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TIME-SENSITIVITY INDICES FOR RISK MANAGEMENT IN COMPLEX CONSTRUCTION PROJECTS

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ABSTRACT: Construction project schedules are highly susceptible to delays, impacting timelines, costs, and overall outcomes. To mitigate these risks, robust sensitivity measures are essential for assessing activity disruptions and supporting effective risk management. Various indices, including the Criticality Index, Cruciality Index, Significance Index, Schedule Sensitivity Index, Management-Oriented Index, and Criticality-Slack Sensitivity Index, quantify schedule risk, each offering a distinct perspective. However, inconsistencies in methodologies, assumptions, and computational complexities often hinder their practical application. This study systematically reviews these indices, comparing their theoretical foundations, implementation feasibility, and effectiveness across diverse project conditions. By synthesizing existing research, it identifies key trends, gaps, and contradictions, particularly the limitations of activity-based indices in capturing project-wide disruptions. Findings suggest that while certain measures excel under specific conditions, no single index comprehensively captures all dimensions of schedule sensitivity. Moreover, the effectiveness of these indices depends on project complexity, network topology, and uncertainty levels. This study highlights the need for a standardized, project-level sensitivity index that integrates the strengths of existing measures while addressing their limitations, ultimately improving schedule resilience and risk mitigation in complex construction projects.

1. INTRODUCTION

The construction industry operates in a complex, dynamic environment where project schedules are critical for timely and cost-effective delivery but remain vulnerable to disruptions from uncertainties, delays, and shifting priorities. Schedule Risk Analysis (SRA) integrates risk and uncertainty into scheduling, enhancing delay mitigation (Acebes et al., 2020; Vanhoucke, 2015). Despite its growing adoption, delays and cost overruns persist due to inconsistent risk assessment applications (Raz et al., 2002). Since effective risk management is integral to project success (Williams, 1995), advancing schedule sensitivity analysis is essential. Sensitivity measures such as the Criticality Index, Significance Index, and Schedule Sensitivity Index evaluate the impact of activity delays on project timelines. However, variations in methodologies, underlying assumptions, and computational demands complicate their practical implementation. Additionally, the interdependence of project activities poses challenges in identifying critical tasks, as delays can propagate throughout the schedule. These methodological inconsistencies limit real-world applicability, highlighting the need for a structured comparison. This study systematically reviews key time-sensitivity measures, with a focus on simulation-based indices utilizing Monte Carlo simulations, to assess their theoretical foundations, feasibility, and clarity. Establishing a standardized framework for their application will enhance scheduling methodologies, strengthening project resilience and efficiency.

This study systematically evaluates time-sensitivity measures in project scheduling by developing an analytical framework to compare their implementation feasibility, computational demands, result clarity, and applicability across diverse project conditions. A comprehensive literature review was conducted using academic search engines (Google Scholar, Semantic Scholar), citation indexing databases (Web of Science, Scopus), and full-text repositories (ScienceDirect, JSTOR, DOAJ, ASCE Library). Broad and refined search terms—including "project risk management," "criticality," "sensitivity measures," and "project scheduling"—were employed to ensure thorough coverage.

From an initial dataset of 60 papers, 30 were selected, prioritizing peer-reviewed journal articles, conference proceedings, book chapters, and master's theses published in English between 1965 and 2025. Studies were included if they presented well-defined time-sensitivity measures, mathematical formulations, and real-world applications, while those lacking formal models or practical relevance were excluded.

The structured evaluation framework compared six key simulation-based indices, assessing their computational complexity, ease of integration into project management workflows, and ability to generate actionable scheduling insights. A narrative synthesis identified overarching trends, similarities, and differences, providing a comprehensive evaluation of their role in construction project risk management. Additionally, the study examined the adaptability of these measures to varying project complexities, uncertainties, and industry constraints, ensuring an objective comparison that highlights their practical utility and potential for methodological advancements in project scheduling.

