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Using modified earned value for cost control in construction projects

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ABSTRACT

The research aims to predict the future costs of project completion stages through basic metrics and indicators by using modified earned value. The project was divided into five stages with improved cost decision. This is an effective way to improve investment projects according to the earned value technique.

The earned value technique is mainly to control costs, make better decision and improve measures taken, after studying the modified method and indicating the cost difference between it and the actual cost. Our research sample includes the Iraq gate residential project, which includes several residential complexes still under construction belonging to the Baghdad Investment Authority.

The most important outcome of this research is the advantage of the modified method in terms of completion of the project at the scheduled time and the lowest possible costs after comparing the results of the prediction and the actual cost, depending on the slope lowest cost of the critical activities for each stage of the project. The results proved that the final cost in the modified method is lower than the predicted cost and less than the actual cost. The results also showed the possibility of overcoming the delay, which was 2.7% in the first stage. We succeeded in completing the project at the scheduled time and the cost was less than the actual cost by (26506.8) dollars.

Keywords: Project management, earned value, modified method, forecasting future cost, performance indicators

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1. Introduction

Project management consists of interrelated dimensions such as time and cost. These dimensions are controlled by the scheduled timetable that determines the beginning and end of each activity and the estimation of the time being utilized by each activity. Through follow-up and planning, resources can be assessed and used optimally to make the project reach the set goals. The most important objectives of the project managers are to complete the project using the lowest costs possible within the prescribed period and the level of quality required using modern techniques and methods. These enhance the overall level of the project and ensure that they meet the deadlines of the mission. It is necessary to resort to methods that will help bring about success and also ensure the completion of the project at its scheduled time Including the method of forecasting the future cost of the project through the earned value analysis depends on the specific indicators and keys for that method that will help to overcome the risks facing the project. The sample of our research is the project of Iraq's residential portal, consisting of residential complexes under implementation, where the problem lies in the lack of adoption of scientific methods in the control and planning of the housing construction projects and relies on the field experience of the workers. The most relevant studies use the earned value to control costs, as essential part of modern project management. This is the direction and basis for decision-making in the institution. The importance of the development of strategic direction is to analyze the cost classification and improve the cost decision that make up the project based on the results in

terms of the project's cost analysis and cost policy. The researchers found that the methods are too old. Also, the management tools and methods of analysis cannot maintain up with the cost control field times. It is also shown that the earned value is mainly used to control the project cost after analyzing the cost characteristics and explaining the steps of the earned value. Furthermore, the overview of the project's overall situation analysis and how to evaluate and design the value technique are the reasons for the cost overrun and the measures taken to enhance the impacts based on the cost analysis outcomes. According to the cost analysis results, and the taken measures to improve the effects, the researchers are interested in estimating the duration and the final cost plan. The cost overrun trend was found in the project control process. The companies developed detailed contingency measures to recover the project loss and to achieve the best cost control effect [1]. A study has shown that the modified earned value helps to manage project progress and it is also used as a measure to analyze project implementation, especially cases that need to be met with deadlines with a limited budget. This method is mostly used in various industries to analyze task execution cases and to analyze budget digestions for a project with deadline. The approved and the largest weight is the energy and not the budget. The researchers actualized the possibility of applying the method of earned value to many areas such as industries and others. Also, they stressed on the possibility of its application in the management of projects and explained the most important steps taken [2]. The use of the "critical path method" and linear programming in the study of the optimization of time and cost of technical processes is to analyze the problematic time delay of the project and how electronic activities are subjected to disruption of time and cost using linear programming. [16] This method is applicable for large networks. It allows for shorter computing time at a lower cost and addresses the problem of application in scheduling the project in the overall maintenance of the project [3]. The modified earned value for highway construction projects has also been used as a significant means of transportation. Its properties include a large investment, a long construction period and a broad social impact. In terms of managing the road effectively, they clarify its cost of building content control including cost projections, cost plan, cost accounting, cost analysis and cost assessment. With the improved theory of earned value method, it actualizes the construction quality with quantitative impact on cost. This determines the control model of highway construction costs and how to achieve the goal of monitoring the cost of highway construction. It has been found that before the method of earned value can be taken into account, the quality level of the cost of highway construction, offer the effect, so as to solve the highway problem control construction costs. Which can effectively reduce the market risk and financial risks faced by the highway construction project [4]. Using the modified earned value in forecasting the future cost of the project is one of the best ways to track the development of events of the project and focused on the need to take corrective action to improve the work performance. It was found that this method reveals whether the project is in its planned schedule or not in terms of time and cost. This method contributes to monitoring the progress of work in a more effective way [5, 9, 10].

