

A SIMPLIFIED METHOD FOR PHYSICAL PROGRESS MEASUREMENT

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Project stakeholders frequently have problems while monitoring the progress of the projects during execution. Since an unbiased measurement system could not be established, progress figures are mainly based on project stakeholders' own experiences or subjective judgements. Considering the size of the projects, small to medium scale projects suffer the most from this problem. Usually, planning and site organizations of such scale projects are not set up adequately due to tight budgets or limited number of qualified personnel. Therefore, progress calculation method could not be defined efficiently or the data required for calculating project progress could not be gathered accurately. In order to overcome aforementioned difficulties and measure the progress correctly, simplified progress measurement techniques can be a solution. This article intends to describe how a simplified and convenient physical progress measurement method can be established. By separating the project into main elements and defining the most indicative commodities of them, number of parameters, which should be followed in the project can be decreased to a manageable level. Project weights of the elements can be calculated by taking into account standard man-hours required to complete each of them. Finally, construction milestones of the elements can be scheduled in a table, which helps to track and calculate the progress. A footbridge example is simply illustrated in the article to describe the method to readers explicitly.

Keywords: Activity weighting, Incremental milestones, Equivalent unit, Standard unit man-hour, Indicative commodity, Unbiased measurement system.

1 INTRODUCTION

Project stakeholders are mostly paying attention to three subjects during the execution of projects. They wonder to know;

- (i) whether the project activities are progressing in line with the target work schedule or not,
- (ii) whether the project cost is within the estimated project budget or not, and
- (iii) how much is the physical progress of the project?

Usually, the answer to the last question is the most inconsistent one. Since an unbiased measurement system could not be established at the beginning, progress figures are mainly based on project stakeholders' own experiences or subjective judgements (Lee 1997). Thus, it will be better to concentrate on the meaning of physical progress in a project in advance.

Physical progress is “the status of a task, activity or discipline, based on pre-established guidelines related to the amount or extent of work completed” (AACE International 2017). It is

well understood from the definition that measurement method which is going to be applied during the project, should be defined at the beginning. Considering the size of the projects, small to medium scale projects suffer from this problem the most since planning organizations and procedures in such projects are not set up properly. On the contrary, in large scale projects, the strategy and the procedures for progress measurement are in place at the beginning of the project, because owners and contractors are well aware about the importance of planning.

Besides, a measurement method should also be designed to follow the amount or extent of work completed against the total amount of work. This may be another disadvantage for small to medium scale projects since the data required for calculating project progress could not be gathered accurately due to insufficient site organizations. In order to overcome aforementioned difficulties, simplified progress measurement techniques can be preferred.

2 COMMON METHODS FOR MEASURING PROJECT PROGRESS

Various progress measurement methods have previously been discussed in several studies (Construction Industry Institute (CII) 1987, Thomas and Mathews 1996, Fleming and Koppleman 1996). Most commonly accepted methods (Del Pico 2013) are listed below:

- (i) Units Completed: This method could be used for repeated works where each of the unit work requires almost the same resources and duration. For example, if it is planned to plant 1,000 trees to a park and 250 of them were already planted, the completion percentage of the work equals to 25%.
- (ii) Incremental Milestones: If a work includes several steps that should be followed in an order, incremental milestones method could be useful for measuring the project progress. For example, construction of a foundation basically includes steps such as lean concrete, formwork, reinforcement and concrete pouring. Taking into account the total effort required for the whole foundation, the ratio of total effort required for each step can be calculated as a weighting in the total scope. Scalar product of progress ratio of each step and its weighting will give the contribution of that step to the project progress.
- (iii) Start / Finish: Some activities have only start and finish points and no other activity has been defined in between. Leakage test of a pipeline can be taken as an example. Progress ratios of each point achievement can be defined as 30% - 70%, 50% - 50%, 0% - 100% and progress of the work can be calculated accordingly.
- (iv) Cost Ratio: This method can be used when the project scope is limited with supply of labor only. Cost will be a linear function of man-hours spent. Thus, cost ratio will be almost same as spent labor ratio of the project.
- (v) Experience / Opinion: This subjective method should be preferred as the last option since progress figures are mainly based on personal experiences of those who makes the judgement.
- (vi) Weighted or Equivalent Units: This method is accepted as the most reliable and consistent technique. Considering the scope of the project, one of the production units is selected as the standard unit, and all others production units are converted to the selected one. For example, welding of a 6" standard sketch carbon steel pipe joint in a pipeline project could be accepted as the standard welding unit. Then, all other joints on the pipeline should be converted to the predefined standard welding unit by using coefficients previously determined for standardization of welding parameters such as diameter, sketch thickness and material type. Progress ratio of the welding activity is the

ratio of total welded 6" equivalent joints to sum of all 6" equivalent joints in the subject pipeline project.

