Applying Re Modified Minimum Moment Method to Construction Projects in India

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Abstract— **The purpose of this work is to apply the re modified minimum moment method of resource leveling to construction projects in India. The method is based upon the critical path method & it was developed with the assumption of no activity splitting and fixed project duration with unlimited availability of resources. The criteria of selecting the activity that has to be shifted from its original position to a better position is judged by the change in the statically moment of the resource histogram before and after such movement as well as by Resource Improvement Coefficient.**

To achieve the objectives of the work, the data of construction of three residential apartment projects in Nashik city is taken. Initially the activities are arranged according to their Earliest Start Time (EST) then as per the Re modified minimum moment method & as per their Latest Finishing Time (LFT). Bar chart & histogram is prepared for each solution. Maximum daily requirement of mason, Effective Force Ration (EFR), Stand by Force Ratio (SFR), moment of histogram & Resource Improvement Coefficient (RIC) are calculated for each solution from the respective histograms. These values are then compared for each solution. It has been observed that Maximum daily requirement of mason, SFR, moment of histogram & RIC are reduced & EFR is increased by Re modified minimum moment method.

Keywords— ***Re-modified, Resource leveling, Resource rate, Resource Histogram, Resource Improvement coefficient***

INTRODUCTION

A project manager frequently comes across two types of the situations i.e. limited availability of resources and limited time which are termed as resource constraints and time constraints respectively. In resource constraint problems, the availability of resources is limited and duration of the project can be extended to the minimum possible extent on the other hand in time constraint problems resources are assumed to be available as and when required and the duration of the project should not be extended. Resource leveling provides the solution to both types of problem when simultaneous activities struggle for the same resource. The time constraint problems requires the shifting of non critical activities to minimize the fluctuations in day to day resource use whereas in resource constraint problems shifting of critical and non critical activity is required to have the uniform resource histogram.

The aim of this paper is to apply the Re-modified Minimum Moment method suggested by Abhay Tawalare [3] to construction projects in India. Minimum Moment Method suggested by Harris [1] is one of the several methods used for resource leveling & which dictates the procedure for leveling

a single resource by means of preparing the resource histogram step-by-step until all activities have been located in time within the constraints of the given network. Hiyassat [2] proposed the modification to the traditional method to reduce the calculations and number of iterations

The content of this paper is divided into four sections. The first section is elaborating the basic concepts of Traditional & modified minimum moment method. Second section is elaborating the basic assumptions, theory & criteria for activity selection of re-modified minimum moment method. Third section is devoted to application of re-modified minimum moment method to construction projects. It also focuses the assumptions to be made in planning the activities so that the above method is applicable. The last section contains conclusion derived from this paper.

MINIMUM MOMENT METHOD

The minimum moment theory is one of the most commonly used methods that assume limited project duration and unlimited resources.

According to this theory, when a given set of elements is arranged into a histogram over a fixed set of intervals, the minimum moment of the elements exist when the histogram is a rectangle over the fixed intervals.

The moment of an element is $1/2y_i^2$ about the axis 0-0. The total moment of the set, therefore, is

$$M = 1/2 \sum (y)^2$$

As the theory states, 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); & it is very difficult to achieve in reality.

The aim of the theory is to reduce, as much as possible, the differences between peaks and valleys in the resource histogram, by means of shifting noncritical activities from their original position to some other position. It should be noted that the new position should have a lower value of the statical moment of a resource histogram than the original one. It is obvious that this location should be within the activity's free float up to which it can be shifted.

A resource improvement factor is computed as per the below mentioned formula for all activities on the last sequence step of a network.

IF (activity J, S) = $R(\sum x - \sum w - mR)$

Where, IF = Improvement factor;

S = Number of days to be shifted;

Sx= Sum of daily resources $x_1, x_2, \ldots, x_m$, to which m daily resource rates (R) are to be deduced;

Sw = Sum of daily resources $w_1, w_2, \ldots, w_m$, 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);

R = Resource rate.

If the calculated improvement factor for a given activity is either positive or zero, the activity may be shifted; otherwise, no shifting is needed.

