Project Tightness Index (PT): A Concise Metric of Schedule Tightness

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Abstract

In this paper, we introduce **Project Tightness** (**PT**), a new topological indicator designed to assess the structural tightness of project schedules. The indicator combines information on the project's network structure and activity durations, yielding a normalised measure on the [0,1] scale. PT quantifies the degree of schedule compression—or "tightness"—by integrating both activity floats and the configuration of the project's critical structure. Unlike the classic XSLACK-R (average relative slack per activity), proposed by Patterson in Project Scheduling: The Effects of Problem Structure on Heuristic Performance (1976), the new indicator normalises total slack by the number of activities that do not belong to the dominant critical path (i.e., the critical path with the greatest number of activities). In doing so, PT penalises the presence of parallel critical branches—that is, critical activities outside the longest critical path—an aspect not captured by XSLACK-R. The paper formally develops the indicator's definition and fundamental properties (boundedness, time-scale invariance, and monotonicity) and presents several illustrative examples to support its interpretation and practical use.

1. Motivation

In the recent literature on project planning and control, topological indicators have proven decisive in explaining the performance of methods and metrics (J. Song et al., 2025, 2026; Y. Song & Vanhoucke, 2025; Ünsal Altuncan & Vanhoucke, 2025; Vanhoucke, 2010, 2011; Vaseghi et al., 2024). Among these, the series–parallel index (I_2 or SP) (L. V. Tavares, 1999; L. V. Tavares et al., 2002; Vanhoucke et al., 2004, 2008) has been repeatedly used as a key moderating variable. The cited studies compare approaches and draw different conclusions depending on the network's degree of parallelism. Their results confirm the role of SP as a reference structural indicator in project network analysis.

Nevertheless, our empirical evidence suggests that SP is not an absolute indicator. In particular, results also depend on the "tightness" of the schedule, understood as the proximity in duration of the project's paths. When several paths compete for criticality (similar durations), the network can become fragile to minor disturbances even while maintaining the same SP value. This dynamic—already observed in our studies on activity correlation, where variation in SP did not explain specific performance patterns as well as expected, while an explicit tightness measure did—could be extrapolated to other areas of analysis in which this indicator has not been considered.

Against this backdrop, we propose the Project Tightness (PT) indicator. A closely related antecedent, XSLACK-R (Kosztyán et al., 2023; Kosztyán & Novák, 2024; Patterson, 1976), summarises the project's average relative slack; however, it does not distinguish whether criticality branches into multiple parallel critical paths. Two projects may share the same average slack yet exhibit very different resilience to local delays if slack is unevenly distributed or if critical branches proliferate outside the dominant backbone.

Project Tightness (PT) addresses this limitation by providing a tension measure that combines: (i) how much slack exists in the project and (ii) how that slack is structured with respect to the critical path with the most significant number of activities. In doing so, PT detects when criticality branches in parallel and how slack is allocated (concentrated in a few activities or distributed), offering a more useful measure for revisiting prior results (e.g., in activity correlation or in the comparison of control methods) and for guiding practical decisions in planning and monitoring.

2. Definition

Consider a project with:

- n: total number of activities (excluding zero-duration dummy activities).
- TPT: planned project duration.
- TF_i: total float of activity $i = 1, \dots, n$.
- $\mathcal{P}_c$: set of critical paths (each with duration = TPT).
- $r = \max_{P \in \mathcal{P}_c} | P |$: number of activities on the critical path with the largest number of activities (among all possible critical paths).

We define **Project Tightness (PT)**, the average relative slack per activity not on the "longest" critical path, as:

$$\boldsymbol{PT = 1 - \frac{\sum_{i=1}^{n} TF_i}{(n-r)\ TPT}}$$

Interpretation:

- Numerator: the project's total slack ($\sum TF_i$).
- Denominador: the capacity available to accommodate that slack: the number of non-r activities $(n - r)$ times the project time scale TPT.
- Outcome**:** the average relative slack per activity outside the dominant critical path.

