Project Progress Measurement under the Circumstance of Interrupted Schedule

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Abstract. Earned Value Method (EVM) is a project management technique for measuring both project progress and performance in project activities. Unfortunately, this method could not provide credible data in project progress measurement these days due to its deficiency. Thus, a new method called Earned Schedule (ES) is designed to cover EVMs limitation. Considering the fact that researches on ES are focus on simply project under certainty, this paper is to fill in the blank of uncertainty. In this paper, a new concept called interrupted Earned Schedule (iES) and its indicators are presented considering the situation of interrupted schedule when doing project progress measurement. This concept can offer accurate description about schedule interrupted project of its progress measurement. With the help of a model project, iES and its indicators are proven practicable. Moreover, a comparison between iES and ES of a schedule interrupted project shows priority of the former one.

1. Introduction

Project Management is a kind of activity that can efficiently manage project activities with the application of knowledge, techniques, tools and skills. Accompanied with the growing number of project activities since the beginning of the 21th century, different kinds of methods of Project Management are developing and improving.

Earned Value Method (EVM) is a kind of method used to help assess and measure project progress and performance with the integration of project scope, cost and schedule. It originally act as an important part of Cost/scheduling Control Systems Criteria (C/SCSC) [1] that is provided by the US Department of Defense in 1967. After 1996, this method is open to US private sectors. Now, it is considered would be developed into one of the leading methods in Project Management [2].

EVM once could provide reliable data for project managers in monitoring and controlling process of Project Management. However, things have changed with the growth of complexity and uncertainty in projects. EVMs weaknesses are as follows. Firstly, the unit of all the indicators in EVM is cost, including the progress indicators. It means that when measuring Schedule Variance, the data provided is in doubtable because of the non-linear relationship between cost and time in reality. Moreover, measuring project

progress with the unit of cost is unintuitive and incomprehensible. Secondly, as to any finished project, Schedule Variance provided by EVM would be zero finally. But actually, Schedule Variance should not be zero if it is a late finished project. So EVM failed in this circumstance. Finally, EVM could only be used for simply project under certainty, rather than project considering complexity and uncertainty.

Since the beginning of the 21th century, considering the inefficiency of EVM represented in project progress measurement, Anbari [3], Jacob [4, 5], Lipke [6–11] and some other scholars try to use their own ways to revise EVM. After the comparison of Stephan Vandevoorde [12, 13], Earned Schedule (ES) by Lipke is the only method that can make precise project progress measurement under the circumstance of both linear and non-linear relationship between cost and time. Lipke [14] himself also makes a comparison between EVM and ES with the use of Hypothesis Testing. After the analysis with 6 groups of real project data, it shows that ES is the best method of project progress measurement. After that, Kym Henderson [15–17] made a revise of Estimate at Completion (EAC) formula based on ES which made the predication indicator a better one. Besides, the concept of ES has been recorded in PMI's Practice Standard for Earned Value Management [18] in 2005 which shows its significant status in the research orientation of EVM.

ES has greatly helped EVM in its limitation of project progress measurement. But when considering project with complexity and uncertainty, more works need to be done. The aim of this paper is to make improvement of ES so that it can be used in projects with uncertainty. This paper introduce a new concept called interrupted Earned Schedule (iES) considering the situation of interrupted schedule when doing project progress measurement. Based on iES, a group of its indictors are presented. With the use of a model project, it shows that iES has an advantage when doing progress measurement of schedule interrupted project.

2. A Brief Review of Earned Schedule

In 2003, Lipke [6] raised a concept Earned Schedule (ES) to cover the limitation of EVM in project progress measurement. The idea of this concept is to measure progress with the unit of time and the three key dimensions of EVM have been matched corresponding with three other dimensions: Planned Duration (PD), Earned Schedule (ES) and Actual Time (AT). The basic formula of ES is:

$$ES_t \approx C + (EV_t - PV_C)/(PV_{C+1} - PV_C) \tag{1}$$

ES_t means ES in period t; C means the maximum whole number of periods in a condition of $EV_t \geq PV_C$; EV_t means EV in period t; PV_C means PV in period t;