2. TIME SENSITIVITY MEASURES

2.1 Criticality Index

The Criticality Index (CI) is a fundamental probabilistic metric in project scheduling that quantifies the likelihood of an activity being on the critical path and affecting project completion time (Martin, 1965). Initially explored by Van Slyke (1963) using Monte Carlo simulations, CI accounts for variability in activity durations, making it particularly valuable in stochastic project networks (Dodin & Elmaghraby, 1985). Unlike deterministic approaches, CI provides a probabilistic perspective, enhancing risk management and decision-making. Martin (1965) also introduced related indices, including the Activity Criticality Index (ACI) and the Path Criticality Index (PCI), but their computational complexity has led to the development of alternative approximation methods (Madadi & Iranmanesh, 2012). Over time, CI has been refined through improved estimation techniques, such as unbiased estimators (Bowman, 1995) and exact formulas for PERT networks (Ghomi & Teimouri, 2002). The CI can be mathematically expressed as shown in Equation 1.

[1] $Q_j = \sum_{i \in D_j} P_i$

where Q_j is the probability that activity a_j is on the critical path, and D_j represents the set of paths containing a_j, with P_i denoting the probability that each path is critical (Martin, 1965). Research advancements have extended CI's applicability, integrating statistical and fuzzy methods (Chen & Huang, 2007), resource constraints (Song et al., 2021), and enhanced computational strategies (Creemers et al., 2014a). However, limitations remain, such as its inability to account for resource constraints (Wang et al., 2012) and variations in activity durations (Elmaghraby, 2000). Despite these challenges, CI remains a cornerstone of project sensitivity analysis, informing risk assessment and decision-making strategies.

2.2 Significance Index

The Significance Index (SI), introduced by Williams (1992), enhances project sensitivity analysis by addressing the limitations of the Criticality Index (CI). While CI quantifies the probability of an activity being on the critical path, SI integrates both this probability and the activity's impact on project duration, providing a more comprehensive assessment of scheduling risks (Creemers et al., 2014a). Unlike CI, which focuses solely on probability, SI prioritizes activities based on their contribution to project uncertainty, making it particularly valuable in stochastic networks (Vanhoucke, 2010). Williams (1992) highlighted that highly critical activities with minimal duration variability may have limited influence on project completion, whereas non-critical activities with significant fluctuations can still cause delays. The SI can be calculated according to Equation 2.

[2] $SI = E\left(\frac{A_D}{A_D + A_{TF}} * \frac{P_D}{E(P_D)}\right)$

where, A_D denotes the activity duration, A_{TF} represents the activity total float, P_D signifies the project duration and $E(x)$ is the expected value (average) across all simulation runs. This formulation balances activity duration, scheduling flexibility, and overall project impact. Since its introduction, SI has been refined and extended, including its application to resource constraints through the Resource Significance Index (RSI) (Song et al., 2021). However, its computational complexity remains a challenge, as calculating SI requires exhaustive network realizations, making it impractical for large projects (Elmaghraby, 2000). Additionally, SI often produces results similar to CI, limiting its distinctiveness in certain cases (Creemers et al., 2014b). Despite these challenges, SI remains a valuable tool in project risk assessment, providing deeper insights into activity significance beyond criticality alone.

2.3 Cruciality Index

The Cruciality Index (CRI), introduced by Williams (1992), refines the Significance Index (SI) by quantifying the correlation between an activity's duration and total project duration, providing a probabilistic measure of its impact on project completion (Vanhoucke, 2010). Elmaghraby (2000) formalized CRI using the Pearson correlation coefficient, which has since become the standard computation method (Peternella, 2016). Alternative formulations include non-parametric measures, such as Spearman's and Kendall's correlation coefficients, which account for potential non-linearity in project scheduling relationships (Vaseghi & Vanhoucke, 2023). The CRI is computed according to Equation 3.
The CRI in Equation 3 is computed as follows:

[3] $CRI = \left|\frac{\sum(A_D - Avg(A_D)) * (P_D - Avg(P_D))}{\sqrt{\sum(A_D - Avg(A_D))^2 * \sum(P_D - Avg(P_D))^2}}\right|$

where, A_D represents the activity duration, $Avg(A_D)$ is the average activity duration, P_D stands for the project duration and $Avg(P_D)$ denotes the average project duration for all simulation runs. This formulation captures the extent to which variations in an activity's duration influence overall project duration. Research has expanded CRI's applications, with Vanhoucke (2015) demonstrating its role in quantifying project uncertainty and Acebes et al. (2021) highlighting the robustness of non-parametric alternatives. Additionally, Hu et al. (2016) integrated CRI into schedule monitoring through the CRI-Based Buffer Monitoring Approach (CRI-BMA), enhancing real-time project control. While Pearson's CRI remains widely used, recent studies advocate for alternative correlation measures to improve sensitivity analysis in complex project environments (Cho & Yum, 1997; Vaseghi & Vanhoucke, 2023).