This paper is in line with the research published in the project monitoring. But, the most important advantage of this research is the adoption of the cost tendency for critical activities. Based on the stages of the project, the earned value has predicted as the total cost of the project to be compared against the method adopted in the research. Also, to reduce the cost of implementation of the Iraq Gate residential project which is considered to be a vital investment project in Iraq.

2. Methods

2.1 Critical path method

The critical path method is a method of scheduling and analyzing projects and representing the tasks that complete a specific project including the trade-off between the duration of activity and cost. The basic rule is that any increase in the duration of critical activity leads to an increase in the duration of the project. Any decrease in duration leads to decrease in critical path length and duration of the project [6, 11].

The critical path method is considered as one of the most important methods of planning and analyzing business networks. The most important tool for the project management plan and the analysis of the schedule plan is that the activity begins when the previous activities have been completed. The network planning has been used based on a large scale for the progress and management of the project using the critical path

method. The start time and the end times for activities in the original schedule plan may be affected and may barely reflect on the critical path [15].

It also represents a set of critical points that determine the total time limit of the project. This causes the delay of achievement of the project in the event of any activity from the critical activities to be delayed, where each task on the critical path plays an important role in the progress of the completion of the project. This is considered as the main part to maintain the duration and the cost of the planned project. [17]. The formulation of the project planning timeline is considered as a clear basis for the implementation of the projects. It is the key to the success of the project and determines the range of the project from the sequence of activities and also to estimate the duration of the activity in order to extract the critical path through the use of a network analysis scheme [18].

This method represents an important tool used to coordinate the activities involved in the project. It also uses the critical path for multiple projects such as construction and manufacturing. The main elements of the critical path method are activities and nodes where the activity is represented by an arrow, the node is represented by a circle, and the length of the arrow is not related to the time taken. The critical path of the project network is the longest route that gives the minimum period of time at which the entire project can be completed. It is important that there should be an impact of a critical path in the project network diagram [19, 20].

2.2 Steps to calculate the critical path

The critical path account includes two basic stages:

1. The first stage is the forward-scroll algorithm which includes the critical path calculation from the beginning of the node to the last node of the grid and this is based on the following equation:

$$ESj = max\{Esi + Dij\} \quad \ldots \quad (1)$$

Dij: Duration of activity

ESi: Early start of a certain activity, usually the *Esi* for the first activity is equal to zero

ESj: Late onset of a particular activity

ESj: The late start of a certain activity

2. The second stage is the backward-scrolling algorithm which is the opposite of the front-scroll algorithm. The calculation starts from the last node and returns to the forward node and it is based on the following equation:

$$LFi = Min\{ LFj - Dij \} \quad \ldots \quad (2)$$

Lfi: Early end of a given activity

Dij: Activity duration

LFj: Late end of a given activity

The time difference between the early start and the late start is called elasticity. It represents the amount of time in which the activity can be delayed without affecting the total duration of the project.

2.3 Project phases

A project can be divided into a certain number of stages where each stage represents a group of activities that culminate in completing one or more of the achievements and are usually completed sequentially. Some activities may overlap some of the project positions. Each project has different stages according to its nature. The phase structure allows the project to be divided into logical subgroups in order to facilitate management, planning and control. The number of stages or the need for stages depends on some important elements such as size, complexity, the potential impact of the project. These characteristics are similar in all types of projects, regardless of their nature. These characteristics are:

1. The nature of the work, which has a biased focus on each stage.
2. Achieving the basic objective or goal of the stage, which requires unique controls or processes [21].

