Forecasting at Completion: Introduction of New Method and Comparing It with the Method of Earned Schedule.

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ABSTRACT

It is more than a decade that EVM as one of the most essential principles of the science of project management, has given up its place to the newfangled method of "Earned Schedule", because of its deficiencies in showing the behaviour of projects. A method which in comparison with the previous methods, has the needed capability to concentrate on the topic "time" without analysing the actual cost and solved the problems of the schedule performance index. However, the continual use of the method Earned Schedule showed that although its indexes in use have been efficient in the condition of projects, in spite of the basic expectation, the issue of forecasting the future is still one of the obsessions of the stakeholders. In this article, based on the identifying the defects of ES method in forecasting the future of the project, a new method named as " Forecasting at completion" has been introduced which is being shown as FC. This method has introduced new parameters to managers and the results of using it show that it is more practical than the previous methods.

Key words

Project management- S-Curve- Forecasting at completion- EVM- ES- SPI (t) - SPI - Regression Analysis

1. INTRODUCTION

Since at the time of delays, the stakeholders criticize the project managers as soon as possible, these people try to consider the five-pieces process of standard PMBOK in initiating process and planning process the project and use them as tools which can decrease the probability of crisis occurrence in project the most. It cannot be denied though that the nonexistence of stability in global economy conditions has increased the effect of external factors on projects and consequently has made experiencing such situations inevitable. Therefore in the recent years the importance of reports of performance has been depleted and the reports that forecast the future conditions will be noticed twice as important.

Maybe the innovation of the Earned Schedule and expanding its use can be considered as the result of needing such reports. Notwithstanding, the consequence of using this method in various projects and comparing it with gathered documents at the end of the project, has changed our attitude toward the quality of the achieved

result of this method. In other words, in some projects, the Earned Schedule after the occurrence of a deviation in projects will overrate in forecasting the final delays of the project and this issue can cause a conflict between the stakeholders and the project management team at the date of reporting. So it made us to innovate a new method. This study has depicted the obtained results of this attempt.

2. The Basic Concepts

In order to introduce a new method to forecast the futures condition of projects, different theoretical principles have been used either the used parameters in "ES" or statistical theories. Since using this method needs to at least have some information related to the mentioned concepts, some concepts related to this approach have been presented as follow:

- Earned Value Management

The Project Management Institute defined EVM as a management methodology for integrating the project's scope, schedule, and resources, and for objectively measuring project performance and progress from project initiation through closeout. EVM relies on three basic performance variables, namely Earned Value (EV), Actual Cost (AC), and Planned Value (PV), to evaluate where a project is and where it was supposed to be. (1)

- Project manager

As a matter of fact, defining the project managers should take place before defining the project, thus one of the most essential principles of the project is that before its commencement, the project manager is chosen with the aim of management of the project. They make project goals their own and use their skill and expertise to inspire a sense of shared purpose within the project team. (2)

- The Linear and Non-linear correlation

If the amount changes of in one variable tends to bear constant ratio to the amount of change in the other variable then the correlation is said to be linear. Correlation would be called not-linear or curvilinear if the amount of change in one variable does not bear a constant ratio to the amount of change in the other variable. (3)

- S-Curve

S-Curve is defined as a tool to illustrate the distribution of expenses, working hours and other expected quantities against the expected period of time. Using the title S is generalized because the formed distribution of quantities against time has a shape similar to S in English. This means that this distribution takes a rough shape of straight line and in the middle has a curve shape (4)

-Linear Regression

The simplest linear model involves only one independent variable and states **model** that the true mean of the dependent variable changes at a constant rate as the value of the independent variable increases or decreases. Thus, the functional relationship between the true mean of Yi, denoted by $\mathcal{E}(Yi)$, and Xi is the equation of a straight line.

$$\varepsilon(y_i) = \beta_0 + \beta_1 x$$

B0 is the intercept, the value of $\mathcal{E}$ (Yi) when $X = 0$, and $\beta1$ is the slope of the line, the rate of change in $\mathcal{E}$ (Yi) per unit change in X. (5)