The construction of formula (1) adopts the principle of similar triangles, as is shown in Figure 1:
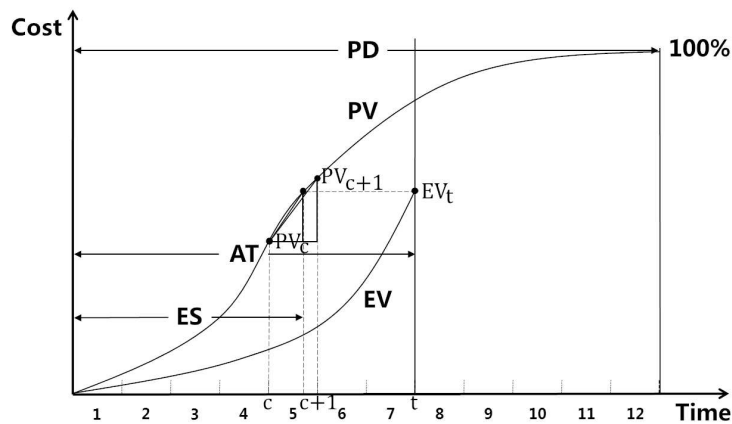

Figure 1: The basic formula of ES

As with EVM, ES also has its variance and index. Because ES only concern about progress measurement, it only has one variance and one index:

$$SV(T) = ES - AT \tag{2}$$
$$SPI(T) = ES/AT \tag{3}$$

As to the forecast part, the formula of EAC that Kym Henderson [16] provides is as follow:

$$EAC(T) = PD/SPI(T) \tag{4}$$

3. Application Condition of iES

Lipke firstly think of the application of ES under the condition of uncertainty. Based on his research, the concept of project progress interrupt is presenting systematically here. During the execution phase of a project, Scheduled Shutdown and Unscheduled Shutdown are two of the most common elements that have effect on project progress. Scheduled Shutdown means that no work is arranged in some periods, such as no work is arranged on weekends or statutory holidays. But in reality, it may come to some works these days for the reason like rushing the progress completion. As to Unscheduled Shutdown, it means that arranged work is forced to stop, mostly for the reasons like unpredicted bad weather or capital shortage. So Unscheduled Shutdown means the circumstance that work is arranged but not do in reality. Thus, some definitions are as follows:

1) Scheduled Shutdown (SSD): the periods that EV is not 0 but PV is 0 in EVM;

2) Unscheduled Shutdown (USD): the periods that PV is not 0 but EV is 0 in EVM;

3) Project progress interrupt: the circumstance that at least Scheduled Shutdown or Unscheduled Shutdown appears alone;

4) Schedule interrupted project: project that contains the circumstance of project progress interrupt.

Besides, as to the condition that both PV and EV are 0 in some periods, it is defined that both SSD and USD appear in this paper.

Based on the definitions above, a late finished schedule interrupted project (short for LFSI project) is shown below to demonstrate the necessity of our research:

Table 1: PV & EV of LFSI project

Period	1	2	3	4	5	6	7	8	9	10
PV	100	327	578	786	1033	1372	1614	2075	2583	2913
EV	100	257	478	631	821	1138	XX	XX	1274	1403
Period	11	12	13	14	15	16	17	18	19	20
PV	3512	3739	4141	4829	5231	5489	5893	XX	XX	XX
EV	1678	1839	2187	2439	2689	2953	3387	3579	3795	4139
Period	21	22	23	24	25	26	27	28	29	30
PV	XX	6012	6231	6381	6451	6535	6580			
EV	4596	5023	5386	5749	6013	6274	6384	6475	6532	6580

In Table 1, XX means no data record. Because the data in this table are cumulative values, so here comes XX rather than 0.

From Table 1 we can see that the planned duration is 27 which include 4 continuous SSD periods (18-21) and the actual duration is 30 which include 2 continuous USD periods (7-8). The thing is, ES cant be calculated during SSD and USD periods for the lack of PV or EV data.

We can also calculate ES with approximate data instead, such as put $EV_8 \approx EV_7 \approx EV_6 = 1138$ in the LFSI project. But in that way, the EAC value would have a larger variance which will be shown later. In order to solve this problem, we raised the concept interrupted Earned Schedule (iES) and a group of its indictors to make the progress measurement more accurate.

4. Progress Measurement of Schedule Interrupted Project based on iES

4.1. The introduction of iES

The basic formula of iES is as follow:

$$iES_t \approx C' + (EV_t - PV_C)/(PV_{C+1} - PV_C) \tag{5}$$

C' presents the maximum whole number of planned work periods under the condition of $EV_t \geq PV_C$.

Compared with (1), the difference between the two formulas is the C and C' part. Under the condition of $EV_t \geq PV_C$, C contains all the periods including planned work periods and SSD periods, but C' only contains the planned work periods. The relationship between C and C' is like this:

$$C = C' + SSD_C \tag{6}$$

SSD_C means the SSD periods before the end of period C.

