Probabilistic Construction Project Duration Prediction Models for High Rise Building Based on Earned Schedule Method in Jakarta

Basuki Anondho, Ayomi Dita Rarasati, Yusuf Latief, and Khrisna Mochtar

***Abstract*—Earned value method (EVM) known as one tools to mitigate cost and schedule while it estimates based on cost only. Improvement on EVM method for duration prediction purpose was developed by several previous research emphases on schedule base approach. This paper describes a similar method in duration forecasting with a probabilistic approach in order to accommodate the uncertainty in the developing countries such as Indonesia and compare it with traditional EVM method. Jakarta city was chosen as the biggest city in Indonesia and as capital city of a developing country where high rise building data is easier to find. The comparison purpose is to find out which one better and more accurate on predicting high rise probabilistic project duration in Jakarta. The result show that there is an improvement in accuracy of forecasting probabilistic duration by using earned schedule technique than traditional EVM method.**

***Index Terms*—Earned value, high rise building, schedule base, uncertainty.**

I. Introduction

Forecast cost and duration of a construction project usually used the earned value method (EVM) as a tool, it recommended by project management institute in 1996 for project performance measurement. It based on cost; therefore it is not appropriate to predict project duration [1]-[3]. Project performance indexes like schedule performance index (SPI) and cost performance index (CPI) normally are not constant. Thus, performance of the project in the next reporting period(s) is not necessarily constant and similar to the past, but rather it is flexible, dynamic, and responsive to the past performance [4].

Improvement on EVM method for duration prediction purpose was developed by several previous research emphases on schedule base approach. One of them is the Earned Schedule (ES) technique. The most important development in ES is its ability to more accurately determine the completion date for projects that are behind schedule. ES uses EV performance data to generate the time-based information and as with earned value (EV), uses very similar calculations to predict future performance. It has also been validated by using data from projects already completed both in the public and private sectors. Both real and simulated data has shown the ES technique to be more accurate when compared to other predictive statistics. It is, in essence, an extension to Earned Value and another project control technique to be used in conjunction with existing methodologies [5]. The ES methods forecast using schedule performance index (SPI_T) shows that the SPI_T produces accurate forecasts, regardless of the progress curve nonlinearity, when a project undergoes the steady SPI_T delay pattern. However, when the schedule delay pattern is the steady schedule variant (SV_T), the SPI_T predictions show large forecast errors during the early stage which tend to generate misleading early warning [6].

Based on previous research above, this paper describe a process of methodology trial to compare EVM to ES on high rise building when it implement on a uncertainty condition such in a developing country, with case study in Jakarta, Indonesia.

II. Methodology

The comparison between traditional EVM and ES methodology conducted in systematical calculation procedure for each methods from several construction projects samples consist of s curve, both planning and realization, and floor area. The algorithm of the comparison shown below:

1) Calculate estimate at complete (EAC) for duration for both methods. This is the step where each output method gives a specific value that shows the difference between those 2 methods.

EVM METHODS

$$\text{Schedule Perfomance Index (SPI)} = \frac{\text{BCWP}}{\text{BCWS}} \quad (1)$$

BCWP = Budgeted cost work progress
BCWS = Budgeted cost work scheduled

$$\text{EAC} = \text{Used Time} + \frac{\text{Rest scheduled time}}{\text{SPI}} \quad (2)$$

ES METHODS

Manuscript received August 15, 2017; revised October 20, 2017.

