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***Research Article***

# ESTIMATINGCOST AT COMPLETION THROUGH EARNED VALUE TECHNIQUE IN BYPASS ROAD OF NORTH EAST OF AHVAZ

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## ABSTRACT
One of the main concerns of project managers is to complete the project according to scheduled time and cost. Various limited methods have been presented in PMBOK Standard, papers and management seminars concerning this issue; however, PMI has introduced earned value technique as the main and best method. This method has been used in Ministry of Defense of America and the factories of other industrial countries of the worldfrom the past century until now. Based on this technique, the project team can do estimate at completion (EAC)c based on various conditions and formulas after 20% progression of project and passing instability stage. Various studies have been carried out comparing Iran projects in different conditionsincluding the present study that has focused on one of the known national projects in Khuzestan province that is bypass road of northeast Ahvaz through earned value method (EVM). In this study, all methods, theories and various formulas have been collected and 6 methods have been used for estimation of project completion cost. At the end, from various formulas and methods, the best methods have been classified and specified concerning the least deviation.

***Keywords:*** *Earned Value, Estimate at Completion Cost (EAC)c, Forecast Indices, Earned Value Management (EVM)*

## INTRODUCTION
Project management is undoubtedly one of the most important and mostly used branches of management in recent decades. The experts have always been seeking for better and more efficient instruments and solutions for project management when the project progresses and become more complex and sensitive. Thus, various instruments and methods have been designed that try to facilitate the processes of project management. “Earned value management” system (EVM)as an efficient and effective project management system has drastically changed in recent 100 years and is currently introduced to the world of projects in some countries such as America and England.
Project performance analysis is the comparison of the real project and scheduledperformance based on performance evaluation that is done with the aim of analyzing the current status of the project. The main aim of earned value management is to provide deep and complete perception of cost performance and project schedule and do logically forecast the final status these two items for management. This perception is necessary for good decision making during project analysis, utilization of opportunities and reduction of undesired controversies. The other aim of EVM data is to provide quick indices for final costs and completion of timing schedule. This analysis provides forecast of future performance of the project.
Various scales can be formed with the use of earned value management system in the project that can deal with past, present and future cost and timing of the project. These scales can be presented in form of data and photo and provide effective instrument for transferring a shared perception to all beneficiaries.
Increased industrial and service projects all over the world made EVM a new and efficient method that playsimportant role in integrated control of the project. One of the main concerns of the project managers and beneficiaries is to obtain precise information of the progress of the project and compare the work performed with the anticipated work and calculate the cost and time controversies with real performance. There are always constrains in precise evaluation of work performed in the project; however, projects’ control is almost impossible without evaluation and measurement of its progress. The most common

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evaluation method of project progression is earned value or variance analysis. Time variation analysis provides the project manager with the possibility of identifying the project problems and barriers and taking required actions for removing of barriers. There are three main axes in each project that the manager should control and supervise.

Certain mechanism should be designed to achieve qualitative objectives. However, concerning the early implementation and lower cost objectives (schedule and cost variance control), the variation of scheduled time and real time and the predicted costs in different defined time intervals should be identified and evaluated and its effect on the whole project also should be specified. To maintain the project economic and to have efficient use of allocated budget, the project management should constantly supervise the real costs of the activities and identify the reasons for deviation from the predicted value and try to fulfill these objectives. Before explaining the details of required obligations of earned value management, it is required to explain some of the key expressions and definitions of project management (PMBOK® Guide-Fifth Edition).

***Related Definitions to Earned Value System***

EVM has certain definitions that are required in estimation of project completion and will be studied in this section. Earned value system has three parameters, through which it is possible to study various analyses of EAC(c), including:

The budget for all activities that should be spent until the date of study according to schedule,

**BCWS**:**B**udget**C**ostfor**W**ork**S**chedule

PV: Plan Value

The budget according to early plan criterion for real work performed,

**BCWP** :**B**udget**C**ostof**W**ork**P**erformed

EV: (Earned Value)

The actual cost paid for work performed,

**ACWP** :**A**ctual**C**ostof**W**ork**P**erformed

AC:(Actual Cost)

(PMBOK® Guide-Fifth Edition).

Imagine the planned budget for performing a project is 100 units, at the certain date that the project is supposed to bestudied, it should have 25% progress according to the schedule; however, its real progress is 20%. On the other hand, the spent budget is 30 units. In this example, the calculation of earned value indices is as follow:

BCWS= Progress according to schedule× the whole planned budget

BCWS= %25× 100= 25

BCWP= Real progress× total scheduled budget

BCWP= %20×100= 20

ACWP= 30

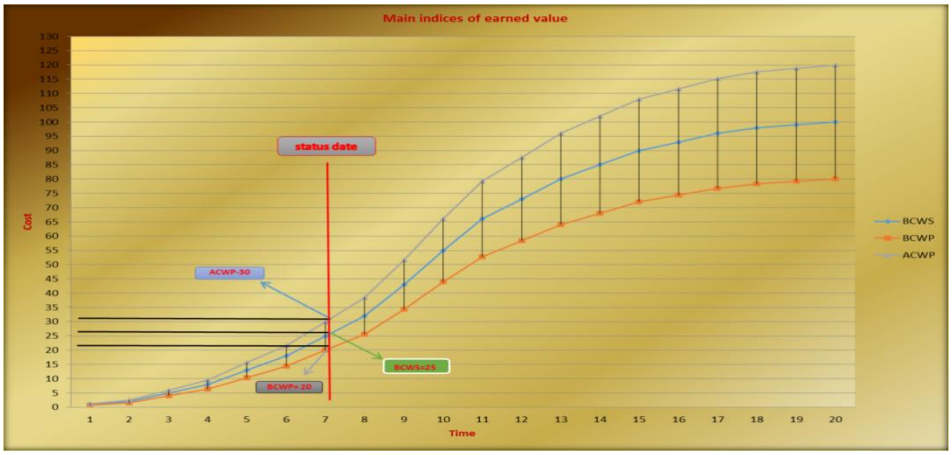


**Figure 1: The main indices in earned value**

***The Indices determining Deviation in Earned Value***

The following equation shows timing deviation from schedule:
SV= (Schedule Variance)= (BCWP-BCWS)
SV= 20-25=-5
The following equation shows cost deviation from schedule:
CV= (Cost Variance) = (BCWP)- ACWP
CV= 20-35=-10
The project lags behind the schedule 5 units in terms of time and 10 units in terms of cost.