The higher the PT, the greater the tightness (i.e., the less time margin per activity outside the primary critical path).

If parallel critical branches appear (more activities with $TF = 0$ outside the longest critical path), $(n - r)$ increases while the numerator does not (those activities contribute no slack). Consequently, PT increases, signalling greater tightness.

Practical note:

In "pure" Critical Path Method (CPM), an activity's total float TF_i should not exceed the project duration TPT. However, owing to modelling/import choices (dummy activities, redundant dependencies, errors), outliers may arise with $TF_i > TPT$. If one sums $\sum TF_i$ without adjustment, the numerator is overstated and the indicator no longer faithfully reflects schedule tightness.

To address this, normalise and cap each float:

$$s_i = \min\left(\frac{TF_i}{TPT}, 1\right)$$

- Si $TF_i \leq TPT, \Rightarrow s_i = TF_i / TPT$ (normalisation).
- Si $TF_i > TPT, \Rightarrow s_i = 1$ (capping the outlier).

The adjusted sum of floats is:

$$\sum TF_i \ = \ TPT \cdot \sum s_i$$

In this way, each contribution is guaranteed to lie in *[0, TPT]*, and the total slack is bounded.

Therefore, Project Tightness is:

$$PT \ = \ 1 - \frac{\sum TF_i}{(n-r)\,TPT} \ = \ 1 - \frac{TPT \cdot \sum s_i}{(n-r)\,TPT} \ = \ 1 - \frac{\sum s_i}{n-r} \Rightarrow 0 \ \leq \ PT \ \leq \ 1$$

3. Properties

This section presents the main theoretical properties of the Project Tightness (PT) indicator, which clarify its behaviour and justify its validity as a measure of a schedule's structural tightness. In particular, we examine its boundedness on [0,1], its invariance under homogeneous time-scale transformations, and its monotonic response to changes in activity floats and in the project's critical structure. These properties provide the conceptual basis for interpreting and applying the indicator across different planning and control contexts.

- **Boundedness** (CPM setting with $TF_i \leq TPT$): $0 \leq PT \leq 1$.
- **Time-scale invariance**: If all durations are scaled by $k > 0$ (e.g., from days to hours, k=*8*), then both TF_i and TPT scale by k, but PT remains unchanged.
- **Monotonicity (parallel criticality)**: Adding critical activities outside the critical path with the most significant number of activities (holding TPT and $\sum TF_i$ constant) increases n while r remains fixed (r =*cte*), hence $(n-r)$ increases and PT increases (greater tightness).
- **Limit cases**:
  - Purely serial network (a single path with $r = n$): by convention, $PT = 1$ (maximum tightness).
  - Highly parallel network with ample slack and $r \ll n$: $PT \to 0$, (low tightness).

4. Computation procedure

The Project Tightness (PT) indicator is computed from the project's precedence network and the estimated activity durations. The general procedure is:

- **Compute individual floats (CPM)**

  Run a Critical Path Method analysis to obtain each activity's total float TF_i and the planned project duration TPT.

- **Identify the dominant critical path**

  Among all critical paths, select the one with the largest number of activities.

  $r = \max_{P \in \mathcal{P}_c} | P |$

- **Determine the set of non-critical (non-r) activities**

  Let n be the total number of activities. The number outside the dominant critical path is $n - r$.

- **Computation of the Project Tightness (PT) indicator**

  The final value of the indicator is obtained directly from the sum of all activity floats and the identified critical structure:

$$PT = 1 - \frac{\sum TF_i}{(n - r) \times TPT}$$

Thus, values of PT close to 1 reflect greater structural tightness (tightly packed schedules with little adequate slack), whereas values near 0 indicate a more relaxed structure with greater temporal flexibility. This procedure enables the systematic computation of Project Tightness and the comparison of schedules of different sizes, durations, or topological configurations, while preserving the coherence and reproducibility of the analysis.