From these computations the largest positive improvement factor is determined, and the associated activity is shifted.

MODIFIED MINIMUM MOMENT METHOD

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. To calculate the improvement factor (IF) the value of R is dropped from equation as its value is constant for the same activity. Thus, the mathematical form of the improvement factor is as follows,

IF(activity J,S) = $\Sigma x - \Sigma w - mR$

If the improvement factor for a given activity is either positive or zero, then only activity can be shifted; otherwise, activity cannot be shifted.

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.

RE-MODIFIED MINIMUM MOMENT METHOD

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

According to this theory, when a given set of elements is arranged into a histogram over a fixed set of intervals, the minimum moment of the elements exist when the histogram is a rectangle over the fixed intervals.

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 throughout their completion.
3. The duration of each activity remains constant.
4. The network logic is fixed.
5. The project's completion date is fixed.

The procedure proposed for carrying out the resource leveling process is as follows:

1. The activities on the last sequence step are examined.
   a. Every activity on the sequence step having a zero free float is passed over.
   b. Every activity on the sequence step having a zero resource rate is shifted to the limit of the activity free float to allow the preceding activities to be shifted.
   c. For each activity on the sequence step having a positive resource rate, the extent of its free float is determined, and they are arranged in ascending order according to the value of resource rate (R).
2. The activity having the largest value of "R" determined in step 1(c) is selected for shifting.
   a. If there is tie in the value of R for two or more activities, the activity with the largest value of free float i.e. "S".
   b. If still tied, select the activity that having largest duration.
   c. If still tied, select the first activity in the queue.
3. For the chosen activity, the improvement factors for all possible positions that the activity may occupy are computed. If the largest improvement factor for the considered activity is greater than or equal to zero, the selected activity is shifted to the position with the maximum value of improvement factor. If there is a tie in the value of the improvement factor at several of the possible activity positions, the activity with the greatest number of time units is shifted. If the largest improvement factor is negative, no shifting takes place. The activity with the next largest value of (R) is considered.
4. If shifting occurs, the activity resource rate is subtracted from each of the daily resource sums at the position being vacated. This same rate is added to each of the daily sums at the position being occupied. The lags, free float, ESD, and EFD in the network are updated.
5. The activity in the sequence step with the next largest value of R is now selected, and steps 2–4 are repeated until all activities in the sequence step have been considered.
6. The next earlier sequence step is examined and algorithm steps 1–5 are repeated. This manner is

continued until all activities have been considered and all possible shifting has taken place on every sequence step. This ends the forward cycle.

7. Beginning with the first sequence step, using back float instead of free float, and progressing to the next latest sequence step instead of the next earliest sequence step, algorithm steps 1–6 are repeated until all activities have been considered and shifted to an earlier time position, if possible. This ends the backward cycle and completes the leveling process.

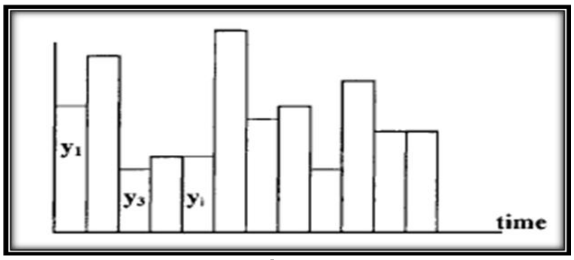

Figure 1:- Daily resource Histogram

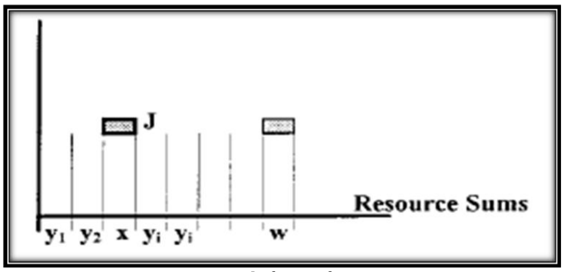

Figure 2:- Shifting of activity

According to above figures, in this method, the calculation of the improvement factor (IF) can be made easier if the value R is dropped from the formula of IF according to modified minimum moment method, since this value is constant for the same activity. The final mathematical form of the improvement factor, therefore, is as follows:

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

If the calculated improvement factor for a given activity is either positive or zero, the activity may be shifted; otherwise, no shifting is needed.