2.4 Cost balancing

There are some complex problems that are often faced by the project manager and he is responsible for solving them. The most important of these problems is the problem of balancing the cost in terms of

planning and implementation and also the need for sufficient funds available at hand [7]. Considering the mapping of complex analysis and critical success factors as identified in planning stage, the manager should compare the available funding with the expected cost of the project to know if it is sufficient or not. If it is not sufficient, the manager should seek additional external funding sources or modify the plan for the project [22, 23].

Taking into account the overall objectives and priorities of the project and considering the design which should commensurate with the ceiling of the budget, sometimes the project requires a redesign and this will break the project in the primary stages. This will result to conflict with the available funding and general budget of the project. It will no longer be in line with the first stages of the project, it will be different from the original estimates. This can affect the overall project estimated cost [24].

2.5 Earned value

It is a standard method for measuring project performance as proposed by the US Department of Defense in 1960. It is based on a set of direct measures that enable it to measure and evaluate the overall health of the project. [8]. These measures serve as early warning and signals to detect project problems in a timely manner or exploit project opportunities and also help to know the difference between costs which includes Budget, actual costs, knowledge of the current project status, future cost of each stage of the project and forecasting the overall cost of the project more accurately. [12,13]. This is a method that can be used to measure physical progress of the project and the integration of the three important elements (time, cost management, and scale) which will also be taken into account before the completion of the work. Also, time and costs incurred for the completion of the project, assess and monitor risks by measuring the progress of the project in monetary policy [14, 25, 26].

Due to the difficulty of obtaining the accurate answer about the actual progress of the project, many companies resorted to use the acquired value method as a global standard for measuring the project performance in terms of cost and schedule. It gives a clear and good picture of the current project situation and measures the general performance of the building. We need to use some administrative tools that will enable the identification of cost data and show the possibility of a change in the schedule during the construction process. Also, to indicate the efficiency of the schedule and to show that the project in the case of early or late is done in a certain phase. However, that does not prevent the remaining works in the future from being exposed to change. Therefore, it is necessary to adjust and take into consideration the future risks of managing the project time successfully [27].

2.6 Key indicators of earned value method

1. Schedule Variance (SV)

$$SV=EV-PV \quad (3)$$

EV: Earned value

PV: Planned Value

2-Schedule Performance Index (SPI).

$$SPI = EV/PV \quad (4)$$

EV: Earned value

PV: Planned Value

3-Cost Variance (CV)

$$CV= EV- AC \quad (5)$$

EV: Earned value

AC: Actual Cost

4. Cost Performance Index (CPI)

$$CPI =EV/AC \quad (6)$$

EV: Earned value

AC: Actual Cost

5. Estimate at Completion (EAC)

$EAC = BAC/CPI$ (7)

BAC: Total project budget

CPI: Cost performance indicator

6. *CV*% : Percentage of cost variance

CV%=(cv/Ev)*100 (8)

CV : Cost variance

EV: earned value

7.SV%: Percentage of Schedule variance

$SV\% = (SV/PV)*100$ (9)

SV : Schedule variance

PV: Planned value

8. (*PV*): Planned value

PV= Percent complete (Planned) * *BAC* (10)

BAC: Total project budget

9. Earned value (*EV*)

EV = Percent complete (Actual) * *BAC* (11)

BAC: Total project budget

2.7 Steps to calculate the modified method

The traditional method of calculating the acquired value indicators is the sum of all the activities of the project stages, where the division is done according to the planned and actual achievement ratios. The modified method calculates the acquired value indicators for the less critical activities [28]. The important steps for calculating this technique can be summarized as follows:

1. After dividing the project into certain stages, we extract the critical activities for the stages.
2. We extracted the cost tendency for the critical activities.
3. We choose the critical activity with the lowest cost slope.
4. We will extract the delayed days in the first stage based on the measurement indicators of the acquired value method. Then, those days (delayed days) are compensated in the second phase of the project to avoid delays and equal working days in the actual time schedule.

