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Homogenizing Schedule Performance Index (SPI) in Construction Projects

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Abstract

Schedule Performance Index (SPI) is one of the Earned Value Method indicators for assessing a project performance schedule. The problem with this index while actual implementation of project for measuring a project scheduling performance is that the denominator and numerator are not homogeneous. In other words, the numerator is made of volume and the denominator made of time. Therefore, the SPI index does not provide project managers with precise guidelines for indicating a project's actual performance in terms of time and project implementation. Therefore, it is necessary to obtain a practical method for homogenizing the numerator and denominator of this indicator that not only provides a precise criterion for a project schedule performance but also proper guidelines to make on-time and correct decisions by project managers and owners. This paper aims to present a method for this purpose by giving an example of unit price contract in the supposed underground hydro power plant project.

1. Introduction

The Idea for putting forward prediction Base Line is the origin of the resulting Earned Value Method (EVM). In this technique, based on two criteria Budgeted Cost of Work Scheduled (BCWS), Budgeted cost of work performed (BCWP) can be made a correct comparison between the actual percentage of the project progress and the planned (scheduled). If the cost-weighted value criterion is used, then the cumulative Base Line cost is called BCWS up to a specific day. BCWP is the finished work or the cumulative amount of planned budget for the actual program until a certain time. In other words, in this case, although the scheduling of the implementation of the activities is actual, the costs are still the same as the planned costs and the actual costs are not. The total of these costs up to a specific time of execution of the project is the same as BCWP [1], [2].

Another type of performance measures are indices also calculated from the three key parameters of EVM. The indices are again used to display how well the project performing. The second index is the Schedule Performance Index (SPI). The SPI shows whether the project is performing on schedule or not [3], [4].

A *SPI* greater than one indicates more work has been accomplished than was planned. Note how this is worded since a *SPI* > 1.0 does not necessarily mean you are ahead of schedule (Plus Variance)! You can accomplish more work than planned by working on non-critical path work packages. You need to look at project float to determine whether you are ahead, on or behind

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schedule. You need to be careful using SPI, because you really can't determine the project health without knowing how the team is doing against the critical path in the project schedule. A team can achieve a *SPI* > 1.0 by working on non-critical path activities. Therefore, it's very possible to have an *SPI* > 1.0 and be behind schedule (Minus Variance). You need to look at the project float to determine complete schedule performance [5].
Time (schedule) performance should be calculated by measuring the value of product delivered at a given time (earned value) and by comparing this time to the time when this value was supposed (planned) to be delivered. How can we explain that the EVM schedule indicators, even though clearly deficient, were used for decades without being seriously questioned and eventually changed? The possible explanation has to take into account that EVM was used mostly to analyze project cost performance which works very well. Fleming and Koppelmann, probably the most cited EVM authors, advocate the use of earned value management primarily for cost management [12]. They recognize that EVM is not reliable for schedule performance analyses, especially to predict the end of a project. Instead of EVM, they recommend the use of the critical path method – CPM as the most reliable way to forecast project duration. Another explanation is related to the fact that the researches about EVM do not address explicitly the non-linearity of a cumulative cost curve. It is interesting because, in those research works, cumulative cost curve is often presented as an S curve, so non-linear, but analyzed as if it were a straight line [6].
EVA (Earned Value Analysis) cannot tell a critical task from a noncritical task. SPI may be misleading when an ahead-of-schedule (Plus Variance) noncritical task overshadows a behind-of -schedule (Minus Variance) critical task. The SPI may indicate a healthier project than actual reality [7].

2. Research Methodology

The research method is descriptive and empirical. The SPI index can be determined through dividing actual progress by planned progress:

$$SPI = \frac{Actual}{plan} = \frac{\%A}{\%P} = \frac{Earned\ value}{planned\ value} = \frac{\%A * BCWS}{\%P * BCWS} \tag{1}$$

The SPI index indicates our performance compared with the project scheduling:
1. If the SPI is greater than one, this means more work has been completed than the planned work. In other words, you have Plus Variance (Actual % Complete - Plan % Complete) or ahead of schedule.
2. If the SPI is equal to one, this means work is being completed at about the same rate as planned, you are on time.
3. If the SPI is less than one, this means less work has been completed than the planned work. In other words, you have Minus Variance or you are behind of schedule.
The problem with this index while actual implementation of project for measuring a project scheduling performance is that the denominator and numerator are not homogeneous.
That is, the numerator (Actual) is usually determined by $\frac{Done\ Volume}{Planned\ Volume}$ and denominator by $\frac{Passed\ Duration}{Total\ Duration}$.