The comparison between ES and iES is shown in Table 2:

Table 2: ES & iES of LFSI project

Period	1	2	3	4	5	6	7	8	9	10
ES	1.00	1.69	2.60	3.25	4.14	5.31	5.31	5.31	5.71	6.13
iES	1.00	1.69	2.60	3.25	4.14	5.31	5.31	5.31	5.71	6.13
Period	11	12	13	14	15	16	17	18	19	20
ES	7.14	7.49	8.22	8.72	9.32	10.07	10.79	11.30	12.14	13.00
iES	7.14	7.49	8.22	8.72	9.32	10.07	10.79	11.30	12.14	13.00
Period	21	22	23	24	25	26	27	28	29	30
ES	13.66	14.48	15.60	16.64	22.00	23.29	24.04	25.29	25.96	27.00
iES	13.66	14.48	15.60	16.64	18.00	19.29	20.04	21.29	21.96	23.00

From Table 2, we can see that ES and iES are different from period 25. The advantage of iES is shown in Table 3:

Table 3: ΔES & ΔiES of LFSI project (part)

Period	23	24	25	26	27	28
ΔES	1.12	1.04	5.36	1.28	0.76	1.24
ΔiES	1.12	1.04	1.36	1.28	0.76	1.24

From Table 3 we can see that the ΔES in period 25 has a large variance. This is because the 4 SSD periods before period 25 are all cumulated abruptly in period 25. But obviously, ΔES in period 25 could only be about 1.3 periods. Thus the concept iES is to solve this problem, reduce the calculation variance and make the measurement more accurate.

Here also comes the explanation of why these 4 SSD periods are all cumulated abruptly in period 25 of ES. Because ES and iES are the concepts that use planned schedule measure actual schedule. As to the condition that SSD periods have not happened before the planned schedule of its corresponding actual schedule, the SSD periods should not be considered timely. For example in Table 3, the SSD periods are period 18 to 21. But when the actual schedule of the project comes to period 18 to 21, the corresponding planned schedule would be approximate period 11.30 to 13.66, which means there is no SSD period happened before the planned schedule. Thus ES = iES at this time. When the actual schedule comes to period 24 and 25, the corresponding planned schedule would be period 16.64 and 18.00. Because there are 4 SSD periods happened before period 18 which is now the planned schedule, thus the value of ES and iES are different. $ES_{25} = 22.00$ and $iES_{25} = 18.00$.

4.2. interrupted Time Schedule Variance iSV(T) and interrupted Time Schedule Performance Index iSPI(T)

Based on iES and formula (2) and (3), two improved indicators are present here.
interrupted Time Schedule Variance iSV(T):

$$iSV(T)_t = (iES_t + SSD_t) - AT_t \tag{7}$$

SSD_t means the SSD periods happened before the end of period t.

interrupted Time Schedule Performance Index iSPI(T):

$$iSPI(T)_t = iES_t/(AT_t - USD_t) \tag{8}$$

USD_t means the USD periods happened before the end of period t.

The advantages of indicator iSPI(T) and iSV(T) can be seen from the USD periods and SSD periods. As to the USD part, part data of LFSI project is like this:

Table 4: data of LFSI project during USD periods (part)

SV(T)	ΔSV(T)	SPI(T)	ΔSPI(T)	Period	iSV(T)	ΔiSV(T)	iSPI(T)	ΔiSPI(T)
-0.69	0.17	0.88	1.17	6	-0.69	0.17	0.88	1.17
-1.69	-1.00	0.76	0.00	7	-1.69	-1.00	0.88	0.00
-2.69	-1.00	0.66	0.00	8	-2.69	-1.00	0.88	0.00

We can see that the iSPI(T) is better than SPI(T) because iSPI(T) stayed the same when no work has been done during the USD periods.

As to the SSD part, part data can be seen from Table 5:

Table 5: data of LFSI project during USD periods (part)

SV(T)	ΔSV(T)	SPI(T)	ΔSPI(T)	Period	iSV(T)	ΔiSV(T)	iSPI(T)	ΔiSPI(T)
-6.21	-0.28	0.63	0.72	17	-6.21	-0.28	0.72	0.72
-6.70	-0.50	0.63	0.50	18	-5.70	-0.50	0.71	0.50
-6.86	-0.16	0.64	0.84	19	-4.86	-0.16	0.71	0.84
-7.00	-0.14	0.65	0.86	20	-4.00	-0.14	0.72	0.86
-7.34	-0.33	0.65	0.67	21	-3.34	-0.33	0.72	0.67
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
-7.36	0.04	0.69	1.04	24	-3.36	0.04	0.76	1.04
-3.00	4.36	0.88	5.36	25	-3.00	0.36	0.78	1.36

In the SSD part, we can see that iSV(T) is better than SV(T) for the reason that the negative effect of 4 SSD periods are all cumulated abruptly in period 25 of SV(T), just as explained in 4.1. iSV(T) is succeeded in avoiding this problem.