-Polynomial Regression

In statistics, polynomial regression is a form of linear regression in which the relationship between the independent variable x and the dependent variable y is modeled as an nth order polynomial. Polynomial regression fits a nonlinear relationship between the value of x and the corresponding conditional mean of y, denoted as $\mathcal{E}$ (y/x). (6)

3. The importance of the Issue

Forecasting is a difficult process of previewing what will happen by a certain time. For predicting the future precisely, accurate knowledge of system and its environment is indispensable i.e. strengths and weaknesses of management, R&D, production, financing, man-power and marketing. (7) In another word, Project managers must be able to make reliable predictions about the final duration and cost of projects starting from project inception. Such predictions need to be revised and compared with the projects objectives to obtain early warnings against potential problems (8)

In order to do so, various methods have been introduced up to now. Earned value management is one of the methods of fast warning which with announcement of problems facing helps to progress of the project to take the reforming actions before the project going out of control. By the usage of indexes of EAC and EDAC can forecast the future of a planned project. Although EVM duration forecasting techniques have been commonly applied over the last 40 years to predict project completion dates, (9) it was known insufficient in 2003 and as the result of Lipkle studies. An issue that ultimately caused the creation of a new method titled as earned schedule. Earned Schedule is a measure of time duration indicating how much of the Earned Value Management performance baseline has been completed. (10) Now that it has past more than a decade of the introduction of this method, the experiment of its usage in various projects has shown us that the forecasts gained by this method, in spite of its being better than the other ones still are not complete. In better words, not having a proper method to forecast the time of project completion is one of the significant issues in the science of project management. Therefore in this project, after the diagnosis of ES method, the new method of forecasting the future of the projects has been introduced and the gained results of using it have been published.

4. Diagnosis

Before the introduction of the index IEAC (t), the most common index used to estimate the needed duration to complete the project, was the index IEAC. During the 1990s and through 2002, a considerable amount of research was performed concerning the independent estimate at completion (IEAC) formulas and the cost performance index (CPI) from Earned Value Management (11). The study on the completed projects shows that presenting the unreal results has drastically decreased using this method.

After the introduction of the new index which was based on the progress of index SPI, it is expected that more genuine results presented by the new index, be the basis of a wide range of changes in provision of controlling reports. But in spite of more than a decade using IEAC (t), the general appreciation to that was less than it was expected. One of the most significant reasons of this occurrence is the great difference of forecasting one period from the other periods. For instance, note the following table. The following information was gained from the documents of final processes of a completed project which depicts the results of applying the new index in various time periods.

Table No. 1- Forecasting the duration of project No. 1 at various times.

AT	596	686	776	866	956	1046	1136	1226
AD	1283	1283	1283	1283	1283	1283	1283	1283
IEAC(t)	3665	3465	3574	2799	2233	2884	1564	1236

AT in which is a day the report is prepared and AD is the actual time been spent on the completion of operating the project. As it is noticed, the more we get close to the actual completion of the project (AD=1283), the presented results get more realistic. However, the variance in different time estimate in is notable. For instance, the estimate at the end of the sixth period has the discrepancy of more than 1000 days with the estimate at the end of the seventh day however there is a gap of only 90 days between these two periods. The most important feedback of such a problem may vary from the distrust of stakeholders of management reports to their changing their turnabout to proceed with the project (considering the estimate of the sixth period). Concerning this issue, while investigating the way to calculate the mentioned index, we decided to evaluate its conformity to the gained actuality. In order to do so, the planned and actual graph of progress of the project has been considered.
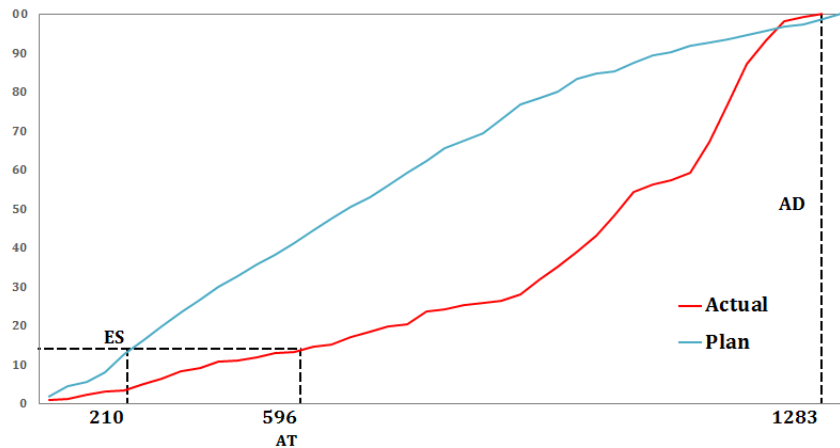
Figure 1- The planned and actual graph of progress of the project No. 1

