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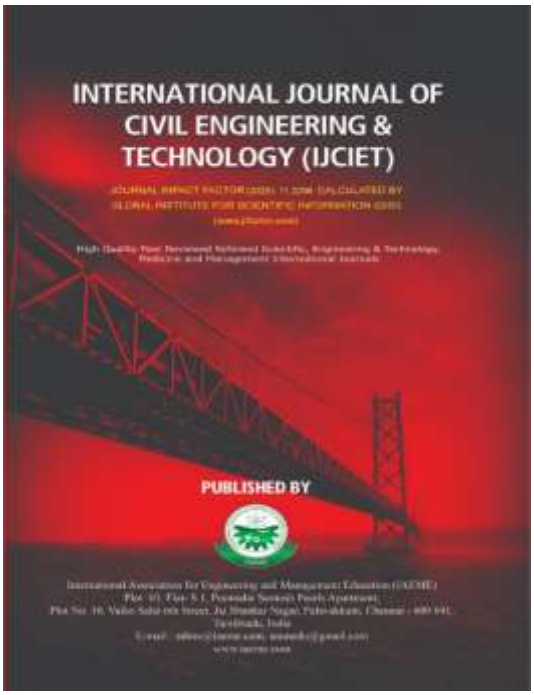


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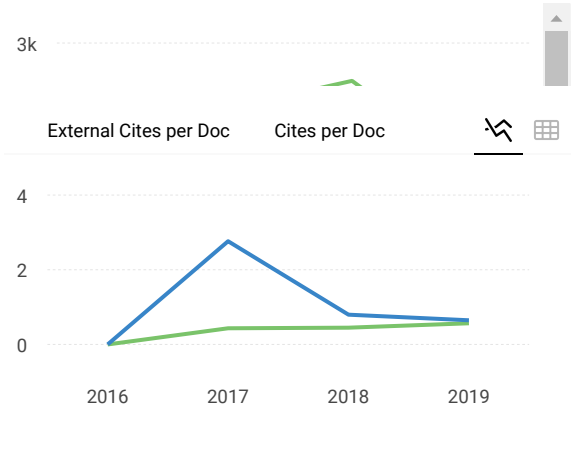



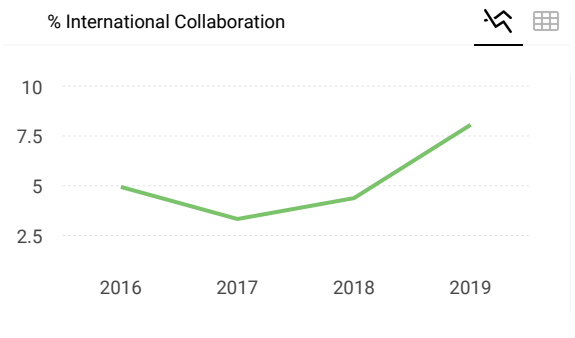


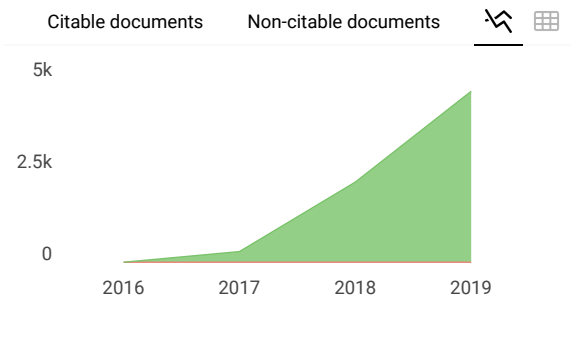


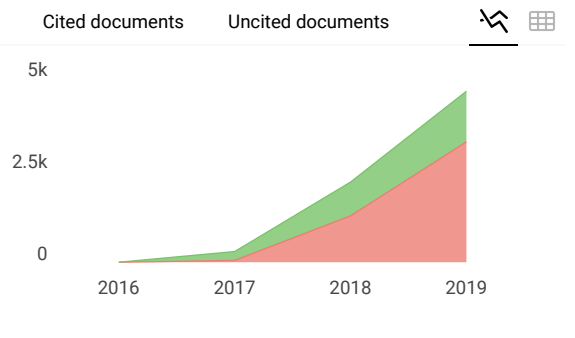



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# PROBABILISTIC DURATION CALCULATION BASED ON EARNED SCHEDULE APPROACH

