duration and location of the activities. The Gantt chart output shows only the progress of activities as horizontal bars on the duration side. This is well illustrated considering activity 12, which shows the exact location of activity 12 during the starting of the monsoon period i.e. on the 93rd day of the project or as on July 1st 2004. Similarly it is only possible as per the LSM schedule to indicate the location
of any activity on a particular day during the progress of a project. The indication of pipe culverts, diversions at various chainages for the scheduled durations further explains this phenomenon.

Further as it is typical of highway projects to have a combination of linear and discrete activities, the determination of critical path by network technique i.e the CPM becomes complex as each linear activity has to be broken down into a number of sections which is practically impossible and incomprehensible. This problem is solved by the LSM schedule representation as it clearly indicates the exact locations and durations for which activities are critical and the results have been tabulated in Table 4.7.

**Table 4.7 Critical Path (km 273.50 – km 277.50)**

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity</th>
<th>Duration (days)</th>
<th>Start (km)</th>
<th>End (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Diversion @ 276.00</td>
<td>1</td>
<td>276.00</td>
<td>276.00</td>
</tr>
<tr>
<td>7</td>
<td>Diversion @ 275.34</td>
<td>275.34</td>
<td>275.34</td>
<td>275.34</td>
</tr>
<tr>
<td>9</td>
<td>Earthwork</td>
<td>39</td>
<td>273.50</td>
<td>277.50</td>
</tr>
<tr>
<td>10</td>
<td>Granular Subbase</td>
<td>22</td>
<td>274.04</td>
<td>277.07</td>
</tr>
<tr>
<td>11</td>
<td>Dry lean concrete</td>
<td>11</td>
<td>273.50</td>
<td>275.07</td>
</tr>
<tr>
<td>12</td>
<td>Pavement quality concrete</td>
<td>33</td>
<td>273.50</td>
<td>274.44</td>
</tr>
<tr>
<td>13</td>
<td>Widening and sealing of transverse joints</td>
<td>33</td>
<td>273.96</td>
<td>277.50</td>
</tr>
<tr>
<td>14</td>
<td>Widening and sealing of longitudinal joints</td>
<td></td>
<td>273.96</td>
<td>277.50</td>
</tr>
<tr>
<td>15</td>
<td>Kerb casting</td>
<td>13</td>
<td>275.24</td>
<td>277.50</td>
</tr>
<tr>
<td>16</td>
<td>Granular shoulder</td>
<td></td>
<td>275.24</td>
<td>277.50</td>
</tr>
<tr>
<td>17</td>
<td>Opening to traffic</td>
<td>1</td>
<td>273.50</td>
<td>276.50</td>
</tr>
<tr>
<td>22</td>
<td>Pipe culvert at 274.78</td>
<td>29</td>
<td>274.78</td>
<td>274.78</td>
</tr>
<tr>
<td>25</td>
<td>Pipe culvert at 277.11</td>
<td>29</td>
<td>277.11</td>
<td>277.11</td>
</tr>
<tr>
<td>Activity ID</td>
<td>Activity</td>
<td>Scheduled Progress Rate Between</td>
<td>Least Progress Rate Between</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------</td>
<td>---------------------------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>From (km)</td>
<td>To (km)</td>
<td>Planned Rate (km/day)</td>
</tr>
<tr>
<td>9</td>
<td>Earthwork</td>
<td>273.50</td>
<td>277.50</td>
<td>0.10</td>
</tr>
<tr>
<td>10</td>
<td>Granular Subbase</td>
<td>274.04</td>
<td>277.07</td>
<td>0.14</td>
</tr>
<tr>
<td>11</td>
<td>Dry lean concrete</td>
<td>273.50</td>
<td>275.07</td>
<td>0.14</td>
</tr>
<tr>
<td>12</td>
<td>Pavement quality concrete</td>
<td>273.50</td>
<td>274.44</td>
<td>0.03</td>
</tr>
<tr>
<td>13</td>
<td>Widening and sealing of transverse joints</td>
<td>273.96</td>
<td>277.50</td>
<td>0.11</td>
</tr>
<tr>
<td>14</td>
<td>Widening and sealing of longitudinal joints</td>
<td>273.96</td>
<td>277.50</td>
<td>0.11</td>
</tr>
<tr>
<td>15</td>
<td>Kerb casting</td>
<td>275.24</td>
<td>277.50</td>
<td>0.17</td>
</tr>
<tr>
<td>16</td>
<td>Granular shoulder</td>
<td>275.24</td>
<td>277.50</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Therefore the duration obtained by adding up the durations of all the major critical segments gives the total critical duration of the project which works out to 214 days as per Figure 4.16. This information which is vital for the scheduler can be given by the LSM schedule in a single report.

