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An Estimation of the Learning Effect on Project Cost Scheduling

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Abstract

The effect of the learning phenomenon (learning curve) on project cost and scheduling is discussed in this paper. Although learning is an essential part of life, traditional scheduling techniques cannot efficiently handle the learning curve effect. It is assumed that the durations of impending repetitive activities, performed by the same workers, are shorter due to the learning curve effect, therefore no additional acceleration cost is necessary and the deployment cost before the second activity can also be neglected if the gap between consecutive activities is small enough. Taking into consideration the effects of the learning curve (or experience curve), it is possible to reduce project duration and cost. According to this study a 0.4%-1% reduction in project cost and a 9-40% reduction in acceleration cost on a given project duration is available. Although the effect is a "simple" calculation, it leads to an exponential time algorithm if the learning effect is applied to traditional project scheduling techniques like Critical Path Method (CPM), or Precedence Diagramming Method (PDM). In this paper, an integer programming model is developed, and an efficient algorithm is used to estimate the project cost curve. The results are validated through an artificial example project.

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Keywords: Project Scheduling, Learning Effect, Learning Curve, integer programming.

1. Introduction

The original cost scheduling problem or least cost scheduling problem developed by Kelley and Walker [1] was to find the minimum cost of a project for a given project duration. There are normal and crash activity time that are smaller or equal to normal activity time, moreover, a normal cost and crash cost for each activity, where crash cost is greater or equal to normal cost The change of the cost is described by linear function within the interval of normal and crash duration. In mathematical terms: given a directed graph, where vertices and directed edges are given. There are three given integer numbers related to each edge. Two of them are the crash time and normal activity time, and the third is the daily acceleration cost. When activity time is equal to its normal time, the acceleration cost is 0; with crash time, it is daily acceleration cost times the days between normal and crash time. The goal in the cost scheduling problem is to find the minimum acceleration cost for a given project duration within the interval of the maximum and minimum project duration [2].

It is assumed that the learning effect can occur and cause a smaller activity time, without increasing the acceleration cost, of a given activity if the same group of workers performed a similar activity as an immediate predecessor of the given activity. The question is: what is or what can be the effect of the sum of the reductions of activity times on the project acceleration cost. In [3],

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in a case study, the minimum project duration decreased to 530 from 467 days. The increment of the project acceleration cost in this interval was € 4 755 537, which suggests that a 63-day shortening of the project duration is possible and this costs less than 10% of the contracted fee.

In a construction project, the general contractor distributes the job among subcontractors. Typically, subcontractors rarely start their work at the earliest possible time. If a subcontractor is scheduled to work on one project, but at different times, typically, they will not want to split the work. It is obvious that they can reduce their costs if they work continuously. There are two main reasons for this: first, they can reduce their construction cost; secondly, they can finish their work earlier because of the learning effect. Unfortunately, this effect in the early phase of scheduling is not considered.

T.P. Wright described the effect of learning on production costs in the aircraft industry [4].

In the literature, there are several papers on the learning effect of construction: [5] , [6] , [7] , [8] , [9], [10]. Learning curve theory can be applied to predict cost and time, generally in units of time, to complete repetitive activities [11], [12]. Several researchers have suggested that Wright's model is the best model available for describing the future performance of repetitive work [13], [14]. In [15] the exponential average method, α =0.5 yielded the most accurate predictions. Of course, there is no consensus on which model provides the best fit and predictability for construction data [16]. Consequently, more theoretical and experimental investigations are necessary to adjust a model according to the real problems.

In [17] and [18] the learning effect on project duration is investigated. Both artificial and real problems were used to study the effects of learning on project duration. It is shown that the cumulative learning effects of activities in a project can cause a 1-3% reduction in project duration.

In construction project management, the proper scheduling of a project is an essential problem. Estimation of an activity's time is a crucial part of the schedule. There is little information in the literature about the use of learning curves in scheduling, although it seems that the principle of learning curves gathers ground in the scheduling of repetitive construction operations [19], [20]. In [21] the learning curve effect on linear scheduling method is discussed. The impact of learning curves is not calculated in recent management software [22].

2. Learning Curve

Learning curve theory applies to the prediction of the cost or time of future work, assuming repetitive work cycles with the same or similar working conditions regarding technology, weather and workers, without delay between two consecutive activities. The direct labour required to produce the (x + 1) st unit is always assumed to be less than the direct labour required for the xth unit. The reduction in time is a monotonically decreasing function, an exponential curve, as described in Wright's 1936 paper.

Wright's linear log x, log y model is as follows:

$$lny = lna + blnx;\vee\, y = ax^{b} = ax^{log_2 r}$$

where x is the cycle number; y is the time required to complete cycle x in labour hours/square meter; 'a' is the time required to complete the first cycle; 'b' is a learning coefficient, and 'r' is the rate of learning. For example, if r=0.9 (90%), then b=-0.151 see Figure 1. Wright discovered that when the labour cost decreases at a constant rate, that is, the learning rate, the production/cycles doubles. So, learning rate is the constant rate with which labour time/cost decreases when the production/cycles double in a linear log x, log y model. This feature of the learning rate comes from the logarithms nature and is true only in the linear log x, log y model.

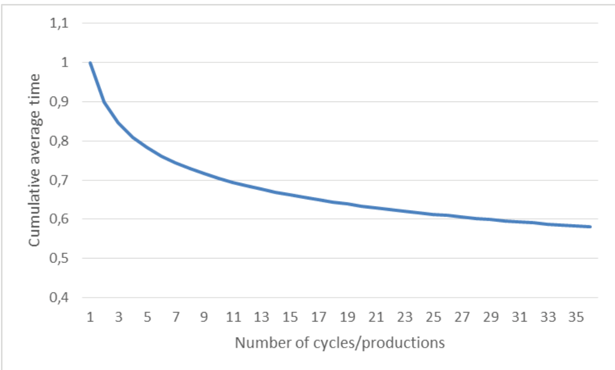

Fig. 1 Learning curve with 90% learning rate