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**ABSTRACT**

*Project duration prediction is an important part on project management. Therefore, a method to predict project duration suitably is required to accommodate uncertainty that may occur in the future. In the other hand, a development of Earned Value Management, which started with a traditional earned value (EV) based on cost, came into Earned Schedule (ES) method, which especially designed to predict project duration based on schedule. The problem is how to change deterministic duration prediction using ES method into a probabilistic duration prediction. This paper describes a research conducted on probabilistic project duration prediction with a developed ES method to accommodate uncertainty that usually occur in a developing country such like Indonesia. The research is conduct in Jakarta as a capital city of Indonesia. S-curve Data collects from several ongoing projects to be calculated each on ES method backward for every its periodical time. Furthermore, a confidential interval is used to determine the optimistic and pessimistic duration. The result shows that population of project's duration prediction with ES method is a part of project realization duration population, and its probabilistic duration could be obtained by backward calculation and confidence interval level.*

**Key words**: Duration, Probabilistic, Prediction, Earned Schedule.

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# 1. INTRODUCTION

Some previous researcher stated that duration is one of the important components in a construction project management. It can be an overall assessment of a construction project. It also a key factor to consider before starting a new project, as it can determine the success or failure of the project (Nguyen et al., 2013).

Therefore, duration prediction or estimating is a crucial stage in construction project life cycle. Difficulties occurred once a duration prediction carried out on an environment uncertainty such like in a developing country. Function distribution that accommodate the variability and uncertainty of the duration of construction project indicated that the prediction of the final duration of the project were probabilistic (Nguyen et al, 2013). For example, Lee et al, 2009, conducted a research on uncertainty involved in high-rise building projects. The research developed on a probabilistic duration estimation models which based on both weather conditions and work cycle times for work units considered to predict the structural work duration.

The duration of a project is often incompatible with prediction, caused by its uncertainty, so the construction schedule may deviate from the original plan (Baqerin et al., 2015). This condition makes it difficult for the estimator to predict the duration accurately. These statements showed that estimator has an important role in duration prediction. A better ability of an estimator to estimate the duration of a project would improve the performance of the construction services industry as one of the development sectors of a country (Tambunan, 1996)

On the other hand, even though it is widely accepted that Earned Value (EV) method is one of a method in Earned Value Management (EVM), to monitoring, analysis and forecasting systems (Kim and Kim, 2014), the use of EV to predict the duration, criticized by Lipke, 2009. The Traditional Earned Value method has disadvantage since this method based on cost (Corovic, 2007) and also cannot provide data of good completion schedule (Chen and Zhang, 2012). During spring 2003, the concept of Earned Schedule (ES) was introduced, suggesting the possibility of describing the performance of the schedule in units of time (Lipke, 2009). The purpose of this EV development method is to eliminate the lack of traditional EV method by using time indicator instead of cost indicator (Batselier et al., 2015).

According to Lipke, 2014, project duration prediction using ES method is more appropriate than others EVM method. This method provided considerable capacity for project managers to analyze project performance. Duration prediction using ES is more precisely compared to traditional EV method (Lipke, 2017). It shows that by using performance factors on ES assessment, the scheduling data from EVM is improved (Lipke, 2017).

The concepts of Schedule Performance Index (SPI-$) and Schedule Varian (SV-$) are no longer applied, since the two parameters are recognized fail to present the project status for completed project where traditional always produces SPI = 1 and SV = 0 values even if the project is delayed. Therefore, ES provides correction schedule performance and schedule variant schedule parameters by SPI (t) and SV (t) (Khamooshi and Abdi, 2016).

Since some previous researcher state that ES is an appropriate method to predict project duration, this paper describes a conducted research of implemented ES on an uncertainty environment to determine range of probabilistic duration with case study in Jakarta and surroundings. The research purpose is to prove that ES is an appropriate method even in an uncertainty environment, such like in Indonesia as a developing country, where probabilistic duration are suitable rather than deterministic duration prediction.

# 2. METHODOLOGY

## Earned Schedule and Its Validation

Earned Schedule method was introduced and developed by Walter Lipke, 2003 and still had been updated until 2017. The basic concept was to change parameter cost on EV by schedule or time parameter of project duration on ES method as seen on figure 1.