3 A SIMPLIFIED METHOD SUGGESTION

Combination of two methods, namely incremental milestones and weighted/equivalent units, can be used as a simplified method for progress measurement. Weighted/equivalent units method will maintain the accuracy of the results. Incremental milestones method will ensure simplicity while monitoring and calculating the project progress. Work flow sequence of the method is as follows:

- (i) Separate the project into main elements,
- (ii) Define the most indicative commodity of each element,
- (iii) Calculate the project weight of each element by converting indicative commodity quantities to the equivalent unit,
- (iv) Tabulate all elements in the rows of a chart versus their incremental milestones and their weightings at the columns,
- (v) Calculate the progress of the project considering the site progress of each element.

3.1 Case Study

A footbridge is selected as a case study to describe the approach explicitly.

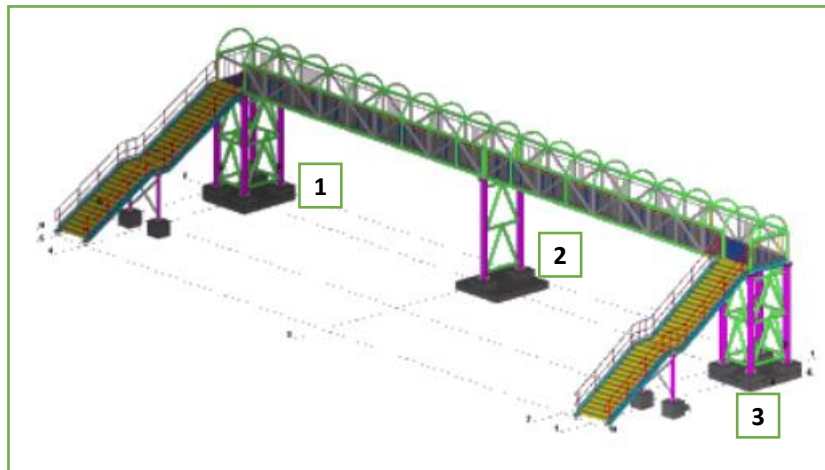


Figure 1. Footbridge.

Step 1: Structure is divided into nine elements as shown in Table 1. The number of elements depends on the monitoring capacity of planning and site organizations of the project. In a detailed study, each activity of level-three schedule can be considered as an element.

Step 2: Most indicative commodity of each element is determined and presented in Table 1. Quantities of the commodities are estimated considering the sketch given in Figure 1.

Step 3: Converting quantities to equivalent standard man-hours is the most convenient way to calculate equivalent unit of the elements. Scalar product of commodity quantity and standard unit man-hour gives the equivalent total man-hours of each element. By this way, weighting of

each element could be easily reckoned as shown in Table 1. Standard unit man-hours should include all construction steps of the elements. Common industrial figures could be utilized while defining the standard unit man-hours. However, it is recommended to calculate those figures according to previous construction experiences like the authors did in Table 1.

Table 1. Summary of Step 1 to Step 3.

Structural Elements	Most Indicative Commodity	Quantity	Standard Unit Man-hours (incl. all steps)	Total Man-hours	Weight in the Project
Foundation-1	m3 of concrete	20	15	300	15%
Foundation-2	m3 of concrete	12	15	180	9%
Foundation-3	m3 of concrete	20	15	300	15%
Column-1	tons of steel	3	70	210	11%
Column-2	tons of steel	1	70	70	4%
Column-3	tons of steel	3	70	210	11%
Ladder-1	tons of steel	0,5	120	60	3%
Ladder-3	tons of steel	0,5	120	60	3%
Deck	m2 of deck	50	12,2	610	31%
TOTAL				2.000	100%

Step 4: The findings are gathered in Table 3 in which elements are placed in the rows versus their incremental milestones, and their weightings at the columns.