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doi: 10.18178/ijimt.2017.8.6.774

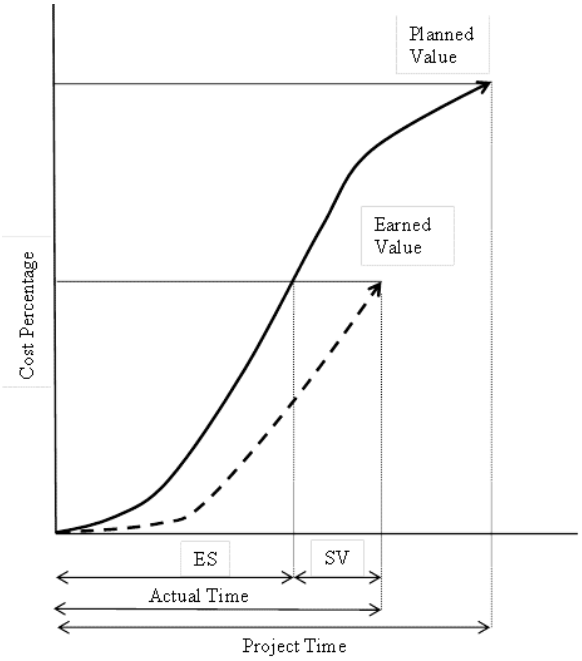

Fig. 1. Earned schedule concept - source: Corovic, [7].

Base on ES concept as shown on Fig. 1, EAC calculation should be transformed to same concept from traditional EVM method. The differences are ES method using ES instead of BCWP for calculating SPI [3].

$$ES = C + I \quad (3)$$

C = Value progress time

where $\sum BCWP \geq \sum BCWS$

$$I = \frac{BCWP - BCWS_c}{BCWS_{C+1} - BCWS_t} \quad (4)$$

I = Linear interpolation

$$SPI = \frac{ES}{\text{Used Time}} \quad (5)$$

$$EAC = \text{Used Time} + \left(\frac{\text{Total duration} - ES}{SPI}\right) \quad (6)$$

2) Divide each sample EAC by floor area to obtain EAC per m2 for each project. By doing this, EAC samples turn into similar data.

$$\frac{EAC_{EVM_n}}{L_n} = x_{EVM\,n} \qquad n = 1.....n \quad (7)$$

$$\frac{EAC_{ES_n}}{L_n} = x_{ES\,n} \qquad n = 1.....n \quad (8)$$

3) Calculate average EAC per m2 and its standard deviation for both methods.

$$\text{Average EAC} = \sum_{i=1}^{n}\left(\frac{x_i}{n}\right) \quad (9)$$

$$sd = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n - 1}} \quad (10)$$

4) Average EAC with smallest standard deviation is more accurate than other since data comes from the same population. This concept come from assumption that small standard deviation is represents of homogeny average, or in other words samples tend to have almost same output on duration prediction.

III. Result and Discussion

A comparison research was conducted in Jakarta where high rise building is a common construction project but still a lot of uncertainty occurs.

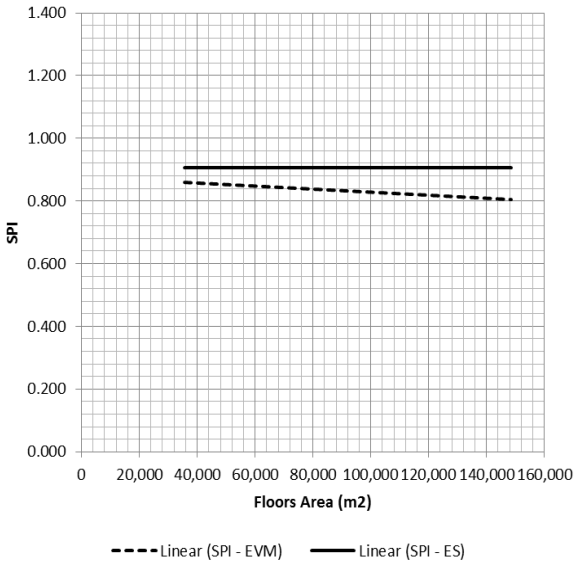

Fig. 2. SPI line trend.

The sample was taken from seven on going high rise building project, consist of four office building, two Apartments and one government facilities building located in Jakarta area. All samples are beyond 8 storeys.

Data processing using traditional EVM method produced gives a result on Table I and II.