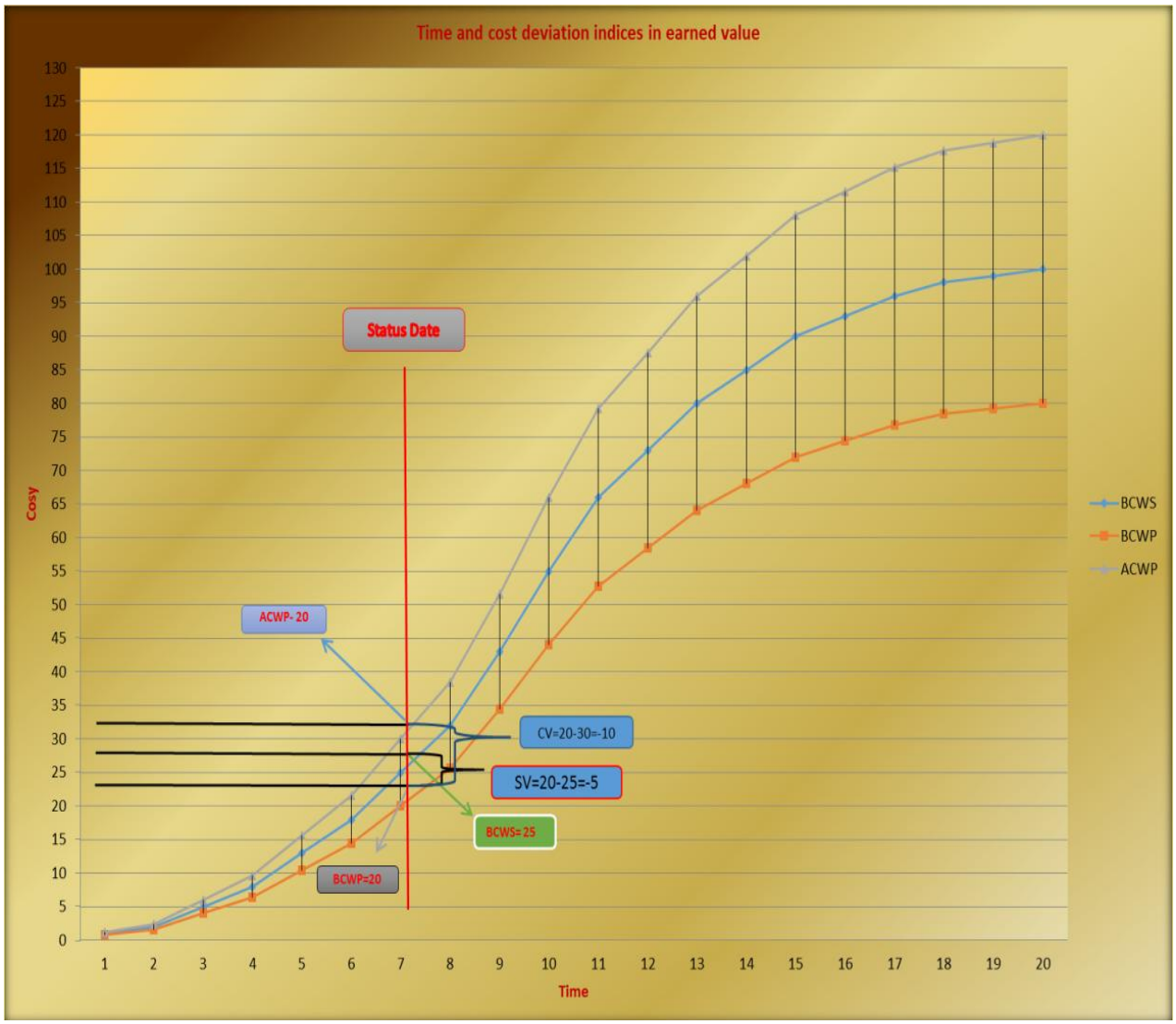


**Figure 2: Deviation indices in earned value**

Efficiency in earned value indices
SPI: Schedule Performance Index
SPI = (BCWP) / (BCWS)= 20/25=0.8
Efficiency index smaller than one indicates time lagging of the project,
CPI: Cost Performed Index
CPI= (BCWP) / (ACWP)= 20/ 30= 0.67
Efficiency index smaller than one indicates that the project's budget has not the required efficiency,

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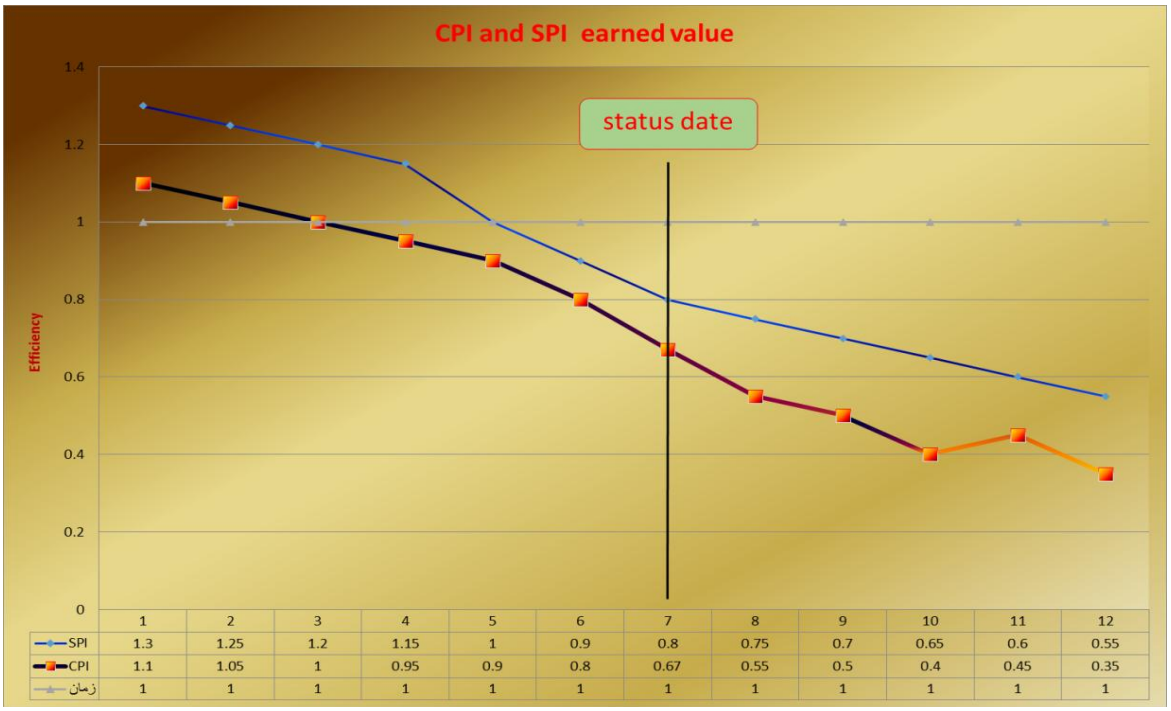
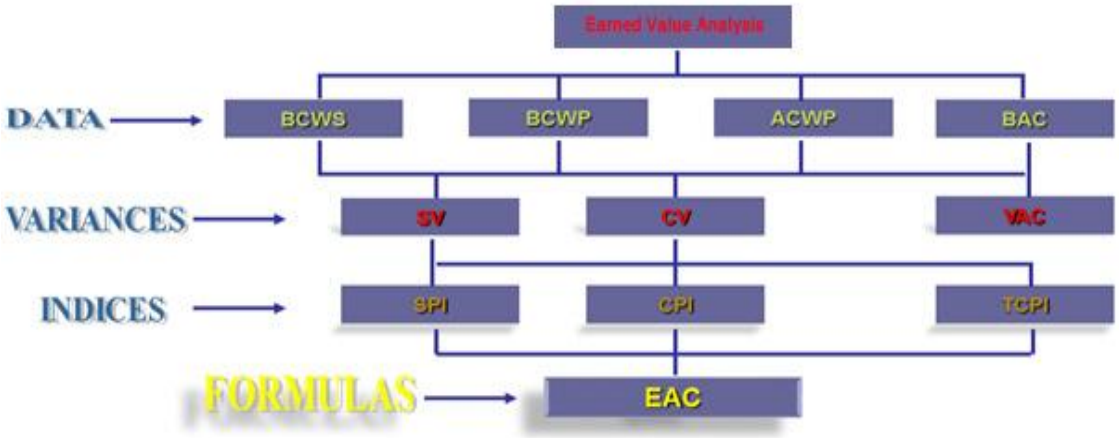



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPI | 1.3 | 1.25 | 1.2 | 1.15 | 1 | 0.9 | 0.8 | 0.75 | 0.7 | 0.65 | 0.6 | 0.55 |
| CPI | 1.1 | 1.05 | 1 | 0.95 | 0.9 | 0.8 | 0.67 | 0.55 | 0.5 | 0.4 | 0.45 | 0.35 |
| زمان | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Figure 3: SPI and CPI in earned value**

Indices for estimation evaluation in earned value
BAC: Budget at Completion
EAC(c): Estimate At Completion (cost)
EAC (t): Estimate At Completion (time)

**Table 1: The study of calculation method and the type of indices used in analysis of earned value in estimation processes**




***EAC(c)***

There are many formulas for EAC(c) in recent years, this paper tries to do a comparison of the most applicable of them as related to Iran projects and especially bypass road of north east of Ahvaz.
The general EAC formal that is also called the last revised estimation can be expressed as:
EAC= Actuals+ ETC
For EAC, most discussions and formulas have been proposed due to difference in ETC. Generally, ETC can be shown as follow:

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$$ETC=\frac{\text{Budgeted Cost Word Remained}}{\text{Performane Factor}}=\frac{BCWR}{P.F}=\frac{BAC-BCWP}{P.F}$$

Where,
BCWR= Budgeted cost for work remained
BAC= Budget at completion
BCWP= Budget Cost of Work Performed
PF= Performance factor
As it is specified in the formula, what is mostly discussed in ETC is the formula or method of calculation of performance factor. (PMBOK® Guide-Fifth Edition).

