
Project Tightness (PT): A Complementary Topological Indicator for Explaining Project Schedule Behaviour

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Keywords: Project Tightness, Series-Parallel Index, Network Topology, Project Control.

1. Introduction

Topological indicators play a central role in the analysis of project scheduling and control, as they describe the structure of activity networks and help explain why projects with similar characteristics may exhibit different dynamic behaviour. They quantify features such as network size (Vanhoucke et al., 2008, 2016).

Among them, the Series–Parallel Index (SP), initially introduced by Tavares (1999), has become the reference measure for distinguishing between predominantly serial and parallel project structures. Over the last two decades, SP and related measures have been widely used in simulation studies and empirical analyses (Vaseghi et al., 2024; Song and Vanhoucke, 2025; Song et al., 2026), consistently confirming that network topology affects project control performance, particularly in terms of time and cost predictability.

Nevertheless, empirical results from our own simulations indicate that seriality alone does not fully explain project behaviour. Networks with identical SP values may exhibit markedly different responses depending on the distribution of activity slack, revealing a latent structural factor: network tightness, that is, how “stretched” or “tense” project paths are in terms of duration proximity.

Consequently, we propose a new topological indicator, Project Tightness (PT), designed to capture this structural tension and complement the information provided by SP. Jointly considering PT and SP yields a richer and more consistent explanation of schedule sensitivity and control performance, extending topology-based approaches through the integration of structural and temporal dimensions.

2. Project Tightness: A New Topological Indicator

Although the Series–Parallel Index (SP) is a valuable structural descriptor, empirical analyses show that it is not an absolute indicator of project behaviour. Projects with identical SP values may respond differently to uncertainty depending on the proximity in duration of alternative paths, that is, on schedule tightness. When several paths compete for criticality, the network becomes more fragile to minor perturbations even if SP remains unchanged. To capture this dimension, we introduce the Project Tightness (PT) indicator, which quantifies the overall temporal tension of the schedule (Acebes & Pajares, 2025).

Unlike measures such as XSLACK-R (Patterson, 1976), PT accounts not only for the amount of total slack but also for its organisation relative to the dominant critical path, allowing networks with similar average slack but different structural resilience to be distinguished. PT is defined as:

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

where n is the number of activities, r is the number of activities on the longest critical path, TPT is the planned project duration, and TF_i is the total float of activity i .

PT takes values in $[0, 1]$, with higher values indicating tighter schedules. It is bounded, invariant to time-scale changes, and monotonic with respect to parallel criticality. While SP captures structural shape, PT reflects temporal tension; together, they provide a two-dimensional description of project morphology.

Figure 1 illustrates two networks with identical topology and $SP = 0.33$ but markedly different PT values (0.349 and 0.984), reflecting different degrees of schedule compression and flexibility.

This example highlights how PT captures variations in temporal tightness that remain invisible to SP alone.

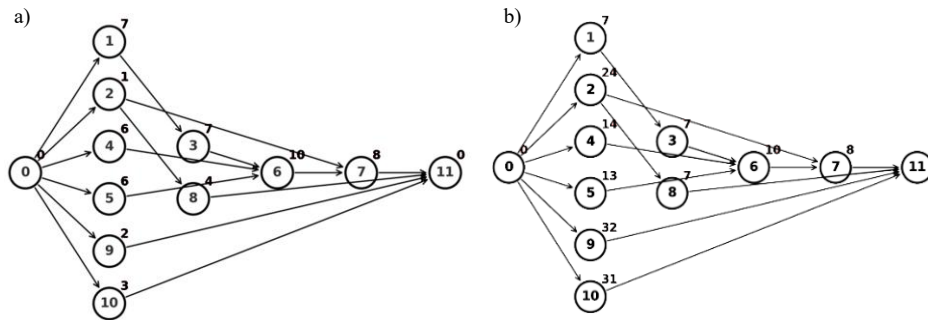


Figure 1. Two project networks with the same Series-Parallel Index ($SP = 0.33$) but different Project Tightness values ($PT_a = 0.349$ and $PT_b = 0.984$), showing how PT reflects differences in schedule tension

3. Case Studies

In this paper, two case studies are presented to illustrate the relevance and practical implications of the proposed Project Tightness (PT) indicator. These experiments aim to demonstrate how PT significantly influences key project outcomes, providing valuable insights into project behaviour under uncertainty. Furthermore, PT complements the traditional Serial-Parallel (SP) indicator: while SP captures the structural arrangement of activities, from more serial to more parallel configurations, PT reveals the underlying temporal tension that determines the project's sensitivity and robustness.