Also, floats available in linear activities have been clearly indicated in the LSM schedule. The progress rates of critical segments of linear activities shown as thick lines and the least progress rates of the non critical segments of linear activities as normal lines have been quantified in Table 4.8. This is vital information for the project manager to reschedule and reallocate his resources.

**Table 4.9 Sample Road Project (km 14.00 to km 16.00)**

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity Description</th>
<th>Start Date</th>
<th>Completion Date</th>
<th>Duration at Start ((T_s))</th>
<th>Duration at end ((T_c))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Clearing and Grubbing</td>
<td>09/02/05</td>
<td>28/02/05</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>Earthwork Excavation</td>
<td>21/02/05</td>
<td>09/03/05</td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td>C</td>
<td>Embankment and Subgrade</td>
<td>25/02/05</td>
<td>17/03/05</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>D</td>
<td>Granular Subbase</td>
<td>18/03/05</td>
<td>07/04/05</td>
<td>37</td>
<td>58</td>
</tr>
<tr>
<td>E</td>
<td>Wet Mix Macadam</td>
<td>22/03/05</td>
<td>21/04/05</td>
<td>41</td>
<td>72</td>
</tr>
<tr>
<td>F</td>
<td>Kerb Casting</td>
<td>12/04/05</td>
<td>24/04/05</td>
<td>62</td>
<td>75</td>
</tr>
<tr>
<td>G</td>
<td>Asphalt Works</td>
<td>11/05/05</td>
<td>31/05/05</td>
<td>91</td>
<td>112</td>
</tr>
<tr>
<td>H</td>
<td>Bituminous Concrete</td>
<td>21/05/05</td>
<td>10/06/05</td>
<td>101</td>
<td>122</td>
</tr>
</tbody>
</table>

### 4.5 PARAMETERS CONTROLLING LINEAR ACTIVITIES

Having understood the basic parameters controlling linear activities, a study of the critical activities has been made with a sample road
project for a stretch of 2 km. Its projected schedule has been indicated in Table 4.9 considering all possible conditions activities can be subjected to in a typical linear project.

Following the stepwise procedure mentioned in the previous sections, the linear schedule graph is drawn between the distance of the road to be covered on the ‘x’ axis and the total duration of the project on the ‘y’ axis which is 2km and 122 days respectively. Activities A to H are drawn one by one on this graph corresponding to their start and completion dates. After the activity scheduling is represented on the graph, the least time intervals are determined and the corresponding least distance lines are drawn on the graph depending upon the difference in $T_s$ and $T_c$ of the consecutive activities. The critical vertices (if any) can be mathematically calculated using the slope equation as all other parameters are known for an activity in consideration.

Having quantified the parameters controlling the critical activities, the critical segments are identified by the tracing a continuous path from the end of the last activity as explained earlier. The linear schedule thus obtained has been shown in Figure 4.17. From this figure, it is once again observed that in linear projects activities can be critical for the entire length of the project or only for intermediate portions or at the beginning or end of the project. The distances and durations for which the activities are critical are tabulated in Table 4.10. From Table 4.10, for instance it is seen that activity B is critical between km 14.47 and km 14.94 for a duration of 4 days. This means that the progress of this portion of activity B is critical between km14.47 and km14.94 for 4 days and floats are available for the balance portion of this activity as shown in the Figure. Similar interpretations can be made for the other activities also. Also, the project can be completed in 122 days only if the progress rates of these critical activities or segments are maintained as scheduled. Therefore the critical activities or segments in a linear schedule
Figure 4.17 Linear Schedule of Sample Road Project
(km14.00 – km 16.00)

determine the optimal duration of a linear project just as the critical path
determines the total duration of the project with the CPM.
Table 4.10 Critical Paths for Sample Road Project (km 14.00 to km 16.00)

