# PERFORMANCE REPORTING USING SCHEDULE COMPRESSION INDEX

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## ABSTRACT

Considerable number of methods and procedures has been introduced for trending and progress reporting of engineering, procurement and construction projects. This paper introduces a novel method, designed to augment the set of indices for measuring schedule performance. The concept behind the developed method is to provide early warning by dynamically evaluating the schedule cumulative impact of construction projects. The proposed method is designed to highlight the gradual deterioration in schedule status resulting in a cumulative impact due to the aggregation of small delays encountered during the execution of non-critical activities, and can be used as an add-on utility to existing software systems that perform CPM scheduling. The proposed method is based on a developed formulation for quantification of the Schedule Compression Index, which takes into consideration the remaining project activities durations. The index is developed based on periodic comparisons of "Current Schedules" and the project "Baseline Schedule" using the summation of the remaining activities durations. A numerical example is presented to demonstrate the application and capabilities of the developed method. It is expected that the developed index together with other schedule performance indices would be of value to decision makers and members of project teams.



## KEYWORDS

Schedule Performance, Critical Path Method, Schedule Cumulative Impact, Progress Reporting.


## INTRODUCTION

CPM as a management methodology has been used from the 1950s. The main objective of the CPM implementation was to determine how best to reduce the time required to perform routine and repetitive tasks that are needed to support an organization. Initially this methodology was identified to conduct routine tasks such as plant overhaul, maintenance and construction. (Moder and Phillips, 1964) Critical path analysis is an extension of the bar chart. The CPM uses a work breakdown structure where all projects are divided into individual tasks or activities.

Several underlying assumptions are made in the CPM approach. The major ones are that a project can be broken down into a series of identifiable tasks, each of which may also be further broken down into subtasks. Once this breakdown has been accomplished, the tasks are then placed in order against a timeline. Each task is assigned a start date, duration, and end date, and may also have various resources attached to it. These resources can include specific personnel, a budget, equipment, facilities, support services, and anything else that's appropriate. The common way to perform this task is to draw the tasks as horizontal boxes against a vertical time scale. The resulting chart is called a Gantt chart. (Moder and Phillips, 1964).

Important for the CPM using either the forward pass or the backward pass is that the total time needed for completion of the project does not change but the dates when the project can be started might differ based on the approach used in the two methods. The selection of either the forward or the backward pass depends on the final desired results and the available documents and accurate data needed to determine the time for every activity on the network diagram. (Baram, 1994) Slack or float is defined as the time between the earliest starting time (using the forward pass method) and the latest starting time (using the backward pass method) used for identifying the critical path. "Total float (float) is the amount of time an activity can be delayed without delaying the overall project completion time." (Winter, 2003)

There are external variables that can affect the CPM logic during the planning, scheduling and management process. "Priority changes, "across the board" budget cuts, negotiations with other agencies, evolving regulations, etc., can jointly or severally impact the CPM schedule, necessitating frequent and potentially complex modifications." (Knoke and Garza, 2003) Organizations also undergo various modifications with respect to the implementation of the management tools that they might use during the duration of the project. These management tools might affect the activities and the manner in which they are undertaken.

In many cases, as the project progresses, the critical paths might change and evolve and past critical paths may no longer be valid and new CP have to be identified for the project at regular intervals. This implies that the project manager and project member have to constantly review the network diagram initially created and identify the shifting and movement of the critical path over time.

Schedule total float is often used by whoever needs it first, unless is specified by the Contract (Prateapusanond, A. 2003). With this methodology and on an EPC project, engineering often uses a large portion of the float resulting in a tighter schedule for procurement and construction. The project is often focused on achieving critical path activities on time forgetting that the consumption of float on non critical path activates creates the bow wave (defined as the cumulative impact) of staked activates that will be difficult to achieve without impacting the resource requirements and cost.

