AN ASSESSMENT TOOL FOR MONITORING PROJECT PERFORMANCE

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Abstract: In the past, productivity assessment and performance evaluation were carried out separately due to cost constraints. Performing both simultaneously could significantly improve a project monitoring system. The appropriate use of schedule compression methods to accelerate the work at hand will reduce additional costs. The aim of this study was to develop a project monitoring tool that combines productivity assessment and schedule compression methods for reporting productivity status and evaluating project performance. Factors Affecting Productivity (FAP) and Schedule Compression Methods (SCM) were identified and measured from completed building projects. The capability of using these factors as project assessment tool and project performance predictor was analysed using fuzzy logic inference system. It is found that the Time Performance Ratio (TPR) can be included in a project status report to monitor and predict project performance.

Keywords: *Productivity; Performance; Evaluation; Assessment; Planning.*

Abstrak: Pada masa lalu, penaksiran produktiviti dan penilaian prestasi telah dibuat secara berasingan disebabkan oleh kekangan kos. Melaksanakan kedua-duanya serentak akan memperbaiki lagi sistem pemantauan projek. Penggunaan kaedah pemendekan jadual yang sesuai untuk mempercepatkan kerja akan mengurangi kos tambahan. Tujuan kajian ini ialah untuk membangunkan satu alat pemantauan projek yang menggabungkan penaksiran produktiviti dan kaedah pemendekan jadual bagi melapor status produktiviti dan menilai prestasi projek. Faktor mempengaruhi produktiviti (FAP) dan kaedah pemendekan jadual (SCM) telah dikenalpasti dan diukur daripada projek bangunan yang telah siap. Kebolehan menggunakan dua elemen tersebut sebagai alat penaksir projek dan peramal prestasi projek telah dianalisis menggunakan sistem taabir logik *fuzzy*. Nisbah prestasi masa (TPR) terbukti boleh dimasukkan ke dalam laporan status projek bagi memantau dan meramal prestasi projek.

Katakunci: *Produktiviti; Prestasi; Penilaian; Penaksiran; Perancangan.*

1.0 Introduction

Productivity issues are crucial in any construction project and become more critical when there is a delay in the work progress (Al-Hammad, 2000). A delay in construction project is defined as the period when a project cannot be completed, partially or as a whole, on or before the scheduled completion date because of factors such as unexpected events, hidden conditions or even additional work assigned during construction (AGC, 1994). The productivity issues may also arise when a project needs to finish earlier than planned because of client's request (Al-Khalil and Al-Ghafly, 1999).

In both cases above, the project must be monitored so that productivity can be increased and effective methods of schedule compression can be applied in order to complete a construction project on time at least costs. Measuring project performance alone will not be very effective because the sources of improving performance come from productivity improvement, which cannot be done without productivity assessment (Allmon et al., 2000). In general, productivity assessment can provide an objective source of information about operating trends, draw attention to problems of performance and inspire a useful exchange of ideas.

This study examines whether the performance of future projects can be predicted based on the level of existing factors affecting productivity (FAP) and efforts given in selecting the appropriate schedule compression method (SCM). The development of a project monitoring tool that combines productivity assessment and schedule compression methods for reporting a project status is presented and discussed. It was based on completed building projects carried out by companies registered with the Construction Industry Development Board (CIDB) Malaysia.

2.0 Proposed Concept of Project Success

In general, the components of project success can be divided into project input and outcome, as shown in Figure 1. Project input consists of independent variables while project outcome consists of project achievements. Project input usually determines the outcome of the project (Lu et al., 2001). Some examples of the independent input variables are the project manager's experience, level of communication, level of pre-project planning effort and project team integration, whereas examples of project achievements are measured in terms of time, cost, quality and safety (Cho and Gibson, 2001).

The monitoring model used in this study is shown in Figure 2. The model contains two main processes, which are assessment and evaluation. The assessment process indicates the level of effort being applied in a project while the evaluation process compares the performance of the project to the planned or target schedule. Many previous studies were unable to focus on both processes simultaneously because of complications and high cost requirement (Mansur, 2004). Therefore, in order to perform both processes, the model needs to be simplified. Productivity assessment process was performed using FAP and SCM as performance indicators and project performance process was evaluated based on the time variance of project duration.