In summary, as to the progress measurement issue of schedule interrupted project, iSPI(T) and iSV(T) can measure the actual schedule better and be able to avoid the large variance.

4.3. interrupted Time Estimation at Completion iEAC(T)

In the forecast aspect, iEAC(T) have the same task as EAC(T). So an improvement of EAC(T) needs to be done to meet the needs of iES. Formula (4) is chosen as the basic formula:

$$EAC(T) = PD/SPI(T)$$

Firstly, because the specific number of SSD periods can be acquired in the planning stage, thus the work periods of planned duration equal to the planned duration minus SSD periods. So:

$$iEAC(T)^1 = (PD - SSD_T)/iSPI(T)_t$$

SSD_T means the SSD periods of the total project.

Besides, during the execution phase, SSD periods that already exist can bring extra working periods that would lead to schedule delay, thus such periods need to be reduced:

$$iEAC(T)^2 = iEAC(T)^1 - SSD_t$$

SSD_t means the SSD periods happened before the end of period t.

As to USD periods, on the contrary, would lead to schedule advance, thus these periods need to be added:

$$iEAC(T)^3 = iEAC(T)^2 + USD_t$$

USD_t means the USD periods happened before the end of period t.

$iEAC(T)^3$ is the one that consider the situation of project progress interrupt. But $iEAC(T)^3$ is only the estimation at completion of project working schedule rather than the project schedule. In order to have an estimation at completion of the whole project schedule, SSD_T needs to be added at last.

In summary, the iEAC(T) formula is:

$$iEAC(T)_t = \frac{PD - SSD_T}{iSPI(T)_t} + USD_t + SSD_T - SSD_t \tag{9}$$

5. The comparison between iES and ES with LFSI project

5.1. The Feasibility of iES

In order to verify the efficiency of iES and its indicators, the LFSI project is used here as an example. With formula (5), (7), (8) and (9), iES, iSV(T), iSPI(T) and iEAC(T) can be calculated as with Table 6:

Table 6: iES and its indicators of LFSI project

Period	1	2	3	4	5	6	7	8	9	10
iES	1.00	1.69	2.60	3.25	4.14	5.31	5.31	5.31	5.71	6.13
iSV(T)	0.00	-0.31	-0.40	-0.75	-0.86	-0.69	-1.69	-2.69	-3.29	-3.87
iSPI(T)	1.00	0.85	0.87	0.81	0.83	0.88	0.88	0.88	0.82	0.77
iEAC(T)	27.00	31.19	30.52	32.27	31.77	29.99	30.99	31.99	34.19	36.03
Period	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
iES	7.14	7.49	8.22	8.72	9.32	10.07	10.79	11.30	12.14	13.00
iSV(T)	-3.86	-4.51	-4.78	-5.28	-5.68	-5.93	-6.21	-5.70	-4.86	-4.00
iSPI(T)	0.79	0.75	0.75	0.73	0.72	0.72	0.72	0.71	0.71	0.72
iEAC(T)	35.00	36.72	36.78	37.66	38.08	37.99	37.97	37.58	36.21	34.86
Period	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
iES	13.66	14.48	15.60	16.64	18.00	19.29	20.04	21.29	21.96	23.00
iSV(T)	-3.34	-3.52	-3.40	-3.36	-3.00	-2.71	-2.96	-2.71	-3.04	-3.00
iSPI(T)	0.72	0.72	0.74	0.76	0.78	0.80	0.80	0.82	0.81	0.82
iEAC(T)	33.99	33.76	32.96	32.40	31.38	30.62	30.69	30.09	30.27	30.00

For the sake of having a better understanding of how the data in Table 6 be calculated, the calculation process of one period is given.

From Table 1 we know that the planned duration of LFSI project is 27 and the total SSD periods is period 18 to 21, so PD = 27 and $SSD_T = 4$.

We assume that the present time is the end of period 26, so t=26. Because there exist 2 USD periods and 4 SSD periods before the present time, so $USD_{26} = 2$ and $SSD_{26} = 4$. If the present time is the end of period 7, $USD_7 = 1$ and $SSD_7 = 0$.