Several indices were introduced to indicate the schedule performance of the project including (NDIA 2012):

- Schedule Performance Index (SPI) is an Earned Value Management tool comparing Baseline Cost of Work Performed (BCWP) with Baseline Cost of Work Scheduled (BCWS) to indicate cumulative and monthly schedule performance. It is an early warning tool used to determine if the schedule is at risk and indicates whether the program should increase efficiency to complete on time. (Moselhi, O. 2011).

$$SPI = \frac{BCWP\ (\,Budgeted\ Cost\ of\ Work\ Performed)}{BWCS\ (Budgeted\ Cost\ of\ Work\ Scheduled)} \tag{1}$$

- Baseline Execution Index (BEI) measures the number of tasks completed as a ratio to those tasks that should have completed to date according to the original (baseline) plan. It reveals the "execution pace" for a program and provides an early warning of increased risk to on-time completion.

$$BEI = \frac{\#\,Tasks\ Actually\ Completed}{\#\,Tasks\ Planned\ to\ be\ Completed} \tag{2}$$

- Current Execution Index (CEI) is a schedule execution metric that measures how accurately the program is forecasting and executing to its forecast from one period to the next. The real benefit of implementing CEI is an increased program emphasis on ensuring the accuracy of the forecast schedule.

$$CEI = \frac{\#\ of\ tasks\ that\ finished\ in\ the\ window\ (of\ those\ tasks\ forecasted\ to\ finish\ in\ the\ defined\ window)}{\#\ of\ tasks\ forecasted\ to\ finish\ in\ the\ defined\ window} \tag{3}$$

- Total Float Consumption Index (TFCI) applies the schedule's current rate of total float consumption to the remaining scope of work and projects a forecast finish date of the entire project. Applying the most recent rate of duration-based efficiency is analogous to applying the most recent rate of cost efficiency (TCPI) to an expected cost at the end of the project (EAC).

$$TFCI = \frac{Project\ Actual\ Duration + Critical\ Path\ Total\ Float}{Project\ Actual\ Duration} \tag{4}$$

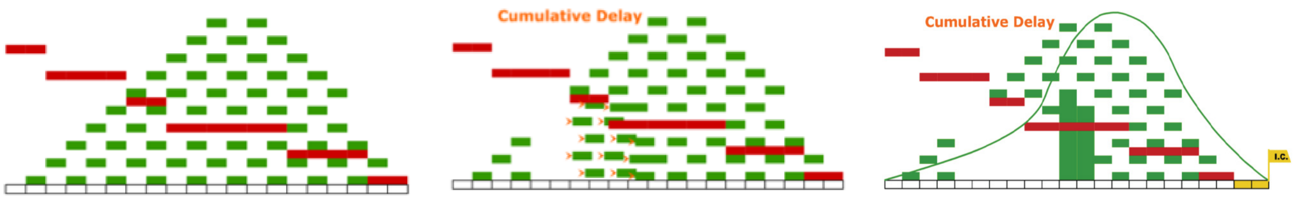
- The Critical Path Length Index (CPLI) measures how realistic the program completion date is, based on the remaining duration of the critical path and the amount of total float available. CPLI is one of DCMA's 14- Point Assessment Metrics and identifies programs that are having difficulty executing their critical path. The target for CPLI is 1.0 or greater. A lower value indicates an increased risk of being late at program completion.

$$CPLI = \frac{Critical\ Path\ Length + Total\ Float}{Critical\ Path\ Length} \quad (5)$$

The cumulative impact is an aggregation of small delays to non-critical path work. Gradual deterioration in schedule status creates a “bow wave” of work, and/or unrealistic production / installation rates, not achievable within the remaining time and resources limits to point that impact to schedule milestones or completion dates are created. Figure 1 shows the schedule update at period m shows the small delays to non-critical path work and the resulting bow wave effect.

Cumulative impacts are more difficult to identify than simple critical path delays, but are just as often a cause of schedule impacts, slowing the rate of progress on a non-critical body of work such that it cannot be completed before the critical path work is finished.