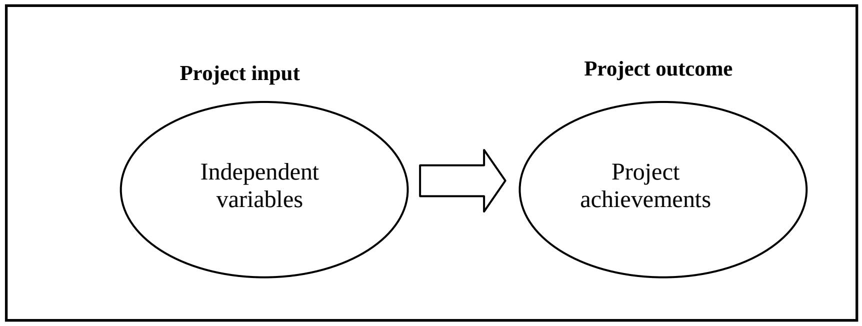

Figure 1: Components of project success

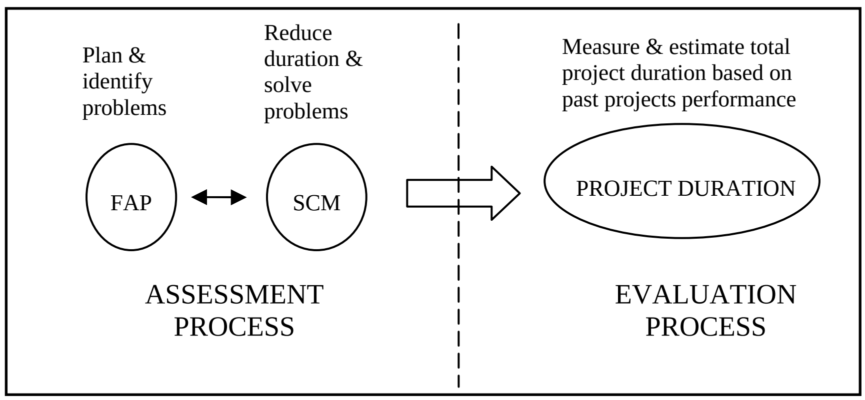

Figure 2: The monitoring model

3.0 Methodology

In the process of identifying the most relevant FAP and SCM, a list of identified factors obtained from literature review was distributed, discussed and filtered using index of importance method. A total of thirty six representatives from the industry were involved in the process. All factors that did not retain any score were eliminated from the list. The remaining FAP and SCM elements were sorted into several categories. The categories for FAP are client, consultant, contractor, materials, labour, tools and equipment, contractual and external related factors, whereas the categories for SCM are labour, materials, tools and equipment, construction methods, information and organisation related factors. The total numbers of elements for the categories are shown in Table 1.

3.1 Developing Element Weights

Since the elements of FAP and SCM are not equally important with respect to their potential effects on the overall project performance, they need to be assigned with different weights, which were relative to their influence. This step was required to develop reasonable and credible weights for each element based on the feedback from the selected professionals. One category of FAP (Client Related Factors) and SCM (Labour Related Factors) are shown in Table 2 and Table 3, respectively.

Table 1: FAP and SCM categories

FAP		SCM	
Category	No. of elements	Category	No. of elements
Client	15	Labour	5
Consultant	14	Materials	5
Contractor	16	Construction methods	4
Materials	4	Tools & equipment	2
Labour	8	Organisation	11
Tools & equipment	5	Information	1
Contractual	6		
External	9		
TOTAL	77	TOTAL	28

Only a blank form (without written weights) is needed to assess the level of FAP and SCM at any point of a project phase. Each assessment has to be done by a key project member. There are six levels of effect listed across the top of the form, thus creating a 6-by-77 matrix with the FAP elements and a 6-by-28 matrix with the SCM elements. The six levels ranged from minimum to maximum, including one level for non-applicable. The total score of each element and category indicates the level of effect that can influence a project. A lower total score would have lower effect on project progress.