Step1) First, we prepare the work breakdown structure and activities that have to be done for scheduled duration with weight of each activity. (PHC in tables below means Power House Cavern in our supposed project that is construction of underground hydro power plant).

Table1.Work Breakdown Structure and Activities Weights

Time Schedule				
no	category	Activity	unit	WF
1	PHC	Drilling and blasting Stage8 EL= 231- 226.84	m^3	22.53%
2	PHC	Mucking Stage 8 EL=231- 226.84	m^3	1.91%
3	PHC	First Layer Shotcreting Stage 8	m^3	2.12%
4	PHC	DCP Drilling Stage 8	no	14.81%
5	PHC	DCP Installing Stage 8	no	15.87%
6	PHC	DCP Sealing Stage 8	no	0.18%
7	PHC	DCP groutting Stage 8	no	3.97%
8	PHC	Second Layer Shotcreting Stage 8	m^3	4.24%
9	PHC	Drainage hole and Installing	no	5.63%
10	PHC	Install load cell Sensor (LC T 1-7)	no	0.04%
11	PHC	install convergency pine	no	0.01%
12	PHC	Start Excavation Stage 9	m^3	13.00%
13	PHC	EXE Drilling	no	0.20%
14	PHC	install EXE	no	0.12%
15	PHC	LC & EXE Groutting	no	0.10%
16	Tunnel	OT1,OT2 Fiber shotcrete	m^3	3.23%
17	Tunnel	EAT 2Layer shotcrete	m^3	3.42%
18	Tunnel	IU1 1st layer shotcrete	m^3	1.23%
19	Tunnel	LPT Left Groutting	no	0.05%
20	Tunnel	LPT Left 2Layer shotcrete	m^3	1.94%
21	Tunnel	LPT Right 2Layer shotcrete	m^3	1.29%
25	Site	Excavation IU2	m^3	2%
26	Site	Excavation OT1	m^3	1%
27	Site	Mucking soil OT1	m^3	0%
28	Site	OT2-second layer shotcreting	m^3	1%
total				100%

Step2) Then, we place the planned volumes column which needs to be done in the time interval beside of each activity.

Table 2. Planned Volumes

Time Schedule					
no	category	Activity	unit	WF	planned volume
1	PHC	Drilling and blasting Stage8 EL= 231- 226.84	m^3	22.53%	2600
2	PHC	Mucking Stage 8 EL=231- 226.84	m^3	1.91%	3170
3	PHC	First Layer Shotcreting Stage 8	m^3	2.12%	33
4	PHC	DCP Drilling Stage 8	no	14.81%	293
5	PHC	DCP Installing Stage 8	no	15.87%	293
6	PHC	DCP Sealing Stage 8	no	0.18%	293
7	PHC	DCP groutting Stage 8	no	3.97%	330
8	PHC	Second Layer Shotcreting Stage 8	m^3	4.24%	66
9	PHC	Drainage hole and Installing	no	5.63%	130
10	PHC	Install load cell Sensor (LC T 1-7)	no	0.04%	4
11	PHC	install convergency pine	no	0.01%	4
12	PHC	Start Excavation Stage 9	m^3	13.00%	1500
13	PHC	EXE Drilling	no	0.20%	4
14	PHC	install EXE	no	0.12%	4
15	PHC	LC & EXE Groutting	no	0.10%	8
16	Tunnel	OT1,OT2 Fiber shotcrete	m^3	3.23%	50
17	Tunnel	EAT 2Layer shotcrete	m^3	3.42%	53
18	Tunnel	IU1 1st layer shotcrete	m^3	1.23%	19
19	Tunnel	LPT Left Groutting	no	0.05%	10
20	Tunnel	LPT Left 2Layer shotcrete	m^3	1.94%	30
21	Tunnel	LPT Right 2Layer shotcrete	m^3	1.29%	20
25	Site	Excavation IU2	m^3	2%	110
26	Site	Excavation OT1	m^3	1%	140
27	Site	Mucking soil OT1	m^3	0%	140
28	Site	OT2-second layer shotcreting	m^3	1%	1309
total				100%	

Step3) In this step we place the unit price of each activity according to the contract beside of their planned volumes. At this stage, the necessary components for calculating Planned Financial have been completed through multiplying planned volume by related unit price.

