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Enhanced Heuristic Method for Scheduling and Leveling Using Heuristic Indices

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Abstract This paper presents an enhanced heuristic method based on five major heuristic indices used in project scheduling and leveling. Many researchers used some of these indices in project management, but few researchers combined multiple indices and used them in scheduling and leveling. The main purpose of this work is to find which of the five indices is the most important in leveling resources using the proposed method where the five heuristic indices were used together, and the method was applied using MATLAB software. The five heuristic indices are: Resource moment about the x-axis (M_x), Resource moment on the y-axis (M_y), Rate of Resource usage (*RR)*, Resource Improvement Coefficient (*RIC)*, and the Maximum Value of the used resource (V_m). Moreover, every index has weight, which is referred to as importance weight. The method was tested on two projects. One of them is a hypothetical project consisting of 24 activities, and the other is an actual project where every index had an extremely bigger weight compared with the others. Also, a parameter (p) which refers to a partial value of the total float for the noncritical activities was used to enhance the heuristic method. It is found that the best (p) which gave the best possible resource histogram in the first project was $p = 1.0$ and $p = 0.87$ for the second. Also, it is found that the resource improvement coefficient (*RIC)* is the most important for the first project, while for the second project the Rate of Resource usage (*RR)* was more important and gave better results. However, changing the value of (p) gave different results that are not related to a fixed relationship in terms of its increase or decrease. Finally, choosing the most important index depends on the nature of the project and its resources.

Keywords Resource Leveling, Heuristic Indices, Resource Improvement Coefficient, Resource Moments, Resource Rate

1. Introduction

Resource leveling is ‘‘the method of scheduling activities within their available float to minimize fluctuation in day-to-day resource requirements’’[1]. Project activities that are not on the critical path can be moved throughout the completion time during the scheduling process. If the resources are insufficient to meet the needs of the activities, the project's duration may be extended. Several approaches for resource-leveling have been developed, such as the dynamic programming technique, which has been proposed in [2], and it is best suited for small projects. Researchers are always trying to devise new ways to achieve the best possible results through optimization techniques, heuristic methods, artificial intelligence, etc. Project managers can use specific indices that differ in their importance; have different weights and effects in leveling and scheduling processes as modified heuristics to achieve their resource management objectives in many ways. Resource moment about the x-axis (M_x) is sometimes called the time axis, and it represents the level of resource variability throughout the project's resource histogram. Harris [3] used (M_x) in the leveling process, he developed a new heuristic for resource-leveling based upon the critical path method; it is clear, logical, and computationally efficient whether the leveling is done manually or by computer. The concept of this method is to assign all activities in the project to particular days so that the histogram of the commonly shared resource approaches the rectangle and the moment of the histogram approaches the minimum value. In other words, when the shape of the resource histogram is rectangular, the value M_x is the minimum. A more recent review of the literature on this topic, Giran, Temur [4] used (M_x) to reduce the daily resource demands to satisfy the daily resource constraint in a resource-constrained project scheduling problem. They used Harmony Search Algorithm to solve the problem. The resource moment on the y axis (M_y) is not used very common, it can be used to forecast the release date of a resource [5]. The rate of resource usage (*RR*) which shows a wait or idle state of the resources is rarely used by researchers and schedulers. Maher and Aldouri [6] used it with other indices and presented a heuristic algorithm for solving resource leveling and allocation problems in medium-scale projects with a low number of critical activities. The resource improvement coefficient (*RIC*) shows resource usage in another way, and reflects merit for leveling goodness. Baviskar and Bhangale [7] used many indices to determine if the re-modified minimum moment method is applicable to resource-leveling construction projects in India. *RIC* had been used to evaluate the leveling process, which is resulted from using this method on three construction projects. This index is used in literature mainly in evaluating different resource-leveling methods to see whether they are performing well or not. In a recent study, Jadhav and Ghaitidak [8] used *RIC* in addition to other factors to evaluate whether re-modified minimum moment method is applicable for resource-leveling of residential construction projects. The maximum value of the used resource (V_m) is used in some project management software like Microsoft Project program and Primavera P6 and it may be a constraint on the efficiency of the leveling process. Selvam and Tadepalli [9] introduced a modified critical path scheduling approach to creating a schedule that determines the partial critical nature of the activity with a start-to-start precedence relationship using a genetic algorithm (GA) optimization approach. Real-time construction project activities were considered for testing the proposed concept. They concluded that the result obtained through a GA is much better than the result obtained in solving a leveling problem in the Microsoft Project program. The index V_m was used to prove that the proposed modified GA gives better results than the Microsoft Project program.

This study considers five different indices to analyze the efficacy of the schedule created by a heuristic technique. This work is an extension of the not yet published thesis [10] where the indices' relative importance was conducted via a questionnaire and the data was analyzed using the Analytical Hierarchy Process (AHP).