A normalising process was performed to place the scores on a common scale prior to weighting each category's normalised score by its relative importance (Cho and Gibson, 2001). The raw value based on subjective responses from participants, varied from one to another because no limits were set to the maximum and minimum values. Each value had to be converted to a same weighting measurement. Since the total raw data exceeded 100 points, all forms were consequently normalised to a 1000-point scale. By normalising the data to 1000 points, it is possible to compare the relative importance of each factor and compute all the final factor weights. A score close to zero indicates minimum impact for FAP and minimum level of effectiveness for SCM. A score closest to 1000 indicates high impact for FAP and high SCM application. When a factor was not applicable, that factor was indicated with a "N/A," which differentiates from zero-weight factor. This would avoid non-applicable elements from affecting the final project score. The ranges of score for the total FAP are from 78 to 1000 and SCM from 0 to 1000, respectively.

3.2 Relationships amongst FAP, SCM and TPR

In order to rate how much each element of FAP and SCM has contributed in the selected projects, survey participants were asked to fill in the blank forms by placing a mark in the corresponding box. After the questionnaires were returned, the responses were converted into their final scores. For development purposes, all responses were obtained from completed projects, regardless of which point in the project it was referred to by the respondents for the assessment.

Table 2: Example of FAP elements under client related category

	Client Related Factors	Effect on time					
		Min	Low	Med	High	Max	N/A
1	Approval of Drawings	1	4	7	9	12	
2	Long Waiting Time when requiring Test or Inspection	1	4	7	10	13	
3	Payment of Completed Work	1	4	8	11	14	
4	Direct Interference by Client	1	4	7	9	12	
5	Decision Making	1	4	8	11	14	
6	Contract Duration	1	4	7	10	13	
7	Too Many or Frequent Design Modifications	1	4	7	10	13	
8	Requirement of Work Quality	1	4	7	10	13	
9	Budget	2	5	9	12	15	
10	Interpersonal Skills	1	4	7	10	13	
11	Complexity of Design	2	5	7	10	12	
12	Scope of Project	1	4	7	9	12	
13	Knowledge on Construction Processes	1	4	7	9	12	
14	Contract Management	1	4	7	9	12	
15	Site Access or various permits	1	4	7	10	13	
	TOTAL	17	61	109	149	193	

Table 3: Example of SCM elements under labour related category

	Labour Related Factors	Effect on time					
		Min	Low	Med	High	Max	N/A
1	Scheduled Overtime	0	10	20	29	39	
2	Incrase No. Of Staff	0	10	20	30	40	
3	Use Second Work Shift	0	10	20	29	39	
4	Use Pre-Work Set-up Crew	0	11	21	32	42	
5	Use Special Shifts	0	8	17	25	33	
	TOTAL	0	49	98	145	193	

Respondents were asked to provide the planned, actual start and finish dates of their selected projects, so that the planned and actual project duration can be compared. The start date refers to the recorded first day of the construction phase while the finish date is set on the substantial completion date of a project. Project time performance ratio (TPR) was then calculated by dividing the actual project duration by the planned duration as follows:

$$TPR = \frac{\text{Actual Project Duration}}{\text{Planned Project Duration}} \quad (1)$$

A TPR value of one indicates that the project is completed exactly as planned; less-than one indicates the project is completed earlier than planned; and more-than one indicates the project is delayed. This calculation was adapted from a similar type of performance measurement (Syal et al., 1992). Project groups with good and poor performance should have different mean TPR value as discussed in the following sections.

3.3 *Fuzzy Inference System*

The application of Fuzzy Inference System (FIS) was simplified by the use of MATLAB® (1984-2003) software. The overall views of FIS are shown in Figure 3, which consist of the FIS editor, MF (Membership Function) editor, rule editor, rule viewer and surface viewer. The FIS editor has two MFs (Total FAP and Total SCM) as the input function, and one MF (TPR) as the output function. This FIS feature used Mamdani-type inference system (Mamdani and Assilian, 1975), which combines fuzzy sets from the consequence of each rule through aggregation operator. The resulting fuzzy set was defuzzified to yield the output of the system.