Step 5: The project progress is calculated according to the site progress report given in Table 2. Sum-product of milestone weightings and site progress ratios of the milestones give the progress of each element. By multiplying that figure with the project weight of the element, contribution of each element to the project progress is calculated. The sum of all element contributions equals to the total progress of the project.

Table 2. The summary of site progress.

Structural Elements	Site Progress
Foundation-1	Completed
Foundation-2	Completed
Foundation-3	Completed
Column-1	Completed
Column-2	Completed
Column-3	Completed
Ladder-1	Supporting structure completed. Stairs and handrails partially completed. (80% - 50%)
Ladder-3	Supporting structure completed. Stairs and handrails partially completed. (60% - 30%)
Deck	Supporting structure completed. Stairs and auxiliary partially completed. (60% - 10%)

Table 3. Calculation of project progress (Step 4 and Step 5).

Structural Elements	Weight in the Project	MILESTONES						Progress of the Element	Progress of the Project
		1	2	3	4	5	6		
		<i>Excavation</i>	<i>Lean Concrete</i>	<i>Formwork</i>	<i>Reinforcement</i>	<i>Anchor Bolts</i>	<i>Concrete Casing</i>		
		10%	5%	25%	40%	10%	10%		
Found.-1	15%	100%	100%	100%	100%	100%	100%	100%	15%
Found.-2	9%	100%	100%	100%	100%	100%	100%	100%	9%
Found.-3	15%	100%	100%	100%	100%	100%	100%	100%	15%
		<i>Base Plate</i>	<i>Structure Preassembly</i>	<i>Structure Erection</i>	<i>Alignment Tightening</i>				
		10%	20%	40%	30%	0%	0%		
Column-1	11%	100%	100%	100%	100%			100%	11%
Column-2	4%	100%	100%	100%	100%			100%	4%
Column-3	11%	100%	100%	100%	100%			100%	11%
		<i>Base Plate</i>	<i>Structure Erection</i>	<i>Stairs</i>	<i>Hand Rails</i>				
		10%	50%	20%	20%	0%	0%		
Ladder-1	3%	100%	100%	80%	50%			86%	3%
Ladder-3	3%	100%	100%	60%	30%			78%	2%
		<i>Platform Preassembly</i>	<i>Platform Erection</i>	<i>Hand Rails</i>	<i>Auxiliary</i>				
		20%	40%	20%	20%	0%	0%		
Deck	31%	100%	100%	60%	10%			74%	23%
TOTAL									91%

3.2 Achievements of the Method

The following points are achieved through this method:

- (i) The procedure which is defined in the work flow is not complex. It is easy to follow.
- (ii) Calculation of the quantities for all project activities is not required. Quantities of the most indicative commodities should be enough. It is less time consuming.
- (iii) Standard man-hours, experienced by the contractors in previous projects, can be used while converting quantities to the equivalent unit. It is easy to adopt.
- (iv) Following the progress by quantities is not required. Following milestones with completion percentages ensures simplicity. It is easy to gather progress information.
- (v) This method ensures a consistent and reliable progress calculation technique.
- (vi) It is applicable with a reasonable number of personnel.

4 CONCLUSION

The project progress rate is one of the indicative parameters that enable the project management to follow the project performance concurrently. However, it is usually difficult to set up an appropriate method to measure the project progress, especially for small scale projects. Due to this concern, similar studies to this article have been conducted by many researchers up to now (Chin *et al.* 2004, De Marco *et al.* 2009, Daneshyar and Walker 2014). The aim of this study is to provide a guideline for individuals who would like to follow project progress in a simple and an accurate way. Two common progress measurement methods are combined, namely incremental milestones and weighted/equivalent units. Weighted/equivalent units method maintains the accuracy of the results. Incremental milestones method ensures the simplicity while reporting and calculating the project progress. Thus, the calculation method is uncomplicated, reliable and easy to follow by less number of personnel. Therefore, the method can be utilized by the contractors which have difficulties to establish sufficient planning and site organizations for small to medium scale projects due to tight budgets or limited number of qualified personnel.

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