2. Heuristic Method and Methodology

In recent years, various analytic and heuristic methods and algorithms have been developed to apply resources during the scheduling phase. Analytic methods seek to identify the best solution in terms of project resources and/or duration [11]. The main issue with using these analytical methods is the lengthy computational time. Later, on the other hand, heuristic algorithms that require an acceptable computational burden garner a lot of attention [12].

The heuristic approach is based on the computation of various indices for assessing resource utilization efficiency. Some of these indices should be minimized, and others should be maximized to get the optimal or suboptimal schedule. Also, they are easy to understand and efficient for project management. The most commonly used indices in terms of resource demand D (number of resources multiplied by the time spent using this number of resources) are [10]:

(1) Resource moment about the x-axis sometimes called time axis (M_x) represents the level of resource variability over the duration of the project. It can be calculated from:

$$M_X = \sum_{i=1}^{n} D_i^2 \quad (1)$$

where; *n* stands for project completion time, while the *i* values are the time in the x-axis, for example, if there is a project that needs 17 days to be completed, the *i* values would be (1, 2, 3, ...,17), and *n* is equal to 17.

(2) The resource moment on the y axis (M_y) shows the uncertainty of demand and the availability of future resources (supply). This index is not very common to use in literature; a higher value of this index suggests higher uncertainty. So, this index should be minimized. It can be computed from:

$$M_y = \sum_{i=1}^{n} i\, D_i \quad (2)$$

(3) The rate of resource usage (*RR*) shows a wait or idle state of the resources. It indicates the rate of total use of a resource compared to the maximum number of resources used. Typically, this index value is given as a percentage; the highest percentage indicates an efficient leveling process, it should get near 100% to achieve better results. As a result, long idle periods lead to poor resource usage performance.

$$RR = \sum_{i=1}^{n} \frac{D_i}{n \times \max(D_i)} \quad (3)$$

(4) The Resource Improvement Coefficient (*RIC*) shows resource usage in another way and reflects merit for leveling goodness. This index is commonly used in leveling and scheduling. The excellent value of this index is 1.0; when RIC is equal to 1.0, that means all demands over the project's time horizon are equal in magnitude. The formula that is used to compute (*RIC*) is:

$$RIC = \frac{n\sum_{i=1}^{n} D_i^{\,2}}{\left(\sum_{i=1}^{n} D_i\right)^2} \tag{4}$$

The maximum value of the used resource (V_m), this index may be a constraint on the efficiency of the leveling process. Within certain limits, the small value of this index is preferred for an efficient leveling process. It should be minimized with respect to its value before leveling process. However, because critical activities cannot be shifted, this index can't be minimized to a certain value. It is found from

$$V_m = max\{Di\}, i = 1,2, \ldots n \tag{5}$$

The heuristic algorithm will be used for scheduling and leveling based on the performance of the heuristic indices will be enhanced by choosing a partial value of the total float for the noncritical activities. This is the approach to gathering the five indices:

$$\min J = w_1 R_1 + w_2 R_2 + \cdots + w_q R_q \tag{6}$$

where; J is the value calculated from using multiple indices together and it has to be minimized as possible, the w_q values are weights from 0.0 to 1.0, the R_q values are specific objectives to be minimized, which are the five indices in this work, and q is the number of indices used. One problem is that this equation can be utilized to minimize the objectives, whereas for the five indices, there is some need to be minimized and some of them do not.

To overcome this problem, the index RR would be entered as $(100 - RR)$ to find the minimum of the difference between the 100% and the computed resource rate, and the RIC index will be modified to $(RIC - 1)$; thus, minimizing these quantities means reaching the ideal case. Two matrices must be defined for Activities on Arrow (AOA) networks, one for activity durations and the other for activity numbers (instead of the usual use of alphabetic letters). The elements of the duration matrices are the durations of activities between nodes, zero values for dummy activities in the diagonal position, and infinity for the absence of activities between two nodes. The activity numbering matrix contains numbers from one to the network's final node, as well as zero values for dummy activities, the diagonal position, and the absence of activities between two nodes. As a result, the two matrices are represented by the symbols D and A, which are mathematically defined as follows:

$$D = \begin{cases} d_{ij}; & \text{i} \neq j,\ \forall\ \text{i}, j \rightarrow \text{vector} \\ 0; & \text{i} = j,\ \forall\ i, j \rightarrow \text{diagonal} \\ \infty; & \text{i} > j, \forall\ \text{i}, j \rightarrow \text{nonexisting activity} \end{cases} \tag{7}$$

$$A = \begin{cases} d_{ij}; & \forall\ \text{i}, j \rightarrow d_{ij} \\ 0; \quad \forall\ \text{i} \geq j, & \forall \text{i}, j \rightarrow d_{ij} = \infty \end{cases} \tag{8}$$

Before running the heuristic algorithm, it is important to know the critical path, the end date of the project, the total and free float, the earliest and latest times of each activity, and the initial values of the indices. A program that represents the Floyd algorithm [13] for solving the Critical Path Method (CPM) problem will be used together with a program that calculates the five indices, plots, and displays the resource histogram.