Figure 4 displays the MF editor for Total FAP. It shows five MFs for Total FAP, representing five levels of effect: “Min”, “Low”, “Med”, “High” and “Max.” The “Min” MF was a trapezoidal type, started from (0, 1) to (100, 1) and finished at (300, 0). The “Low” MF was a triangular type, started from (100, 0), peaked at (300, 1) and finished at (500, 0). The “Med” MF was a triangular type, started from (300, 0), peaked at (500, 1) and finished at (700, 0). The “High” MF was a triangular type, started from (500, 0), peaked at (700, 1) and finished at (900, 0). The “Max” MF was a trapezoidal type, started from (700, 0) to (900, 1) and finished at (1000, 1).

Figure 5 shows the FIS layout with five MF for Total SCM, representing five levels of effect: “Min”, “Low”, “Med”, “High” and “Max.” The “Min” MF was a trapezoidal type, started from (0, 1) to (100, 1) and finished at (300, 0). The “Low” MF was a triangular type, started from (100, 0), peaked at (300, 1) and finished at (500, 0). The “Med” MF was a triangular type, started from (300, 0), peaked at (500, 1) and finished at (700, 0). The “High” MF was a triangular type, started from (500, 0), peaked at (700, 1) and finished at (900, 0). The “Max” MF was a trapezoidal type started from (700, 0) to (900, 1) and finished at (1000, 1).

Figure 6 shows the FIS layout of the five MFs for TPR, representing five levels of effect: “Min”, “Low”, “Med”, “High” and “Max.” The “Min” MF was a trapezoidal type, started from (0.7, 1) to (0.83, 1) and finished at (1.09, 0). The “Low” MF was a triangular type, started from (0.83, 0), peaked at (1.09, 1) and finished at (1.35, 0). The “Med” MF was a triangular type, started from (1.09, 0), peaked at (1.35, 1) and finished at (1.61, 0). The “High” MF was a triangular type, started from (1.35, 0), peaked at (1.61, 1) and finished at (1.87, 0). The “Max” MF was a trapezoidal type started from (1.61, 0) to (1.87, 1) and finished at (2, 1).

After the variables and the MFs were appropriately shaped and named, fuzzy rules were defined (see Table 4) using the Rule Editor. For example, if Total FAP is “Med” and SCM is “Med” then TPR is “Low.” Choosing “none” as one of the variable qualities will exclude that variable from a given rule, and choosing “not” under any variable name will negate the associated quality. Rules may also be changed, deleted, or added accordingly.