Table 3. Planned Financial (Planned Value)

Time Schedule							
no	category	Activity	unit	WF	planned volume	unit price	Planned Financial
1	PHC	Drilling and blasting Stage8 EL= 231- 226.84	m^3	22.53%	2600	72	187,200
2	PHC	Mucking Stage 8 EL=231- 226.84	m^3	1.91%	3170	5	15,850
3	PHC	First Layer Shotcreting Stage 8	m^3	2.12%	33	536	17,608
4	PHC	DCP Drilling Stage 8	no	14.81%	293	420	123,060
5	PHC	DCP Installing Stage 8	no	15.87%	293	450	131,850
6	PHC	DCP Sealing Stage 8	no	0.18%	293	5	1,465
7	PHC	DCP groutting Stage 8	no	3.97%	330	100	33,000
8	PHC	Second Layer Shotcreting Stage 8	m^3	4.24%	66	536	35,215
9	PHC	Drainage hole and Installing	no	5.63%	130	360	46,800
10	PHC	Install load cell Sensor (LC T 1-7)	no	0.04%	4	86	344
11	PHC	install convergency pine	no	0.01%	4	23.18	92.72
12	PHC	Start Excavation Stage 9	m^3	13.00%	1500	72	108000
13	PHC	EXE Drilling	no	0.20%	4	420	1,680
14	PHC	install EXE	no	0.12%	4	250	1000
15	PHC	LC & EXE Groutting	no	0.10%	8	100	800
16	Tunnel	OT1,OT2 Fiber shotcrete	m^3	3.23%	50	536	26,800
17	Tunnel	EAT 2Layer shotcrete	m^3	3.42%	53	536	28,408
18	Tunnel	IU1 1st layer shotcrete	m^3	1.23%	19	536	10,190
19	Tunnel	LPT Left Groutting	no	0.05%	10	44	440
20	Tunnel	LPT Left 2Layer shotcrete	m^3	1.94%	30	536	16,080
21	Tunnel	LPT Right 2Layer shotcrete	m^3	1.29%	20	536	10,720
25	Site	Excavation IU2	m^3	2%	110	153	16,830
26	Site	Excavation OT1	m^3	1%	140	72	10,080
27	Site	Mucking soil OT1	m^3	0%	140	5	700
28	Site	OT2-second layer shotcreting	m^3	1%	1309	5	6,545
total				100%			830,758

Step4) In this step we add the actual or performed volumes (that have been reported by executive unit of the project daily) to the schedule table.

Table 4. Actual (Performed) Volumes

Time Schedule								
no	category	Activity	unit	WF	planned volume	unit price	planned Financial	performed volume
1	PHC	Drilling and blasting Stage8 EL= 231- 226.84	m^3	22.53%	2600	72	187,200	2100
2	PHC	Mucking Stage 8 EL=231- 226.84	m^3	1.91%	3170	5	15,850	2035
3	PHC	First Layer Shotcreting Stage 8	m^3	2.12%	33	536	17,608	34
4	PHC	DCP Drilling Stage 8	no	14.81%	293	420	123,060	180
5	PHC	DCP Installing Stage 8	no	15.87%	293	450	131,850	174
6	PHC	DCP Sealing Stage 8	no	0.18%	293	5	1,465	172
7	PHC	DCP groutting Stage 8	no	3.97%	330	100	33,000	172
8	PHC	Second Layer Shotcreting Stage 8	m^3	4.24%	66	536	35,215	49.5
9	PHC	Drainage hole and Installing	no	5.63%	130	360	46,800	0
10	PHC	Install load cell Sensor (LC T 1-7)	no	0.04%	4	86	344	0
11	PHC	install convergency pine	no	0.01%	4	23.18	92.72	4
12	PHC	Start Excavation Stage 9	m^3	13.00%	1500	72	108000	1309
13	PHC	EXE Drilling	no	0.20%	4	420	1,680	4
14	PHC	install EXE	no	0.12%	4	250	1000	4
15	PHC	LC & EXE Groutting	no	0.10%	8	100	800	4
16	Tunnel	OT1,OT2 Fiber shotcrete	m^3	3.23%	50	536	26,800	4
17	Tunnel	EAT 2Layer shotcrete	m^3	3.42%	53	536	28,408	53
18	Tunnel	IU1 1st layer shotcrete	m^3	1.23%	19	536	10,190	0
19	Tunnel	LPT Left Groutting	no	0.05%	10	44	440	0
20	Tunnel	LPT Left 2Layer shotcrete	m^3	1.94%	30	536	16,080	0
21	Tunnel	LPT Right 2Layer shotcrete	m^3	1.29%	20	536	10,720	0
25	Site	Excavation IU2	m^3	2%	110	153	16,830	110
26	Site	Excavation OT1	m^3	1%	140	72	10,080	140
27	Site	Mucking soil OT1	m^3	0%	140	5	700	140
28	Site	OT2-second layer shotcreting	m^3	1%	1309	5	6,545	1309
total				100%			830,758	