***Used Formulas***

**Table 2: Main and secondary indices of earned value**

| Row | Explanation | Abbreviation | Formula |
|---|---|---|---|
| 1 | Actual cost for work performed | ACWP=AC | Actual cost for work performed (from accounting sector) |
| 2 | Budget cost for works scheduled | BCWS-PV | Budget cost for scheduled plan |
| 3 | Budget cost for work performed | BCWP=EV | Budget for actual progress |
| 4 | Schedule variance | SV | BCWP-BCWS |
| 5 | Cost variance | CV | BCWP-ACWP |
| 6 | Schedule performance index | SPI | BCWP/BCWS |
| 7 | Cost performance index | CPI | BCWP/ACWP |
| 8 | Budget at completion | BAC | Budget specified for work completion |

***Method of using the above Formulas in Proposed Methodology***

To select the most appropriate forecast index (FI) and concerning the varied behavior of these indices during project life, it has been divided into four functional areas according to table …. And the predictability of each index in each of these areas will be studied and investigated. In table …..that is calculated by EV/BAC, area 4 is for identification of the index that during the project life (20%- 100%) has in average more precise prediction compared to other indices. The selection of progress percentage 20% for the beginning is based on Christensen studies in 1993 to 2006 concerning the stability of CPI (Christensen *et al.*, 1993-2006).

**Table 3: Four areas studied in each project**

| Explanation | Progress | Area | No. |
|---|---|---|---|
| Initial stages of the project | 20%- 40% | Initial | 1 |
| Mid stages of the project | 40%- 70% | Mid | 2 |
| Final stages of the project | 70%- 100% | Final | 3 |
| Total duration of the project after instability stage | 20%- 100% | Total | 4 |

These studies that are based on review of hundreds projects and use of statistical analysis show that CPI(c) will become stable when the project has 20% progress and stability is defined in this way that the final CPI value won't change more than 0.1 of its value in progress percentage of 20%.
In other words,
CPI %20- 0.1< CPI Final< CPI %20+ 0.1
Thus, in this study, the progress area before 20% progress is called pre-stability area.
After classification of projects to four areas, for all reporting months of these areas, cost estimation indices will be calculated (Christensen *et al.*, 1993-2006).

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***Cost Estimation Induces***

Indices in form of the following table's formulas are in fact indices that are used as P.F more than other indices in research backgrounds.

**Table 4: Indices, formulas, methods and their applications in EAT(c)**

| Method | Performance index | Application | Formula |
|---|---|---|---|
| First method | P.F=1 | According to schedule | AC+(BAC-EV)/PF |
| Second method | PF=CPI>1 | Inappropriate performance in cost | AC+(BAC-EV)/CPI |
| Third method | PF=SPI>1 | Inappropriate performance in time | AC+(BAC-EV)/SPI |
| Fourth method | PF=CPI>1 & SPI>1 | Inappropriate in terms of time and cost | AC+(BAC-EV)/(CPI*SPI) |
| Fifth method | PF=CPI>>1 & SPI>1 | Inappropriate more in terms of cost and less in terms of time | AC+(BAC-EV)/(0.8CPI+0.2SPI) |
| Sixth method | PF=(CPI1+CPI2+CPI3)/3 | Constant cost performance in three past months | AC+(BAC-EV)/(CPI3) |

As it is observed, these indices have been used in form of 6 formulas. Each estimate at completion model has taken certain approach and uses the related index for future performance of the project that is specified according to their application (PMBOK® Guide-Fifth Edition) (Christensen *et al.*, 1993-2006; Lipke *et al.*, 2007).

Evaluation methodology and the selection of the best method for EAC(c)

Since EAC (c) and awareness of the spent budget at the project completion has certain significance in most projects, the selection of a method than can do this properly with the least variance with actual value at the project completion is one of the main and critical issues in project management.

Various methods have been proposed for this in previous studies. Thus, in this section, a methodology will be introduced for selection of the best method that uses available data.

The idea for using this method is such that the best performance index will be selected based on project performance at the specified time.

For simplicity purpose and project management, projects are divided to various control levels and for each of these work packages; the required data for earned value management will be collected. These data includes parameters that were explained in previous sectors. This method is used such that since the actual cost values are available until reporting time, its estimation in previous months concerning various performance indices and the selection of their best in terms of the least variance can be a good method. Now, for selection of the best index from the six mentioned indices for EAC(c), the following procedures should be followed.

***EAC (c) with Earned Value Method***

1. Metering and estimation of project and data collection in each stage, especially actual costs
2. Preparation of failure structure of activities WBS
3. Preparation of schedule according to implementation items
4. Calculation of main indices of earned value such as ACWP- BCWS- BCWP
5. Calculation of secondary indices of earned value such as CV- SV- CPI- SPI
6. Entrance intro tables and preparation of related figures
7. Study and comparison of 6 formulas for EAC (c)
8. Collection and transferring data into table with time group division
9. Preparation of tables for comparison of obtained values with actual values
10. Use of statistical comparison method of sum of squares for precise comparison
11. Ranking based on the least variance with actual values

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***Example***

Various projects have been studied with earned value method that in the same condition have shown similar results with earned value method. One of the studied projects is bypass road of northeast of Ahvaz with the following specifications.

***Specifications of Bypass Road of Northeast of Ahvaz***

Employer: Ministry of transportation
Consultant: Haraz Rah consultant engineers
Contractor: Nasr Misagh Ahvaz Company
Initial estimated budget: 140,138,310,184
Final budget: 156,863,653,611
Estimated schedule: 24 months
Actual schedule: 26 months
Location: Ring belt of northeast of Ahvaz