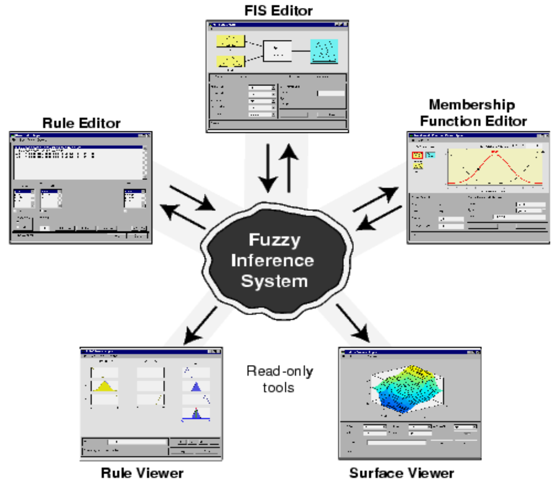

Figure 3: FIS in MATLAB®

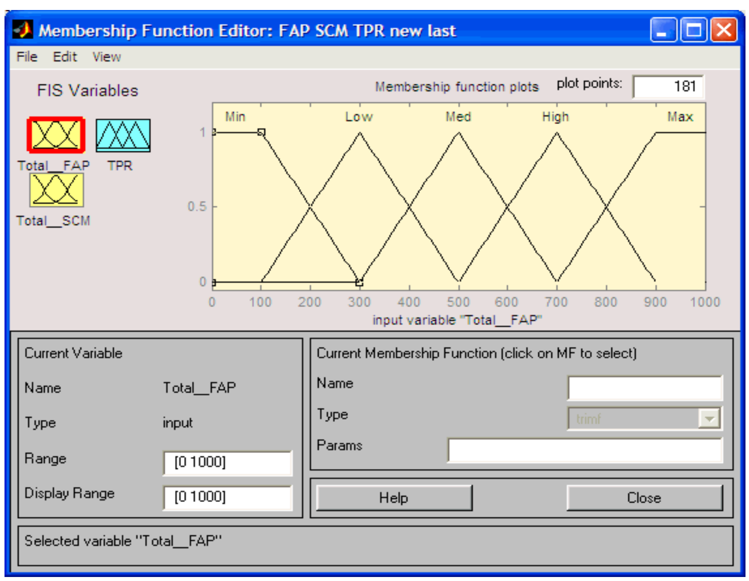

Figure 4: MF editor for total FAP

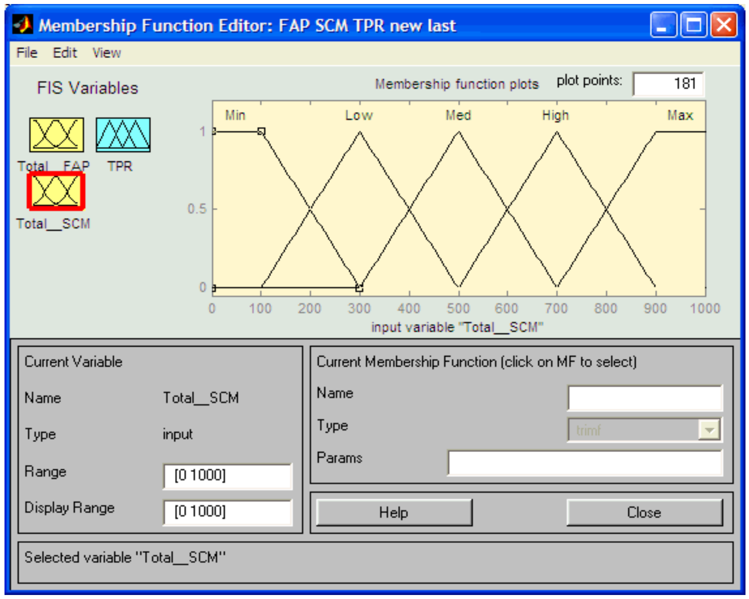

Figure 5: MF editor for total SCM

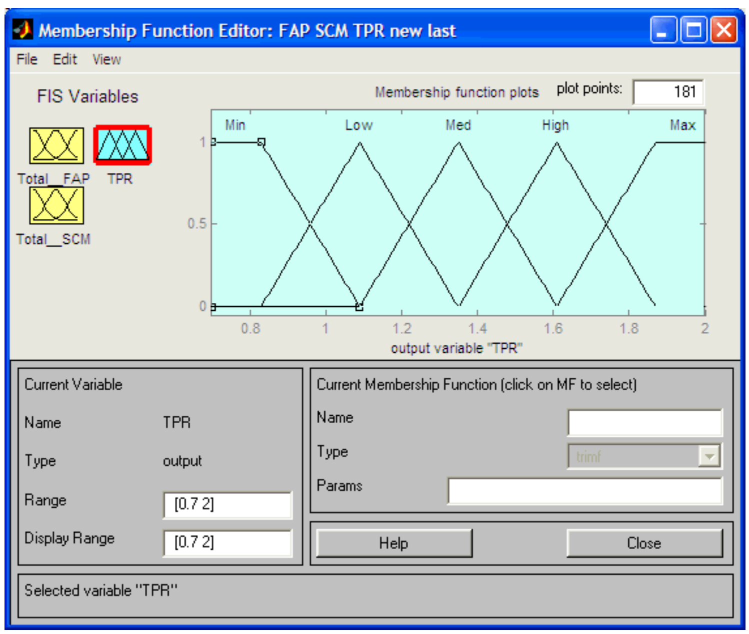

Figure 6: MF editor for TPR

Table 4: Fuzzy rules

				SCM			
		Min	**Low**	**Med**	**High**	**Max**	
	Max	High	High	Med	Med	Low	
F	**High**	High	Med	Med	Low	Low	**T**
A	**Med**	Low	Low	Low	Min	Min	**P**
P	**Low**	Low	Low	Low	Min	Min	**R**
	Min	Min	Min	Min	Min	Min	
				TPR			