ES = 210
AD = 1283
AT = 596

$$SPI_{(t)} = \frac{ES}{AT} = 0.35$$

$$IEAC_{(t)} = \frac{AD}{SPI_{(t)}} = 3665$$

Since the amount of AD in all the reported forecasts is similar, it can be concluded that the estimates are relevant to the reverse of schedule performance index of time (SPI (T)). In better words, independent estimation at completion (IEAC (T)) is calculated based on schedule performance index at the moment of "t". Unaware of the fact that the actual progress at the moment "t" can have an illogical ascending performance, affected by the sharp decline of budget, the unusual descending performance or increase of human resource at a certain time.

In addition, given that in order to calculate ES, the actual progress curve is depicted on planned progress curve. Forecasting the future condition of the project is based on the assumption that all the next periods will encounter the deviation from the schedule based on the current amount SPI (T). While with the assumption of making special conditions, the mentioned index may be reported more or less because of the illogical reasons. For instance, if at the point AT= 626 we forecasted the future of the project, the following information would be gained:

ES = 243
AD = 1283
AT = 626

$$SPI_{(t)} = \frac{ES}{AT} = 0.38$$

$$IEAC_{(t)} = \frac{AD}{SPI_{(t)}} = 3376$$

However, the study on the condition of progress around this point shows that this condition had a sudden growth at the end of 2013 only due to the injection of budget. Thus, the first problem of the method ES can be known as the ignoring the actual progress of curve performance in predicting the future condition.

One of the other issues which can cause error in estimating the completion of the project is evaluating the actual performance according to the planned progress curve. In this relation none of the previous methods have noticed the issue that what makes the future condition of the project is the actual performance of the project team, and not the basic plan. Thus, the index SPI (t) is practical to compare the actual progress and the planned one, and also calculating the momentary deviation from the schedule, I cannot be an appropriate criterion to forecast the actual performance of the project though. Hence in order to estimate the duration needed to complete the project at a specific time, analyzing the performance and behavior of project on a specific date is more necessary than comparing any momentary of the project to the basic plan.

5. Experimental Methods

After analyzing the problems of "Earned schedule" and studying various project, the idea of using performance of actual progress curve were mentioned. In order to estimate what is expected from the future performance of the project, it is required that the behavior of progress curve of the project be evaluated from the beginning till the reporting date. In the suggested method, The behavior of the curve is modeled. In order to do so, we use various regressions. Selecting the type of regression method depends on the type of actual progress of curve performance. Provided that the performance of the curve looks like linear performance, we use the linear regression; otherwise we will use curvilinear regression. To analyze the type of the curve performance, we review the correlation between time variable and actual progress percentage. Since the expectation of complete correlation between these two variables is not generally actual, in case of having correlation core equal or bigger than 99%, the linear regression is used otherwise curvilinear regression will be used.