**Table 5: Estimation of project data in each stage especially actual costs**

| Row | date (month) | scheduled cost (cumulative) | scheduled cost (monthly) | Actual cost (cumulative) | scheduled progress | actual progress | Area | |
|---|---|---|---|---|---|---|---|---|
| 1 | Month 1 | 4,204,149,306 | 4,204,149,306 | 4,449,930,342 | 3 | 3 | | |
| 2 | Month 2 | 7,006,915,509 | 2,802,766,204 | 7,843,182,631 | 5 | 5 | | |
| 3 | Month 3 | 9,809,681,713 | 2,802,766,204 | 10,980,455,683 | 7 | 7 | | |
| 4 | Month 4 | 14,013,831,018 | 4,204,149,306 | 14,117,728,735 | 10 | 9 | | |
| 5 | Month 5 | 18,217,980,324 | 4,204,149,306 | 18,823,638,313 | 13 | 12 | | |
| 6 | Month 6 | 23,823,512,731 | 5,605,532,407 | 25,098,184,418 | 17 | 16 | | Pre-Stability |
| 7 | Month 7 | 29,429,045,139 | 5,605,532,407 | 31,372,730,522 | 21 | 20 | | |
| 8 | Month 8 | 36,435,960,648 | 7,006,915,509 | 37,647,276,627 | 26 | 24 | | |
| 9 | Month 9 | 43,442,876,157 | 7,006,915,509 | 45,490,459,257 | 31 | 29 | | |
| 10 | Month | 51,851,174,768 | 8,408,298,611 | 53,333,641,888 | 37 | 34 | | |
| 11 | Month | 60,259,473,379 | 8,408,298,611 | 62,745,461,044 | 43 | 40 | Initial | |
| 12 | Month | 70,069,155,092 | 9,809,681,713 | 72,157,280,201 | 50 | 46 | | |
| 13 | Month | 79,878,836,805 | 9,809,681,713 | 81,569,099,358 | 57 | 52 | | |
| 14 | Month | 89,688,518,518 | 9,809,681,713 | 92,549,555,040 | 64 | 59 | | |
| 15 | Month | 98,096,817,129 | 8,408,298,611 | 101,961,374,19 | 70 | 65 | | |
| 16 | Month | 106,505,115,74 | 8,408,298,611 | 109,804,556,82 | 76 | 70 | Mid | |
| 17 | Month | 113,512,031,24 | 7,006,915,509 | 116,079,102,93 | 81 | 74 | | |
| 18 | Month | 120,518,946,75 | 7,006,915,509 | 122,353,649,03 | 86 | 78 | | |
| 19 | Month | 126,124,479,16 | 5,605,532,407 | 128,628,195,14 | 90 | 82 | | |
| 20 | Month | 131,730,011,57 | 5,605,532,407 | 133,334,104,71 | 94 | 85 | | |
| 21 | Month | 134,532,777,77 | 2,802,766,204 | 138,040,014,29 | 96 | 88 | | |
| 22 | Month | 137,335,543,98 | 2,802,766,204 | 142,745,923,87 | 98 | 91 | | |
| 23 | Month | 138,736,927,08 | 1,401,383,102 | 147,451,833,45 | 99 | 94 | | |
| 24 | Month | 140,138,310,18 | 1,401,383,102 | 150,589,106,50 | 100 | 96 | | Total area |
| 25 | Month | 140,138,310,18 | | 153,726,379,55 | 100 | 98 | Final | |
| 26 | Month | 140,138,310,18 | | 156,863,652,61 | 100 | 100 | | |
| | | 140,138,310,184 | 140,138,310,184 | 156,863,652,611 | | | | |

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**Table 6: Preparation of failure structure of activities WBS**

| Task Name | Duration | Start | Finish | Scheduled cost | actual cost | weight percentage |
|---|---|---|---|---|---|---|
| **Bypass Road of Northeast of Ahvaz** | 730 days | Saturday 21/3/2009 | Sunday 20/3/2011 | 140,138,310,184 | 156,863,652,611 | 100% |
| **Start** | 0 days | Saturday 21/3/2009 | Saturday 21/3/2009 | 0 | 0 | 0 |
| **Land delivery and workship equipment** | 31 days | Saturday 21/3/2009 | Monday 20/4/2009 | 11,371,553,064 | 11,371,553,064 | 8/19 |
| **Digging** | 185 days | Tuesday 21/4/2009 | Thursday 22/10/2009 | 423,673,600 | 430,000,000 | 0/31 |
| **Concrete work** | 458 days | Monday 22/6/2009 | Wednesday 22/9/2010 | 8,658,658,320 | 8,752,000,000 | 6/24 |
| **Construction operation** | 288 days | Tuesday 7/7/2009 | Tuesday 20/4/2010 | 214,462,500 | 215,300,000 | 0/15 |
| **Blinding** | 62 days | Friday 22/5/2009 | Wednesday 22/7/2009 | 91,450,000 | 92,320,000 | 0/07 |
| **Excavating** | 244 days | Friday 5/6/2009 | Thursday 3/2/2011 | 21,104,832,875 | 21,260,300,000 | 15/2 |
| **Embankment** | 365 days | Friday 22/5/2009 | Friday 21/5/2010 | 62,824,178,025 | 63,100,420,000 | 45/24 |
| **Ligh and heavy steel work** | 334 days | Thursday 23/7/2009 | Monday 21/6/2010 | 7,898,148,000 | 8,256,412,000 | 5/69 |
| **Formwork** | 334 days | Sunday 23/8/2009 | Thursday 22/7/2010 | 3,152,930,700 | 3,152,930,700 | 2/27 |
| **Tvnan** | 183 days | Thursday 21/1/2010 | Thursday 22/7/2010 | 190,750,000 | 200,150,000 | 0/14 |
| **Road shoulder** | 425 days | Sunday 22/11/2009 | Thursday 20/1/2011 | 1,856,010,000 | 1,920,100,000 | 1/34 |
| **Base** | 305 days | Thursday 21/1/2010 | Saturday 21/11/2009 | 3,819,601,000 | 3,910,100,000 | 2/75 |
| **Hot asphalt** | 245 days | Wednesday 21/4/2010 | Tuesday 21/12/2010 | 10,666,084,000 | 10,860,020,000 | 7/68 |
| **Guardrail and sign installaiton** | 151 days | Monday 23/8/2010 | Thursday 20/1/2011 | 4,291,360,000 | 4,301,200,120 | 3/09 |
| **Road stripping** | 60 days | Wednesday 22/12/2010 | Saturday 19/2/2011 | 2,178,029,000 | 2,201,504,300 | 1/57 |
| **Removing workshop and temporary delivery of the project** | 29 days | Sunday 20/2/2011 | Sunday 20/3/2011 | 114,000,000 | 114,000,000 | 0/08 |
| **End of project** | 0 days | Sunday 20/3/2011 | Sunday 20/3/2011 | 0 | 0 | 0 |

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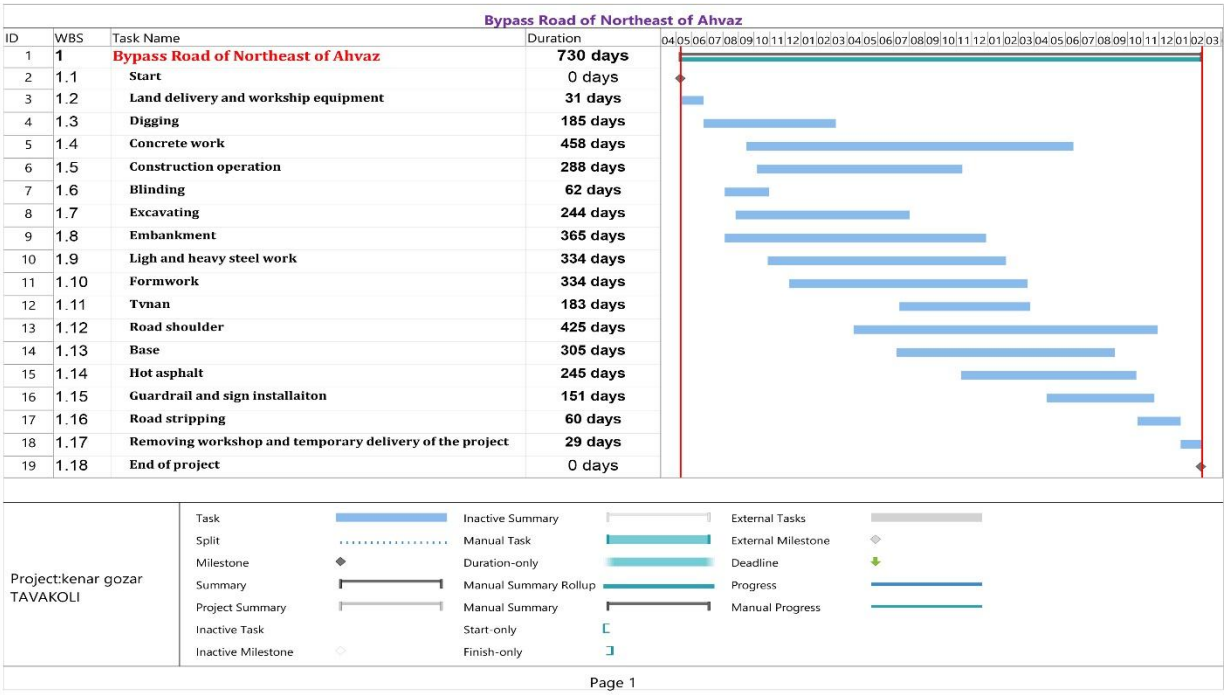