Because the heuristic algorithm does not provide optimal solutions, a parameter p referring to the maximum allowed percentage of the total floats of the noncritical activities will be changed during the leveling process to assist the heuristic algorithm. In other words, the p value is used for scheduling by reducing all of the float time to a fraction of the total float time. The p value is suggested to be a constraint in the heuristic method that can be used to improve it to achieve better results. Finally, every index will get a high weight compared with others and the heuristic algorithm will be run on two projects, then the results will be discussed.

3. Projects for Testing the Algorithm

The first project is hypothetical, while and the other is an actual project taken from the literature.

3.1. The Hypothetical Project

The project consists of 24 activities, the AOA network is shown in (Figure 1). The duration is in days, and the resources are costs.

The initial results are:

- The project completion time is 47 days, the critical path is A-D-J-O-T-V-X.
- Table 1 shows the project's activities, durations, start time, finish time, resources, and total float before leveling.

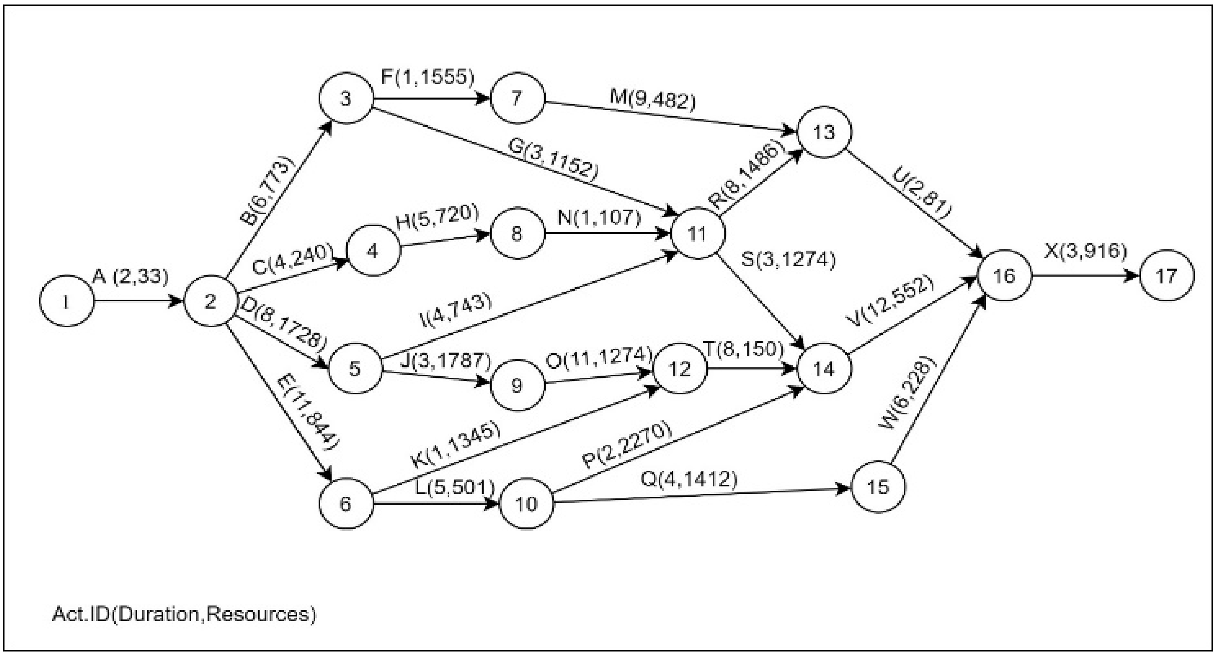

Figure 1. The Hypothetical Project's AOA Network

Table 1. Project's Initial State before Leveling (First Project)

Activity ID	Duration	Resource ($)	Start Time	Finish Time	Total Float
A	2	33	0	2	0
B	6	773	2	8	18
C	4	240	2	6	17
D	8	1728	2	10	0
E	11	844	2	13	10
F	1	1555	8	9	24
G	3	1152	8	11	18
H	5	720	6	11	17
I	4	743	10	14	15
J	3	1787	10	13	0
K	1	1345	13	14	10
L	5	501	13	18	12
M	9	482	9	18	24
N	1	107	11	12	17
O	11	1274	13	24	0
P	2	2270	18	20	12
Q	4	1412	18	22	16
R	8	1486	14	22	20
S	3	1274	14	17	15
T	8	150	24	32	0
U	2	81	22	24	20
V	12	552	32	44	0
W	6	228	22	28	16
X	3	916	44	47	0

(Figure 2) shows the resource histogram before leveling. The values of J, $RR\%$, RIC and V_m are 0.99663, 35.018%, 1.8654 and 6442 respectively.