5. Illustrative Example

To facilitate the understanding and practical application of the Project Tightness (PT) indicator, this section presents an illustrative example based on a simple project (Fig. 1). Through this example, the calculation procedure is shown step by step—from the determination of activity floats to the computation of the final PT value—as well as the interpretation of the obtained results. This example serves to verify the fulfillment of the theoretical properties described and to highlight the indicator's ability to distinguish different levels of structural tightness in project schedules.

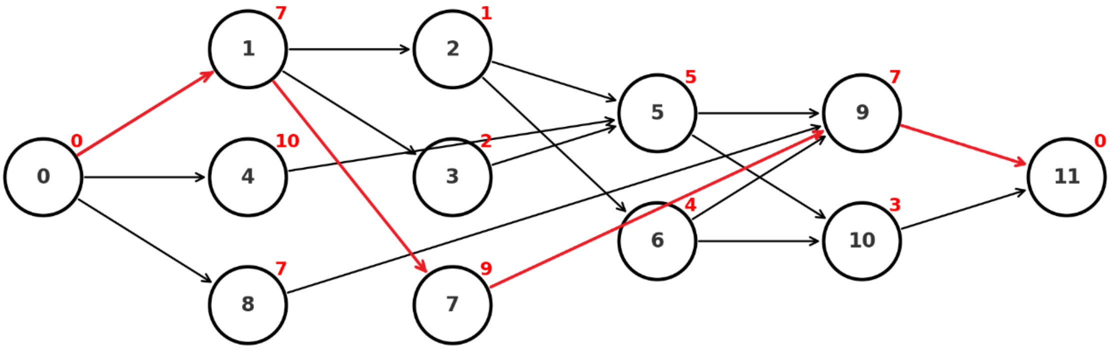

Figure 1. *AON Diagram corresponding to the Example Project*

- **Calculation of Individual Floats**

  Number of project activities: $n = 10$. Activities 0 and 11 are dummy start and finish activities, respectively.

  Critical path formed by activities: A1 – A7 – A9 (arrows in red in Fig. 1).

  Duration of the critical path (TPT): $TPT = 23$

  Floats of non-critical activities: $HA_2 = 3$; $HA_3 = 2$; $HA_4 = 1$; $HA_5 = 1$; $HA_6 = 4$; $HA_8 = 9$; $HA_{10} = 5$

- **Identification of the Dominant Critical Path**

  Dominant critical path: only one critical path exists (A1 – A7 – A9).

  Number of activities belonging to the critical path: $r = \max_{P \in \mathcal{P}_c} | P | = 3$

- **Determination of the Set of Non-Critical Activities**

  Activities that do not belong to the dominant critical path: *n − r = 10 − 3 = 7*.

- **Calculation of the Project Tightness Indicator (PT)**

$$PT = 1 - \frac{\sum TF_i}{(n-r)\,TPT} = 1 - \frac{(3+2+1+1+4+9+5)}{(10-3)\;23} = 1 - \frac{25}{7 \text{ x } 23} = 0.845$$

6. Conclusions

In this work, we have presented Project Tightness (PT) as a simple, normalised, and operational measure of schedule tightness that integrates both the level of float and its organisation with respect to the dominant critical path. Unlike XSLACK-R, PT distinguishes cases with the same average float but different resilience (for example, when parallel critical paths exist), thus providing a more meaningful interpretation for comparative analyses and for decision-making in project planning and monitoring. The indicator is bounded within [0,1], invariant to changes in the time scale, and monotonic with respect to increases in parallel criticality, which enhances its interpretability and comparability across projects.

As potential applications, we propose reporting PT alongside the SP indicator (I_2, series/parallel) to improve network segmentation and guide the selection of control strategies. Among its current limitations, the definition relies on the Critical Path Method (CPM) without resource constraints; therefore, future work should empirically validate PT on real project datasets, develop extensions incorporating resources and calendars, and explore its role as a moderating variable in performance models (prediction, sensitivity, and risk analysis), including decision maps in the (I_2, PT) plane and robustness assessments under uncertainty.

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