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Evaluation of Critical Path Methods For Linear Projects

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Abstract

Critical path determination in a linear schedule is essential in order to provide a widely accepted method for scheduling linear projects. The last five years, two methods have been proposed for the determination of the critical path. Research done on the comparison of the two methods, concluded that their results coincide for some simple activity configurations. This paper expands the comparison by including a third method developed by the authors and more complicated activity configurations. The results obtained are discussed.

Keywords

Construction, Linear Projects, Linear Schedule, Repetitive Projects

1. Introduction

It is argued that network-scheduling methods (CPM, MPM etc) are not effective when applied to projects that include repetitive activities (Birrell 1980; Selinger 1980; Johnston 1981; Russell and Wong 1993). Such projects, called linear projects, include highways, pipelines, tunnels, multi-story buildings, multi-housing units etc. Some reasons that support the abovementioned argument are: the arbitrary division of repetitive activities, the inability to schedule the continuity of resources, the large number of activities necessary to represent a linear schedule in a network method, the fact that the progress rate is not indicated, and the fact that network methods do not provide any information where on the project site work is currently being performed (Mattila 2003). A series of alternative methods have been proposed for linear projects under the rubrique term of linear scheduling methods (Stradal and Cacha 1982; Arditi and Abdulak 1986; Chrzanowski and Johnston 1986; Al Sarraj 1990; Harmelink 1998, Harris and Ioannou 1998). These methods produce an easily understandable way of planning and measuring progress against time in a X-Y axis plot. Nevertheless, linear scheduling methods have limitations, the most important being that they can be applied only on linear projects; and even in linear projects non-repetitive activities have to be scheduled with network methods. Moreover, none of the abovementioned methods has had wide acceptance and use. Another reason why linear scheduling has not become a popular method is because there is no straightforward, unanimously accepted method for identifying the critical path, like the CPM. Mattila (2003) presented a comparison of two linear scheduling methods, the LSM (Harmelink 1998) and the RSM (Harris 1998) in simple activity configurations and concluded that for these specific cases, the two methods gave the same controlling activity path. The authors developed the (Kallantzis-Lambropoulos) Repetitive Project Model (RPM), for identifying the controlling activity path in a linear schedule. This paper compares the results of the three methods for some simple activity configurations similar to the ones used by Mattila (2003), and expands the comparison in some more complicate examples initiated by the authors. The methodology of the three models is discussed briefly below, being more elaborate on the (KL)RPM.

2. Methodology for Determining the Controlling Activity Path

2.1 LSM

Determination of the controlling activity path with the Linear Scheduling Model (LSM) consists of three steps. First, the activity sequence list is found, then, in analogy with the CPM, an upward and a downward pass are performed. The activity sequence list, a list of potential paths in the linear schedule, is detemined by drawing a vertical line through the schedule. From all the potential paths, the controlling will be the one with the shortest Least Time (LT) interval duration, where LT is the shortest vertical line between two consecutive activities (activities that can be connected vertically without crossing another activity). The upward pass is performed next. The aim of the upward pass is to identify the potential controlling segments of the activities. Starting with the first activity in the activity sequence list, the segment from the origin up to where the Least Distance (LD) with the target activity occurs, is a potential controlling segment. The target activity becomes the origin activity and the procedure is iterated until all activities in the sequence list are examined. Finally, the downard pass is performed in order to identify which part of the potentially controlling segments is actually on the controlling path. Starting from the last activity, the path follows it until the potential controlling link with the previous activity is reached; there it moves horizontally towards it; the process is repeated until the first activity is reached.

2.2 RSM

The Repetitive Scheduling Method (RSM) method for identifying the controlling path hinges on control points. Control points are the points in the schedule where the controlling path will pass from one activity to another; they will take place towards the end or the start of an activity depending on whether two consecutive activities are converging or diverging respectively. Once the control points are determined, the controlling path is found by tracing through the project from the last activity, shifting from activity to activity at the control points.

2.3 (KL)RPM

Controlling path determination in the (KL)RPM is based on time and distance constraints, similar to the time and stage buffers as defined by Reda (1990). Activities in the schedule are placed the closest possible to each other as long as the time and distance constraints between them are not violated. The method consists of two steps: First the potential critical activities are identified and then the critical path is calculated. In order to identify the potential critical activities the process starts from the last activity of the project moving through every activity's driving predecessor until the first activity is reached. This procedure ensures that the longest path in the schedule has been identified. After the potential critical activities have been identified, their critical parts are determined. Starting from the end of the last activity, the critical path moves through it until it reaches the point where the constraint with the driving predecessor lies; there it shifts towards its driving predecessor horizontally or verticaly depending on whether it is a distance or a time constraint. The procedure continues until the beginning of the first activity is reached. The segment of each activity between the trace of the constraints of its driving predecessor and its driving successor belongs to the controlling sequence.