This Paper introduces a new index (focused on measuring the cumulative impacts) in addition to the above mentioned, that provides additional early warning information to project managers, thereby enabling improved decision making and enhancing the probability of project success.




Baseline Schedule Schedule Update at Period n Schedule Update at period m

Figure 1 - Schedule cumulative impact

## SCHEDULE COMPRESSION INDEX

### Description

Schedule Compression Index (SCI) measure how well the program (or a portion of the program) has performed against the baseline plan by looking forward at the remaining work, predicting the generation of schedule bow waves due to accumulation of small delays to non-critical activities. It is a ratio for the sum of remaining durations in the original plan (in the schedule unit of time) for all tasks falling after the reporting date to that from the current forecast schedule. It reveals the “execution pace” for a program and provides an early warning of increased risk to on-time completion due to cumulative impact of delays.

SCI is a summary level snapshot, which measures how well the program (or a portion of the program) has actually performed against the baseline plan. As with most industrial indices, 1.0 is ideal, a number greater than 1.0 indicates that the schedule is more relaxed than planned and a number less than 1.0 indicates that the schedule is being compressed compared to plan. Management can use this metric to evaluate the schedule performance or status in view of cumulative impact of delays. SCI is a more objective metric than SPI since it is based on the planned and actual Potency completion or time extension of activities.

Level-of-Effort (LOE) tasks are excluded from SCI calculations. The primary reason for this exclusion is to keep the LOE from masking the true state of the program. SCI places equal importance/weight on all activities. Because of this, completing a complex100-hour activity will affect the metric calculation the same as completing a routine 5-hour activity. However, a simple modification to the calculations of the SCI can be made to include a weight factor on activities. This weight factor can be based on man-hours, Importance, risk, etc. or combination of multiple factors. Most programs will have certain areas that are performing better or worse than other areas. SCI can be calculated on each of these areas rather than a mixed performance into a single index.

SCI need to be looked at together with all other indices such as Baseline Execution Index BEI, Current Execution Index CEI, Critical Path Length Index CPLI, Total Float Consumption Index TFCI and Schedule Performance Index SPI. A radar chart as shown in Figure 2 can be produced to show a summary level snapshot measuring how well the program (or a portion of the program) has performed.