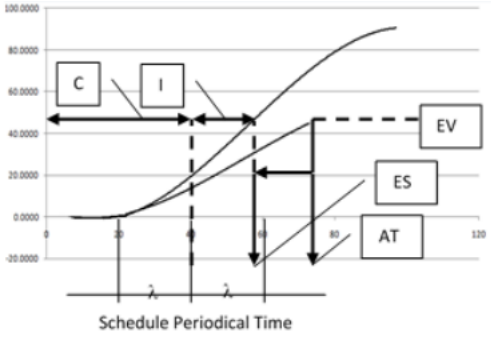


**Figure 1** EV and ES Method for Project Duration Prediction.

The ES calculation at point of monitoring as follows (Lipke, 2009):

$ES = C + I$ (1)

C = Value progress time

Where $\sum BCWP \geq \sum BCWS$

$$I = \frac{BCWP - BCWS_C}{BCWS_{C+1} - BCWS_t} \quad (2)$$

I = Linear interpolation

$$EAC_t = \text{Used Time} + \frac{\text{Total Duration} - ES}{SPI\ (t)} \quad (3)$$

ES calculation performed for each project data. The purpose of this calculation is to obtain average project duration prediction ($\overline{EAC't}$) and its standard deviation.

The result should be validating by comparing the mean against real duration of finished project ($Du_r$) which also collected as realization data. The process carried out by conducted ratio test for independent population for ensure that both two samples stand on the same population or has the same meaning (Harinaldi, 2005)

$H_0 : \mu_1 = \mu_2 \rightarrow$ Average ES duration ($\overline{x_1}$)=Average Du realization( $\overline{x_2}$)

$H_1 : \mu_1 \neq \mu_2 \rightarrow$ Average ES duration ≠ Average Du realization

## The test ratio:

$$\sigma_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}} \quad (4)$$

$$R_{test} = \frac{\overline{x_1} - \overline{x_2}}{\sigma_{\bar{x}_1 - \bar{x}_2}} \quad (5)$$

## Backward Earned Schedule Prediction

After pass the population validation test clearance, a development of basic concept of ES was performed by backward calculation as seen on figure 2, where each project could give several project duration predictions. Numbers of duration prediction depend on how far point of observation or monitoring last and how much schedule time sequences in S-Curve data ($EAC'_t$). By doing this calculation, the performance of project time prediction was carrying out more proper.

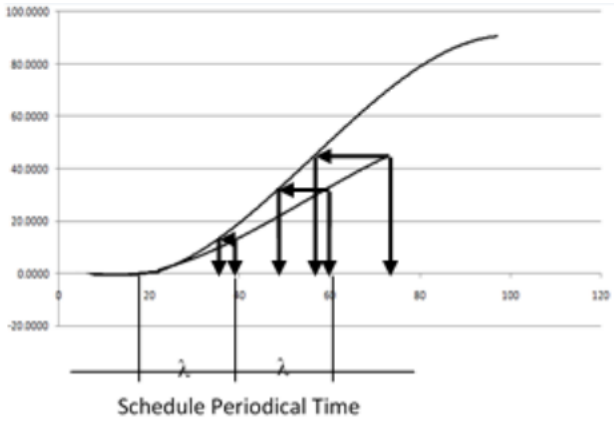


**Figure 2** Backward Project Duration Calculation Based On ES

The result for all project data ($EAC'_t$) should be divided by floor area to obtain a same unit named as sample data 1. A real Project Duration data of several finished project ($Du_r$) also be collected and divided by floor area, named as sample data 2.

In this stage, a ratio test similarly conducted to ensure that average of all projects duration prediction is in the same meaning with average real duration data of finished project.

## Probabilistic Duration Prediction by ES

Backward calculation gives several projects duration prediction data for each ongoing projects, that should have the same meaning with an average real finished projects duration In that case, a ratio test should also be conducted, compare to realization data.

ES method is deficient on duration prediction, if the result shown that ES duration average is not in the same population with average realization duration

In the contrary, ES method quite suitable for duration prediction in Jakarta and surroundings, if ES duration average is in the same population with average realization duration, it shown that.