3. Application

The project of the Iraqi residential portal was chosen because of the problems of delaying the time of completion of the work and delay the deadline for the delivery of the residential apartments to the registrars. The general information of the project was reviewed and the reasons for delaying the completion of the work was also reviewed. We tried to solve these problems with modern and sophisticated scientific methods after the division of the project into the five stages. The first phase is after the passage of (150) days of the completion of the project. The actual cost of actual work is (4844135) dollars. The second phase will be after (360) days of completion of the project, where the total cost at this stage is (8141387) dollars. The third phase after (420) days of the completion of the project will be the actual cost of this phase of the project which is (10555161) dollars and the fourth stage will be after (515) days of the completion of the project. The actual cost of this stage is (11754431) dollars. The final phase is the stage of completion of the project after the passage of (675) days with actual cost of (13379731) dollars. Table 1 explains the past and subsequent activities, times and natural costs of the project. Figure 1 depicts the graphic representation of the project activities.

Table 1. Past and subsequent activities, times and natural costs of the project

	Work	**Activity**	**Predecessors**	**Duration(day)**	**Cost (dollars)**
1	Preliminary work	A	-	30	25000
2	Site processing works	B	A	30	4000
3	Earthworks	C	A	15	9802

	Work	Activity	Predecessors	Duration(day)	Cost (dollars)
4	Concrete works	D	A,B,C	90	4757371
5	Construction works	E	D	60	429104
6	Health business	F	D,E	80	599867
7	Electrical Works	G	D,E	150	2268281
8	Mechanical works	H	D,E	110	518510
9	Metal Works	I	D,E	60	55045
10	Door & Window Works	J	G,H	90	646940
11	Heat insulation works	K	I	60	59679
12	Works of fumes and whiteness	L	G,H,I	60	1133600
13	Works of secondary ceilings	M	L	60	102350
14	Tiles and ceramics works	N	L	65	887205
15	Stone works	O	N	30	209715
16	Painting works	P	O	30	689150
17	Works of Terminations	Q	P,F,J	80	678510
18	Furnishing works	R	Q,M	50	257640