The heuristic algorithm would run multiple times with M_x weight is higher than the others to find the best p value which remains the same for the same project even when changing the indices weight [10]. The p value would be used to run the algorithm another four times, the weights would be changed so in every run, one of the indices takes the highest weight value. Table 2 shows that the best p value for this project is $p = 1.0$. The weight combination used is:

$$[W_{M_x} = 0.90, W_{M_y} = 0.025, W_{V_m} = 0.025, W_{RR} = 0.025, W_{RIC} = 0.025].$$

Table 2. The J Values when Changing p Value

p	J
1.0	0.61903
0.9	0.67495
0.8	0.66507
0.7	0.69561
0.6	0.73613
0.5	0.76500
0.4	0.80504

Table 3 shows the iterations to get the best possible results from using the mentioned weight combination.

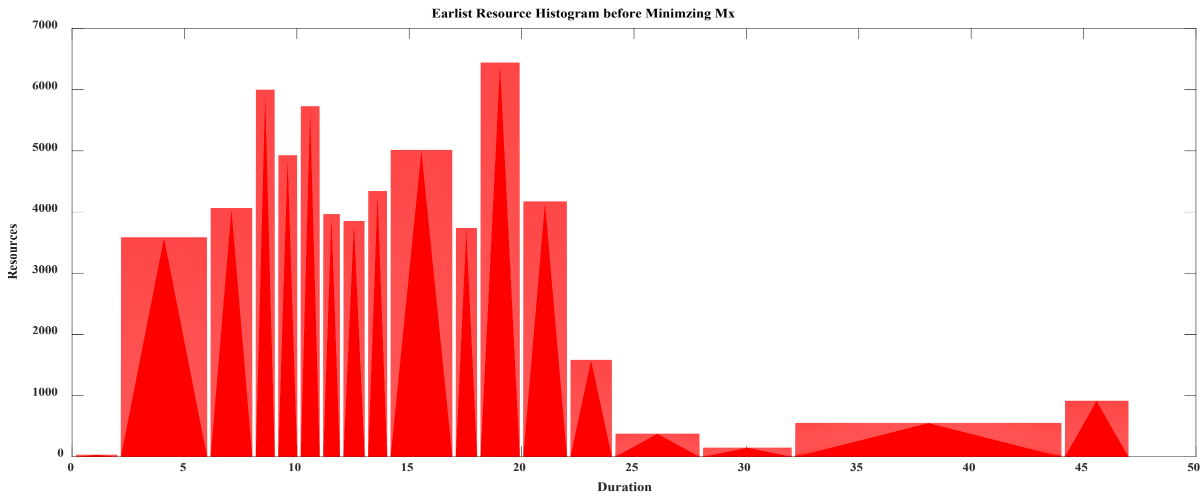

Figure 2. Resource Histogram Before Leveling (First Project)

Table 3. Leveling Process Iterations (First Combination)

$W_{M_x} = 0.90, W_{M_y} = 0.025, W_{V_m} = 0.025, W_{RR} = 0.025, W_{RIC} = 0.025$			
J	V_m	RR%	RIC
0.99663	6442	35.018	1.8654
0.97838	6442	35.018	1.8294
0.93492	6442	35.018	1.7438
0.91399	6442	35.018	1.7025
0.87910	6442	35.018	1.6338
0.82068	6442	35.018	1.5187
0.80982	6442	35.018	1.4972
0.80955	6442	35.018	1.4967
0.79556	6442	35.018	1.4692
0.67555	4956	45.518	1.2520
0.66003	4956	45.518	1.2214
0.62484	3694	61.068	1.1735
0.62341	3694	61.068	1.1707
0.61903	3694	61.068	1.1620

Table 4 shows the iterations to get the best possible results when M_y has the highest weight value.

Table 4. Leveling Process Iterations (Second Combination)

$W_{M_x} = 0.025, W_{M_y} = 0.90, W_{V_m} = 0.025, W_{RR} = 0.025, W_{RIC} = 0.025$			
J	V_m	**RR%**	**RIC**
0.99663	6442	35.018	1.8654
0.99525	6442	35.018	1.8294
0.99196	6442	35.018	1.7438
0.99038	6442	35.018	1.7025
0.98774	6442	35.018	1.6338
0.98332	6442	35.018	1.5187
0.98250	6442	35.018	1.4972
0.98248	6442	35.018	1.4967
0.98142	6442	35.018	1.4692
0.96327	4956	45.518	1.2520
0.96210	4956	45.518	1.2214
0.94938	3694	61.068	1.1735
0.94927	3694	61.068	1.1707
0.94894	3694	61.068	1.1620

Table 5 shows the iterations to get the best possible results when V_m has the highest weight value.