The probabilistic parameter could be calculated by explore further by confidence interval of the average ES duration prediction ($\overline{EAC't}$) to gain range of probabilistic duration prediction

$$\overline{EAC't} + Z_{\alpha/2}\frac{\sigma}{\sqrt{n}} \geq \rho_{du} \geq \overline{EAC't} - Z_{\alpha/2}\frac{\sigma}{\sqrt{n}} \quad (6)$$

In other words, optimistic and pessimistic duration could be presented as follow:

$\overline{EAC't} + Z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$ Represent pessimistic duration

$\overline{EAC't} - Z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$ Represent optimistic duration

A calculation of duration prediction should be on this range with success level probability of duration prediction based on average $\overline{EAC't}$ as follow:

$$Z = \frac{\overline{EAC't} - x}{\sigma} \quad (7)$$

Probability a certain prediction accomplishment could be obtained from Norm Distribution tabel.

## 3. RESULT AND DISCUSSION

A research based on the methodology above was conducted in Jakarta and surroundings as case study.

Data collected consist of 43 ongoing projects and 35 finished projects. Data for both sample described on table 1.

**Table 1** ES and Dur Data

| Parameter | Earned Schedule On Going Project | Realization Duration Finished Project |
|---|---|---|
| N | 43 | 35 |
| n After Backward Calculated | 1548 | 35 |
| Average Duration (After Calculation) weeks/m2 | 0.00243 | 0.002792 |
| б | 0.003234 | 0.001941381 |

**Based on data on table 1 above, with level of significance α = 0.05 (95%)**

→ $\alpha/2 = 0.0025$

→ $Z_{\alpha/2} = \pm 1.96$,

the test ratio ($R_t$) is

$R_t = \sigma_{\bar{x}_1 - \bar{x}_2} = 0.000592$

$-1.96 \leq R_t \leq +1.96$

The test ratio show that there is no difference between 43's ES calculation and 35's realization duration samples is quite suitable for project duration prediction. It could be used on this research as duration prediction.

The next stage is establishing the upper and lower limit of ES prediction data based on realization performance of duration estimation. Upper limit gives longer time duration, while lower limit gives less time duration. In that case, a range of duration could be established as probabilistic range (confidence interval). Confidence interval with 95% ($Z\alpha_{/2} = 1.96$) level of significance is calculated as follow:

$$\overline{EAC't} + Z_{\alpha/2}\frac{\sigma}{\sqrt{n}} \geq \rho_{du} \geq \overline{EAC't} - Z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$$

$$0.00243+1.96\ \frac{0.00323}{\sqrt{43}} + \geq \rho_{du} \geq 0.00243-1.96\ \frac{0.00323}{\sqrt{43}}$$

$0.002923$ Week/m2 $\geq \rho_{du} \geq 0.001937$ Week/m2

This result applied at least in Jakarta, Indonesia, since data obtained at this certain area. The used in another certain uncertainty area, data would be better based on originated area, but the model could be the same as it is, as long as the mathematical requisite full filled.

In this case study, first of all, a ratio test for both 43 data ES ongoing sample of duration per square meter area and 35 data finished realization duration is an important process, which

will gives clearance for further calculation. If it is not passed the ratio test, a continuation calculation could not be held further.

The research shows that ES method could be used as based of probabilistic duration prediction in a certain uncertainty environment area. Some requirements to be used in the model are: ongoing project to be predicted data and finished project data as base performance of certain environment. This concept makes the development method could be used in certain institution, including a construction firm.

## 4. CONCLUSION

Earned Schedule method prediction was a suitable method as a base to predict construction project probabilistic duration since it proofed has a same sample mean with real project duration. The innovation in this research was shown on multiplying project duration estimation data for each project. By doing so, a probabilistic duration was calculated on a range of project time. Conducted a mathematical method was helpful in this research to determine the conclusion, both ratio test and confidence interval, to fulfill the purpose of the research. A small range level of significance indicate less uncertainty, a wide level of level significance indicate that probabilistic condition is in significant uncertainty condition.

A prediction of project duration should be obtain by put an ordinary estimation duration either on range of level of significant or not. After pass the level of significant, the estimation of duration should be tested on level of its level of significant on realization duration average to determine its level of significant. The output should be managed and considered to take longer or shorter duration on appropriate comfortable percentage level of success prediction purpose.

This model helps construction project stakes holder to predict project duration with its possibility level appropriately and decide whether the duration prediction could be applied. The result of this research should be used in all stages from initiating stage up to monitoring stage and has its benefit either on an uncertainty area or an area where a proper prediction is needed.

However, the research limitation occurred on source of data that only gain from specific area Jakarta and surroundings only. Source data from another and wider area could give some change on the result, depends on specific area characteristic. Therefore, a research conducted in another area will gives contribution on model improvement.

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