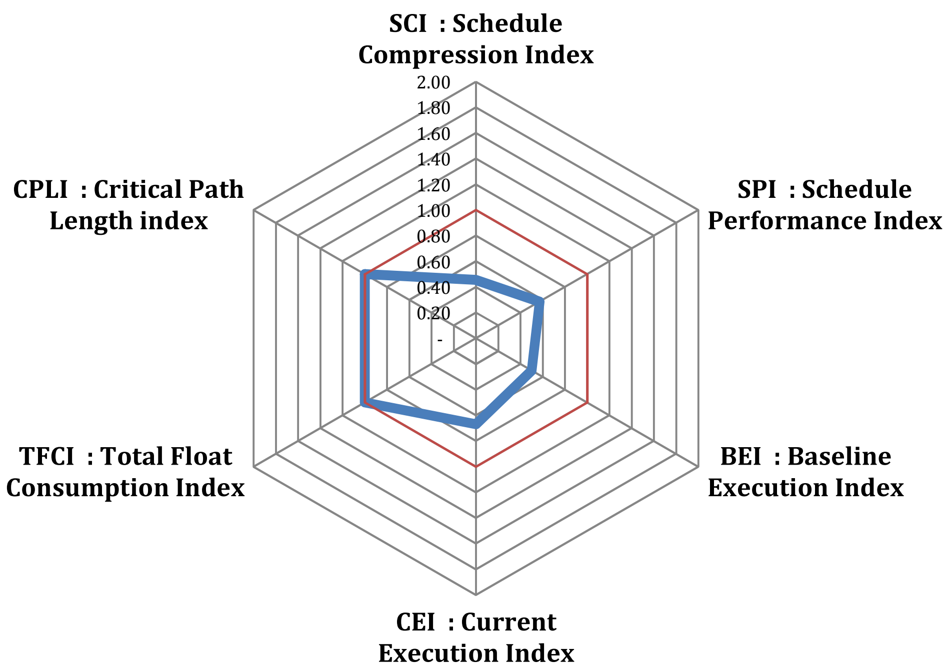



Figure 2 – Project Schedule Performance Radar Chart

**SCI Calculation Formula**

$$SCI = \frac{\sum Baseline\ schedule\ Remaining\ Duration\ (Not\ Planned\ to\ be\ Completed)\ (Days)}{\sum Current\ schedule\ Remaining\ Duration\ (Days)} \tag{6}$$

It is recommended, except where there may be exceptions under certain circumstances, to exclude from the calculations the Level of Effort (LOE) activities. SCI can be calculated as often as the schedule has its status updated (typically weekly or monthly). Similar to the interpretation of SPI values, SCI value of 1.00 indicated the effort is progressing consistent with the baseline completion rate. Values above 1.00

denote the schedule is more relaxed than in its original plan while values below 1.00 suggest the schedule is taking a downstream direction and getting tighter; indicating warning for schedule delays (Table 1).

Table 1 – SCI Interpretative Guide

| SCI Value | Implication |
|---|---|
| > 1.00 | **Favourable**<br>– The program on average is being accomplished at a faster rate than that planned. |
| = 1.00 | **On Track**<br>– The program on average is being performed at the planned baseline completion rate. |
| < 1.00 | **Unfavourable**<br>– The program on average is performing at a slower rate than that depicted by the baseline completion rate. It suggests that the schedule is staking downstream; consuming the bet-in floats and progressively becoming more critical. |

**Numerical Example**

A Numerical example is performed to demonstrate the application and use of the developed Schedule Compression Index, along with it's use jointly with the other schedule indices. A simple CPM schedule is developed as shown in Figure 3. The schedule duration is 7 days to perform 14 activities (A through N). To simplify the calculation, it is assumed that each activity has the same earned value per day. The schedule runs through 5 critical path activities (highlighted in red). The schedule is updated daily. Figure 4 shows the status at end of each day. The CPM calculations are performed after each status update. The schedule maintained its completion date but non-critical path activates have slipped; becoming near critical and eventually critical. The SCI index is calculated at the end of each status period for 5 consecutive days. The BEI, CEI, SPI, CPLI and the TFCI indices are also calculated for a complete analysis of the schedule performance.