TABLE I: Traditional EAC Calculation by EVM Methods

EVM Calculation		
SPI	EAC (weeks)	Duration per m2
1.070	72.297	0.002
1.024	122.309	0.001
0.676	136.090	0.001
0.347	192.054	0.003
0.545	143.932	0.002
1.033	145.567	0.002
1.168	86.666	0.002
	Average	0.00194
	sd	0.00090

Then, by using the same samples, EAC calculation using ES method is conducted to compares if there any difference to traditional EVM calculates above.

TABLE II: EAC CALCULATION BY ES METHODS

ES Calculation			
ES (weeks)	SPI	EAC (weeks)	Duration per m2
49.207	1.025	72.185	0.002
94.556	1.017	120.975	0.001
32.298	0.873	119.140	0.001
46.908	0.690	160.911	0.003
47.305	0.622	181.545	0.003
103.657	1.016	144.650	0.002
61.011	1.109	82.936	0.002
		Average	0.001898
		sd	0.000821

Both calculations duration prediction express that each method comes with difference result. Traditional EVM method gives a SPI trend with negative slope. The wider project floor area, SPI of the project tend to smaller.

On the other hand, ES SPI trend line tends more stable for various floor area. Both characteristics of SPI trend line illustration in Fig. 2. These two trend graphic explain that traditional EVM gives various project SPI value possibility, depends on floor area. ES gives more logic explanation by gives stable SPI which represent almost same project productivity for any floor area in a certain area. The consequence of this calculation demonstrates that ES method is more appropriate than traditional EVM method in predicting project duration since ES gives logic by same productivity in a certain area.

TABLE III: DURATION PER SQUARE M STATISTIC

		EVM	ES
N	Valid	7	7
	Missing	0	0
Mean		.001935	.001898
Std. Error of Mean		.0003392	.0003102
Std. Deviation		.0008975	.0008206
Skewness		.491	-.400
Std. Error of Skewness		.794	.794
Kurtosis		.607	-1.209
Std. Error of Kurtosis		1.587	1.587
Percentiles	25	.000953	.000834
	50	.002031	.002028
	75	.002342	.002631

Further comparison analyses on descriptive statistic for both calculations give a choice to determine accuracy of project duration prediction of model calculation as shown on Table III. Traditional EVM gives a progressive calculation by assuming that every activity in the past had SPI = 1, rather than consider that there are a possibility of past activity gave contribution on SPI value less than 1 [3]. ES consider this problem by pull backward project performance to time planning value (PV) as seen on Fig. 1. This pull backward brings any activity in the range of time in the PV should be calculated in the SPI at the point of pull backward observation. The comparisons output is showing which method more accurate than the other in duration prediction.

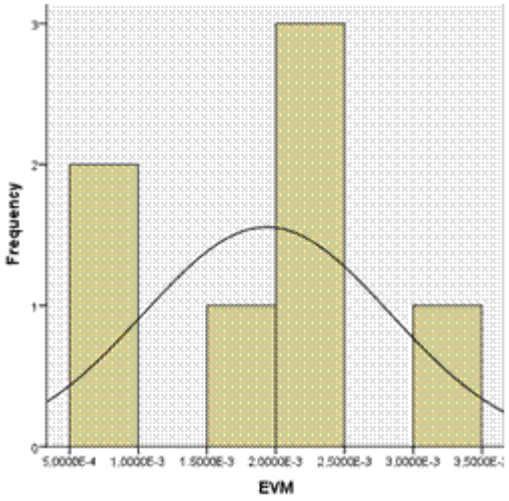

Fig. 3. Frequencies and normal data distribution of Du//m2 by EVM traditional calculation.

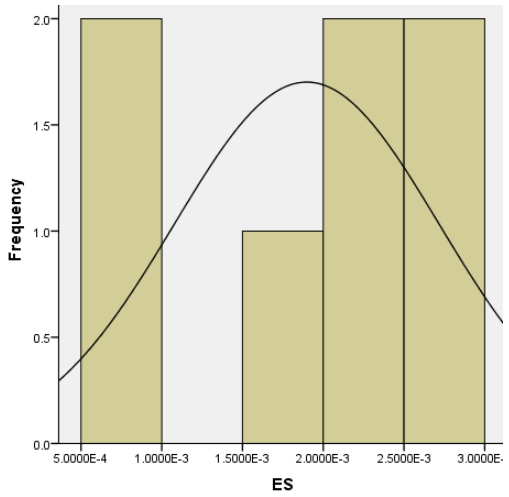

Fig. 4. Frequencies and normal data distribution of Du//m2 by ES calculation.