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity Description</th>
<th>Start (km)</th>
<th>End (km)</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Clearing and Grubbing</td>
<td>14.00</td>
<td>16.00</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>Earthwork Excavation</td>
<td>14.47</td>
<td>14.94</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>Embankment and Subgrade</td>
<td>14.00</td>
<td>16.00</td>
<td>21</td>
</tr>
<tr>
<td>D</td>
<td>Granular Subbase</td>
<td>14.00</td>
<td>14.38</td>
<td>4</td>
</tr>
<tr>
<td>E</td>
<td>Wet Mix Macadam</td>
<td>14.00</td>
<td>16.00</td>
<td>31</td>
</tr>
<tr>
<td>F</td>
<td>Kerb Casting</td>
<td>15.54</td>
<td>16.00</td>
<td>3</td>
</tr>
<tr>
<td>G</td>
<td>Asphalt Works</td>
<td>14.00</td>
<td>16.00</td>
<td>21</td>
</tr>
<tr>
<td>H</td>
<td>Bituminous Concrete</td>
<td>14.00</td>
<td>16.00</td>
<td>21</td>
</tr>
</tbody>
</table>

Having analyzed the linear schedule in Figure 4.17 and the critical paths in Table 4.10 for the above illustration, the following inferences are drawn.

i) As \( T_c(H) - T_c(G) = T_s(H) - T_s(G) \), Activity H is totally critical allowing no floats between them. In other words the end or the last activity in a linear project becomes totally critical when the difference between its \( T_s \) and the \( T_s \) of the preceding activity is equal to the difference between its \( T_c \) and the \( T_c \) of the preceding activity. Also, when the least time intervals at the start and end of a last activity with its preceding activity become equal, their least distances also become equal, making the last activity entirely critical.

Consequently the first or the starting activity in a linear project also becomes entirely critical when the least time intervals at the start and end of a first activity with its succeeding activity becomes equal. Further when the least time intervals for an intermediate activity with both its succeeding and preceding activity at its start and end become equal, such an intermediate activity also becomes entirely critical.
ii) As $T_c(H) - T_c(G) = T_s(H) - T_s(G)$ and $T_s(G) > T_c(F)$, activity G becomes totally critical allowing no floats. In general an intermediate activity in consideration becomes totally critical when the least time intervals between it and its succeeding activity are equal at its start and end and when the starting duration of this activity is equal to or greater than the ending duration of the preceding activity. Conversely when the least time interval for an intermediate activity with its preceding activity becomes equal at its start and end and if its ending duration is lesser than or equal to the starting duration of its succeeding activity, such an intermediate activity becomes entirely critical.

Consequently, an end activity satisfying only the second condition as mentioned above can make it totally critical (i.e.) when the starting duration of an end activity is greater than or equal to the ending duration of its preceding activity. On the contrary, the first activity becomes entirely critical when its ending duration is lesser than or equal to the start of its succeeding activity.

iii) As $T_c(F) < T_s(G)$ and $T_c(F) - T_c(E) < T_s(F) - T_s(E)$, activity F becomes critical at the ending portion for a distance of $L_c(F) - L_{dc}(F)$ km and duration $T_c(F) - T_{dc}(F)$ days. In general an intermediate activity in consideration becomes critical at its ending portion for a distance of $(L_c - L_{dc})$ km of that activity and for a duration of $(T_c - T_{dc})$ days when its completion time is less than or equal to the start time of its succeeding activity and the least time interval of this activity with its preceding activity is at their ends. Further an intermediate activity can also become critical at its end when the least time intervals are at its end with both its succeeding and preceding activity.
Consequently an end activity can become critical at its end when it satisfies only the second condition as mentioned above (i.e.) when its least time interval with its preceding activity is at their ends.

iv) As $T_c(F)-T_s(E)< T_s(F)- T_s(E)$ and $T_c(E)- T_s(D)> T_s(E)-T_s(D)$, activity E becomes entirely critical for a distance of $L_c(E) - L_s(E)$ km and duration $T_c(E)-T_s(E)$ days. In general an intermediate activity in consideration becomes totally critical for its duration when the least time interval between it and the succeeding activity is at their ends and least time interval between it and the preceding activity is at their starts.