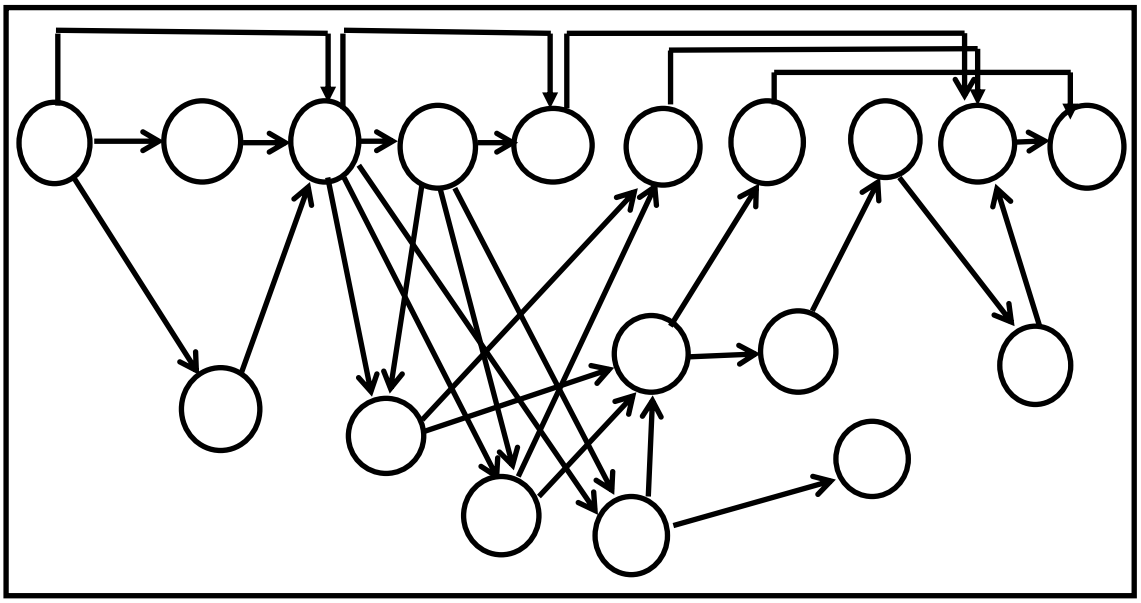

Figure 1. The graphic representation of the project activities

The percentage of the completion of the project progress is determined based on the nature of the activity and as follows:

Table 2. The planned cost and percent complete (actual & planned) for each activity

	Activity	Planned Cost	Cumulative cost	Actual completion rate	Planned completion rate
1	A	25000	25000	%1	%1
2	B	4000	29000	%2	%2
3	C	9802	38802	%10	%11
4	D	4757371	4796173	%35	%36
5	E	429104	5225277	%39	%38
6	F	599867	5825144	%47	%46
7	G	2268281	8093425	%59	%58
8	H	518510	8611935	%63	%63
9	I	55045	8666980	%65	%66

	Activity	Planned Cost	Cumulative cost	Actual completion rate	Planned completion rate
10	J	646940	9313920	%69	%70
11	K	59679	9373599	%73	%73
12	L	1133600	10507199	%81	%80
13	M	102350	10609549	%83	%83
14	N	887205	11496754	%86	%86
15	O	209715	11706469	%88	%88
16	P	689150	12395619	%92	%93
17	Q	678510	13074129	%98	%98
18	R	257640	13331769	%100	%100

3.1 Solution

According to equations 1 and 2 and using winQSB, the critical and flexible activities were extracted. Table 3 shows the results.

Table 3. The start and end times of the activities

	Activities	Activities time (days)	Earliest start	Earliest finish	Latest start	Latest finish	slack
1	A	30	0	30	0	30	0
2	B	30	30	60	30	60	0
3	C	15	30	45	45	60	15
4	D	90	60	150	60	150	0
5	E	60	150	210	150	210	0
6	F	80	210	290	465	545	255
7	G	150	210	360	210	360	0
8	H	110	210	320	250	360	40
9	I	60	210	270	300	360	90
10	J	90	360	450	455	545	95
11	K	60	270	330	615	675	345
12	L	60	360	420	360	420	0
13	M	60	420	480	565	625	145
14	N	65	420	485	420	485	0
15	O	30	485	515	485	515	0
16	P	30	515	545	515	545	0
17	Q	80	545	625	545	625	0
18	R	50	625	675	625	675	0

3.2. Results of the traditional method

Based on equations (3-11), the following indicators were extracted:

Table 4. The results of indicators and measures of the earned value method

Phase / Indicators	First	Second	Third	Forth	Fifth
EV	4666119.15	7865743.7	10798732.8	11731956.7	13331769
PV	4799436.8	7732426.02	10665415.2	11731956.7	13331769
SV	-133317.6	133317.6	133317.6	0	0

Phase / Indicators	First	Second	Third	Forth	Fifth
CV	-178015.8	-275643.3	243571.8	-22474.3	-47962
SPI	0.9722	1.0172	1.012	1	1
CPI	0.96325	0.96614	1.0230	0.99808	0.99641
EAC	13840403.8	13799003.2	13032032.2	13357415.2	13379802.4
CV%	-3.81%	-3.50%	2.25%	-0.19 %	-0.35%
SV%	- 2.77%	1.724%	1.24%	0%	0 %

Figure 2 shows the increase in cost as the stages of the project progresses, the matching of the planned value curve and the earned value curve. Also, it shows the simple difference between the actual cost curve and the planned and earned value curve.