3. Methodology Comparison

The three methods are compared initially for some simple activity configurations, similar to the ones presented by Mattila (2003) for the LSM and the RSM. Since the results for the RSM and the LSM have been extensively commented, more focus is given on the results of the KLRPM. Further down the text, the three methods are compared for some more complex configurations initiated by the authors.

3.1 Simple activity configurations

The three methods are compared for the simple situations of two diverging activities (fig. 1), two converging activities (fig 2) and two activities with changing production rates (fig.3).

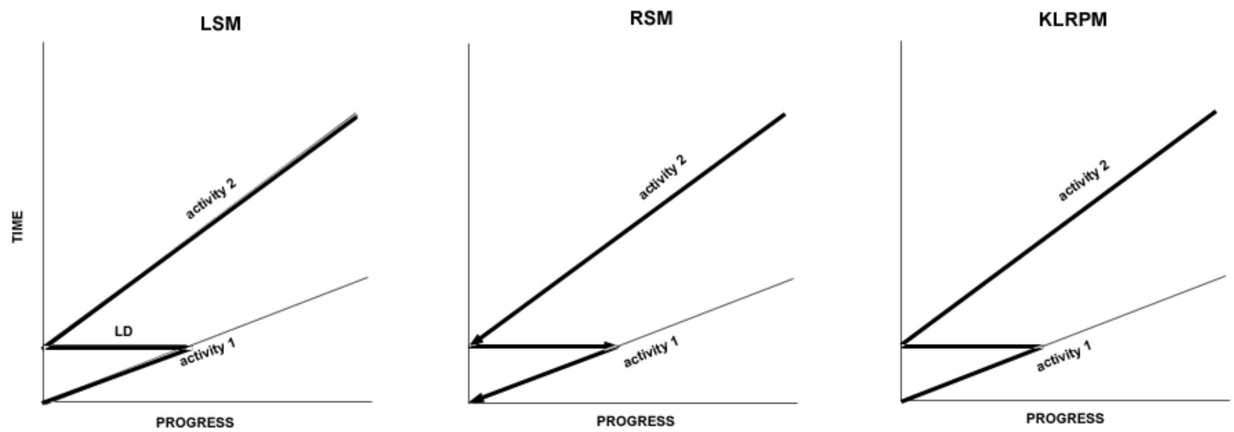

Figure 1. Diverging activities

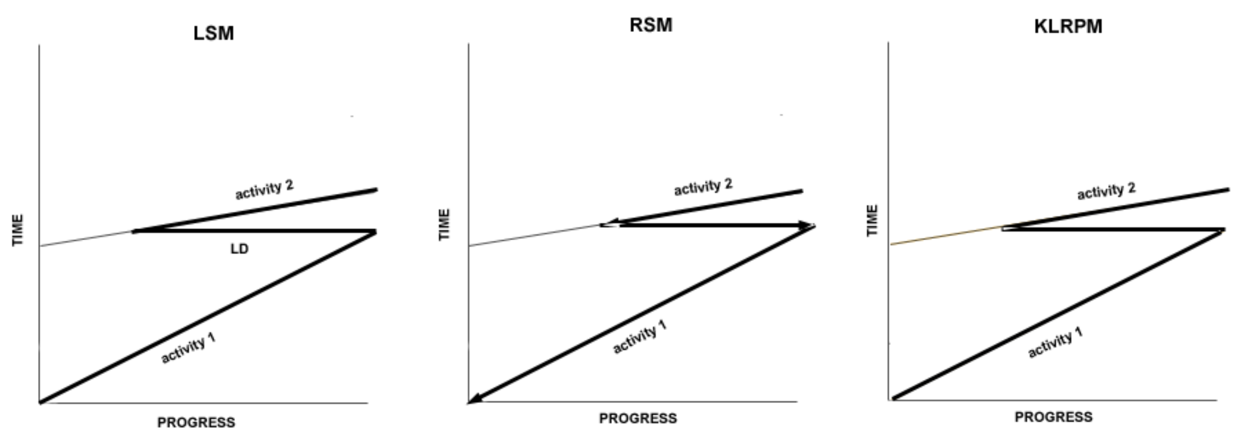

Figure 2. Converging activities

For the example of figure 1, it is assumed for the KLRPM that activities 1 and 2 are linked with a distance constaint, indicating that they cannot approach more than a specified amount in the horizontal axis e.g. stations in a highway project, floors in a high-rise building or units in a multi-unit housing project. Potential critical activities are activity 2 (last activity) and activity 1 (its driving predecessor). Starting from the end of activity 2 the controlling path is moving until the point where the constraint with activity 1 lies. There, the path shifts horizontally to activity 1 since the two activities are linked with a distance constraint. The same procedure is followed for the examples in figure 2 and 3. As it can be seen, the three methods give the same results for these simple configurations. It has to be noted though, that the proposed mehod and the RSM, contrary to the LSM, take under consideration the relationships between the activities in order to identify the controlling sequence.

