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Resource Leveling in Construction Projects using Re- Modified Minimum Moment Approach

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***Abstract*—**An attempt in this paper proposes a re-modification to the minimum moment approach of resource leveling which is a modified minimum moment approach to the traditional method by Harris. The method is based on critical path method. The new approach suggests the difference between the methods in the selection criteria of activity which needs to be shifted for leveling resource histogram. In traditional method, the improvement factor found first to select the activity for each possible day of shifting. In modified method maximum value of the product of Resources Rate and Free Float was found first and improvement factor is then calculated for that activity which needs to be shifted. In the proposed method the activity to be selected first for shifting is based on the largest value of resource rate. The process is repeated for all the remaining activities for possible shifting to get updated histogram. The proposed method significantly reduces the number of iterations and is easier for manual computations.

***Keywords*—**Re-Modified, Resource Leveling, Resources Rate, Free Float, Resource Histogram

I. INTRODUCTION

RESOURCE leveling is a solution to the problem of resource conflicts, which results from two or more activities struggle for the same resources, with limited time constraint. The problem of resource leveling can be solved either with situations of limited resources which often leads to the extension of project duration or the situation of unlimited resources within time constraint.

The aim of this paper is to introduce re modification to modified minimum moment approach suggested by Mohammad Hiyassat [1], which is a modification to traditional minimum moment method by Harris[2]. The proposed method is based on the assumptions of unlimited availability of resources with limited time duration. The objective of this paper is to simplify the calculations of resource leveling by minimum moment approach without Sacrificing the accuracy of the final result. To provide the better understanding of re-modified method, its applicability in construction project, the minimum moment approach theory by Harris [2] and modified minimum moment approach suggested by Mohammad

Hiyassat [1] are presented in short. A re-modified approach is developed and explained with the results of earlier methods.

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II. MINIMUM MOMENT METHOD

The minimum moment theory was presented by Harris [2]. It assumes limited project duration and unlimited resources. According to this theory, for each daily resource histogram, a statical moment can be found about its axis. Fig. 1 shows a given set, {A}, of elements y1, y2, y3, . . . , yn over the fixed set of intervals 1 to n. The set represents the area of a resource histogram. The elements yi represent the daily resource sums. Hence

$$\sum Y_i = \{A\} \tag{1}$$

The moment of an element about the axis 0-0 is $\frac{1}{2}(Y_i)^2$

The total moment of the set, therefore, is

$$M = \frac{1}{2}\sum(Y)^2 \tag{2}$$

As per theory, this moment tends to be minimal over a period of time if the shape of the resource histogram over that period is rectangle (i.e., without peaks and valleys). But it is difficult to achieve in reality. The objective is to reduce the differences between peaks and valleys in the resource histogram by shifting non critical activities from their original position to some other position. The duration for which the activity ‘i’ may be shifted is restricted to the value of its free float.

To explain the mathematical model of this theory, Fig. 2 shows a part of a bar chart in which activity J is to be shifted from its original position to another position. It is assumed that in a network a 1-day activity J having a resource rate (R) is to be shifted S days from an element Yi with X units of resources to an element Y2 that has W units of resources. The value of the moment of the resource histogram M0 before shifting is

$$M0 = \frac{1}{2}X^2 + \frac{1}{2}W^2 + \frac{1}{2}(\sum(\text{remaining ordinates})^2$$

The value of the moment M1 after shifting is

$$M1 = \frac{1}{2}(X-R)^2 + \frac{1}{2}(W+R)^2 + \frac{1}{2}(\sum(\text{other ordinates})^2$$

The difference between these two values, $M_1 - M_0$

$$\Delta M = \frac{1}{2}(X-R)^2 + \frac{1}{2}(W+R)^2 - \frac{1}{2}X^2 - \frac{1}{2}W^2$$