PROBLEM STATEMENT

The data is collected from Construction of 3 Residential apartment projects in Nashik. The data collected includes only the work items involved in the projects with their respective quantities. Resource rate is identified for each work item and for the work item which needs machinery, resource rate is taken 0. According to the resource rate, duration required for each activity is found out. The activities are arranged according to their inter relationship. According to the inter relationship of the activities bar chart, network and histogram is prepared for each project.

First the activities are arranged with their EST, then as per the Re modified Minimum Moment Method & thereafter as per their LFT. Histogram is drawn for all these three stages and EFR, SFR, Moment & RIC are calculated

The details of 1 project are given and results of all the three projects are discussed in the paper.

The construction project involves the following activities.

Sr. no.	Activity	Description	Quantity	Unit	Resource Rate (Man days)	Duration (days)
1	A	Excavation	200	m^3	0	6
2	B	PCC for foundation	50	m^3	1	10
3	C	RCC footing	100	m^3	2	17
4	D	RCC columns up to plinth	10	m^3	1	4
5	E	RCC ground beams	85	m^3	2	15
6	F	Murum filling	1000	m^3	0	14
7	G	Soling of plinth	500	m^3	0	7
8	H	Ground floor PCC below flooring	192	m^3	4	10
9	I	RCC columns up to first floor slab	16	m^3	1	7
10	J	RCC first floor slab& beam	250	m^3	3	28
11	K	Ground floor brickwork	800	m^3	5	23
12	L	Ground floor neeru plaster	1500	m^2	7	22
13	M	RCC columns up to second slab	14	m^3	1	5
14	N	RCC second floor slab& beam	250	m^3	6	15
15	O	First floor brickwork	800	m^3	15	8
16	P	First floor neeru plaster	1500	m^2	7	22
17	Q	Ground floor flooring	2000	m^2	14	30
18	R	Doors & windows	300	m^2	0	16
19	S	First floor flooring	2000	m^2	14	30
20	T	External sand faced plaster	1500	m^2	3	39
21	U	Painting	3200	m^2	7	88
22	V	Site cleaning	L.S.	L.S	0	14

Table 1: Activities involved in project

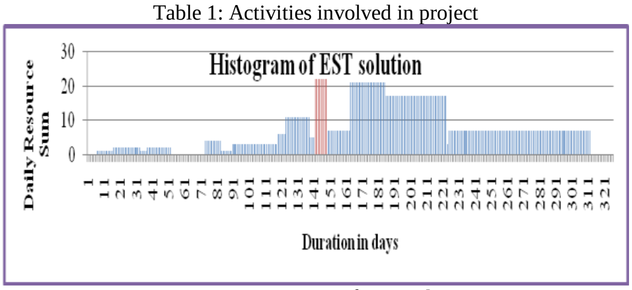

Figure 3:- Histogram of EST solution

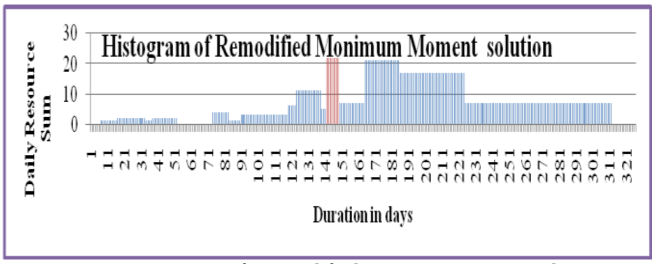

Figure 4:- Histogram of Re-modified Minimum Moment solution

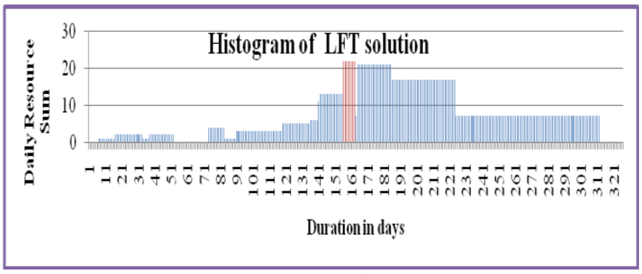

Figure 5:- Histogram of LFT solution

The following presents the calculations of above project.
Sample calculations of forward cycle are given below.