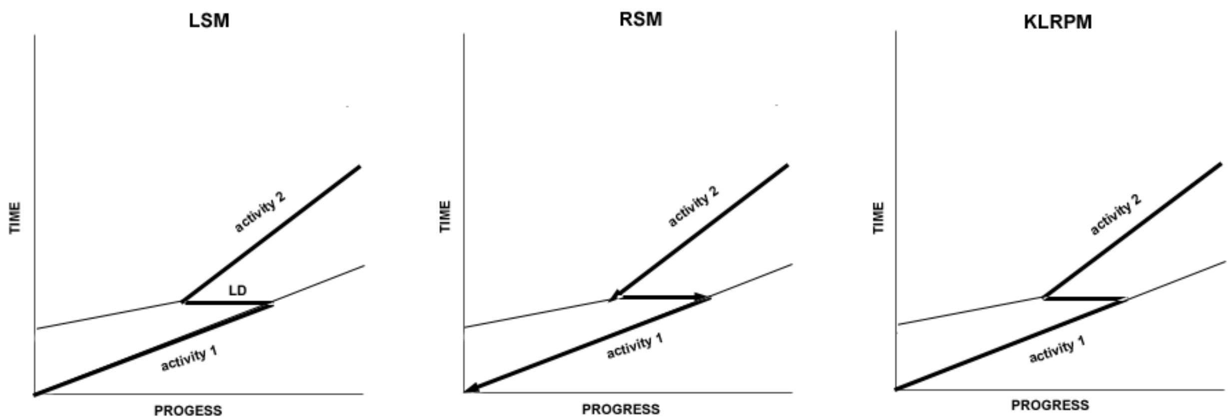

Figure 3. Activities with multiple production rates

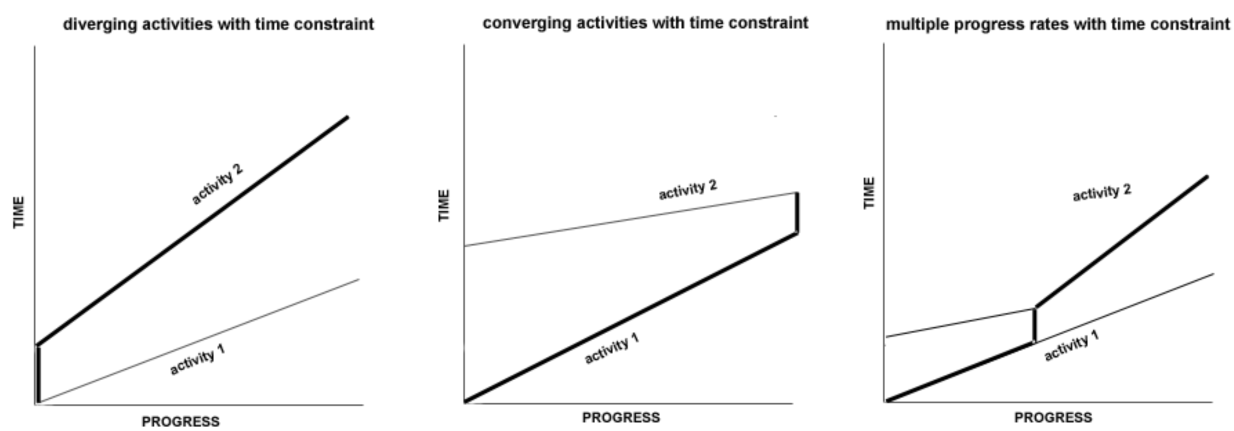

Figure 4. Proposed method with time buffer

In the situation where activity 2 was linked to activity 1 with a time constraint, instead of a distance constraint which was the situation in figures 1-3, the result for KLRPM would be the one shown in figure 4. In this situation, when the point of the constraint is reached in activity 2, the path moves vertically to activity 1, so the controlling path is different.

3.2 Complex activity configurations

The more complex activity configurations include an example with three activities and another with four activities, two of them are intersecting. In the activity configuration of figure 5, the controlling path for the LSM is different than the one of the RSM and the (KL)RPM (which coincide). The critical path for (KL)RPM starts from the end of activity 3 until it reaches the point of the distance constraint. There it shifts horizontally to activity 2 and moves upward in time until it reaches the point of the distance constraint with activity 1. Then it shifts horizontally and follows activity 1 until its start.