Data analysis on average of duration per square meter for both methods and its standard deviation determine that ES calculation gives a smaller average duration and standard deviation compare to EVM traditional calculation. It confirms that ES method is more accurate than traditional EVM. The graph result of this data analysis using SPSS V 17® shown in Fig. 3. and Fig. 4.

Traditional EVM method data analysis on its frequency and distribution shows a heterogenic distribution with 0.0008975 standard deviation, while ES method gives more homogeny distribution with 0.0008206 standard deviation as shown in graphics. These results have meaning that ES method is more accurate than EVM in duration prediction

since ES method relatively has homogeny output on duration per square meter for any construction project. It confirms that since ES has a smaller standard deviation than traditional EVM, ES prediction more accurate than traditional EVM.

Base on ES calculation in this model experiment, a probabilistic duration prediction approach could be calculated base on small sample.

Average:	.001898
sd:	.0008206
df :	7 – 1 = 6
Level of confidence:	99%

$\alpha = 1 - 0.99 = 0.01$

$t_{\alpha/2} = t_{0.005} = 3.707$ ..... (t distribution table)

Confidence interval:

$$\bar{x} \pm t_{\alpha/2} \frac{sd}{\sqrt{n}}$$

$$1898 \text{ x } e^{-6} - \left(3.707 \text{x} \frac{8206 \text{ x } e^{-8}}{\sqrt{7}} \right) < \mu$$

$$\mu < 1898 \text{ x } e^{-6} + \left(3.707 \text{ x } \frac{8206 \text{ x } e^{8}}{\sqrt{7}} \right)$$

$$0.000748 < \mu < 0.003048$$

This is the range of duration per square meter prediction on construction project based on samples in this experiment with level of confidence on 99%. Any prediction value number between these intervals could be chosen as project duration per square meter with a certain success probabilities (since this experiment uses small sample, probability of certain prediction should uses t test)

IV. Conclusion

This trial research affirms the statement of previous researches that ES method is more accurate than traditional EVM method on high rise building project duration prediction. This confirmation is not only comes from smaller standard deviation as previous Lipke's (2009) research, but it also comes from stable SPI output per square meter which consistent with what Homayoun and Abdulah (2016) was finding in their research. Small standard deviation means sharper prediction output calculation or more accurate prediction. Stable SPI output for several floor areas in this research, means prediction calculation for any floor area could use same SPI output. The development of this research is transform ES data set into a probabilistic duration prediction method. This stable characteristic becomes base on probabilistic method on duration prediction, since a set of ES duration data has its mean and standard deviation for any floor area.

This research conducted in an uncertainty condition area like Jakarta as a representative of a city in a developing country. Jakarta was chosen since as a capital city, high rise building project commonly easier to found. Further development on ES method in this research is by utilizing probability concept on the method based on assumption that data set is could be analyzed within smaller data than 30. A number of data set more than 30 is recommended for a proper statistical result. The result express a tighten confidence interval which means even though a prediction calculated in a uncertainty area, chosen value limited in tighten range with specific success confidence. This condition gives estimator an option to choose a duration with its success confidence, but still more accurate than other method with wide range of standard deviation.

The finding of this research shows Lipke's earned value method improvement for schedule prediction which name is Earned Schedule Method is also prevails on an uncertainty condition. This can be realized because of stable SPI for any floor area.

However, a further research could be conducted to assure this result by increase number of samples since its procedure based on average of the total sample. Instead of Jakarta, a difference area might give a difference value of SPI result. It depends on certain factors that influence specifically on that area.

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