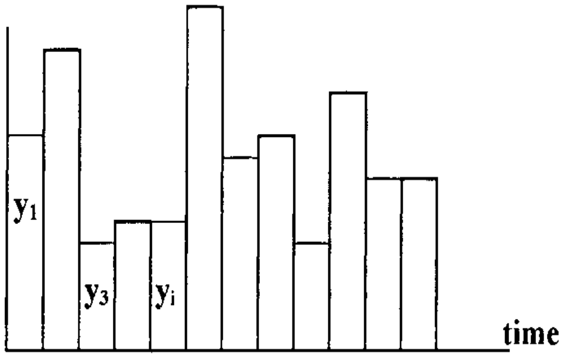

Fig. 1 Daily Resource Histogram

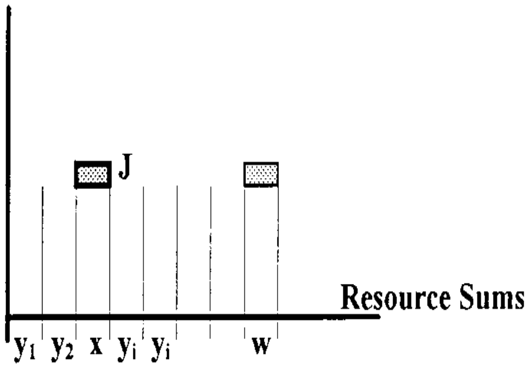

Fig. 2 Activity J—Part of Network

The above formula can be modified for the activity with t days of duration,

$$\Delta M = \frac{1}{2}\sum(X_i - R)^2 + \frac{1}{2}\sum(W_i + R)^2 - \frac{1}{2}\sum(X_i)^2 - \frac{1}{2}\sum(W_i)^2$$

A reduction in the moment i.e. negative value of ΔM indicates a positive improvement in the shape of the resource histogram. From the earlier equation the improvement factor is derived as follows,

$$\text{IF(activity J,S)= R}(\sum x - \sum w - mR) \quad (3)$$

Where,

IF = improvement factor;

S = number of days to be shifted;

∑x = sum of daily resources x1, x2, . . . , xm,
to which m daily resource rates (R) are to be deduced;

∑w = sum of daily resources w1, w2, . . . , wm,
to which m daily resource rates (R) are to be added;

m = minimum of either the days that the activity is to be shifted (S) or the activity duration (t) ; and,

R = resource rate.

If the improvement factor for a given activity is either positive or zero, then only activity can be shifted; otherwise, activity cannot be shifted. This method requires two cycles of calculations; one is forward cycle and other is backward cycle. In case of forward cycle, a resource improvement factor is calculated for all activities on the last sequence step of a network. From these calculations the largest positive improvement factor is determined, and the associated activity is shifted. These two processes are successively repeated for each sequence step until the first step is reached. A back float ki is created which is the lag time if an activity i is shifted while the preceding activity k remains in its early start position or is partially shifted. This back float is used in the backward cycle to examine for possible back shifting of the activities for further improvement. For this purpose, the calculations are repeated again, beginning from first sequence step and ending at the last step.

III. Modified Minimum Moment Method

This method is suggested by Mohammad Hiyassat [1]. This is the modification over traditional minimum moment approach in terms of the criteria of selecting the activity that has to be shifted from its original position to a better position. According to this method, the activities that lie at the same sequence step, the activity that is to be shifted first is selected based upon both the value of its free float(S) and the value of its resource rate (R). The criteria used for selecting an activity for possible shifting is the value in terms of multiplication of activity resource rate (R) and the free float(S) of that corresponding activity. In a sequence step of network, the values of (RxS) are calculated for all the activities and the activity having maximum value of (R x S) is considered for first possible shifting. At this stage the same improvement factor introduced by the traditional method is calculated. If the improvement factor for a given activity is either positive or zero, then only activity can be shifted; otherwise, activity cannot be shifted. To calculate the improvement factor (IF) the value of R is dropped from equation (3) as its value is constant for the same activity. Thus, the mathematical form of the improvement factor is as follows,

$$\text{IF(activity J,S)} = \sum x - \sum w - mR \quad (4)$$

The chosen activity is shifted to get maximum moment improvement within its limit of free float. The network and resource histogram is updated for selection of the next activity with the largest value of the term (R x S). The process continues up to first sequence step of the same network where forward cycle ends.