The FIS is completely defined after the variables, MFs and the rules are in place. The functionality and accuracy of a known fuzzy inference diagram can be tested and verified using the Rule Viewer, which displays a roadmap of the whole process, and shows how the shape of certain MF influences the overall result. For every pair of FAP-SCM, a value of TPR will be produced automatically. For example, a value of 450-200 produces a TPR value of 1.09. This TPR value indicates that the project was approximately 9% behind the planned completion time. Once the whole process was completed, various combinations of FAP-SCM values can be loaded so that the correspondent TPR values can be produced and tabulated. These values can also be used for predicting future projects performance.

3.4 Project Performance Group

Productivity assessment is one of the features in this study that is very useful to the documentation and reporting of a construction project. For this purpose, the categories of FAP, SCM and other project variables were identified as performance factors, and sorted according to their level of influence on the project outcomes. The categories were grouped according to their relative correlation coefficient values under each category, as shown in Table 5.

All categories in each group have their own benchmark score. The score is actually a ratio of good and poor performance which is calculated using the following equation:

$$\text{Benchmark Score} = \frac{\sum \text{Score per Group}}{\sum \text{"Medium" Score per Group}} \quad (2)$$

The benchmark score was converted into meaningful criteria before they could be tested. Each category and group was assigned a value of 5, 3 or 1, depending on its benchmark score. Each category and group also has different score to be used as the "medium" score. For example, for a project with "Contractor and Resources" group total score of 371, the benchmark score is 371 divided by 261 ("medium" score), which ratio equal to 1.42. This score was assigned a value of 1 (or above "medium"). However, for readability purposes, the number was converted again into meaningful terms so that the status of the categories and groups can be understood well (Gibson and Hamilton, 1994). The values of “5”, “3” and “1” become “Good”, “Cautionary” and “Critical” for FAP, or “High”, “Medium” and “Low” for SCM, respectively (see Table 6).

Table 5: Project performance groups

	Group	Variable Category
FAP	Contractor and Resources	Contractor Material Labour Tools & Equipment
	Management and Surroundings	Client Consultant Contractual External
	Means and Methods	Construction Methods
	Resources	Labour Material Tools and Equipment
	Project Organisation	Organisation Information

Table 6: Scoring criteria for factor and group assessments

Factor and Group	Criteria	Assigned Value
FAP Categories	Score Below “Low” Score In Between Score Above “Medium”	5 3 1
Contractor and Resources Group	Score Below “Low” Score In Between Score Above “Medium”	5 3 1
Management and Surroundings Group	Score Below “Low” Score In Between Score Above “Medium”	5 3 1
SCM Categories	Score Above “Medium” Score In Between Score Below “Low”	5 3 1
Means and Methods Group	Score Above “Medium” Score In Between Score Below “Low”	5 3 1
Resources Group	Score Above “Medium” Score In Between Score Below “Low”	5 3 1
Project Organisation Group	Score Above “Medium” Score In Between Score Below “Low”	5 3 1

4.0 Results and Discussion

An example of a project status report for a selected project is shown in Table 7. Productivity assessment was shown per category and per group so that different perspectives can be obtained from the assessment. It can be seen from the table that both assessment ratings per group were critical. Efforts to recover from poor project conditions based on SCM were also shown as per category and per group. They were mostly at medium level, which were probably not sufficient to cater for the critical assessment rating. This was shown by the TPR value of 1.89, which means that the project would most likely be delayed by 89% from the planned project completion date if no action is taken to improve the situation. The report has revealed in this case that currently the performances of the consultant, contractor, labour, tool and equipment, among others, were in critical or very poor condition.