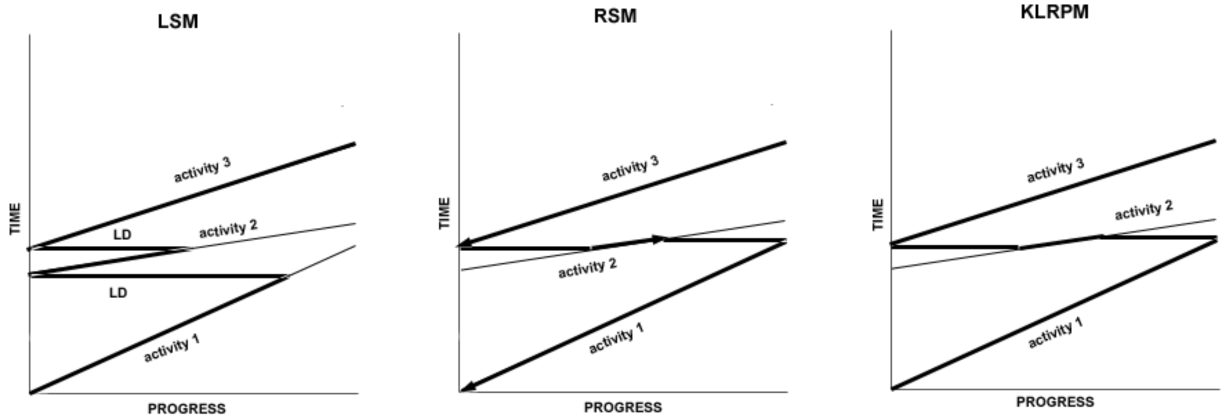

Figure 5. Example with three activities

Let's assume the configuration of figure 6. The LSM cannot provide a solution; the least distance between activity 4 and 2 or 3 cannot be calculated since activities 2 and 3 are intersecting. The RSM and the KLRPM though provide solution, which is the same providing that the activities are linked with a distance constraint. For (KL)RPM, the potential critical activities are found starting from the activity 4, following its driving predecessors. Activity 2 proceeds in parallel with activity 3, but it is not a driving predecessor of activity 4.

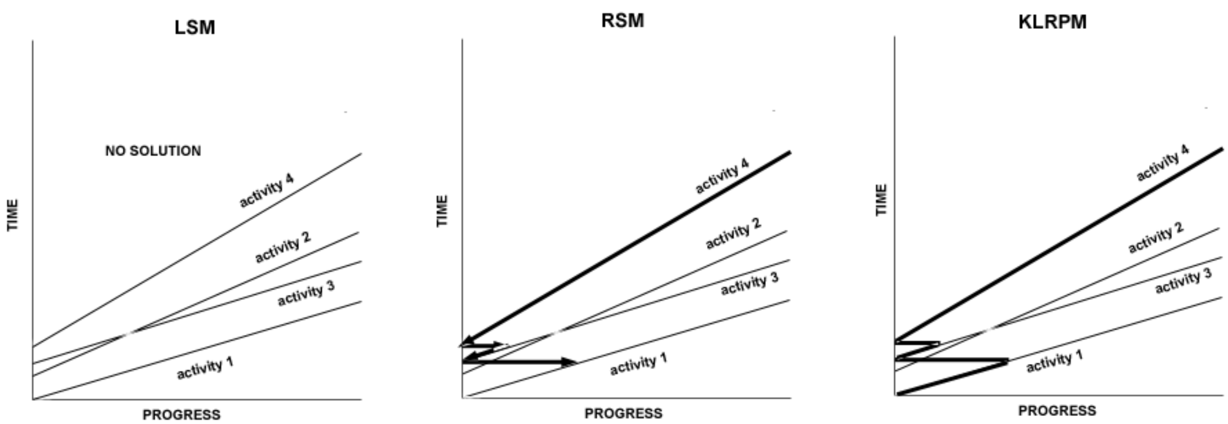

Figure 6. Example with intersecting activities

The critical path is found starting from the end of activity 4 until the constraint with activity 3 (its driving predecessor) is reached; it then shifts horizontally to activity 2 and proceeds until the constraint with activity 1 is reached. Finally, it shifts to activity 1 and follows it until its start.

4. Conclusions

Taking the above examples under consideration it is apparent that the three methods provide the same results for two-activity situations (assuming a distance constraint for the (KL)RPM), but tend to differentiate when applied to more complex configurations. In contrary to LSM, (KL)RPM and RSM provide similar results for the examined configurations. This is due to the fact that both methods take under consideration the links between the activities when calculating the controlling path. It has to be noted though, that the (KL)RPM has variable results depending on the type of relationship between an activity and its driving successor or predecessor. Besides the above, the three methods have different limitations, as shown in the example of figure 6, a fact that makes comparison even more difficult. Due to space limitation, neither the results of each method were explained extensively - even though more weight was given on the (KL)RPM - nor other examples that demonstrate the differences between the three models were presented. The purpose of this paper was to show that there are differences among the results of the three methods and further research should be conducted towards the evaluation of the most applicable method.

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