3.1. Correlation analysis between project activities

To demonstrate the importance of the Project Tightness (PT) indicator in explaining project responses under uncertainty, a first case study was conducted, analysing how key project parameters (mean value, variance, and sensitivity indicators (Criticality Index - CI, Cruciality Index - CrI, Schedule Sensitivity Index - SSI)) vary when correlations between two project activities are introduced.

Within the different simulation scenarios, correlations were established in two directions: highly positive and highly negative correlations between activities. Moreover, the correlated activities were selected either from the same initial critical path or from different paths with distinct initial criticalities. Correlations were introduced by imposing fixed Pearson coefficients ($\rho = \pm 0.8$) between the stochastic durations of selected activity pairs using a Gaussian copula, while preserving marginal duration distributions.

The analysis was conducted using a set of fictitious project networks, whose Serial-Parallel (SP) indicator ranged from approximately 0.1 (highly parallel projects) to 0.9 (highly serial projects). For each network, the PT indicator was calculated based on its structural and temporal properties. In addition, for the same projects (while maintaining their SP value), we modified the duration of specific activities to generate tighter configurations by proportionally reducing the total floats of non-critical activities, while preserving the precedence structure and thus maintaining a constant SP value. One of the main results is shown in Figure 2, which depicts the relationship between PT and the percentage change in project variance when activity correlations are introduced ($\rho = 0.8$), distinguishing between networks with high and low SP structures. To distinguish SP regimes, networks were split by the sample median SP ($SP \geq \text{median}$: High-SP; otherwise: Low-SP).

A general downward trend can be observed: as PT increases, the variance sensitivity decreases, indicating a lower capacity for correlation propagation in tighter networks. However, the steeper slope observed for low-SP projects suggests that more parallel networks are more sensitive to internal correlation effects when they exhibit moderate tension levels. Overall, the figure confirms that PT moderates the effect of SP on project variance, revealing a differentiated behaviour between networks with similar structural arrangements but distinct levels of temporal tightness.

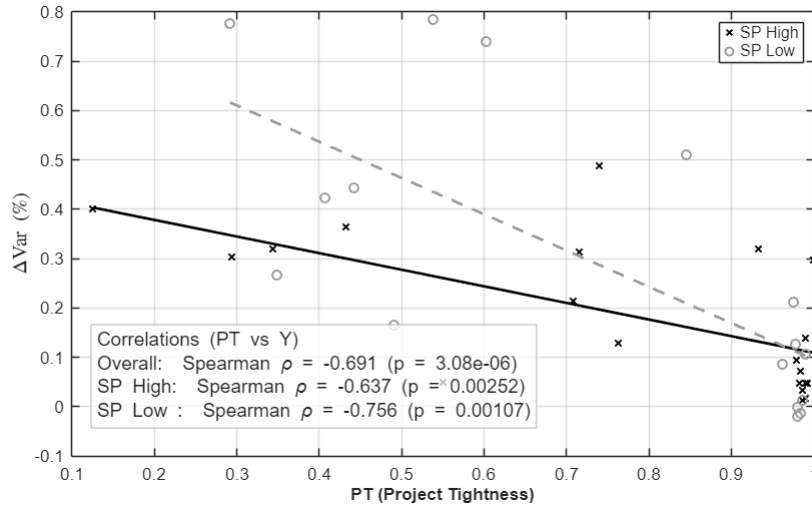


Figure 2. Relationship between Project Tightness (PT) and project variance, showing distinct trends for high and low Serial-Parallel (SP) structures

3.2. Time-control simulations

The second simulation study was inspired by the experimental framework proposed by Vanhoucke (2010). Two fictitious project networks were selected, representing opposite Serial-Parallel (SP) configurations (one highly parallel (SP ≈ 0.2) and one highly serial (SP ≈ 0.8)). For both projects, the Total Contribution (TC) metric was computed following Vanhoucke’s corrective-action simulation approach. To examine the additional influence of Project Tightness (PT), each network was also modified to create a “tighter” version, with PT values close to 1, representing schedules with minimal slack and stronger temporal tension.