Forward cycle:-

Sequence step 17:-

Activity "V" is the only one activity in sequence step 17 & it is critical activity, hence neglect it.

Sequence step 16:-

Activity "U" is the only one activity in sequence step 16 & it is critical activity, hence neglect it.

Sequence step 15:-

Consider activity "S" which is having FF = 1
IF (S,1) = (17-3-(1*14)) = 0
Shift activity "S" by 1 day.

Sequence step14:-

Consider activity "Q" which is having FF = 1
IF (Q,1) = (21-3-(1*14)) = 4
Shift activity "Q" by 1 day.

Sequence step 13:-

Consider activity "O" having FF = 14, R = 15
IF (O,1) = (22-7-(1*15)) = 0
IF (O,2) = (44-14-(2*15)) = 0
IF (O,3) = (66-21-(3*15)) = 0
IF (O,4) = (88-28-(4*15)) = 0
IF (O,5) = (110-35-(5*15)) = 0
IF (O,6) = (132-42-(6*15)) = 0
IF (O,7)=(154-49-(7*15)) = 0
IF (O,8) = (176-56-(8*15)) = 0
IF (O,9)=(176-63-(8*15))= -7
IF (O,10)=(176-70-(8*15)) = -14
IF (O,11) = (176-77-(8*15)) = -21
IF (O,12) = (176-84-(8*15)) = -28
IF (O,13) = (176-91-(8*15)) = -35
IF (O,14) = (176-98-(8*15)) = -42
Shift activity "O" by 8 day.

Sample calculations of backward cycle are given below.

Backward pass:-

Sequence step 11:-

Consider activity R having BF = 13 for shifting.
IF (R,1) = (7-11-(1*0)) = -4, IF (R,2) = (14-22-(2*0)) = -8
IF (R,3) = (21-33-(3*0)) = -12, IF (R,4) = (28-44-(4*0)) = -16
IF (R,5) = (35-55-(5*0)) = -20, IF (R,6) = (42-66-(6*0)) = -24
IF (R,7) = (49-77-(7*0)) = -28, IF (R,8) = (56-83-(8*0)) = -27
IF (R,9) = (67-89-(9*0)) = -22
IF (R,10) = (78-95-(10*0)) = -27
IF (R,11) = (89-101-(11*0)) = -12
IF (R,12) = (100-107-(12*0)) = -7
IF (R,13) = (111-112-(13*0)) = -1
As all the activities are having –ve IF, so no back shifting of activity "R".

Sequence step 11:-

Consider activity "M" having BF = 3
IF (M,1) = (6-5-(1*1)) = 0
IF (M,2) = (12-10-(2*1)) = 0
IF (M,3) = (18-15-(3*1)) = 0
Activity "M" will be back shifted by 3 days.

RESULTS & DISCUSSIONS

Project 1:-

	Max. Y	EFR (%)	SFR (%)	Moment	RIC
EST solution	37	23	77	37206.5	2.662
Re modified MMM	32	26.595	73.405	32965.5	2.358
LFT solution	32	26.595	73.405	35173.5	2.516

Table no.2:- Comparative values of various factors for EST, Re modified minimum moment & LFT solution for project 1

Project 2:-

	Max. Y	EFR (%)	SFR (%)	Moment	RIC
EST solution	30	19.149	80.851	10079.5	2.556
Re modified MMM	28	20.517	79.483	9119.5	2.312
LFT solution	28	20.517	79.483	9610.5	2.437

Table no.3:- Comparative values of various factors for EST, Re modified minimum moment & LFT solution for project 2

Project 3:-

	Max. Y	EFR (%)	SFR (%)	Moment	RIC
EST solution	22	33.742	66.258	16097	1.792
Re modified MMM	22	33.742	66.258	16041	1.786
LFT solution	22	33.742	66.258	16209	1.805