2.4 Schedule Sensitivity Index

The Schedule Sensitivity Index (SSI), introduced by Vanhoucke (2010), assesses the relative importance of project activities by integrating their criticality and contribution to project duration variability. Building on Cho & Yum's (1997) work on activity duration uncertainty, SSI aligns with PMBOK (2004) recommendations by incorporating the standard deviations of activity and project durations alongside the Criticality Index (CI). This approach provides a comprehensive measure of activity sensitivity, capturing both probability and uncertainty-driven impacts on project duration. The SSI is computed using Equation 4.

[4] $SSI = CI * \frac{\sigma_i}{\sigma_P}$

where, CI represents the Criticality Index (CI) indicating the probability of an activity being on the critical path, σ_i is the standard deviation of the activity duration, and σ_P is the standard deviation of the project duration. This formulation effectively balances criticality and uncertainty, distinguishing high-sensitivity activities from lower-priority ones. Empirical studies confirm SSI's effectiveness in project tracking and corrective action. Vanhoucke (2011) validated SSI against other indices (CI, SI, CRI), demonstrating its superiority in differentiating activity sensitivity levels. Acebes et al. (2020) reinforced SSI's utility in evaluating corrective actions, while Vaseghi & Vanhoucke (2023) highlighted its effectiveness in managing uncertainty. Additionally, the Resource Schedule Sensitivity Index (RSSI) extends SSI by incorporating resource constraints (Song et al., 2021), further refining project control strategies. Recent studies (Hadad et al., 2014; Hu et al., 2016) confirm SSI's reliability in prioritizing activities under uncertainty, solidifying its role as a key metric in project sensitivity analysis.

2.5 Management-Oriented Index

The Management-Oriented Index (MOI), introduced by Madadi & Iranmanesh (2012), evaluates the significance of project activities in reducing duration and mitigating risk variability. Influenced by the work of Williams (1992) and Tavares et al. (2002), it was the first metric to integrate activity variability, project duration impact, and network morphology into a unified sensitivity framework (Acebes et al., 2020). Unlike conventional measures, MOI explicitly accounts for activity duration uncertainty and structural complexity (Ballesteros-Pérez et al., 2019). Equation 5 illustrates how MOI is calculated.

[5] $MOI_i = \frac{\sigma_{d_i}}{\sigma_{Max}} * \frac{1}{E(Tf_i) - Post\_Density_i + 1}$

Where, σ_i represents the standard deviation of activity i, σ_{max} is the maximum variance among all project activities, $E(Tf_i)$ denotes the expected value of the total float of activity i and $Post\_Density_i$ quantifies the density of successor activities. This formulation encompasses both activity uncertainty and network connectivity, thereby enhancing its effectiveness in sensitivity analysis. Empirical studies confirm the robustness of the Management-Oriented Index (MOI). Madadi & Iranmanesh (2012) demonstrated its superiority over other indices in reducing the mean duration and variability of projects, particularly within large networks. Vaseghi & Vanhoucke (2023) validated MOI's effectiveness in implementing corrective actions, reinforcing its practical utility. Acebes et al. (2020) emphasized MOI's comprehensive assessment of activity impact, while Song et al. (2021) highlighted its dynamic nature, which accounts for the evolution of risk throughout project execution. These findings establish MOI as a leading tool in project monitoring and risk management.