Table 5. Leveling Process Iterations (Third Combination)

$W_{M_x} = 0.025, W_{M_y} = 0.025, W_{V_m} = 0.90, W_{RR} = 0.025, W_{RIC} = 0.025$			
J	V_m	**RR%**	**RIC**
0.99663	6442	35.018	1.8654
0.99525	6442	35.018	1.8294
0.99196	6442	35.018	1.7438
0.99038	6442	35.018	1.7025
0.98774	6442	35.018	1.6338
0.98332	6442	35.018	1.5187
0.98250	6442	35.018	1.4972
0.98248	6442	35.018	1.4967
0.98142	6442	35.018	1.4692
0.76143	4956	45.518	1.2520
0.76026	4956	45.518	1.2214
0.57613	3694	61.068	1.1735
0.57602	3694	61.068	1.1707
0.57569	3694	61.068	1.1620

Table 6. Leveling Process Iterations (Fourth Combination)

$W_{M_x} = 0.025, W_{M_y} = 0.025, W_{V_m} = 0.025, W_{RR} = 0.90, W_{RIC} = 0.025$			
J	V_m	**RR%**	**RIC**
0.99663	6442	35.018	1.8654
0.99525	6442	35.018	1.8294
0.99196	6442	35.018	1.7438
0.99038	6442	35.018	1.7025
0.98774	6442	35.018	1.6338
0.98332	6442	35.018	1.5187
0.98250	6442	35.018	1.4972
0.98248	6442	35.018	1.4967
0.98142	6442	35.018	1.4692
0.82189	4956	45.518	1.2520
0.82072	4956	45.518	1.2214
0.59861	3694	61.068	1.1735
0.59850	3694	61.068	1.1707
0.59817	3694	61.068	1.1620

Table 7. Leveling Process Iterations (Fifth Combination)

$W_{M_x} = 0.025, W_{M_y} = 0.025, W_{V_m} = 0.025, W_{RR} = 0.025, W_{RIC} = 0.90$			
J	V_m	**RR%**	**RIC**
0.87884	6442	35.018	1.8654
0.84597	6442	35.018	1.8294
0.76776	6442	35.018	1.7438
0.73008	6442	35.018	1.7025
0.66730	6442	35.018	1.6338
0.56215	6442	35.018	1.5187
0.54258	6442	35.018	1.4972
0.54211	6442	35.018	1.4967
0.51693	6442	35.018	1.4692
0.30877	4956	45.518	1.2520
0.28084	4956	45.518	1.2214
0.22620	3694	61.068	1.1735
0.22362	3694	61.068	1.1707
0.21573	3694	61.068	1.1620

Table 8. Summary of the Results

Index Which Had the Highest Weight Value	**The Percentage which *J* had Improved**
M_x	37.9%
M_y	4.80%
V_m	42.2%
RR	39.9%
RIC	75.4%

Table 6 shows the iterations to get the best possible results when RR has the highest weight value.

Table 7 shows the iterations to get the best possible results when RIC has the highest weight value.

When examining tables from (3-7), it is noticed that for the project provided, the most important index is *RIC*.

Table 8 summarizes the results from changing indices weights to find the most important index for this project.

(Figure 3) shows the final resource histogram when using the weight combination [$W_{M_x} = 0.025, W_{M_y} = 0.025, W_{V_m} = 0.025, W_{RR} = 0.025, W_{RIC} = 0.90$] which gave the best result.

It is noticed that the resource profile improved significantly in (Figure 3) compared with before leveling in (Figure 2) where the shape was getting nearer to rectangular. Table 9 shows the activities' start time, finish time, resources, and total float after leveling

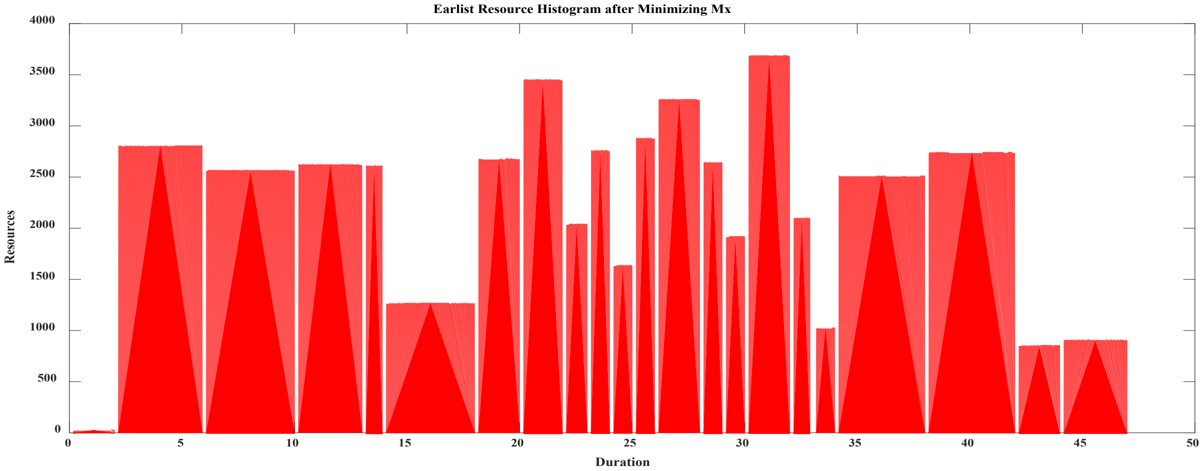

Figure 3. Resource Histogram after Leveling (First Project)