From formula (1) we know that C should be the maximum integer under the condition of $EV_t \geq PV_C$. Because we can see that $EV_{26} = 6274$ from Table 1, so $PV_C = 6231$ and thus C=23. So from formula (6) we know that:

$$C' = 23 - SSD_{23} = 23 - 4 = 19$$

Then, with formula (5), (7), (8) and (9), all the indicators of iES can be calculated:

$$iES_{26} = C' + \frac{EV_{26} - PV_{23}}{PV_{24} - PV_{23}} = 19 + \frac{6274 - 6231}{6381 - 6231} = 19.29$$

$$iSV(T)_{26} = (iES_{26} + SSD_{26}) - AT_{26} = (19.29 + 4) - 26 = -2.71$$

$$iSPI(T)_{26} = \frac{iES_{26}}{AT_{26} - USD_{26}} = \frac{19.29}{26 - 2} = 0.80$$

$$iEAC(T)_{26} = \frac{PD - SSD_{26}}{iSPI(T)_{26}} + USD_{26} + SSD_T - SSD_{26} = \frac{27 - 4}{0.80} + 2 + 4 - 4 = 30.62$$

From Table 6 we can see that both $iSV(T)_{30}$ and $iSPI(T)_{26}$ clearly identify that the project is delayed and $iSV(T)_{30}$ even shows the exact delayed number of periods. Besides, iEAC(T) moves towards the actual duration as time goes by and finally reach the exact value in period 30. So iES and its indicators are truly efficient.

In order to testify the advantage of iES compared with ES when measuring the schedule interrupt project, the data of ES and its indicators with LFSI project is shown in Table 7:

Table 7: ES and its indicators of LFSI project

Period	1	2	3	4	5	6	7	8	9	10
ES	1.00	1.69	2.60	3.25	4.14	5.31	5.31	5.31	5.71	6.13
SV(T)	0.00	-0.31	-0.40	-0.75	-0.86	-0.69	-1.69	-2.69	-3.29	-3.87
SPI(T)	1.00	0.85	0.87	0.81	0.83	0.88	0.76	0.66	0.63	0.61
EAC(T)	27.00	31.92	31.13	33.18	32.60	30.51	35.60	40.68	42.55	44.06
Period	11	12	13	14	15	16	17	18	19	20
ES	7.14	7.49	8.22	8.72	9.32	10.07	10.79	11.30	12.14	13.00
SV(T)	-3.86	-4.51	-4.78	-5.28	-5.68	-5.93	-6.21	-6.70	-6.86	-7.00
SPI(T)	0.65	0.62	0.63	0.62	0.62	0.63	0.63	0.63	0.64	0.65
EAC(T)	41.60	43.27	42.70	43.37	43.45	42.91	42.53	43.03	42.26	41.55
Period	21	22	23	24	25	26	27	28	29	30
ES	13.66	14.48	15.60	16.64	22.00	23.29	24.04	25.29	25.96	27.00
SV(T)	-7.34	-7.52	-7.40	-7.36	-3.00	-2.71	-2.96	-2.71	-3.04	-3.00
SPI(T)	0.65	0.66	0.68	0.69	0.88	0.90	0.89	0.90	0.90	0.90
EAC(T)	41.50	41.01	39.81	38.93	30.68	30.15	30.32	29.90	30.16	30.00

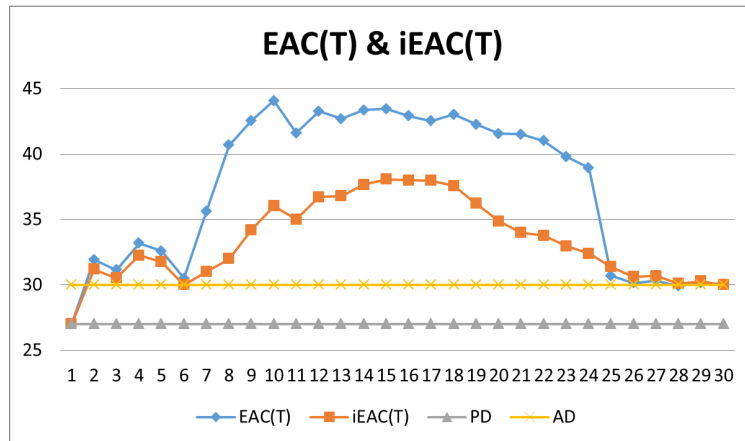It is more clear when we compare EAC(T) and iEAC(T) of the whole project:

Figure 2: EAC(T) and iEAC(T) of LFSI project

From Figure 2 we can see that iEAC(T) is more smooth than EAC(T). Besides, in most of the periods, iEAC(T) is closer to the actual duration than EAC(T). This figure directly shows the priority of iES when measuring schedule interrupt project.