**Gant figure No. 4: Preparation of schedule according to implementation items**

**Table 7: Main financial indices of earned value**

| Date (month) | ACWP=AC<br>Actual Cost FOR Work Performed | BCWS=PV<br>Budget Cost for Work Scheduled | BCWP=EV<br>Budget Cost FOR Work Performed |
|---|---|---|---|
| Month 1 | 4,449,930,342 | 4,850,941,506 | 4,204,149,306 |
| Month 2 | 7,416,894,608 | 7,006,915,509 | 7,006,915,509 |
| Month 3 | 10,384,019,050 | 9,809,681,713 | 9,809,681,713 |
| Month 4 | 13,545,899,311 | 14,013,831,018 | 12,612,447,917 |
| Month 5 | 18,212,260,393 | 18,217,980,324 | 16,816,597,222 |
| Month 6 | 23,594,195,496 | 23,823,512,731 | 22,422,129,629 |
| Month 7 | 28,875,327,913 | 29,429,045,139 | 28,027,662,037 |
| Month 8 | 35,533,374,921 | 36,435,960,648 | 33,633,194,444 |
| Month 9 | 43,688,817,445 | 43,442,876,157 | 40,640,109,953 |
| Month 10 | 51,441,659,966 | 51,851,174,768 | 47,647,025,463 |
| Month 11 | 60,731,867,457 | 60,259,473,379 | 56,055,324,074 |
| Month 12 | 71,288,781,254 | 70,069,155,092 | 64,463,622,685 |
| Month 13 | 82,035,456,309 | 79,878,836,805 | 72,871,921,296 |
| Month 14 | 92,795,017,969 | 89,688,518,518 | 82,681,603,009 |
| Month 15 | 101,945,821,402 | 98,096,817,129 | 91,089,901,620 |
| Month 16 | 110,634,047,827 | 106,505,115,740 | 98,096,817,129 |
| Month 17 | 117,787,558,302 | 113,512,031,249 | 103,702,349,536 |
| Month 18 | 124,412,405,358 | 120,518,946,758 | 109,307,881,944 |
| Month 19 | 131,041,612,856 | 126,124,479,166 | 114,913,414,351 |
| Month 20 | 136,265,997,821 | 131,730,011,573 | 119,117,563,656 |
| Month 21 | 141,493,065,914 | 134,532,777,777 | 123,321,712,962 |
| Month 22 | 145,143,071,404 | 137,335,543,980 | 127,525,862,267 |
| Month 23 | 148,774,729,592 | 138,736,927,082 | 131,730,011,573 |
| Month 24 | 150,818,324,560 | 140,138,310,184 | 134,532,777,777 |
| Month 25 | 153,726,379,559 | 0 | 137,335,543,980 |
| Month 26 | 156,863,652,611 | 0 | 140,138,310,184 |

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**Table 8: Calculation of secondary financial indices of earned value**

| **SV($)** | **CV($)** | **SPI($)** | **CPI($)** | **BAC** |
|---|---|---|---|---|
| Schedule Variance | Cost Variance | Schedule Performance Index | Cost Performance Index | Budget At Completion |
| BCWP-BCWS | BCWP-ACWP | BCWP/BCWS | BCWP/ACWP | Budget At Completion |
| -646,792,201 | -245,781,036 | 0/87 | 0/94 | 140,138,310,184 |
| 0 | -409,979,099 | 1/00 | 0/94 | 140,138,310,184 |
| 0 | -574,337,337 | 1/00 | 0/94 | 140,138,310,184 |
| -1,401,383,102 | -933,451,395 | 0/90 | 0/93 | 140,138,310,184 |
| -1,401,383,102 | -1,395,663,171 | 0/92 | 0/92 | 140,138,310,184 |
| -1,401,383,102 | -1,172,065,867 | 0/94 | 0/95 | 140,138,310,184 |
| -1,401,383,102 | -847,665,876 | 0/95 | 0/97 | 140,138,310,184 |
| -2,802,766,204 | -1,900,180,477 | 0/92 | 0/95 | 140,138,310,184 |
| -2,802,766,204 | -3,048,707,491 | 0/94 | 0/93 | 140,138,310,184 |
| -4,204,149,306 | -3,794,634,504 | 0/92 | 0/93 | 140,138,310,184 |
| -4,204,149,306 | -4,676,543,384 | 0/93 | 0/92 | 140,138,310,184 |
| -5,605,532,407 | -6,825,158,569 | 0/92 | 0/90 | 140,138,310,184 |
| -7,006,915,509 | -9,163,535,013 | 0/91 | 0/89 | 140,138,310,184 |
| -7,006,915,509 | -10,113,414,960 | 0/92 | 0/89 | 140,138,310,184 |
| -7,006,915,509 | -10,855,919,782 | 0/93 | 0/89 | 140,138,310,184 |
| -8,408,298,611 | -12,537,230,698 | 0/92 | 0/89 | 140,138,310,184 |
| -9,809,681,713 | -14,085,208,766 | 0/91 | 0/88 | 140,138,310,184 |
| -11,211,064,815 | -15,104,523,414 | 0/91 | 0/88 | 140,138,310,184 |
| -11,211,064,815 | -16,128,198,505 | 0/91 | 0/88 | 140,138,310,184 |
| -12,612,447,917 | -17,148,434,164 | 0/90 | 0/87 | 140,138,310,184 |
| -11,211,064,815 | -18,171,352,952 | 0/92 | 0/87 | 140,138,310,184 |
| -9,809,681,713 | -17,617,209,137 | 0/93 | 0/88 | 140,138,310,184 |
| -7,006,915,509 | -17,044,718,019 | 0/95 | 0/89 | 140,138,310,184 |
| -5,605,532,407 | -16,285,546,783 | 0/96 | 0/89 | 140,138,310,184 |

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**Table 9: EAC(c) formulas and estimation methods**