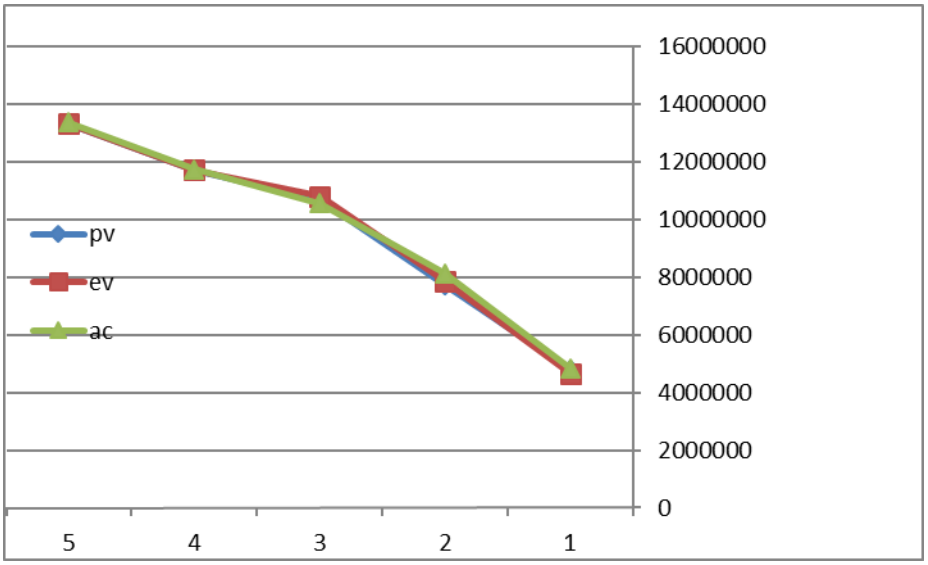

Figure 2. The relationship between the planned value, the earned value and the actual cost

Figure 3 depicts the difference between the actual cost curve and the planned cost curve. The first phase of the project was found to exceed the planned cost, as it is in the case of the second stage where the curve started to rise. In phase 3, it stabilizes and becomes identical with the schedule in the fourth stage and the final stage which is the stage of completion of the project.

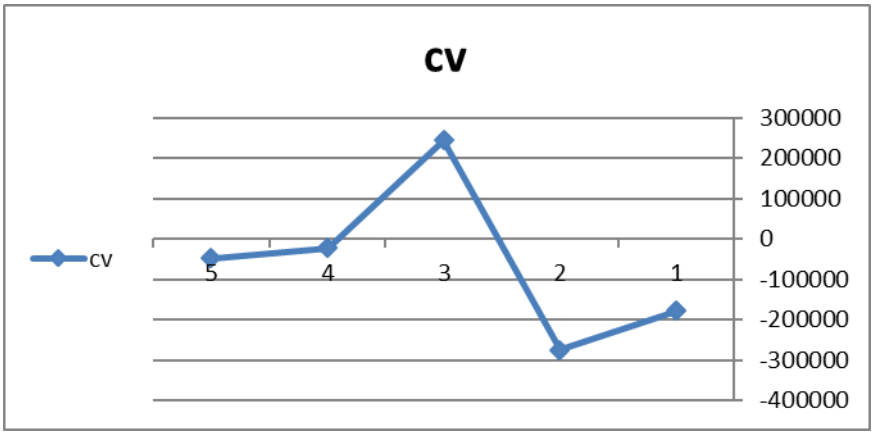

Figure 3. The difference between the actual cost and the planned cost and earned value