5.2. The General Applicability of iES

From 5.1 it is clear that iEAC(T) is efficient and has priority when measuring schedule interrupt project. But actually the test only concern about LFSI project. In order to consider a wider using condition of iES, this part is to test the general applicability of iEAC(T).

Several aspects need to be considered:

(1) Considering the effect of SSD and USD separately to iEAC(T).

(2) Considering the effect of late start and early start project to iEAC(T). Generally, most projects start the same as the planned time, so as to LFSI project. But in order to think about the general applicability of iEAC(T), the two listed circumstances need to be considered.

(3) Considering the effect of advanced finish during the SSD periods to iEAC(T). During the test, this special condition makes a huge negative effect to the result of iEAC(T), thus it is listed out to make a separate condition.

5.2.1. The Effect of SSD and USD Separately to iEAC(T)

In order to understand the separate effects of SSD and USD to iEAC(T), here I designed a project (LFSI project 1) only contains SSD periods and a project (LFSI project 2) only contains USD periods based on LFSI project. The comparison between EAC(T) and iEAC(T) of these two projects are shown in Figure 3 and Figure 4:
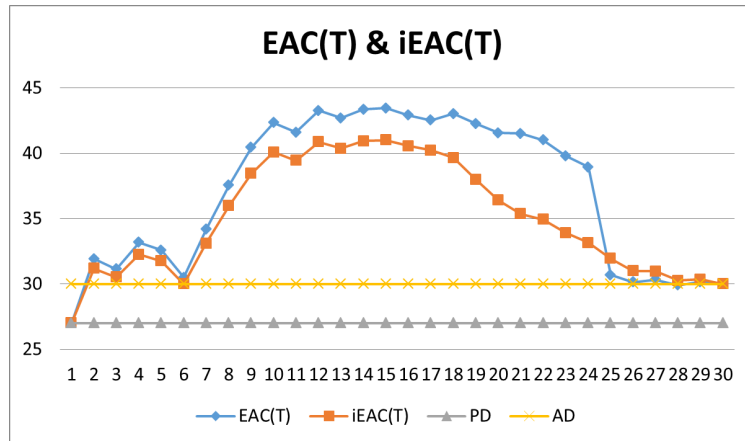
Figure 3: The comparison between EAC(T) and iEAC(T) of LFSI project 1
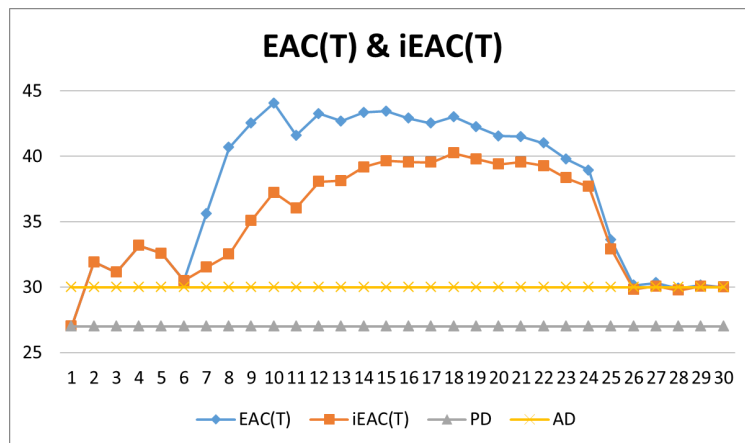

Figure 4: The comparison between EAC(T) and iEAC(T) of LFSI project 2

In Figure 3 we can see that in period 25 there exists a huge fluctuation. Just as explained in 4.1, this is because the abrupt accumulation of 4 SSD periods in period 25. ES is enlarged abruptly and at meantime EAC(T) is quite small.

In Figure 4 we can see that the advantage of iEAC(T) is quite obvious since the appearance of USD periods. Because EV remains the same during USD periods, thus ES stays the same. Along with the increase of AT, SPI(T) decreases. Thus during the USD periods, EAC(T) increases gradually and reaches the maximum value in the last USD period.

To sum up, with the separate analysis from LFSI project 1 and LFSI project 2, we can see that iEAC(T) can have better calculation when facing the effect of SSD or USD separately.

