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ScienceDirect

Procedia Engineering 196 (2017) 730 – 737

Procedia Engineering

www.elsevier.com/locate/procedia

Creative Construction Conference 2017, CCC 2017, 19-22 June 2017, Primosten, Croatia

An Estimation of the Learning Curve Effect on Project Scheduling with Calendar Days Calculation

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Abstract

Although learning is an essential part of life, traditional scheduling techniques cannot efficiently handle this effect. Considering the effects of the learning curve, it is possible to make a better prediction of project duration thus saving time and money. In this paper, a learning curve (or experience curve) effect on project duration is shown and calculated with calendar days. In the literature, project scheduling has been studied; however, only a few papers take the learning effect on project duration into consideration. The learning effect on project duration with the help of test problems and real problems was investigated. In test problems learning curve effect can occur between two consecutive activities. These pairs are chosen randomly. After calculating project duration, these pairs are allocated to be closer to each other using the predecessor’s total float time. It is assumed that the duration of impending repetitive activities is shorter due to the learning curve effect if the gap between consecutive activities is small enough. This iteration is carried out until it is not possible to shorten the successor’s activity time in a pair. It is shown that this effect brings a 1-3% shorter project duration. This “Calendar Days” calculation led to an integer programming problem that was solved by Matlab Parallel Computing Toolbox. 2.

Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2017

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

1. Introduction

In this paper, project scheduling in mathematical terms means finding the longest path in a directed graph, where vertices and directed edges are given. Also, there is a given integer number attributed to each edge. In engineering terms, directed edges represent activities or connections between activities, vertices are nodes or events, and integer numbers represent activity times or time lags between activities. It is assumed that the learning effect can occur and result in a smaller activity time of a given activity if the same group of workers perform a similar activity as an immediate predecessor of the given activity. The question is: what is or what can

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Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2017
doi:10.1016/j.proeng.2017.08.001

be the effect of the sum of the reductions of activity times on the project duration. This effect is calculated using calendar days, which leads to a more complex mathematical model and algorithm than calculating using only working days [1].

In a construction project, the general contractor distributes the work 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 costs; secondly, the work will be completed sooner because of the learning effect. Unfortunately, in the early phase of scheduling, this effect is not considered.

Fundamentally, there are two different methods for calculating the activity time of repetitive activities: unit time and cumulative average time methods. The unit time method means that the time of a doubled unit equals the time of the unit times the slope of the learning curve. The cumulative average method means that the cumulative average time of a doubled unit equals the cumulative average time of the unit times the slope of the learning curve. This was used in the original formulation of the learning curve method, referred to as Wright's model, in Wright's famous paper on the subject [2].

In [3], in a multi-project environment, the learning effect of staff was considered when periodically scheduling the tasks for each project and assigning staff to the tasks. The solution leads to a mixed nonlinear program for project scheduling and staff allocation problems, which considers the learning effect of staff. A genetic algorithm (GA) is proposed to solve the problem. [4] investigate the project scheduling problem with multiskill learning effect, where both autonomous and induced learning is considered.

In practice, project scheduling methods suffer from a lack of precision; consequently, it is a significant challenge to create a realistic and usable project schedule. It is difficult and time-consuming to estimate time, assign resources, determine interdependencies between tasks, and manage changes. It is, therefore, important to identify and investigate the differences between the practice and theory of scheduling methods [5] (Francis et al., 2013). In the literature, there are several papers on learning effect of construction: [6], [7], [8], [9], [10], [11], [12], [13]. Learning curve theory can be applied to predict cost and time, generally in units of time, to complete repetitive activities [14], [15]. Several researchers have suggested that Wright's model is the best model available for describing the future performance of repetitive work [9], [13]. In the exponential average method [16], 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 [17]. Consequently, more theoretical and experimental investigations are necessary to adjust a model according to the real problems.

In construction project management, the appropriate 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 is gathering ground in the scheduling of repetitive construction operations [18], [19]. In [20], the learning curve effect on linear scheduling method is discussed. However, it should be noted that the impact of learning curves is not calculated in recent management software [21].

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:

$$lny = lna + blnx; \vee\ y = ax^b = ax^{log_2 r} \quad (1)$$

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.