IV. Proposed Method

The proposed method is also based upon minimum moment approach theory by Harris but it is re modification over modified minimum moment method by Mohammad Hiyassat in terms of selecting criteria of the activity in sequence step of network. Therefore the assumptions for proposed method are same as that of Harris and Hiyassat.

The assumptions are as follows:

1. No interruption is expected once the activity started up to its completion.
2. Resources applied to each activity remains constant Through out their completion.
3. The duration of each activity remains constant.
4. The network logic is fixed.

5. The project's completion date is fixed

As in the earlier both the methods, the procedure starts from the last sequence step.

Among all the activities in sequence step, the criteria considered for selection of an activity for possible shifting is the largest value of activity resource rate (R). The improvement factor is computed by equation (4). If the improvement factor for a given activity is positive, then only activity can be shifted; otherwise, activity cannot be shifted. The chosen activity is shifted for moment improvement, within the constraint of its free float (S). If activity resource rate (R) are same for more than one activity, then criteria for selection of an activity for possible shifting is the largest value of free float (S) among the activities of same resource rate (R). If activity free float (S) is also same for more than one activity then select the activity having maximum duration. If still tied, then select any activity in the queue. The next activity to be considered for possible shifting is the activity having next largest R.

V. Discussion And Conclusion

The problem is solved by all the three methods resource histograms are compared as shown in fig.(3). The minimum moment by traditional method and re-modified method is identical. The resource improvement coefficient (RIC) is 1.2079 for both the methods and 1.19 by modified method.

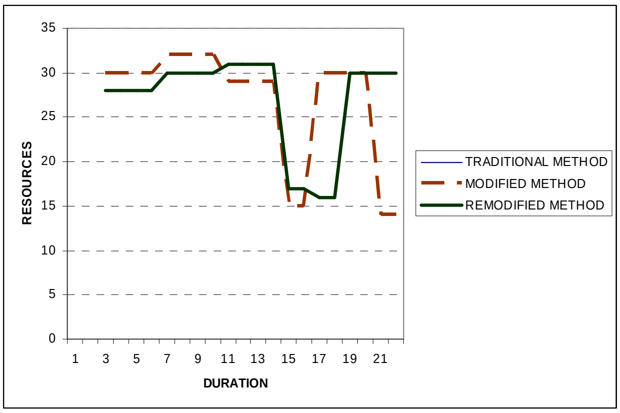

Fig. 3 Resource Histogram

The major difference between proposed Re – Modified method and modified method and traditional method is the criterion for selecting the activity to be shifted. The basis of selecting activity for possible shifting is largest activity resource rate and if tied then the largest value of free float. Possible shifting is to be carried out only for that activity which has maximum positive improvement factor. Mathematically these selection criteria can not be justified; still it is observed that the probability of a better histogram increases.

The accuracy of results by proposed Re-Modified method is identical or very close to that of Modified method and traditional method. It was checked by means solving several hypothetical networks against all the three methods. In most of cases results are identical or slight negligible deviations. But using proposed method, the calculations itself is easier and reduces the no. of iterations. The calculations by proposed method can be easily programmed in excel spread sheet.

As the algorithm assumes that every activity is independent with its position assignment, which is not necessary in every case. The final result may not provide true minimum moment of histogram every time.

Appendix

NOTATIONS

The following symbols are used in this paper:

M0 = statical before-shifting-moment of daily resource about axis 0-0;

M1 = statical after-shifting-moment of daily resource about axis 0-0;

m = minimum of either the days that activity is to be shifted (S) or the activity duration (t);

R = resource rate;

S = number of days up to which the activity can be shifted;

Wi = daily resource to which m daily resource rates (R) are to be added;

Xi = daily resource to which m daily resource rates (R) are to be deduced; and

Yi = daily resources.

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