Table no.4:- Comparative values of various factors for EST, Re modified minimum moment & LFT solution for project 3

Comparative histograms are shown below

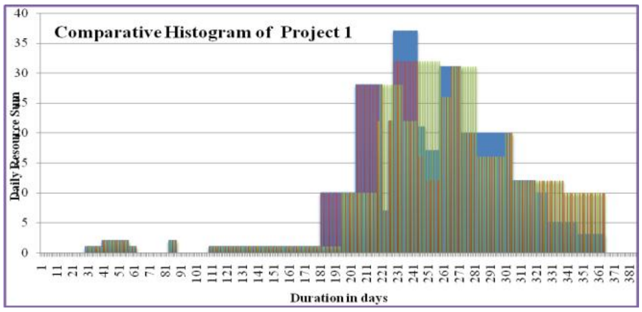

Figure 6:- Comparative Histogram of Project 1

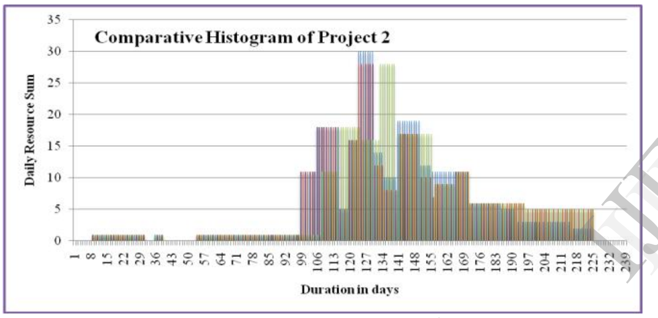

Figure 7:- Comparative Histogram of Project 2

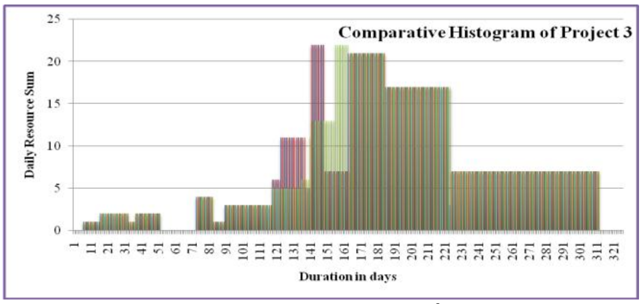

Figure 8:- Comparative Histogram of Project 3

This study aimed to determine whether Re modified Minimum Moment method is applicable for resource leveling of Construction projects in India.
On the basis of this study the conclusion was elaborated as below:-

1. Maximum daily resource sum of a construction project is reduced or remains same by application of Re modified Minimum Moment Method. As the maximum daily resource sum is reduced, the cost of the project is also reduced.
2. Stand by force ratio of a construction project is reduced or remains same by application of Re modified Minimum Moment Method, which reduces the idle time of the mason.
3. Effective force ratio is increased or remains same by application of Re modified Minimum Moment Method, which increases the utilization of the masons.
4. Though all the above three mentioned factors are remain same but moment & RIC of histogram drawn by Re modified Minimum Moment method is reduced.
5. Reduction in the moment results into overall utilization of the mason as it reduces the peak and valleys in the histogram.
6. RIC equals to 1 shows rectangular shape of resource histogram. Though it is difficult to achieve in practice but reduction in RIC results into improvement in the utilization of the available resources.
7. The cost of the project is reduced by application Re modified Minimum Moment method of resource leveling to construction project
8. As Maximum daily resource sum, Stand by force ratio, moment & RIC of histogram, cost of the project are reduced and Effective force ratio is increased, Re modified Minimum Moment method used for resource leveling is applicable to construction project.
9. The method is applicable to construction project on the basis of following assumptions
   a) The activities are arranged in end to start interrelationship without overlapping of the activities
   b) The masons are assumed to be multi skilled.
   c) The resources will be made available as & when required but has to complete the project on the scheduled date.
10. This method will improve the overall resource utilization efficiency in order to improve construction productivity and reduce project duration and cost.

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