5.2.2. *The Effect of Late Start and Early Start Project to iEAC(T)*

In order to test the effect of late start and early start, here I designed a delayed 4 days to start project (LSSI project) and an advanced 4 days to start project (ESSI project) based on LFSI project:
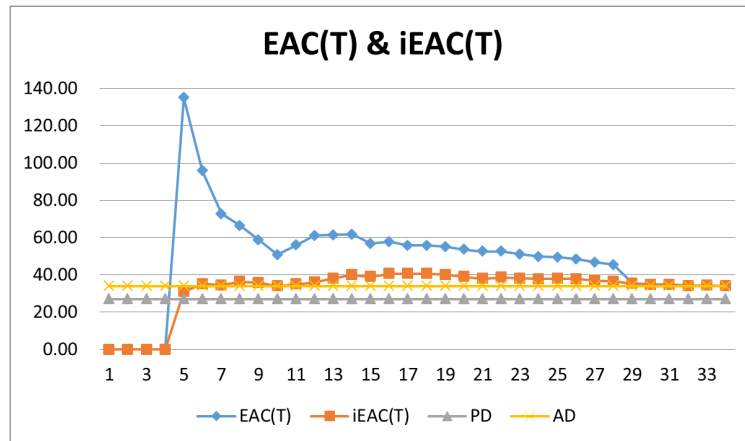
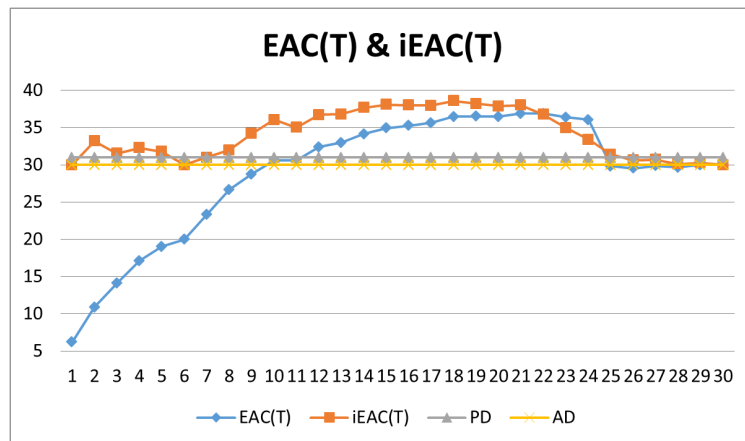Figure 5: The comparison between EAC(T) and iEAC(T) of LSSI project

Figure 6: The comparison between EAC(T) and iEAC(T) of ESSI project

As to the LSSI project(Figure 5), this test assumes that the calculation starts along with the project plan. So together with the 4 day delay, the project completion is a little bit longer. According to formula (3), the initial value of SPI(T) is quite small, thus the initial value of EAC(T) is very large. So the value of EAC(T) in the early stage has no meaning. But as to iEAC(T), the 4 day delay can be considered as USD periods, thus the calculation has no error happened in the early stage. It is the same to ESSI project(Figure 6).

5.2.3. The Effect of Advanced Finish During the SSD Periods to iEAC(T)

This case is quite different from the cases above and actually leads to an error when calculating the value of iEAC(T). According to formula (9),SSD_T is a fixed value that is known before the start of a project, thus the value is assumed fixed during the execution phase. But when a project is finished during the SSD periods, it means that SSD_T is changed at the same time. Thus the calculation of iEAC(T) will be wrong. Here we designed an early finished project during the SSD periods based on LFSI project (EFSI project):
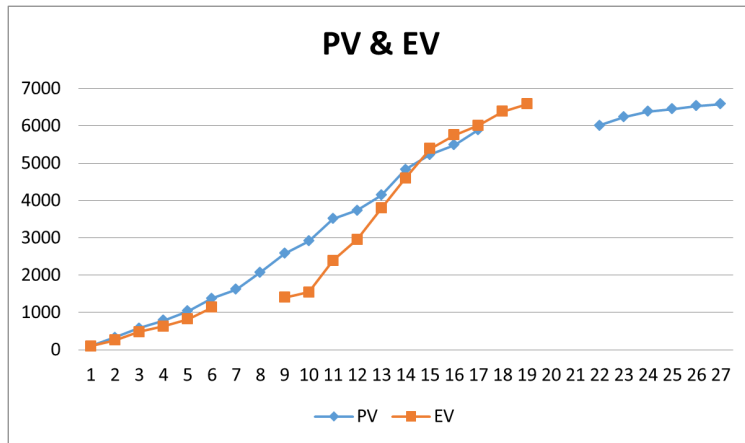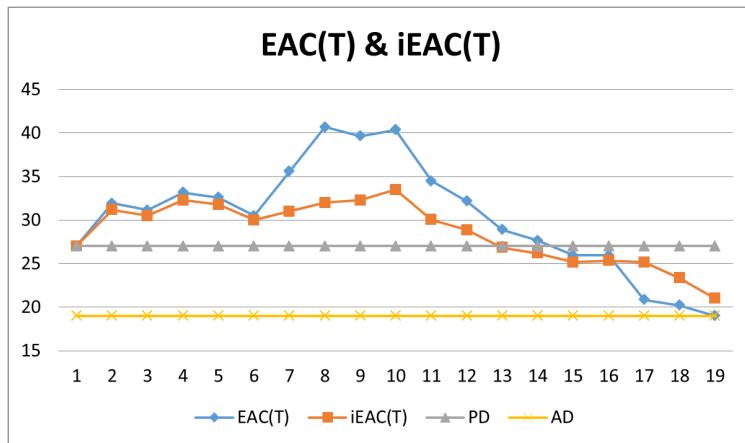
Figure 7: PV & EV of EFSI project