| **First method** | **Second method** | **Third method** |
|---|---|---|
| P.F=1 | PF=CPI>1 | PF=SPI>1 |
| according to schedule | Inappropriate function in terms of cost | Inappropriate function in terms of time |
| AC+(BAC-EV)/PF | AC+(BAC-EV)/CPI | AC+(BAC-EV)/SPI |
| 140,384,091,220 | 148,331,011,400 | 161,297,039,048 |
| 140,548,289,283 | 148,337,892,163 | 140,548,289,283 |
| 140,712,647,521 | 148,343,129,281 | 140,712,647,521 |
| 141,071,761,579 | 150,509,992,349 | 155,241,301,831 |
| 141,533,973,355 | 151,768,836,607 | 151,810,782,768 |
| 141,310,376,051 | 147,463,721,853 | 148,667,637,336 |
| 140,985,976,060 | 144,376,639,565 | 146,591,508,468 |
| 142,038,490,661 | 148,055,728,838 | 150,913,916,973 |
| 143,187,017,675 | 150,651,094,637 | 150,048,962,519 |
| 143,932,944,688 | 151,298,999,901 | 152,093,940,399 |
| 144,814,853,568 | 151,829,668,644 | 151,121,077,526 |
| 146,963,468,753 | 154,975,611,421 | 153,543,876,362 |
| 149,301,845,197 | 157,760,492,902 | 155,769,767,206 |
| 150,251,725,144 | 157,279,691,473 | 155,120,937,617 |
| 150,994,229,966 | 156,839,725,233 | 154,767,184,471 |
| 152,675,540,882 | 158,048,639,752 | 156,279,097,429 |
| 154,223,518,950 | 159,172,376,083 | 157,670,163,876 |
| 155,242,833,598 | 159,503,083,792 | 158,404,928,802 |
| 156,266,508,689 | 159,806,844,947 | 158,727,474,137 |
| 157,286,744,348 | 160,312,938,612 | 159,512,470,451 |
| 158,309,663,136 | 160,787,574,902 | 159,838,444,702 |
| 157,755,519,321 | 159,497,880,664 | 158,725,707,622 |
| 157,183,028,203 | 158,270,988,928 | 157,630,278,129 |
| 156,423,856,967 | 157,102,421,417 | 156,657,420,818 |
| 156,529,145,762 | 156,863,652,611 | 156,586,345,073 |
| 156,863,652,611 | 156,863,652,611 | 156,863,652,611 |

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**Table 10: EAC(c) formulas and estimation methods**

| Fourth Method | Fifth Method | Sixth method |
|---|---|---|
| PF=CPI>1 & SPI>1 | PF=CPI>>1 & SPI>1 | PF=(CPI1+CPI2+CPI3)/3 |
| Inapproproate function in terms of cost and time AC+(BAC-EV)/(CPI*SPI) | Inapproproate function more in terms of cost and less in terms of AC+(BAC-EV)/(0.8CPI+0.2SPI) | Constant cost performance in last three months AC+(BAC-EV)/(CPI3) |
| 4,449,930,343 | 153,766,329,425 | 151,297,631,628 |
| 7,416,894,609 | 149,640,333,172 | 151,304,650,006 |
| 10,384,019,051 | 149,678,904,219 | 151,309,991,867 |
| 13,545,899,313 | 154,461,244,761 | 153,520,192,196 |
| 18,212,260,394 | 154,812,791,081 | 154,804,213,340 |
| 23,594,195,498 | 150,657,610,350 | 150,412,996,290 |
| 28,875,327,914 | 147,711,360,213 | 147,264,172,356 |
| 35,533,374,922 | 151,591,839,721 | 151,016,843,415 |
| 43,688,817,446 | 153,539,737,671 | 153,664,116,530 |
| 51,441,659,968 | 154,487,749,206 | 154,324,979,899 |
| 60,731,867,459 | 154,718,902,883 | 154,866,262,016 |
| 71,288,781,255 | 157,774,050,526 | 158,075,123,649 |
| 82,035,456,310 | 160,492,058,537 | 160,915,702,760 |
| 92,795,017,970 | 159,960,012,772 | 160,425,285,302 |
| 101,945,821,403 | 159,524,677,831 | 159,976,519,738 |
| 110,634,047,828 | 160,820,492,419 | 161,209,612,547 |
| 117,787,558,303 | 162,022,593,571 | 162,355,823,605 |
| 124,412,405,359 | 162,447,395,462 | 162,693,145,468 |
| 131,041,612,857 | 162,755,698,527 | 163,002,981,846 |
| 136,265,997,822 | 163,332,793,977 | 163,519,197,385 |
| 141,493,065,915 | 163,772,790,312 | 164,003,326,400 |
| 145,143,071,405 | 162,490,596,869 | 162,687,838,277 |
| 148,774,729,593 | 161,255,804,213 | 161,436,408,706 |
| 150,818,324,561 | 160,102,952,568 | 160,244,469,845 |
| 153,726,379,560 | 159,881,562,090 | 160,000,925,663 |
| 156,863,652,612 | 159,927,785,531 | 160,000,925,663 |

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**Table 11: Use of statistical comparison method of sum of squares for more precise comparison**

**First method**

| **∑(%VAC^ 3/n)** | **∑(%VAC^ 3/n)** | **(%VAC)^2** | **(VAC/BAC )** | **BAC-EAC** | **AC+(BAC-EV)/PF** |
|---|---|---|---|---|---|
| Mean of variance percentage of all area | Mean of variance percentage | (%VAC)^2 | %VAC | VAC | EAC |
| | | 0/003 | -0/06 | -7899488746/53 | 143,186,857,424 |
| | | 0/006 | -0/08 | -10219660811/82 | 143,351,055,487 |
| | | 0/010 | -0/10 | -13186785253/38 | 143,515,413,725 |
| 0/031 | | 0/020 | -0/14 | -17750048616/94 | 143,874,527,783 |
| | | 0/034 | -0/18 | -22416409698/41 | 144,336,739,558 |
| | | 0/057 | -0/24 | -27798344801/95 | 144,113,142,255 |
| | | 0/089 | -0/30 | -33079477218/55 | 143,788,742,264 |
| | | 0/16 | -0/40 | -41138907328/59 | 144,841,256,865 |
| | 0/394 | 0/26 | -0/51 | -49294349852/06 | 145,989,783,879 |
| | | 0/44 | -0/66 | -58448575475/60 | 146,735,710,892 |
| | | 0/72 | -0/85 | -67738782966/62 | 147,617,619,771 |
| | | 1/29 | -1/14 | -79697079864/73 | 149766234956/73 |
| | | 2/32 | -1/52 | -91845138021/79 | 152104611400/91 |
| | 5/589 | 4/14 | -2/03 | -102604699681/71 | 153054491347/95 |
| | | 7/07 | -2/66 | -111755503114/54 | 153796996169/74 |
| | | 13/12 | -3/62 | -121845112641/24 | 155478307085/40 |
| 1848/26 | | 23/98 | -4/90 | -130400006218/24 | 157,026,285,153 |
| | | 49/78 | -7/06 | -138426236376/18 | 158,045,599,802 |
| | | 107/14 | -10/35 | -145055443874/67 | 159,069,274,893 |
| | | 325/42 | -18/04 | -151681211940/76 | 160,089,510,552 |
| | | 769/60 | -27/74 | -155506896932/30 | 161,112,429,340 |
| | 5538/80 | 3168/07 | -56/29 | -157755519320/77 | 160,558,285,524 |
| | | 12805/82 | -113/16 | -158584411305/02 | 159,985,794,407 |
| | | 12683/50 | -112/62 | -157825240069/33 | 159,226,623,171 |
| | | 12700/43 | -112/70 | -157930528864/30 | 159,331,911,966 |
| | | 12754/29 | -112/93 | -158265035712/84 | 159,666,418,815 |

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**Table 12: Use of statistical comparison method of sum of squares for more precise comparison**