2.6 Criticality-Slack Sensitivity Index

The Criticality-Slack Sensitivity Index (CSS), introduced by Ballesteros-Pérez et al. (2019), enhances existing sensitivity metrics by incorporating both the probability of an activity's criticality and the variability in its total float under deterministic and stochastic conditions. Unlike prior indices such as the Schedule Sensitivity Index (SSI) and the Management-Oriented Index (MOI), CSS explicitly accounts for scheduling instability caused by fluctuations in float and duration uncertainty, making it a more comprehensive tool for sensitivity analysis. The CSS index is shown in Equation 6.

[6] $CSS = SSI * \frac{E(Tf_i) - (Tf'_i)}{E\ (PD)}$

Where $E(Tf_i)$ represents the expected total float of activity i under stochastic conditions, Tf'_i is the total float of activity i under deterministic scheduling, $E\ (PD)$ is the expected project duration, and SSI is the Schedule Sensitivity Index. The CSS index provides a holistic assessment by integrating criticality, total float adjustments, and duration variability, offering project managers a more effective tool for prioritizing high-risk activities. Unlike simpler indices, CSS captures both direct and indirect schedule instability effects, enhancing its applicability in project risk management (Acebes et al., 2020; Vaseghi & Vanhoucke, 2023). Empirical studies confirm its superiority over alternative metrics, particularly for early-stage project assessments (Song et al., 2021; Saffirio, 2023).

Table 1 provides an overview of the studies reviewed, emphasizing the advantages and disadvantages of each time-sensitivity measure essential for construction project scheduling. These measures help identify critical activities and assess their impact on overall project performance.

Table 1: Evaluation of Time-Sensitivity Measures: Advantages and Disadvantages

Study	Advantages	Limitations
Martin, 1965	CI: Critical Path Finder	
Dodin & Elmaghraby, 1985	CI: Practical Computational Method	
Williams, 1992	CRI: Can Handle Resource Constraints	CI: Not an Intuitively Helpful Metric CRI: Counter-Intuitive Results
Cho & Yum, 1997	CI: Identifies Critical Activities	
Elmaghraby, 2000	SI: Provides Relative Importance of Activities CRI: Can Handle Resource Constraints	CI: Unable to Handle Resource Constraints SI: Difficult to Compute CRI: Difficult to Compute
Ghomi & Teimouri, 2002	CI: Practical Computational Method	
Bowman, 2003	CI: Identifies Critical Activities	
Cui et al., 2006		CI: Ineffective Activity Criticality Reflection SI: Difficult to Compute CRI: Cannot Reflect Criticality
Vanhoucke, 2010	CI: Widely Implemented CRI: Relatively Better Results SSI: Relatively Better Results	CI: Ignores Project Duration Impact
Vanhoucke, 2011	SSI: Best Performing Metric	
Vanhoucke, 2012	SSI: High Potential for Improvement	
Madadi & Iranmanesh, 2012	CI: Extensively Studied Index MOI: Surpasses SI and CRI	SI: Surpassed by MOI CRI: Surpassed by MOI
Elshaer, 2013	CI: High Reliability SSI: More Reliable Measure	SSI: Drops to Zero with Stable Duration
Tang et al., 2013		CI: Limited Project Control after Start
Creemers et al., 2014a	CI: Identifies Critical Activities SI: Identifies Critical Activities	
Creemers et al., 2014b		CI: Ignores Activity Duration Variance SI: Ignores Activity Duration Variance CRI: Does not Consider Criticality SSI: Ignores Covariance
Vanhoucke, 2015	CI: Intuitive and Straightforward SI: Partial Answer to CI Criticism	CI: Based solely on Probability
Brožová et al., 2016		CI: Criticalness of Tasks Cannot be Determined by a Single Principle
Hu et al., 2016	CRI: Reduces Control Effort	
Paternella, 2016	CRI: Reflects Task Importance	
Rabbani et al., 2016	CI: Provides Superior Results	
Ballesteros-Pérez et al., 2019	CRI: Top-Performing Metric SSI: Top-Performing Iterative Metric	CI: Worst Performer Among Sensitivity Measures SI: Worst Performer Among Sensitivity Measures MOI: Outperformed by CSS and CRI
Acebes et al., 2020	SSI: Relatively Better Results MOI: Most Representative Metric	CI: Ignores Project Duration Impact
Song et al., 2020		SSI: Values Change Significantly
Raheem et al., 2021	SI: Comprehensive Measure CRI: Assesses Activity Impact SSI: Assesses Activity Impact	
Song et al., 2021	SSI: Useful Sensitivity Information	
Zarghami & Dumrak, 2021	SI: Addresses Activity Significance	CI: Not an Intuitively Helpful Metric SI: Ignores Variation in Time Duration