Since assessments of required time to complete the project, are obtained from drawing S-curve, the vertical axis (Y) represents the percentage of actual progress and horizontal axis (X) represents the duration. So the date of reporting amount of X will represent AT. According to the fact that at the point X=0 the progress of the project must equal to 0 and the regression equation at this point must equal. So based on this interpretation, the intercept in both of the equations both linear and curvilinear regression will be considered as zero. On the other hand as said before, the criterion for measuring the future behavior of the curve, is its previous performance. Therefore unlike method of ES which sets the earned schedule as the criterion to measure the schedule performance index, in the new method the earned regression is considered as a criterion. According to the explanation we will have:

$$SPI(R) = \frac{ER}{AT}$$

To calculate ER (earned regression) it would be enough that in the fitted regression equation, consider the percentage of actual progress until the reporting date as the amount of Y. Referring to the fact that the baseline has changed from the primary schedule to regression, estimating IEAC will be wrong on the planned duration. Since the maximum actual percent complete of the project will equal to 100, if we consider the maximum for the regression equation, the required duration of project at completion shall be earned. It is to mention that the new assessment will be achieved based on the performance of actual progress curve until the reporting date. So we will have:

$$MD(R) = \frac{100}{\beta_1} \qquad\qquad Y = \beta_1 X$$

$$MD(R) = \frac{-\beta_2 + \sqrt{\beta_2^2 + 400\beta_1}}{2\beta_1} \qquad\qquad Y = \beta_1 X^2 + \beta_2 X$$

As the actual performance may not face any changes compared to the current condition since the date of reporting till the project completion, MD(R) will be estimated as the maximum time of project completion. But as the occurrence of such an event is almost impossible, the estimated required duration for project can be gained by the following method:

$$IEAC(R) = \frac{MD(R)}{SPI(R)}$$

Also according to the fact that one of the cases which help the better management of the next projects, is using the lessons learned from the previous projects. As it was mentioned before, at the end of the project, the actual duration of the project has been depicted as duration and we calculate and distinguish it as AD. Accordingly, from now on the new method will be recognized with the title "Forecasting at Completion" and is shown as FC. The following table presents the introduced indexes in the new methods and comparing it with indexes of earned schedule (ES).

Table No. 2- Comparing the indexes used in ES and FC methods

ES: Analysis in Data Date	FC: Forecast in Data Date
ES	ER
PD	MD(R)
AT	AT
SPI(t)	SPI(R)
IEAC(t)	IEAC(R)
----	AD

The following figure depicts the condition of each one of the indexes used in FC method on performance of project No. 1 curve.
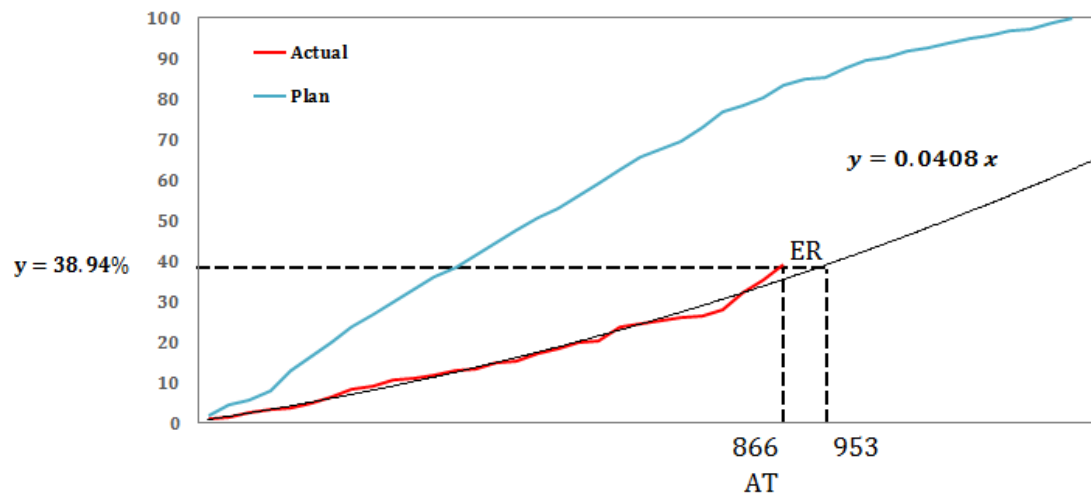

Figure 2- The condition of indexes of method FC on performance of project curve

6. Case study

After presenting the method FC to complete the project, we examined it on three completed projects which the earned data from executing ES method was available to them. For instance, FC method was examined on the previous project and the results have been shown on the following table.