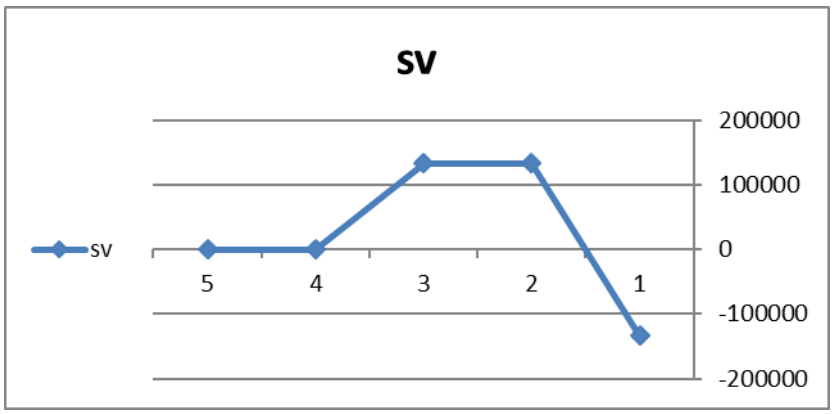

Figure 4. The schedule variation graph

Figure 4 shows the time difference between the plan and the actual. The curve shows that the project has exceeded the planned time in the first stage of the project completion and begins its early achievement in the second stage. It continues in the third stage until it returns to the planned schedule. The plan is identical to the active phase 4 and the final stage of completion of the project, which will overcome the violations during the process of completion and avoid the factors leading to delay of the project completion within the scheduled time.

3.3 Results analysis of the traditional method

The results of the first phase show that the amount budgeted for the actual work completed at this stage of the project is (4666119) dollars. While the value of the plan scheduled to be completed in this phase is (4799436.8) dollars. The variation of the schedule is shown by the negative sign, which means that the project exceeded the scheduled time limit. The results of the cost variance also show a negative sign, which means that the project exceeded the budget of (178015.8) dollars. The expected value for the completion of the project was (13840403.8) dollars, which represents the total cost of the project at the completion. The percentage of exceeding the estimated cost of the project is 3.8%, and the percentage of time exceeded for the project is 2.7%.

The results of the second phase show that the amount included in the budget for the actual work of the project at the stage of completion is (7865743.7) dollars. While the value of the plan scheduled to be completed in this phase is (7732426) dollars .The results of the variation in the schedule show that the delay in the first phase has been processed. The indicator showed the positive result. Namely, the project is in its early time. The results of the variance of the cost also indicate negative sign, which means that the project exceeded the budget of the value of (275643) dollars. We noted that the predicted value for the completion of the project was (13799003.2), which represents the total of the project upon completion. The percentage of the estimated overruns cost of the project is 3%. The percentage of time exceeded for the project is 2%.

The results of the third phase show that the budgeted amount of the actual work completed at this stage of the project is (10798732.8) dollars. The value of planned and due date to be completed for this stage is (10665415) dollars. The results of the variation of the schedule show that the project is in its early stage because the indicator shows positive value. The results of the cost variance are also shown by the positive sign which means that the project is within its budget and at a cost difference of (243571.8) dollars, indicating that the project is moving towards the best and with good results. Note that the predicted value for the completion of the project was (13032032.2) dollars. This is amount for the project will cost upon completion. The percentage of the estimated cost overruns of the project is 2%. The percentage of time exceeded for the project is 1%.

Forth phase results show that the amount budgeted for the actual work completed at this stage of the project is (11731956.7) dollars. The value of the planned and due date to be completed for this stage is (11731956.7) dollars. The results of the variation of the timetable show that the project is in line with the plan because the variance is shown at zero value. The results of the cost variance are also shown by the

negative sign which means that the project exceeded the planned budget and a cost difference of (22474.3) dollars. We noted that the forecast value of the completion of the project was (13357415.2) dollars, which represents the total cost of the project upon completion. We also show that the percentage of the project cost overrun is 0.19%. The percentage of time exceeded for the project is 0%.

The results of fifth phase also show that the budgeted amount of the actual work completed at this stage of the project is (13331769) dollars. The output of the planned value to be completed for this stage is (13331769) dollars. The results of the variation of the schedule show that the project is within the plan because the variance is shown at zero values. The results of the cost variance are also shown by the negative sign, which means that the project exceeded the planned budget at a cost difference of (47962) dollars. We noted that the expected value of the completion of the project was (13379802.4) dollars, which represents the total cost to be incurred by the project at the end. The percentage of the estimated cost of the project is 0.35%. The percentage of time exceeded for the project is 0%.