		SSI: Does not Discriminate Non-Critical Activities
Chen et al., 2023	CI: Reliable Risk Identification	
Saffirio, 2023	CI: Directly Assesses Activity Criticality SI: Partial Answer to CI Criticism CRI: Relatively Better Results SSI: Relatively Better Results CSSI: Improves SSI and MOI	CI: Ignores Project Duration Impact SI: Counter-Intuitive Results MOI: Absence of SSI in Evaluation
Vaseghi & Vanhoucke, 2023	CI: Merges Impact of Uncertainty and Probability SI: Performs Well for Parallel Networks CRI: Relatively Better Results SSI: Relatively Better Results MOI: Top-Performing Metric CSSI: Performs Well for Parallel Networks	CI: Low Performance for Serial Projects SI: Low Performance for Serial Projects CRI: Focuses on Linear Relationship CSSI: Performance Drops for Serial Projects

3. DISCUSSION

Evaluating time-sensitivity indices is crucial for assessing their practical applicability in project scheduling and risk management. Each of the six indices discussed in this study has unique strengths and weaknesses, affecting their effectiveness across different project scenarios. A comparative framework is essential to assess these indices based on predefined criteria, including ease of implementation, computational complexity, and result interpretability. While indices like CI and SI offer straightforward assessments, others, such as CRI and CSS, incorporate advanced probabilistic elements, enhancing accuracy but increasing computational demands (Bowman, 2003; Hu et al., 2016). Some indices prioritize network topology and risk variability (Vanhoucke, 2011), while others emphasize deterministic factors (Elshaer, 2013). This study provides insights into their relative effectiveness and practical considerations, guiding project managers in selecting the most suitable index based on project characteristics and available resources.

3.1 Ease of Implementation

The ease of implementing time-sensitivity measures varies significantly based on computational complexity, integration feasibility, and practical applicability. The Criticality Index (CI) is widely adopted due to its straightforward computation and seamless integration into project management tools, offering a probabilistic yet computationally efficient approach to sensitivity analysis (Dodin & Elmaghraby, 1985; Vanhoucke, 2015). However, its reliance on probability alone limits its effectiveness, prompting the development of indices that incorporate impact magnitude (Vanhoucke, 2010; Brožová et al., 2016). The Significance Index (SI) enhances CI by factoring in both criticality and impact, making it particularly effective in parallel networks (Creemers et al., 2014a; Vaseghi & Vanhoucke, 2023). Despite its theoretical advantages, SI requires an understanding of advanced probabilistic concepts and sometimes yields counterintuitive results, reducing its practical usability (Vanhoucke, 2016; Raheem, 2021; Saffiro, 2023).
Similarly, the Cruciality Index (CRI) provides a more dynamic assessment by accounting for stochastic dependencies, making it valuable in resource-constrained environments (Elmaghraby, 2000; Hu et al., 2016). Additionally, it reflects task importance within a project (Paternella, 2016). However, its reliance on Monte Carlo simulations increases computational demands, limiting accessibility for organizations without advanced simulation capabilities (Cho & Yum, 1997; Williams, 1992). The Schedule Sensitivity Index (SSI) excels in risk analysis by effectively identifying activities most sensitive to project delays (Vanhoucke, 2011; Acebes et al., 2020). However, its dependence on iterative Monte Carlo simulations makes implementation complex, requiring frequent recalculations that may be impractical for smaller projects (Raheem et al., 2021; Song et al., 2021).

The Management-Oriented Index (MOI) enhances project monitoring by integrating activity variability, network topology, and risk evolution, outperforming CI and SI in large-scale projects (Acebes et al., 2020; Madadi & Iranmanesh, 2012). However, its reliance on advanced variability reduction strategies necessitates specialized expertise, limiting widespread adoption (Saffiro, 2023). The Criticality-Slack

Sensitivity Index (CSSI) improves upon existing indices by incorporating activity float variations under stochastic and deterministic conditions, making it highly effective in complex, multi-path networks (Ballesteros-Pérez et al., 2019; Vaseghi & Vanhoucke, 2023). However, its effectiveness declines in sequential project structures, and its static nature may require supplementary methodologies for continuous project monitoring (Saffiro, 2023).