Step5) In order to obtain Actual or Performed Financial, we multiply performed or actual volumes by related activity unit price (based on contract):

Table5. Actual or Performed Financial

Time Schedule									
no	category	Activity	unit	WF	planned volume	unit price	Planned Financial	performed volume	Performed Financial
1	PHC	Drilling and blasting Stage8 EL= 231- 226.84	m^3	22.53%	2600	72	187,200	2100	151,200
2	PHC	Mucking Stage 8 EL=231- 226.84	m^3	1.91%	3170	5	15,850	2035	10,175
3	PHC	First Layer Shotcreting Stage 8	m^3	2.12%	33	536	17,608	34	18,224
4	PHC	DCP Drilling Stage 8	no	14.81%	293	420	123,060	180	75,600
5	PHC	DCP Installing Stage 8	no	15.87%	293	450	131,850	174	78,300
6	PHC	DCP Sealing Stage 8	no	0.18%	293	5	1,465	172	860
7	PHC	DCP groutting Stage 8	no	3.97%	330	100	33,000	172	17,200
8	PHC	Second Layer Shotcreting Stage 8	m^3	4.24%	66	536	35,215	49.5	26,532
9	PHC	Drainage hole and Installing	no	5.63%	130	360	46,800	0	0
10	PHC	Install load cell Sensor (LC T 1-7)	no	0.04%	4	86	344	0	0
11	PHC	install convergency pine	no	0.01%	4	23.18	92.72	4	93
12	PHC	Start Excavation Stage 9	m^3	13.00%	1500	72	108000	1309	94,248
13	PHC	EXE Drilling	no	0.20%	4	420	1,680	4	1,680
14	PHC	install EXE	no	0.12%	4	250	1000	4	1,000
15	PHC	LC & EXE Groutting	no	0.10%	8	100	800	4	400
16	Tunnel	OT1,OT2 Fiber shotcrete	m^3	3.23%	50	536	26,800	4	2,144
17	Tunnel	EAT 2Layer shotcrete	m^3	3.42%	53	536	28,408	53	28,408
18	Tunnel	IU1 1st layer shotcrete	m^3	1.23%	19	536	10,190	0	0
19	Tunnel	LPT Left Groutting	no	0.05%	10	44	440	0	0
20	Tunnel	LPT Left 2Layer shotcrete	m^3	1.94%	30	536	16,080	0	0
21	Tunnel	LPT Right 2Layer shotcrete	m^3	1.29%	20	536	10,720	0	0
25	Site	Excavation IU2	m^3	2%	110	153	16,830	110	16,830
26	Site	Excavation OT1	m^3	1%	140	72	10,080	140	10,080
27	Site	Mucking soil OT1	m^3	0%	140	5	700	140	700
28	Site	OT2-second layer shotcreting	m^3	1%	1309	5	6,545	1309	6,545
total				100%			830,758		540,219

Step6) Now, we can calculate Homogeneous SPI Index:

$$HSPI = \frac{\text{Performed Financial}}{\text{Planned Financial}} = \frac{\text{Actual (done)Volume*Price}}{\text{Planned Volume*Price}} \quad (2)$$

Through dividing step 5 by the step 3.