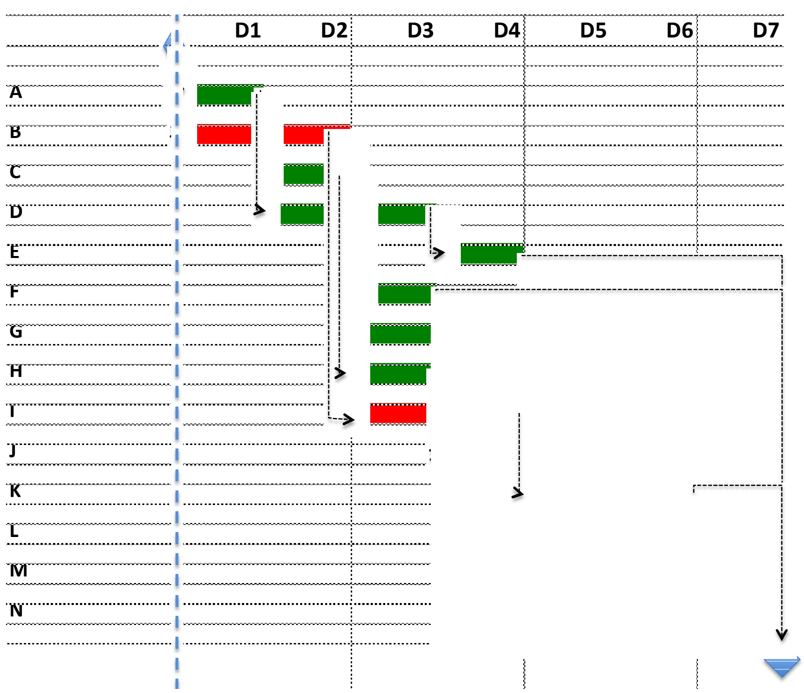



Figure 3 Numerical Example – Baseline schedule

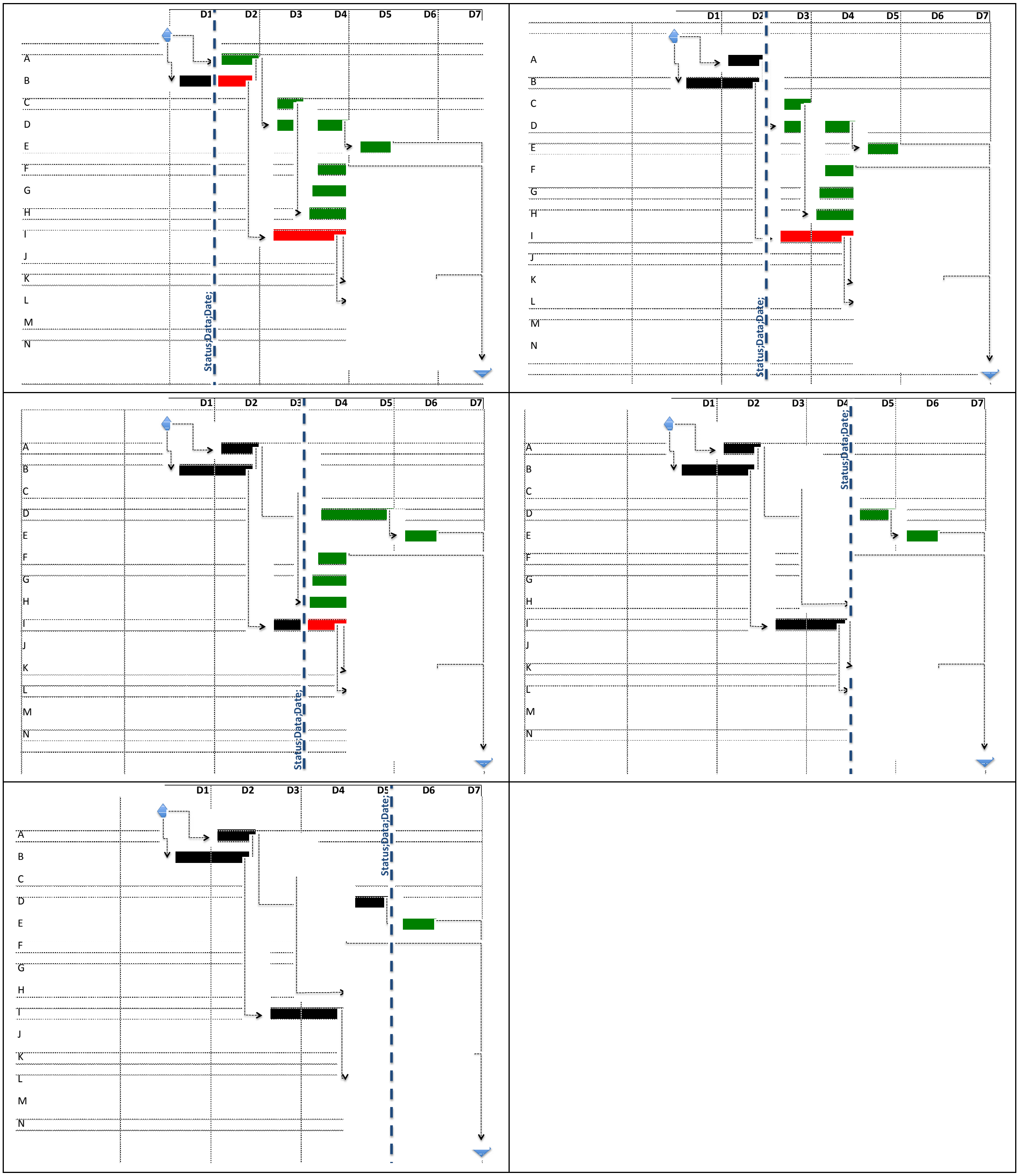



Figure 4 Numerical Example – Current schedule

**RESULTS**

Six different indices are calculated (SCI, BEI, CEI, SPI, CPLI and the TFCI) using Equations 1 to 6, respectively. The results are shown in Table 2. Figure 5 shows a plot of all above indices across time. It is noticed that the SCI is less than 1.00, which indicates that the program on average is performing at a slower rate than the baseline completion rate. This suggests that the schedule is staking downstream; giving an early warning for schedule overrun. This Cumulative effect can be visualized using diagrams such as that shown in Figure 6.

A radar chart is developed for all six schedule performance indices at schedule status day 4, as shown in Figure 2. The results were as follows:

- SCI : Schedule Compression Index is 0.45, which indicates that the work to go is significantly larger than what was planned for the remaining schedule periods; signalling warning for schedule slipping and likely delayed completion date.
- SPI : Schedule Performance Index is 0.57, which is unfavorable, indicating that the program on average is being accomplished at a slower rate than that planned.
- BEI : Baseline Execution Index is 0.50, which is unfavorable, indicating that the program on average is completing tasks at a slower rate than that stipulated in the program baseline schedule.
- CEI : Current Execution Index is 0.67, (i.e, 67% of tasks finished in the period (out of those forecasted to finish in the period), which is unfavorable indicating poor accuracy of the forecast schedule performance.