Table 7: Example of project status report

Project ID: *SB16*	
Project Name: *GO*	
Project Location: *P1*	
Productivity assessment per category	**Rating**
Client	Caution
Consultant	Critical
Contractor	Critical
Material	Caution
Labour	Critical
Tools and equipment	Critical
Contractual	Critical
External	Critical
Productivity assessment per group	**Rating**
Contractor and resources	Critical
Management and surroundings	Critical
Schedule compression methods per category	**Rating**
Labour	Medium
Material	Medium
Construction methods	Medium
Tools and equipment	Low
Organisation	Medium
Information	Low
Schedule compression methods per group	**Rating**
Means and methods	Medium
Resources	Medium
Organisation	Medium
Project performance evaluation	
Total project ratio	1.89
Percent delay (%)	89

A common project will have a planning process as shown in Figure 7 (Russell et al., 1997; Griffith et al., 1999; Barraza et al., 2000) but with the assessment tool the process is modified as shown Figure 8. In most situations, project progress is expected to improve if such assessments can be made at regular intervals during the life-cycle of the projects. The recommended project assessment interval is shown in Figure 9. The project status report will provide project managers with some ideas about the source of problems and enable them to take remedial actions. The report can be attached with project schedule and progress report.

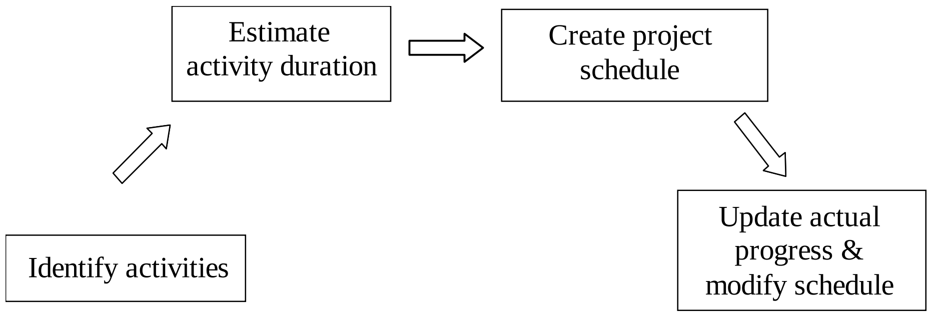

Figure 7: Common planning process

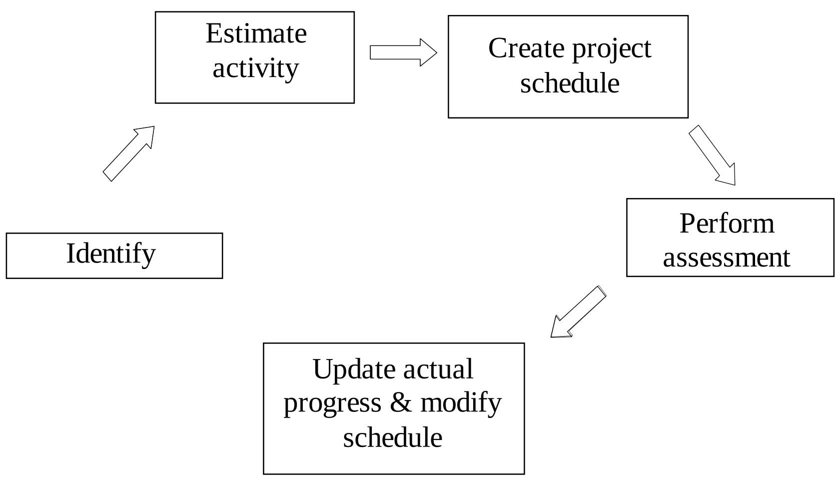

Figure 8: Planning process with assessment