Consequently, it is possible for an end activity to be entirely critical if it satisfies only the second condition mentioned above (i.e.) when the least time interval between it and its preceding activity is at their starts.

v) As $T_c(E) - T_c(D)> T_s(E)-T_s(D)$ and $T_s(D)=T_c(C)$, activity D becomes critical at the beginning portion for a distance $L_{ds}(D)-L_{s}(D)$ km and duration $T_{ds}(D)-T_s(D)$ days. In general an intermediate activity in consideration becomes critical at its start when the least time interval between it and its succeeding activity is at their starts and the start of this activity is greater than or equal to ending duration of its preceding activity. Also, an intermediate activity can become critical at its start when its least time intervals with both its succeeding and preceding activity are their starts.

Consequently, it is possible that the first activity can become critical at the beginning portion when the least time interval between it and its succeeding activity is at their starts.

vi) As $T_s(D)=T_c(C)$ and $T_c(C) - T_c(B)> T_s(C)-T_s(B)$, activity C becomes entirely critical for a distance of $L_c(C) - L_s(C)$ km and duration $T_c(C)-T_s(C)$ days. In general an intermediate activity can also become totally
critical when its completion time is equal to or less than the start of the succeeding activity and the least time interval between it and the preceding activity is at their starts.

vii) As $T_s(C)-T_s(B)<T_s(C)-T_s(B)$ and $T_s(B)-T_s(A)<T_s(B)-T_s(A)$ activity B becomes critical at the intermediate portion for a distance of $L_{dc}(B)-L_{ds}(B)$ km and duration $T_{dc}(B)-T_{ds}(B)$ days. In general if the least distance interval between the activity in consideration and its succeeding activity is at their starts and that with the preceding activity is at their ends, then an intermediate activity becomes critical at the middle portion for a period $(T_{dc}-T_{ds})$ days and for a distance $(L_{dc}-L_{ds})$ km.

viii) As activity A is the first activity, it becomes totally critical as $T_s(B)-T_s(A)<T_s(B)-T_s(A)$. In general the first activity becomes totally critical when its least time interval with its succeeding activity is at their ends.

From the above analysis of the parameters and its various conditions, the following general equations can be used to identify the criticality of the activities in linear projects with continuous full span activities.

a) The last or ending activities in linear projects become totally critical for $L_{c}(a_e)-L_{s}(a_e)$ km and for a duration $T_{c}(a_e)-T_{s}(a_e)$ days when

1) $T_c(a_e)-T_c(a_{e-1})=T_s(a_e)-T_s(a_{e-1})$ \hspace{1cm} (4.7)

or when

2) $T_s(a_e)>or=T_c(a_{e-1})$ \hspace{1cm} (4.8)

or when

3) $T_c(a_e)-T_c(a_{e-1})>T_s(a_e)-T_s(a_{e-1})$ \hspace{1cm} (4.9)
b) Ending activities become critical at its end for a distance $L_c(a_c)$-$L_{dc}(a_c)$ km for a duration $T_c(a_c)$-$T_{dc}(a_c)$ days when

1) $T_c(a_c) - T_c(a_{c-1}) < T_s(a_c) - T_s(a_{c-1})$ \hspace{2cm} (4.10)

In Equations 4.7 to 4.10, ‘$a_c$’ represents any end activity and ‘$a_{c-1}$’ represents the preceding activity to any end activity.

c) Intermediate activities become critical entirely for $L_c(a_m)$-$L_s(a_m)$ km for a duration $T_c(a_m)$-$T_s(a_m)$ days when

1) $T_c(a_{m+1}) - T_c(a_m) = T_s(a_{m+1}) - T_s(a_m)$ \hspace{2cm} (4.11)

and

$T_s(a_m) \geq T_c(a_{m-1})$ \hspace{2cm} (4.12)

or when

2) $T_c(a_m) - T_c(a_{m-1}) = T_s(a_m) - T_s(a_{m-1})$ \hspace{2cm} (4.13)

and

$T_c(a_m) \leq T_s(a_{m+1})$ \hspace{2cm} (4.14)

or when

4) $T_c(a_{m+1}) - T_c(a_m) < T_s(a_{m+1}) - T_s(a_m)$ \hspace{2cm} (4.15)

and

$T_c(a_m) - T_c(a_{m-1}) > T_s(a_m) - T_s(a_{m-1})$ \hspace{2cm} (4.16)

or when

5) $T_c(a_m) - T_c(a_{m-1}) > T_s(a_m) - T_s(a_{m-1})$ \hspace{2cm} (4.17)

and

$T_s(a_{m+1}) \geq T_c(a_m)$ \hspace{2cm} (4.18)
Intermediate activities become critical at the end for a distance of $L_c(a_m) - L_{dc}(a_m)$ km and for a duration $T_c(a_m) - T_{dc}(a_m)$ days when