- TFCI : Total Float Consumption Index is 1.00, indicating that the program can still be completed on-time without mitigation. (Note, this numerical example is not rich enough of activates and with no schedule contingency to properly calculate the TFCI)
- CPLI : Critical Path Length index is 1.00, which is favorable, indicating that the critical path is on target, total float is zero, and an efficiency rate of 100% on critical activates is required moving forward.

Table 2 – Numerical Example Calculation

| Period End | D1 | D2 | D3 | D4 | D5 |
|---|---|---|---|---|---|
| ∑Baseline schedule Remaining Duration (Not Planned to be Completed) | 17 | 14 | 9 | 5 | 3 |
| ∑Current schedule Remaining Duration (Days) | 18 | 16 | 14 | 11 | 8 |
| **SCI** : Schedule Compression Index | 0.94 | 0.88 | 0.64 | 0.45 | 0.38 |
| Plan Cum | 2 | 5 | 10 | 14 | 16 |
| Earned Actual Cum | 1 | 3 | 5 | 8 | 11 |
| **SPI** : Schedule Performance Index | 0.50 | 0.60 | 0.50 | 0.57 | 0.69 |
| # Tasks Actually Completed | 0 | 2 | 1 | 2 | 3 |
| # Tasks Planned to be Completed | 1 | 2 | 3 | 4 | 1 |
| **BEI** : Baseline Execution Index | - | 1.00 | 0.33 | 0.50 | 3.00 |
| # of tasks forecasted to finish in the window | 1 | 2 | 1 | 3 | 3 |
| # of tasks that finished in the window (out of those forecasted to finish in the window) | 0 | 2 | 1 | 2 | 3 |
| **CEI** : Current Execution Index | 0 | 1.00 | 1.00 | 0.67 | 1.00 |
| Project Actual Duration + Critical Path Total Float | 7 | 7 | 7 | 7 | 7 |
| Project Actual Duration | 7 | 7 | 7 | 7 | 7 |
| **TFCI** : Total Float Consumption Index | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Critical Path Length + Total Float | 7 | 7 | 7 | 7 | 7 |
| Critical Path Length | 7 | 7 | 7 | 7 | 7 |
| **CPLI** : Critical Path Length index | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