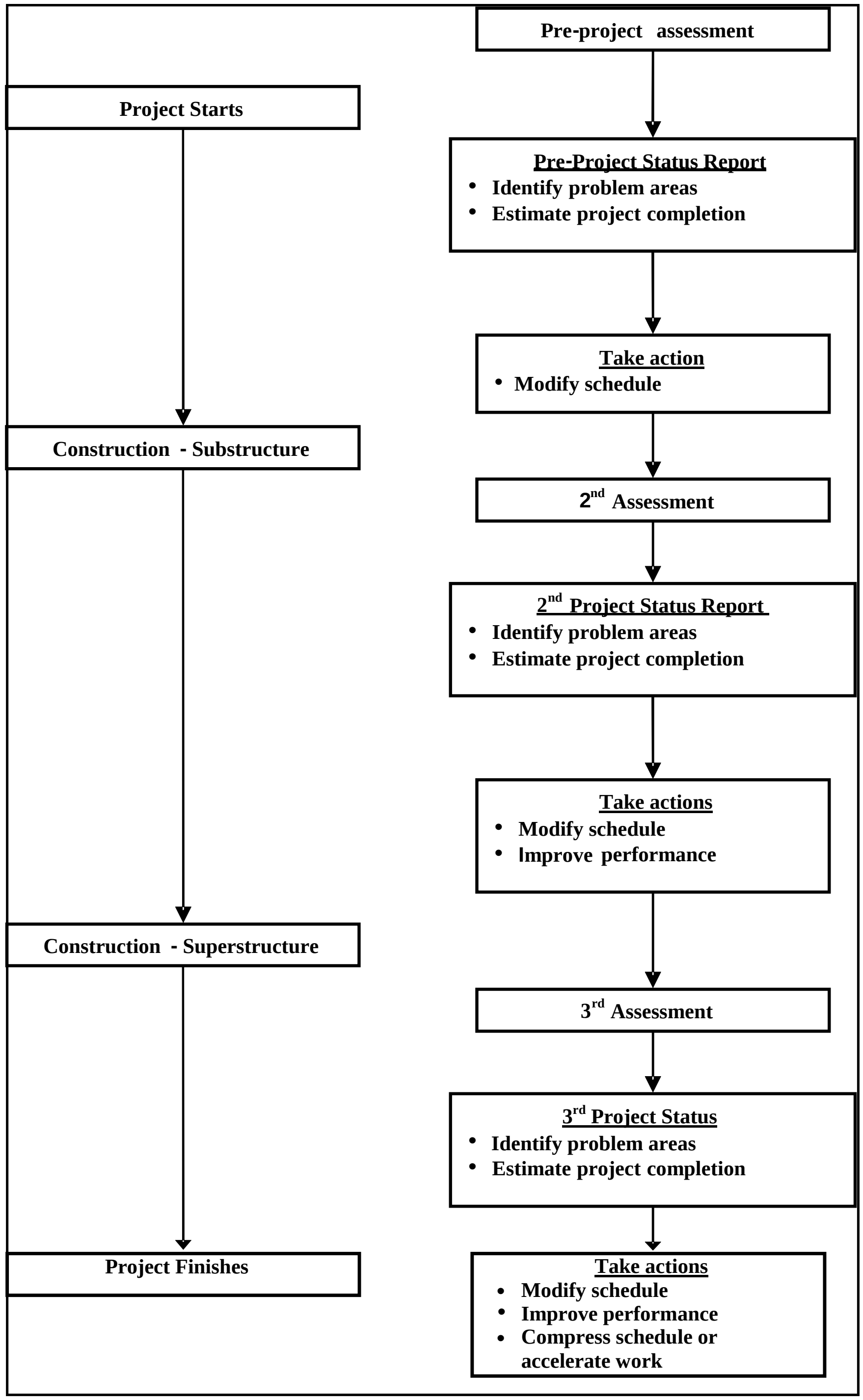

Figure 9: The recommended assessment intervals

5.0 Conclusions

This paper has presented a tool for monitoring the performance of building projects. This tool comprises three factors, which are FAP, SCM and TPR that can be used together as indicators for assessment and performance of past and future projects. By utilising the tool and documenting project status reports, project condition can be monitored more effectively. The source of problems can be speculated and traced so that appropriate action can be made to improve project condition. The tool was developed and intended to be used for general building construction projects, such as schools, offices, institutional buildings, etc. In order to avoid significant discrepancies, the tool is limited from being applied in other types of projects or in other countries. This research can be extended in the future by developing different versions of the tool that are specific for building, industrial or infrastructure projects. The existing methodology and data can be used as guides to significantly reduce research efforts in developing the new version of the tool. Furthermore, obtaining on-going project data and especially project cost data may enhance the reliability of the data, thus increase the accuracy of the conclusions. A more systematic mechanism for assessment and evaluation is also strongly recommended, such as better factor groupings on schedule and cost performance in order to yield contingency allowance measurements.

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