1) $T_c(a_m) - T_c(a_{m-1}) < T_s(a_m) - T_s(a_{m-1})$ (4.21)

and

$$T_s(a_{m+1}) \geq T_c(a_m)$$ (4.22)

or when

2) $T_c(a_{m+1}) - T_c(a_m) < T_s(a_{m+1}) - T_s(a_m)$ (4.23)

and

$$T_c(a_m) - T_c(a_{m-1}) < T_s(a_m) - T_s(a_{m-1})$$ (4.24)

Intermediate activities become critical at the starts for a distance of $L_{ds}(a_m) - L_s(a_m)$ km and for a duration $T_{ds}(a_m) - T_s(a_m)$ days when

1) $T_s(a_{m+1}) - T_s(a_m) < T_c(a_{m+1}) - T_c(a_m)$ (4.25)

and

$$T_s(a_m) > T_c(a_{m-1})$$ (4.26)

or when

2) $T_s(a_{m+1}) - T_s(a_m) < T_c(a_{m+1}) - T_c(a_m)$ (4.27)

and


\[ T_s(a_m) - T_s(a_{m-1}) < T_c(a_m) - T_c(a_{m-1}) \] (4.28)

Intermediate activities become critical at the middle portions for a distance of \(L_{dc}(a_m) - L_{ds}(a_m)\) km and for a duration \(T_{dc}(a_m) - T_{ds}(a_m)\) days when

1) \(T_s(a_{m+1}) - T_s(a_m) < T_c(a_{m+1}) - T_c(a_m)\) \hspace{1cm} (4.29)

and

\[ T_s(a_m) - T_s(a_{m-1}) > T_c(a_m) - T_c(a_{m-1}) \] (4.30)

In Equations 4.11 to 4.30 ‘\(a_m\)’ represents any intermediate activity, ‘\(a_{m+1}\)’ represents the succeeding activity to any intermediate activity and ‘\(a_{m-1}\)’ represents the preceding activity to any intermediate activity.

Starting activities in linear projects become totally critical for \(L_c(a_s) - L_s(a_s)\) km for a duration \(T_c(a_s) - T_s(a_s)\) days when

\[ T_c(a_{s+1}) - T_c(a_s) = T_s(a_{s+1}) - T_s(a_s) \] (4.31)

or when

\[ T_s(a_{s+1}) \geq T_c(a_s) \] (4.32)

or when

\[ T_c(a_{s+1}) - T_c(a_s) < T_s(a_{s+1}) - T_s(a_s) \] (4.33)

Starting activities in linear projects become critical at their starts for \(L_{dc}(a_s) - L_s(a_s)\) km for a duration \(T_{dc}(a_s) - T_s(a_s)\) days when

\[ T_c(a_{s+1}) - T_c(a_s) > T_s(a_{s+1}) - T_s(a_s) \] (4.34)

In Equations 4.31 to 4.34 ‘\(a_s\)’ represents any starting activity, ‘\(a_{s+1}\)’ represents the succeeding activity to any starting activity.
Therefore, it is seen from the equations presented in this section that critical activities in linear projects are totally controlled by the relationships and values of the parameters discussed. LSM provides us with vital information as far as scheduling sections of a road project for smoothened progress rates. Complex methods to deal with LSM for varying progress rates have also been suggested (Lucko 2009) but may become difficult for site personnel unless more user friendly software is made available. Linear schedules are best suited for road projects where appreciable section distances are available to accommodate crews following each other maintaining minimum buffer distances.

Highway construction projects typically exhibit work progress simultaneously in various sections at different locations of the project. Distance-time scheduling of individual sections in the project may confine planning only to a portion of the project depending on the size of the project and does not include all the dimensions of the activity. Hence, the scheduling approach of constructors needs to be oriented towards achieving their production objectives and a tool that can assist them in such a situation.