Table No. 3- Comparison of the earned results of ES and FC method in the first project

AT	596	686	776	866	956	1046	1136	1226
AD	1283	1283	1283	1283	1283	1283	1283	1283
IEAC(t)	3665	3465	3574	2799	2233	2884	1564	1236
(t,%C)ρ	0.99	0.99	0.99	0.96	0.95	0.93	0.92	0.93
Kind of Regression	linear	Linear	Linear	Polynomial	Polynomial	Polynomial	Polynomial	Polynomial
IEAC(R)	2935	2705	2773	2223	1360	1396	1217	1230

According to table No. 3, the process of calculation of IEAC(R) when it has passed 866 days of the start of project is as below:

$$y = 0.040832\, x$$

$$y = 38.94$$

$$x = ER = 953$$

$$SPI(R) = \frac{ER}{AT} = \frac{953}{866} = 1.101228$$

$$MD(R) = \frac{100}{0.040832} = 2449$$

$$IEAC(R) = \frac{MD(R)}{SPI(R)} = 2223$$

So the mentioned indexes were measured for other time periods. As it is being noticed, in the final period and because of point forecasting, the amount of IEAC (t) is more optimum, the earned amount though has been reported more logical and more realistic in all the periods of time. The deviation of exercised forecasts on average equals to 1395 days for ES method and equals to 697 days for FC method. The following graph shows more conformity in results earned from the ratio of IEAC(R) index to IEAC (t).
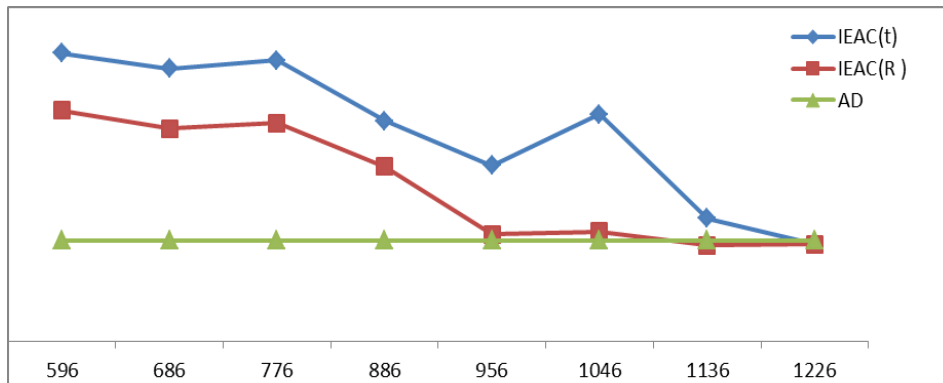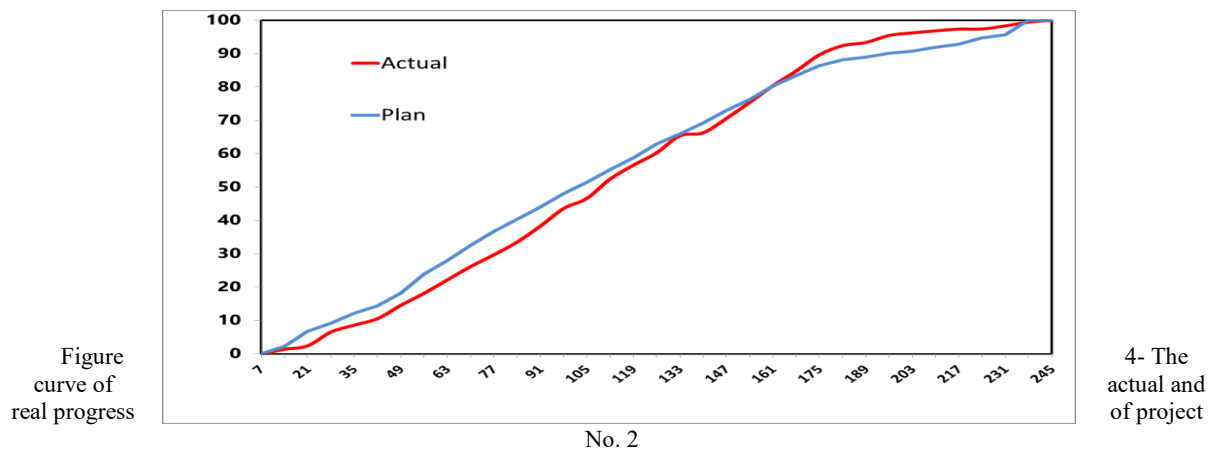