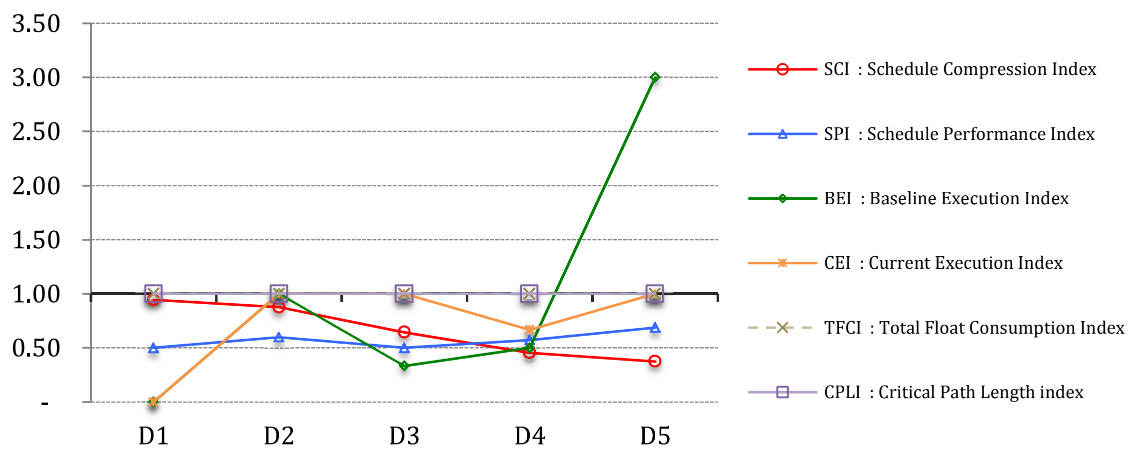



Figure 5 Numerical Example – SCI, SPI, BEI, CEI, TFCI and CPLI

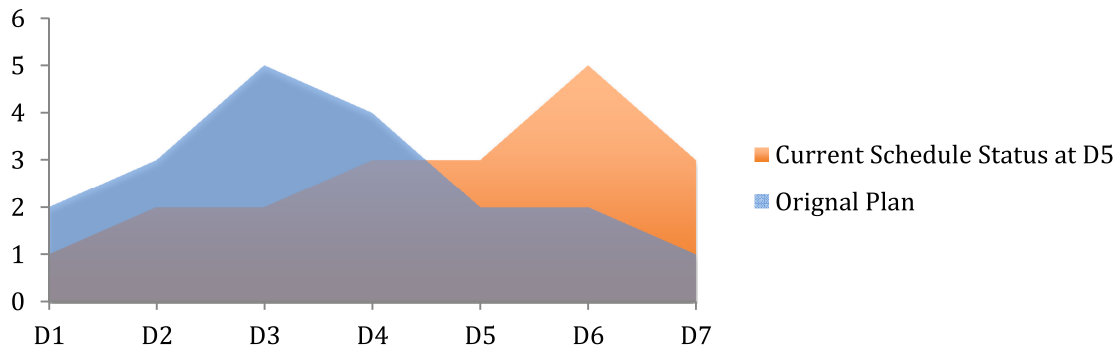


Figure 6 Numerical Example – Schedule Cumulative Impact (Bow wave)

## CONCLUSIONS

The widely used schedule performance measurement indices, described in this paper, may provide valuable information to project manager. The new schedule compression index SCI introduced in this paper provides a simple method for quantifying cumulative impacts; providing another dimension for assessment of schedule performance. Therefore it is recommended to use the schedule compression index side by side with the other indices in a radar chart to provide additional early warning information, thereby enabling manager's improved decision-making and enhancing the probability of project success.

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