**Second method**

| **∑(%VAC^3/n)** | **∑(%VAC^3/n)** | **(%VAC)^2** | **(VAC/BAC)** | **BAC-EAC** | **AC+(BAC-EV)/CPI** |
|---|---|---|---|---|---|
| Mean of variance percentage of all area | Mean of variance percentage | (%VAC)^2 | %VAC | VAC | EAC |
| | | 0/009 | -0/10 | -13043642722/37 | 148,331,011,400 |
| | | 0/013 | -0/11 | -15206497488/05 | 148,337,892,163 |
| | | 0/019 | -0/14 | -18014500810/30 | 148,343,129,281 |
| 0/043 | | 0/037 | -0/19 | -24385513183/48 | 150,509,992,349 |
| | | 0/060 | -0/24 | -29848506747/35 | 151,768,836,607 |
| | | 0/072 | -0/27 | -31148924399/99 | 147,463,721,853 |
| | | 0/092 | -0/30 | -33667374519/81 | 144,376,639,565 |
| | | 0/18 | -0/43 | -44353379302/30 | 148,055,728,838 |
| | 0/454 | 0/31 | -0/56 | -53955660609/93 | 150,651,094,637 |
| | | 0/51 | -0/71 | -63011864485/24 | 151,298,999,901 |
| | | 0/81 | -0/90 | -71950831838/66 | 151,829,668,644 |
| | | 1/47 | -1/21 | -84906456329/06 | 154975611421/06 |
| | | 2/62 | -1/62 | -97501019522/63 | 157760492901/75 |
| | 5/942 | 4/48 | -2/12 | -106829899806/36 | 157279691472/60 |
| | | 7/46 | -2/73 | -114798232178/13 | 156839725233/33 |
| | | 13/68 | -3/70 | -124415445308/01 | 158048639752/17 |
| 1798/47 | | 24/78 | -4/98 | -132546097148/40 | 159,172,376,083 |
| | | 50/84 | -7/13 | -139883720366/27 | 159,503,083,792 |
| | | 108/23 | -10/40 | -145793013928/27 | 159,806,844,947 |
| | | 326/38 | -18/07 | -151904640001/34 | 160,312,938,612 |
| | 5389/01 | 766/39 | -27/68 | -155182042494/79 | 160,787,574,902 |
| | | 3125/63 | -55/91 | -156695114460/28 | 159,497,880,664 |
| | | 12530/37 | -111/94 | -156869605825/97 | 158,270,988,928 |
| | | 12344/38 | -111/11 | -155701038314/96 | 157,102,421,417 |
| | | 12306/55 | -110/93 | -155462269509/16 | 156,863,652,611 |
| | | 12306/55 | -110/93 | -155462269509/16 | 156,863,652,611 |

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**Table 13: Use of statistical comparison method of sum of squares for more precise comparison**

**Third method**

| ∑(%VAC^3/n) | ∑(%VAC^3/n) | (%VAC)^2 | (VAC/BAC) | BAC-EAC | AC+(BAC-EV)/SPI |
|---|---|---|---|---|---|
| Mean of variance percentage of all area | Mean of variance percentage | (%VAC)^2 | %VAC | VAC | EAC |
| | | 0/037 | -0/19 | -26009670370/31 | 161,297,039,048 |
| | | 0/003 | -0/06 | -7416894608/14 | 140,548,289,283 |
| | | 0/006 | -0/08 | -10384019049/70 | 140,712,647,521 |
| 0/049 | | 0/053 | -0/23 | -29116822665/20 | 155,241,301,831 |
| | | 0/060 | -0/25 | -29890452908/23 | 151,810,782,768 |
| | | 0/077 | -0/28 | -32352839882/93 | 148,667,637,336 |
| | | 0/105 | -0/32 | -35882243422/23 | 146,591,508,468 |
| | | 0/21 | -0/46 | -47211567436/56 | 150,913,916,973 |
| | 0/457 | 0/30 | -0/55 | -53353528491/87 | 150,048,962,519 |
| | | 0/52 | -0/72 | -63806804982/63 | 152,093,940,399 |
| | | 0/80 | -0/89 | -71242240721/22 | 151,121,077,526 |
| | | 1/42 | -1/19 | -83474721269/69 | 153543876361/69 |
| | | 2/51 | -1/58 | -95510293826/60 | 155769767205/72 |
| | 5/745 | 4/30 | -2/07 | -104671145950/53 | 155120937616/77 |
| | | 7/19 | -2/68 | -112725691415/82 | 154767184471/02 |
| | | 13/30 | -3/65 | -122645902985/15 | 156279097429/31 |
| 1789/64 | | 24/22 | -4/92 | -131043884940/71 | 157,670,163,876 |
| | | 50/04 | -7/07 | -138785565376/66 | 158,404,928,802 |
| | | 106/64 | -10/33 | -144713643118/12 | 158,727,474,137 |
| | | 322/95 | -17/97 | -151104171840/00 | 159,512,470,451 |
| | 5362/72 | 757/04 | -27/51 | -154232912294/26 | 159,838,444,702 |
| | | 3094/90 | -55/63 | -155922941418/36 | 158,725,707,622 |
| | | 12428/22 | -111/48 | -156228895027/46 | 157,630,278,129 |
| | | 12273/92 | -110/79 | -155256037715/96 | 156,657,420,818 |
| | | 12262/68 | -110/74 | -155184961970/90 | 156,586,345,073 |
| | | 12306/55 | -110/93 | -155462269509/16 | 156,863,652,611 |

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**Table 14: Use of statistical comparison method of sum of squares for more precise comparison**

| **Fourth Method** | | | | | |
|---|---|---|---|---|---|
| **∑(%VAC^3/n** | **∑(%VAC^3/n** | **(%VAC)^2** | **(VAC/BAC** | **BAC-EAC** | **AC+(BAC-** |
| Mean of variance percentage of | Mean of variance percentage | (%VAC)^2 | %VAC | VAC | EAC |
| | | 0/935 | 0/97 | 130837438334/48 | 4,449,930,343 |
| | | 0.892 | 0.94 | 125714500065/66 | 7,416,894,609 |
| | | 0.847 | 0.92 | 119944609420/42 | 10,384,019,051 |
| 0/768 | | 0.797 | 0.89 | 112578579853/07 | 13,545,899,313 |
| | | 0.724 | 0.85 | 103708069466/10 | 18,212,260,394 |
| | | 0.635 | 0.80 | 92720601955/22 | 23,594,195,498 |
| | | 0.546 | 0.74 | 81833937131/27 | 28,875,327,914 |
| | | 0.43 | 0.66 | 68168974613/83 | 35,533,374,922 |
| | 0.241 | 0.30 | 0.55 | 53006616581/17 | 43,688,817,446 |
| | | 0.17 | 0.42 | 36845475448/41 | 51,441,659,968 |
| | | 0.06 | 0.24 | 19146969346/35 | 60,731,867,459 |
| | | 0.00 | -0.02 | -1219626162/82 | 71288781254/82 |
| | | 0.13 | -0/36 | -21775982930/95 | 82035456310/07 |
| | 1/621 | 0.70 | -0.84 | -42345226303/75 | 92795017969/99 |
| | | 2.03 | -1.42 | -59904328347/62 | 101945821402/82 |
| | | 5.24 | -2.29 | -77000853383/53 | 110634047827/70 |
| 1669.18 | | 11.72 | -3.42 | -91161279367/92 | 117,787,558,303 |
| | | 28.53 | -5.34 | -104793041933/23 | 124,412,405,359 |
| | | 69.74 | -8/35 | -117027781839/08 | 131,041,612,857 |
| | | 231.23 | -15.21 | -127857699210/71 | 136,265,997,822 |
| | | 587.66 | -24.24 | -135887533507/76 | 141,493,065,915 |
| | 5005.67 | 2579.18 | -50.79 | -142340305201/73 | 145,143,071,405 |
| | | 11059.21 | -105.16 | -147373346491/47 | 148,774,729,593 |
| | | 11368.05 | -106/62 | -149416941459/45 | 150,818,324,561 |
| | | 11814.86 | -108.70 | -152324996458/08 | 153,726,379,560 |
| | | 12306.55 | -110.93 | -155462269510/28 | 156,863,652,612 |