Figure 3- Comparison of ES and FC method in project No. 1

After confirming the better performance of new method, it was decided to execute it on another completed action. In spite of the previous example, the actual performance of this project was suitable and as figure No. 3 shows, its planned and actual S-Curve go along an almost the same path. The following table shows the earned results of mentioned methods in these conditions.

Figure curve of real progress

No. 2

4- The actual and of project

Table No. 4- Comparing the earned results of ES and FC methods in project No. 2

AT	63	105	133	147	189
AD	243	243	243	243	243
IEAC(t)	338	304	266	275	216
(t,%C)ρ	0.99	0.99	0.99	0.99	0.99
Kind of Regression	Linear	linear	linear	Linear	Linear
IEAC(R)	284	225	203	267	202

As the table above shows, the rate of project progress in a period of time has an almost linear form and this issue causes the proximity of earned forecasts of the two methods. Nevertheless studying the results of this analysis in figure No. 5, shows that however the deviation of two methods compared to the happened reality are so close to each other, according to less cumulative deviation, the results of using IEAC(R) method is closer to reality.
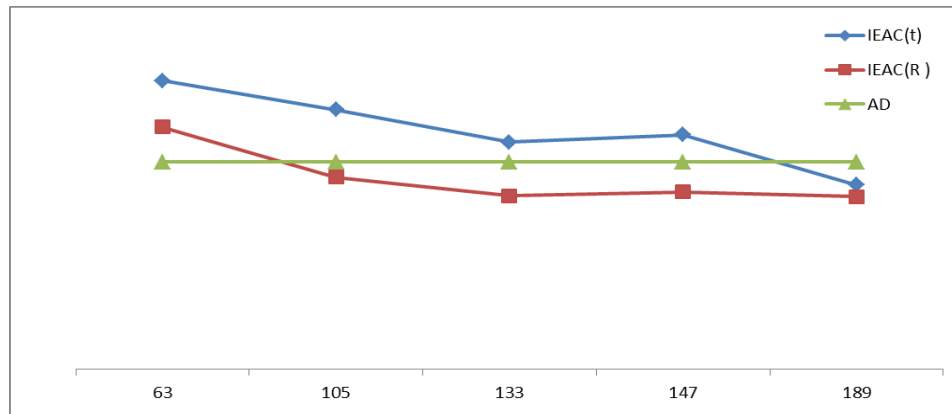
Figure 5- Comparing ES and FC in project No. 2

Ultimately, as the last example, among the completed projects, a sample was chosen that, considering the performance, it would be different from the previous samples. In spite of the quick primary progress, this project was finally completed with delay, having various deviations. The following figure depicts the condition of the curve of actual performance in the projects comparing with the base plan.
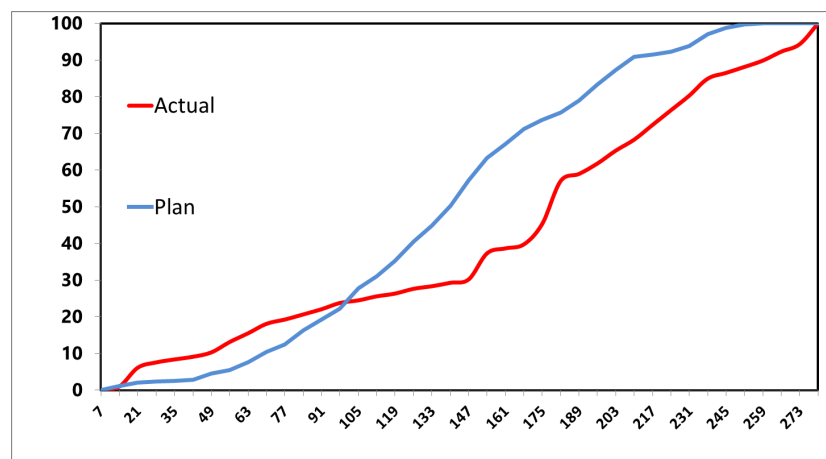
Figure actual and progress of