Table 9. Project's Final State after Leveling (First Project)

Activity ID	Resource ($)	Start Time	Finish Time	Total Float
A	33	0	2	0
B	773	20	26	0
C	240	2	6	17
D	1728	2	10	0
E	844	2	13	10
F	1555	32	33	0
G	1152	26	29	0
H	720	23	28	0
I	743	25	29	0
J	1787	10	13	0
K	1345	13	14	10
L	501	25	30	0
M	482	33	42	0
N	107	28	29	0
O	1274	13	24	0
P	2270	30	32	0
Q	1412	18	22	16
R	1486	34	42	0
S	1274	29	32	0
T	150	24	32	0
U	81	42	44	0
V	552	32	44	0
W	228	38	44	0
X	916	44	47	0

Table 10. Project's Initial State before Leveling

Activity ID	Duration	Resource ($)	Start Time	Finish Time	Total Float
A	9	2940	0	9	0
B	10	4930	9	19	0
D	1	8550	9	18	2
C	9	24860	19	20	0
E	1	2350	19	20	12
F	12	11280	20	32	0
H	12	50550	32	49	0
G	17	45540	49	61	0
J	25	48740	61	75	53
I	14	16680	61	86	0
M	4	2000	61	65	22
L	10	4000	86	96	32
O	4	4050	86	89	0
K	5	4350	86	90	2
N	3	11000	65	70	22
P	7	20250	89	96	32
S	2	2700	89	90	15
R	3	4200	89	92	0
U	1	1000	92	98	0
V	2	2400	98	107	0
Q	6	21800	90	92	15
W	9	44250	107	111	0
Y	4	4800	128	132	0
AB	17	24370	128	131	2
Z	4	18000	132	133	0
T	1	1250	133	135	0
X	3	6300	111	128	0
AC	1	1800	111	112	23
AD	4	10500	111	115	22
AE	2	3000	135	137	0
AF	2	2100	137	139	0
AG	5	3780	139	144	0

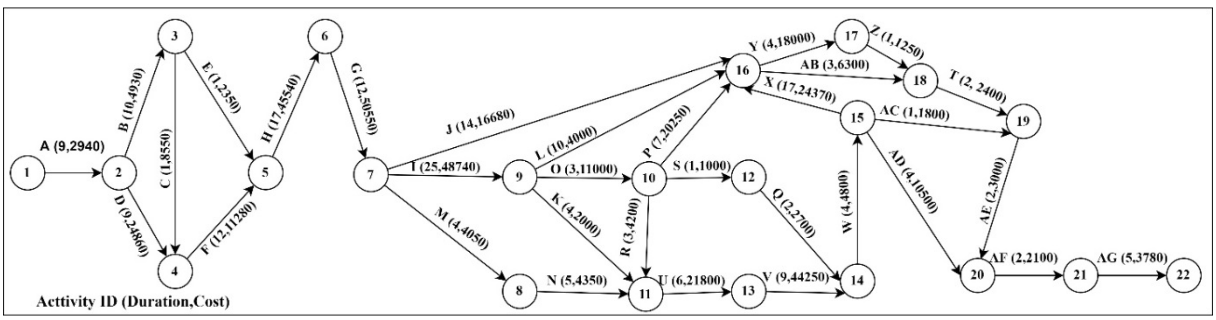

Figure 4. The second Project's AOA Network

3.2. The Actual Project

This project is consisting of 32 activities, the AOA network is shown in (Figure 4). The duration is in days, and the resources are costs. The project is a two-story healthy center with a 700-square-meter area and a 350-square-meter ceiling area on each floor. This case is taken from a thesis [14] where it was a part of a megaproject consisting of multiple buildings. It costs 414,320 dollars in total. By a factor of more than one, the number of critical activities outnumbers non-critical activities.

The initial results are:

- The project completion time is 144 days, the critical path is A-B-C-F-H-G-I-O-R-U-V-W-X-Y-Z-T-AE-AF-AG.
- Table 10 shows the project's activities, durations, start time, finish time, resources, and total float before leveling.

(Figure 5) shows the resource histogram before leveling. The values of J, $RR\%$, RIC and V_m are 0.98480, 46.688%, 1.392 and 69770 respectively.

The same procedure as in the previous example was used to find the best p value for this project, which remains the same for the same project no matter how the indices weights change because the value of p mainly depends on the nature of the project and its activities distribution. It is found that $p = 0 \cdot 87$ is the ideal p value for the project. Table 11 shows the iterations to get the best possible results when M_x has the highest weight value.

Table 11. Leveling Process Iterations (First Combination)

$W_{M_x} = 0.90, W_{M_y} = 0.025, W_{V_m} = 0.025,\ W_{RR} = 0.025, W_{RIC} = 0.025$			
J	V_m	RR%	RIC
0.98480	69770	46.688	1.3920
0.98243	69770	46.688	1.3885
0.91154	53350	61.057	1.3017
0.90789	53350	61.057	1.2963
0.90713	53090	61.356	1.2955
0.89638	53090	61.356	1.2795

Table 12 shows the iterations to get the best possible results when M_y has the highest weight value.