The results, presented in Figure 3, indicate that when PT remains low, the outcomes are consistent with those reported by Vanhoucke (2010): low-SP projects (i.e., more parallel networks) achieve greater total contributions under corrective actions, whereas high-SP networks show more limited improvements. However, as PT increases, this pattern changes: tighter projects display larger deviations in TC, and in some cases, the expected relationship between SP and TC is even reversed.

These findings suggest that PT complements the traditional SP indicator, offering an additional dimension to explain project control performance. By integrating both structural (SP) and temporal (PT) characteristics, the analysis provides a more comprehensive understanding of how network topology and schedule tension jointly influence the effectiveness of corrective actions.

4. Conclusions

This paper introduced Project Tightness (PT) as a topological indicator that captures the temporal tension of project networks and complements the traditional Series-Parallel (SP) index. Through two simulation studies, focused on variance propagation and corrective-action performance, we demonstrated that considering PT alongside SP provides a more complete and consistent understanding of project behaviour.

While SP describes the structural configuration of activities, PT reflects the degree of schedule compression and its impact on project sensitivity and robustness. The first study showed that networks with comparable SP values may exhibit distinct variance responses depending on their internal tension. The second confirmed that Total Contribution (TC) under corrective actions depends not only on SP, as reported in earlier work, but also on PT, since tighter projects can amplify or invert expected patterns of control performance. Overall, the joint use of SP and PT provides a practical framework for classifying and interpreting project behaviour under uncertainty, linking structural and temporal perspectives. By combining structural and temporal dimensions, it helps explain differences in performance across networks and supports more informed control decisions.

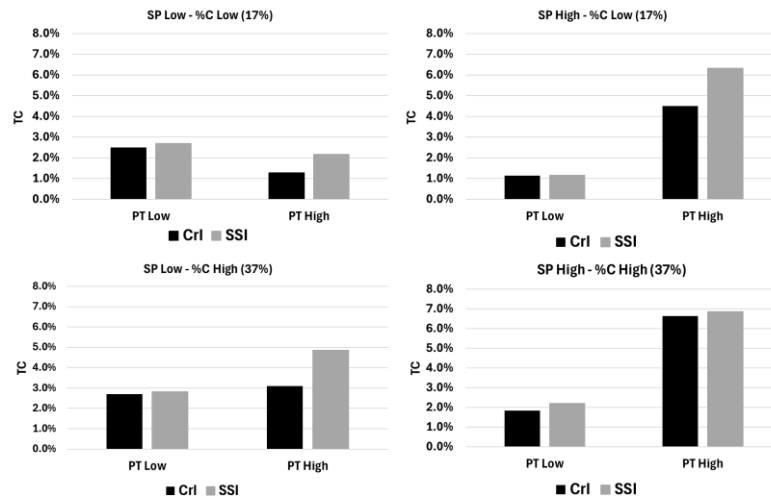


Figure 3. Impact of Project Tightness (PT) on Total Contribution (TC) for Project Networks with Different Serial-Parallel (SP) Structures, Extending the Topology-Based Analysis of Vanhoucke (2010)

Future research could revisit previous studies based solely on the SP indicator to examine whether their conclusions remain consistent when project tension (PT) is considered. In addition, this approach could be extended to resource-constrained environments, where schedule tightness and structural configuration may interact differently, further testing the robustness and practical relevance of the PT indicator.

Funding

This project has been partially funded by the Regional Government of Castile and Leon (Spain) under the Regional Accredited Research Groups Support Program, with grant VA042G2.

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