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**Table 15: Use of statistical comparison method of sum of squares for more precise comparison**

| Fifth Method | | | | | |
|---|---|---|---|---|---|
| **∑(%VAC^3/n)** | **∑(%VAC^3/n)** | **(%VAC)^2** | **(VAC/BAC)** | **BAC-EAC** | **AC+(BAC-EV)/(0.8CPI+0.2SPI)** |
| Mean of variance percentage of all area | Mean of variance percentage | (%VAC)^2 | %VAC | VAC | EAC |
| | | 0.013 | -0.11 | -15462467836/80 | 150,749,836,514 |
| | | 0.010 | -0.10 | -13576496464/81 | 146,707,891,140 |
| | | 0.016 | -0.13 | -16417751849/29 | 146,746,380,320 |
| 0.044 | | 0.040 | -0.20 | -25306328059/05 | 151,430,807,225 |
| | | 0.060 | -0.24 | -29856893872/21 | 151,777,223,732 |
| | | 0.073 | -0.27 | -31387849761/59 | 147,702,647,214 |
| | | 0.095 | -0.31 | -34103655355/66 | 144,812,920,401 |
| | | 0.19 | -0.43 | -44913632112/69 | 148,615,981,649 |
| | 0.454 | 0.31 | -0.56 | -53834689391/22 | 150,530,123,418 |
| | | 0.51 | -0.72 | -63169846459/23 | 151,456,981,875 |
| | | 0.81 | -0.90 | -71808226225/41 | 151,687,063,030 |
| | | 1.46 | -1.21 | -84616135816/88 | 154685290908/89 |
| | | 2.60 | -1.61 | -97094321068/97 | 157353794448/09 |
| | 5.901 | 4.45 | -2.11 | -106386267859/42 | 156836059525/66 |
| | | 7.40 | -2.72 | -114370814158/35 | 156412307213/55 |
| | | 13.60 | -3.69 | -124050645187/93 | 157683839632/09 |
| 1796.60 | | 24.67 | -4.97 | -132236669260/00 | 158,862,948,195 |
| | | 50.67 | -7.12 | -139658449527/65 | 159,277,812,953 |
| | | 107.90 | -10.39 | -145570458941/11 | 159,584,289,960 |
| | | 325.68 | -18.05 | -151740166406/49 | 160,148,465,018 |
| | 5383/44 | 764.44 | -27.65 | -154984440133/72 | 160,589,972,541 |
| | | 3119.19 | -55.85 | -156533735125/89 | 159,336,501,330 |
| | | 12508.74 | -111.84 | -156734152455/92 | 158,135,535,558 |
| | | 12329.42 | -111.04 | -155606693463/35 | 157,008,076,565 |
| | | 12297.10 | -110.89 | -155402587722/55 | 156,803,970,824 |
| | | 12306.55 | -110.93 | -155462269509/16 | 156,863,652,611 |

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**Table 16: Use of statistical comparison method of sum of squares for more precise comparison**

| | | Sixth method | | | |
|---|---|---|---|---|---|
| **∑(%VAC^3/n)** | **∑(%VAC^3/n)** | **(%VAC)^2** | **(VAC/BAC)** | **BAC-EAC** | **AC+(BAC-EV)/(CPI3)** |
| Mean of variance percentage of all area | Mean of variance percentage | (%VAC)^2 | %VAC | VAC | EAC |
| | | 0.009 | -0.10 | -13043642722/37 | 148,331,011,400 |
| | | 0.013 | -0.11 | -15206497488/05 | 148,337,892,163 |
| | | 0.019 | -0.14 | -18014500810/30 | 148,343,129,281 |
| 0.043 | | 0.037 | -0.19 | -24385513183/48 | 150,509,992,349 |
| | | 0.060 | -0.24 | -29848506747/35 | 151,768,836,607 |
| | | 0.072 | -0.27 | -31148924399/99 | 147,463,721,853 |
| | | 0.092 | -0.30 | -33667374519/81 | 144,376,639,565 |
| | | 0.18 | -0.43 | -44353379302/30 | 148,055,728,838 |
| | 0/454 | 0.31 | -0.56 | -53955660609/93 | 150,651,094,637 |
| | | 0.51 | -0.71 | -63011864485/24 | 151,298,999,901 |
| | | 0.81 | -0.90 | -71950831838/66 | 151,829,668,644 |
| | | 1.47 | -1.21 | -84906456329/06 | 154975611421/06 |
| | | 2.62 | -1.62 | -97501019522/63 | 157760492901/75 |
| | 5/942 | 4.48 | -2.12 | -106829899806/36 | 157279691472/60 |
| | | 7.46 | -2.73 | -114798232178/13 | 156839725233/33 |
| | | 13.68 | -3.70 | -124415445308/01 | 158048639752/17 |
| 1798/47 | | 24.78 | -4.98 | -132546097148/40 | 159,172,376,083 |
| | | 50.84 | -7.13 | -139883720366/27 | 159,503,083,792 |
| | | 108.23 | -10.40 | -145793013928/27 | 159,806,844,947 |
| | | 326.38 | -18.07 | -151904640001/34 | 160,312,938,612 |
| | 5389/01 | 766.39 | -27.68 | -155182042494/79 | 160,787,574,902 |
| | | 3125.63 | -55.91 | -156695114460/28 | 159,497,880,664 |
| | | 12530.37 | -111.94 | -156869605825/97 | 158,270,988,928 |
| | | 12344.38 | -111.11 | -155701038314/96 | 157,102,421,417 |
| | | 12306.55 | -110.93 | -155462269509/16 | 156,863,652,611 |
| | | 12306.55 | -110.93 | -155462269509/16 | 156,863,652,611 |

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***Conclusion***

There are many methods for EAC (c), the best of which is earned value method that includes various formulas and indices in this area. Many Iranian projects have dealt with this issue; especially this paper has studied the bypass ring road of northeast of Ahvaz and concluded that most projects in Iran confront with delay in payment of bill or due to some problems change the schedule that lead to change in prediction indices. In this thesis, the application of each formula in various situations has been mentioned and concerning the fact that the project is national and the contractor has high financial power, it is mentioned that the changes are less tangible. Thus, concerning the obtained values of different time intervals of the project and the use of formulas extracted from PMBOK, books and papers, a comparison of various formulas and methods has been done and they have been ranked based on least variance of actual values in terms of cost that are presented in the following table.

**Table 17: Ranking based on least variance with actual values in cost**

| | | | **Precision** | | |
|---|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** | **6** |
| Initial | | | | | |
| Forth method | First method | Second method | Fifth Method | Sixth method | Third method |
| AC+(BAC-EV)/(CPI*SPI) | AC+(BAC-EV) | AC+(BAC-EV)/CPI | AC+(BAC-EV)/(0.8CPI+0.2SPI) | AC+(BAC-EV)/(CPI3) | AC+(BAC-EV)/SPI |
| 0/241 | 0/356 | 0/454 | | | 0/457 |
| Mid | | | | | |
| Forth method | First method | Third method | Fifth Method | Second method | Sixth method |
| AC+(BAC-EV)/(CPI*SPI) | AC+(BAC-EV) | AC+(BAC-EV)/SPI | AC+(BAC-EV)/(0.8CPI+0.2SPI) | AC+(BAC-EV)/CPI | AC+(BAC-EV)/(CPI3) |
| 1/621 | 5/309 | 5/745 | 5/901 | 5/942 | |
| Final | | | | | |
| Forth method | First method | Third method | First method | Second method | Sixth method |
| AC+(BAC-EV)/(CPI*SPI) | AC+(BAC-EV) | AC+(BAC-EV)/SPI | AC+(BAC-EV) | AC+(BAC-EV)/CPI | AC+(BAC-EV)/(CPI3) |
| 5005/67 | 5344/03 | 5362/72 | 5005/67 | 5389/01 | |
| Total | | | | | |
| Forth method | First method | Third method | First method | Second method | Sixth method |
| AC+(BAC-EV)/(CPI*SPI) | AC+(BAC-EV) | AC+(BAC-EV)/SPI | AC+(BAC-EV) | AC+(BAC-EV)/CPI | AC+(BAC-EV)/(CPI3) |
| 1669/18 | 1783/23 | 1789/64 | 1669/18 | 1798/47 | |

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