Figure 8: The comparison between EAC(T) and iEAC(T) of EFSI project

As is shown in Figure 7, 8, the project is finished in period 19 which is one of the SSD periods. Just as what I have explained, although we choose $SSD_T = 4$ during the execution phase of the project, the actual $SSD_T = 2$ and we only know it as soon as the project is finished. Thus the calculation of iEAC(T) is wrong. So iEAC(T) is unable to provide reliable data in this circumstance.

6. Conclusion

Earned Value Management is a traditional method that integrates project progress measurement and project performance measurement during the monitoring and controlling process. Unfortunately, this method has defect when doing project progress measurement. Thus a new method based on EVM called Earned Schedule has been provided by Lipke to fulfill the deficiency of EVM. Considering the fact that ES is mainly focused on single project under certainty, the method need to be improved to face the need of uncertainty and complexity. The research of this paper is to face the need of uncertainty in doing project progress measurement. We provide iES and a group of its indicators that can measure the project progress under the circumstance of project progress interrupt. With the use of cases, it can be proven that these indicators can help provide more reliable data in progress measurement and estimation at completion. However, when the project is finished during the SSD periods, the value of iEAC(T) is wrong. This problem needs to be fixed in the future.

References

[1] Fleming, Q.W., Cost/schedule control systems criteria: The management guide to C/SCSC. 1988, Chicago: Probus Publishing Company.

[2] Abba, W.F., Earned Value Management-Reconciling Government and Commercial PracticesFor People Involved In Earned Value-GovernmentIndustryAcademiaOr Consulting-These Are Exciting Times. Program Manager, 1997. 1: p. 58-63.

[3] Anbari, F.T., Earned Value Project Management Method And Extensions. Project Management Journal, 2003. 34(4): p. 12-23.

[4] Jacob, D.S., Forecasting Project Schedule Completion With Earned Value Metrics. The Measurable News, 2003. March: p. 1. 7. 9.

[5] Jacob, D.S., Forecasting Schedule Completion Using Earned Value Metricsrevisited. The Measurable News, 2004. Summer: p. 1. 11-17.

[6] Lipke, W., Schedule Is Different. The Measurable News, 2003. Summer: p. 31-34.

[7] Lipke, W., Connecting Earned Value to the Schedule. Cross Talk, 2005. June.

[8] Lipke, W., Why Should CPI = 1? The Measurable News, 2011. 2: p. 11-15.

[9] Lipke, W., Is Something Missing from Project Management? The Measurable News, 2011. 1: p. 23-27.

[10] Lipke, W., Further Study of the Normality of CPI and SPI(t). The Measurable News, 2012. 2: p. 16-18.

[11] Lipke, W., Earned Schedule-Ten Years After. The Measurable News, 2013. 3: p. 15-21.

[12] Vandevoorde, S. and M. Vanhoucke, A comparison of different project duration forecasting methods using earned

[13] Vanhoucke, M. and S. Vandevoorde, Measuring the Accuracy of Earned Value/Earned Schedule Forecasting Predictors. The Measurable News, 2007. Winter: p. 26-30.

[14] Lipke, W., Project Duration Forecasting A Comparison of Earned Value Management Methods to Earned Schedule. The Measurable News, 2009. 2: p. 24-31.

[15] Henderson, K., Earned schedule: a breakthrough extension to earned value theory? A retrospective analysis of real project data. The Measurable News, 2003. Summer: p. 13-17. 21.

[16] Henderson, K., Further Developments in Earned Schedule. Vol. Spring. 2004. 15-17. 20-22.

[17] Henderson, K., Earned Schedule in Action. The Measurable News, 2005. Spring: p. 23-28. 30.

[18] Institute, P.M., Schedule Analysis And Forecasting, in Practice Standard for Earned Value Management. 2005, Project Management Institute. p. 17-18.