Table 12. Leveling Process Iterations (Second Combination)

$W_{M_x} = 0.025, W_{M_y} = 0.90, W_{V_m} = 0.025, W_{RR} = 0.025, W_{RIC} = 0.025$			
J	V_m	RR%	RIC
0.98480	69770	46.688	1.3920
0.98465	69770	46.688	1.3885
0.96830	53350	61.057	1.3017
0.96807	53350	61.057	1.2963
0.96780	53090	61.356	1.2955
0.96711	53090	61.356	1.2795

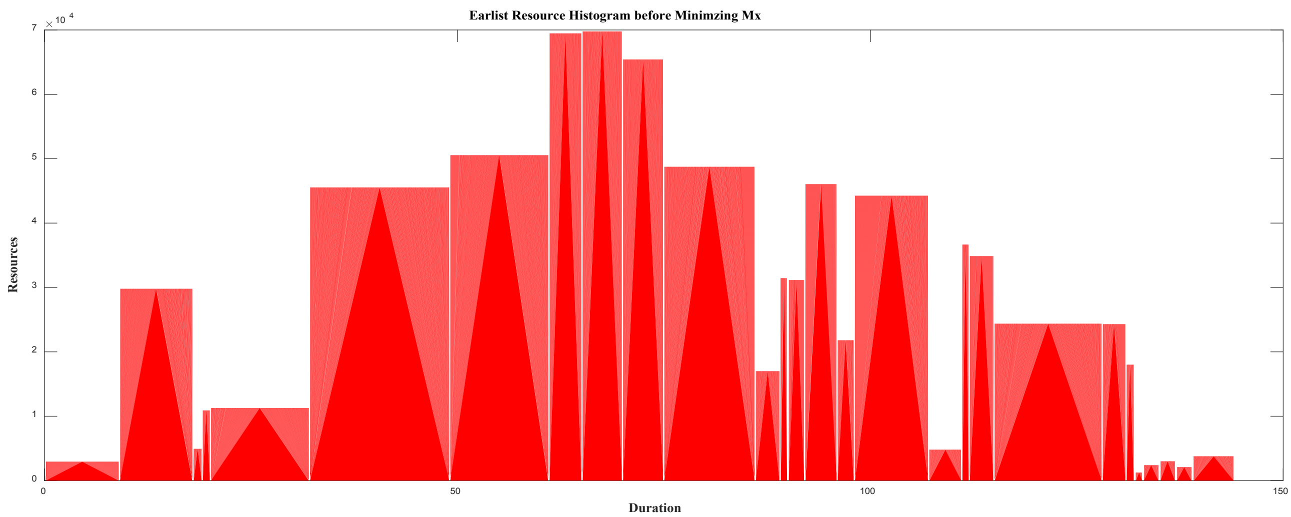

Figure 5. Resource Histogram Before Leveling (Second Project)

Table 13 shows the iterations to get the best possible results when V_m has the highest weight value.

Table 13. Leveling Process Iterations (Third Combination)

$W_{M_x} = 0.025, W_{M_y} = 0.025, W_{V_m} = 0.90, W_{RR} = 0.025, W_{RIC} = 0.025$			
J	V_m	**RR%**	**RIC**
0.98480	69770	46.688	1.3920
0.98465	69770	46.688	1.3885
0.76237	53350	61.057	1.3017
0.76214	53350	61.057	1.2963
0.75861	53090	61.356	1.2955
0.75792	53090	61.356	1.2795

Table 14 shows the iterations to get the best possible results when RR has the highest weight value.

Table 14. Leveling Process Iterations (Fourth Combination)

$W_{M_x} = 0.025, W_{M_y} = 0.025, W_{V_m} = 0.025, W_{RR} = 0.90, W_{RIC} = 0.025$			
J	V_m	**RR%**	**RIC**
0.98480	69770	46.688	1.3920
0.98465	69770	46.688	1.3885
0.73246	53350	61.057	1.3017
0.73222	53350	61.057	1.2963
0.72705	53090	61.356	1.2955
0.72636	53090	61.356	1.2795

Table 15 shows the iterations to get the best possible results when RIC has the highest weight value.

Table 15. Leveling Process Iterations (Fifth Combination)

$W_{M_x} = 0.025, W_{M_y} = 0.025, W_{V_m} = 0.025, W_{RR} = 0.025, W_{RIC} = 0.90$			
J	V_m	**RR%**	**RIC**
0.45283	69770	46.688	1.392
0.44958	69770	46.688	1.3885
0.35731	53350	61.057	1.3017
0.35233	53350	61.057	1.2963
0.35137	53090	61.356	1.2955
0.33668	53090	61.356	1.2795

When examining tables from (11-15), it is noticed that for this project, the most important index is RR which is not the same as the first project. Table 16 summarizes the results.