6- The graph of planned project No. 3

In accordance to the request of the stakeholders the duration was forecasted in every five-week period. In addition the results of completion documents showed that the project lasted for 280 days in reality. The following table depicts the better assessment of FC compared with ES.

Table No. 5- Comparing the earned results of ES and FC methods in project No. 3

AT	42	77	112	147	182	217	252	273
AD	280	280	280	280	280	280	280	280
IEAC(t)	189	223	272	328	303	305	300	286
(t,%C)ρ	0.9	0.98	0.99	0.99	0.98	0.98	0.97	0.98
Kind of Regression	Polynomial	Polynomial	linear	linear	Polynomial	Polynomial	Polynomial	Polynomial
IEAC(R)	286	277	381	372	301	271	273	283

In contrary with the last two projects, the special trend of progress of this project indicates the mistaken forecasts of ES method. As we notice the amounts of the table above and comparing it with figure No. 6, it is evident that the mentioned project, has had a significant progress in the first period of time while in all the later periods it has encountered a descending flow until AT=77. In a way that in the next 10 cases of presented

weekly reports, there has been a less noticeable progress compared with the planned progress. This is while the IEAC(t) index, instead of forecasting risks before the projects, considering the conditions of reporting day compared to the planned progress, has presented promising repots by mistake. This mistake in reporting would lead to delayed awareness of the managers from the critical conditions of the execution (AT=150) and as a result the project would face a delay. While, provided that the report of forecasting the duration of the project was presented at the point of AT=77, the IEAC(R) would report the amount 277, which was more than the initial (PD=243). The following figure is displaying the comparison of reports which these two methods have presented in similar dates.
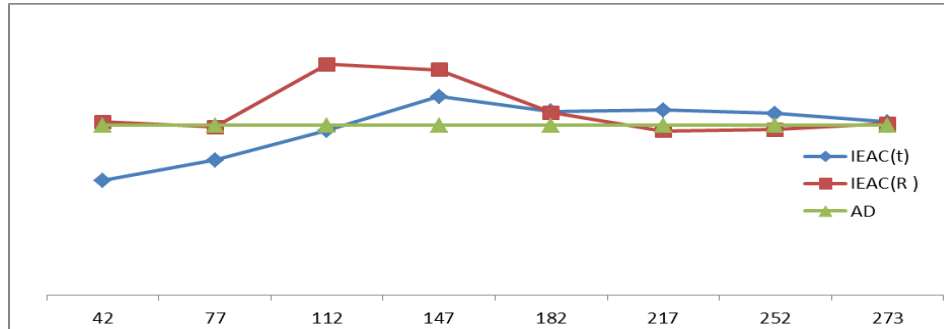

Figure 7- Comparing ES and FC methods in project No. 3

7. Conclusion

In this project, after analyzing "Earned Value" method, we have concluded that although this method has shown a much better performance than "Earned Value Management" in estimating the project duration, analyzing the completed projects proved that the total dependency of this method on schedule performance index, and its ignoring the performance that actual progress curve has shown from the beginning till the reporting time, has made a distance between the forecasts and realities. In this project after confirming the analysis performance of ES method against EVM, we recognized and solved its deficiencies. Ultimately, we introduced a new method with the title of FC which could enable the managers in presenting more appropriate forecasts for future. Implementing this method in three projects with different conditions in performance of actual progress, displayed that the new index (IEAC(R)) gives better results in comparison with (IEAC (t)). Therefore aside with the deficiency of the mentioned index, it is suggested that in order to forecast the future conditions of the projects, FC method replaces ES method.

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