Table 6. Homogeneous SPI Index

Time Schedule										
no	category	Activity	unit	WF	planned volume	unit price	Planned Financial	performed volume	Performed Financial	Actual %C(SPI index)
1	PHC	Drilling and blasting Stage8 EL= 231- 226.84	m^3	22.53%	2600	72	187,200	2100	151,200	80.77%
2	PHC	Mucking Stage 8 EL=231- 226.84	m^3	1.91%	3170	5	15,850	2035	10,175	64.20%
3	PHC	First Layer Shotcreting Stage 8	m^3	2.12%	33	536	17,608	34	18,224	103.50%
4	PHC	DCP Drilling Stage 8	no	14.81%	293	420	123,060	180	75,600	61.43%
5	PHC	DCP Installing Stage 8	no	15.87%	293	450	131,850	174	78,300	59.39%
6	PHC	DCP Sealing Stage 8	no	0.18%	293	5	1,465	172	860	58.70%
7	PHC	DCP groutting Stage 8	no	3.97%	330	100	33,000	172	17,200	52.12%
8	PHC	Second Layer Shotcreting Stage 8	m^3	4.24%	66	536	35,215	49.5	26,532	75.34%
9	PHC	Drainage hole and Installing	no	5.63%	130	360	46,800	0	0	0.00%
10	PHC	Install load cell Sensor (LC T 1-7)	no	0.04%	4	86	344	0	0	0.00%
11	PHC	install convergency pine	no	0.01%	4	23.18	92.72	4	93	100.00%
12	PHC	Start Excavation Stage 9	m^3	13.00%	1500	72	108000	1309	94,248	87.27%
13	PHC	EXE Drilling	no	0.20%	4	420	1,680	4	1,680	100.00%
14	PHC	install EXE	no	0.12%	4	250	1000	4	1,000	100.00%
15	PHC	LC & EXE Groutting	no	0.10%	8	100	800	4	400	50.00%
16	Tunnel	OT1,OT2 Fiber shotcrete	m^3	3.23%	50	536	26,800	4	2,144	8.00%
17	Tunnel	EAT 2Layer shotcrete	m^3	3.42%	53	536	28,408	53	28,408	100.00%
18	Tunnel	IU1 1st layer shotcrete	m^3	1.23%	19	536	10,190	0	0	0.00%
19	Tunnel	LPT Left Groutting	no	0.05%	10	44	440	0	0	0.00%
20	Tunnel	LPT Left 2Layer shotcrete	m^3	1.94%	30	536	16,080	0	0	0.00%
21	Tunnel	LPT Right 2Layer shotcrete	m^3	1.29%	20	536	10,720	0	0	0.00%
25	Site	Excavation IU2	m^3	2%	110	153	16,830	110	16,830	100.00%
26	Site	Excavation OT1	m^3	1%	140	72	10,080	140	10,080	100.00%
27	Site	Mucking soil OT1	m^3	0%	140	5	700	140	700	100.00%
28	Site	OT2-second layer shotcreting	m^3	1%	1309	5	6,545	1309	6,545	100.00%
total				100%			830,758		540,219	65.03%

As you can see, the result of the above equation, is homogeneous. In this equation, the numerator and denominator are both made of volume and price and the result can be an appropriate index for indicating a project actual progress. In this case, the SPI index is equal to 65.03% [8].

3. Conclusion

Obtaining homogenous SPI index is very essential for the project managers and owners to assess the trend of the project and decide about the future of it. So having the correct SPI index plays very important role for noticing and decision building for them and can lead them in to the right way. If you do not use appropriate index it will result to the wrong path and conduce misleading for the project bases and directors.

We suggest other methods like for evaluation of projects Analytic Hierarchy Process [9, 10], or Data envelopment analysis [11] for future research and combining with this research.

References

[1] Sabzehparvar, M. (2011). Project Control, 6th Edition, Termeh Publication.

[2] Franceschini, F., Galetto, M., & Turina, E. (2013). Techniques for impact evaluation of performance measurement systems. International Journal of Quality & Reliability Management.

[3] Buyse, P., Vandenbussche, T., & Vanhoucke, M. (2010). Performance analysis of Earned Value Management in the construction industry. UNIVERSITEIT GENT.

[4] Bouckaert, G., & van Dooren, W. (2002, April). Progress and regress in performance measurement systems. In International research symposium on public management. University of Edinburgh, Scotland (pp. 8-10).

[5] Lukas, M. J. A., & Cce, P. (2008). EVM. 01 Earned Value Analysis–Why it Doesn't Work. AACE International Transactions, 240-243.

[6] Corovic, R. Why EVM Is Not Good for Schedule Performance Analyses (and how it could be…), The Measurable News, Winter 2006-2007.

[7] https://bizfluent.com/info-8584095-disadvantages-earned-value-project.html

[8] Author Experience in Uma Oya under Ground Hydro Power Plant Project, Sri Lanka Country, 2016.

[9] Touti, E., & Chobar, A. P. (2020). Utilization of AHP and MCDM Integrated methods in Urban Project Management (A Case Study for Eslamshahr-Tehran). International journal of industrial engineering and operational research, 2(1), 16-27.

[10] Nazeri, A., & Keshavarzi, M. (2019). Assessing the Performance of Branches of Refah Bank in Tehran Province by Combining Analytic Hierarchy Process (AHP) and Data Envelopment Analysis (DEA) Algorithms in Fuzzy Conditions. International journal of industrial engineering and operational research, 1(1), 11-27.

[11] Akhlaghi, R., & Rostamy-Malkhalifeh, M. (2019). A linear programming DEA model for selecting a single efficient unit. International journal of industrial engineering and operational research, 1(1), 60-66.

[12] Fleming, Q. W., & Koppelman, J. M. (2016, December). Earned value project management. Project Management Institute.