Table 16. Summary of the Results

Index Which Had the Highest Weight Value	The Percentage which J had Improved
M_x	08.9%
M_y	01.8%
V_m	23.0%
RR	26.2%
RIC	25.6%

(Figure 6) shows the final resource histogram when using the weight combination [$W_{M_x} = 0.025, W_{M_y} = 0.025, W_{V_m} = 0.025, W_{RR} = 0.90, W_{RIC} = 0.025$] for the second project where using RR gave the best result. Table 17 shows the activities' start time, finish time, resources, and total float after leveling.

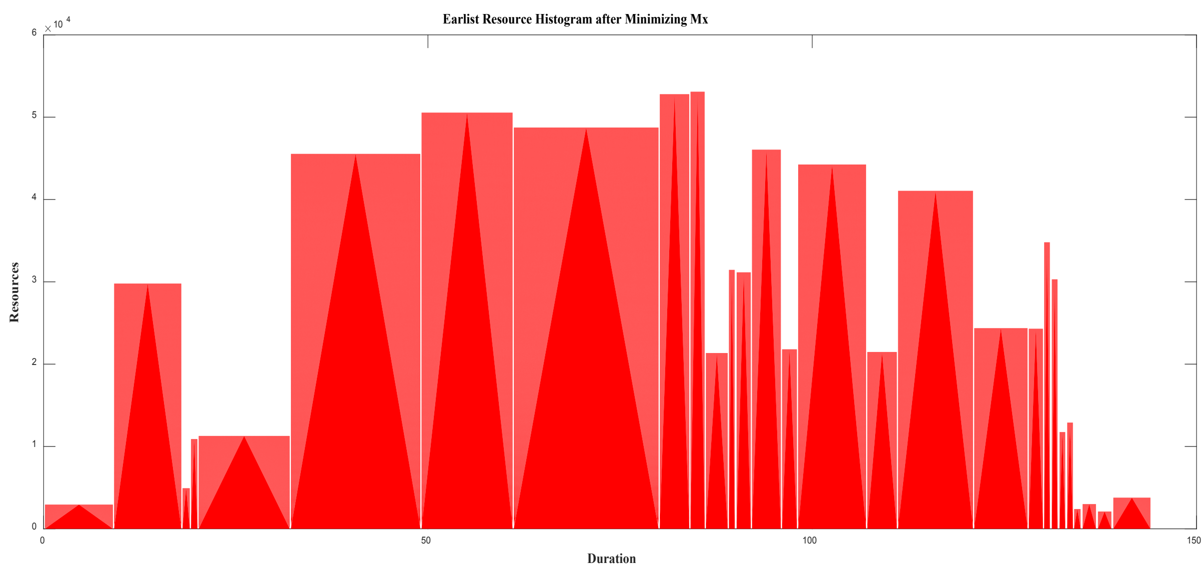

Figure 6. Resource Histogram after Leveling (Second Project)

Table 17. Project's Final State after Leveling (Second Project)

Activity ID	Resource ($)	Start Time	Finish Time	Total Float
A	2940	0	9	0
B	4930	9	19	0
D	8550	9	18	2
C	24860	19	20	0
E	2350	19	20	12
F	11280	20	23	0
H	50550	32	49	0
G	45540	49	61	0
J	48740	107	121	7
I	16680	61	86	0
M	2000	80	84	3
L	4000	86	96	32
O	4050	86	89	0
K	4350	86	90	2
N	11000	84	89	3
P	20250	89	96	32
S	2700	89	90	15
R	4200	89	92	0
U	1000	92	98	0
V	2400	98	107	0
Q	21800	90	92	15
W	44250	107	111	0
Y	4800	128	132	0
AB	24370	128	131	2
Z	18000	132	133	0
T	1250	133	135	0
X	6300	111	128	0
AC	1800	131	132	3
AD	10500	130	134	3
AE	3000	135	137	0
AF	2100	137	139	0
AG	3780	139	144	0

Because of the variety of noncritical activities' floats that can be used in the leveling process, and the best p value here is not equal to 1, the mechanism of how p works is more obvious than in the previous example. As shown in Table 10, activity J had a float of 53 before leveling and a value of 7 after leveling as in Table 17, indicating that 86.7% of the float was used, which is less than 87%.

4. Conclusions

An enhanced heuristic algorithm was proposed for scheduling and leveling. The algorithm was tested on two projects, and it mainly depends on the heuristic indices M_x, M_y, V_m, RR, and RIC. The indices weights affect the leveling goodness so different combinations of weights were used and a parameter (p) which refers to a partial value of the total float of noncritical activities was to enhance the heuristic algorithm. The major finding is that the relative importance of the indices the most important index depends on the nature of the project and the resource distribution throughout its time. In closing, for the first project, the index RIC is the most important as this index had the greatest impact on the leveling process, while for the second project. The index *RR* was the most important.

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