3.4 Modified Method

The modified method depends on the cost of the critical activities and each stage of the project. This represents the amount of increase that occurs from each day when the project is compressed and it is based on the delay in the stage and compensation for the delayed days in the next phase of completion. The results of the prediction by the earned value method shows that there is a delay in the first stage. So, an improved plan should be developed to address the delay and to rely on the least critical activity.

Table 5. The critical activities and the cost of each critical activity

Activities	Natural time (day)	Compressed time (day)	Natural cost (dollars)	Compressed cost (dollars)	Difference (day)	SLOPE= Δc / Δt
A	30	20	25000	25250	10	25
B	30	20	4000	4040	10	4
D	90	75	4757371	5946713.7	15	79289.5
E	60	45	429104	493469.6	15	4291.04
G	150	120	2268281	2449743.48	30	6048.7
L	60	40	1133600	1167608	20	1700.4
N	65	55	887205	931565.25	10	4436
O	30	25	209715	211812.15	5	419.43
P	30	20	689150	696041.5	10	689.15
Q	80	65	678510	746361	15	4523.4
R	50	35	257640	260216.4	15	171.76

3.5 Results of the modified method

Following the steps of calculating the average method (1-4), in the results of our research by predicting the first stage of the project, the delay occurs in the first stage that requires speeding to catch up with the schedule depending on the critical activities in the second stage. The cost of the activity is reduced by five days from the activity at a cost of (21455.2) dollars. This returns the project to the normal plan at a cost that is less than the difference of the cost in the indicators for this stage which was (275643.3) dollars. For third, the fourth and fifth stages, there is no excess in the prescribed period, which leads to the completion of the project at its scheduled time and with a final cost less than the cost of truth and less than the predicted cost to complete the project.

3.6 The analysis of the results of the modified method

To impose a delay, the first phase is compensated through the second stage and through the activity that achieves the lowest cost which is activity E. The cost of reduction per day is (4291.04) dollars. If the delay continues, it will lead to the largest activity, which is activity G where the cost of reduction per day is (6048.7) dollars.

In the case of delay in the second phase, we can address this in the third phase by taking the activity (L) in this stage where the cost of reduction for one day is (1700.4) dollars.

In the case of delay in the third phase, we address this in the fourth phase by taking the actions that achieves the lowest cost which is activity O. The cost of reduction for one day is (419) dollars. If the reduction continues, we will resort to the largest activity which is activity N. Here, the cost of reduction for one day is (4436) dollars.

In the case of delay in the fourth phase of the project, we addressed this in the fifth and final phase of the project as well as taking the activity with the lowest cost which is activity R. The cost of reducing the activity per day is (171.76) dollars. Then, the activity with the greatest inclination is Activity P. The cost of reduction for one day is (689) dollars and the last activity on the stage and the largest mile cost is activity Q, where the cost of reduction for one day is (4523.4) dollars.

4. Conclusions

This research's primary result can be summarized as follows:

1. The findings showed that the modified method's final price is the lowest of the expected price and the real cost. This is the altered method's average. At the given moment and at the lowest possible price, we were able to exceed the project delay and closure. The results proved that the final cost of the modified method is the lowest of the predicted cost and the actual cost. This is the average of the modified method. We were able to exceed the delay and the completion of the project at the specified time and at the lowest possible cost. Resorting to the activity represents the lowest mile cost.
2. The results show that the modified method reduces the total cost of the project by (26506.8) dollars for the actual cost under the same time of the completion of project.
3. We recommend relying on the modified method in the investment of projects, especially the construction of residential complexes. It contains the accuracy and indicates the possibility of reduction of critical activities and for each stage of the project, especially in Iraq because the projects are subjected to exceptional circumstances that lead to delayed completion of projects.

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