Ultimately, while CI and SI offer computational simplicity, their limitations necessitate careful consideration in dynamic environments. CRI and SSI provide greater predictive accuracy but demand substantial computational resources, whereas MOI and CSSI introduce advanced methodologies that enhance risk assessment but require specialized expertise. Selecting an appropriate sensitivity measure depends on project complexity, available analytical resources, and adaptability needs. Future research should explore hybrid models that integrate these indices' strengths to enhance their applicability across diverse project scenarios.

3.2 Computational Requirement

The computational requirements of time-sensitivity measures significantly impact their practicality in project management. The Criticality Index (CI) is computationally efficient, relying on probability-based estimation rather than extensive simulations, making it ideal for rapid sensitivity analysis in large-scale projects (Dodin & Elmaghraby, 1985). However, its simplicity limits adaptability to dynamic conditions and interdependencies, reducing its effectiveness in real-time project control (Rabbani et al., 2007; Tang, 2023). The Significance Index (SI), while improving sensitivity measurement, has high computational demands due to its enumeration of all possible network realizations, making real-time application impractical (Elmaghraby, 2000; Cui et al., 2006). Additionally, SI struggles to differentiate activity impacts effectively, reducing its ranking utility (Zarghami & Dumrak, 2021).

The Cruciality Index (CRI) further amplifies computational intensity by requiring Monte Carlo simulations to assess correlations between activity durations and project completion, making it unsuitable for large-scale applications (Elmaghraby, 2000; Demeulemeester et al., 2002). While alternative correlation-based formulations enhance accuracy, they also impose greater computational burdens (Madadi & Iranmanesh, 2012). The Schedule Sensitivity Index (SSI) provides high accuracy in identifying sensitive activities through iterative Monte Carlo simulations, but its computational intensity limits feasibility in resource-constrained projects (Song et al., 2020; Saffiro, 2023). Similarly, the Management-Oriented Index (MOI) balances precision and complexity by integrating network topology and expected float values but remains computationally demanding, particularly in large-scale projects (Madadi & Iranmanesh, 2012; Saffiro, 2023).

In contrast, the Criticality-Slack Sensitivity Index (CSSI) offers computational efficiency by incorporating float variations, making it suitable for static applications. However, iterative recalculations enhance its predictive accuracy at the cost of increased complexity (Ballesteros-Pérez et al., 2019; Acebes et al., 2020). Ultimately, CI and CSSI provide efficiency but limited adaptability, whereas SSI and MOI offer greater precision with higher computational costs. Selecting an appropriate sensitivity index depends on project complexity, available computational resources, and the need for real-time monitoring. Future research should explore optimization techniques, including hybrid models and algorithmic refinements, to improve computational feasibility across diverse project environments (Vaseghi & Vanhoucke, 2023; Saffiro, 2023).

3.3 Clarity and Practicality

The clarity and practicality of sensitivity indices in project scheduling depend on their ability to provide meaningful and actionable insights while accounting for project network complexities. The Criticality Index (CI) is widely used due to its intuitive probabilistic nature, enabling project managers to assess schedule risks effectively (Bowman, 2003). By identifying activities with higher CI values, managers can prioritize risk mitigation and resource allocation (Cho & Yum, 1997; Creemers et al., 2014a). However, CI focuses solely on probability, which does not always correlate with an activity's impact on project duration (Acebes et al., 2020). This limitation becomes evident when short-duration activities with high CI values exert minimal influence on the total project timeline (Vanhoucke, 2010). Additionally, CI-based metrics struggle in serial network structures and do not account for resource constraints, necessitating alternatives like the Resource Criticality Index (RCI) (Vaseghi & Vanhoucke, 2023; Song et al., 2021).

The Significance Index (SI) refines activity importance assessment but often produces inconsistent rankings, especially in serial networks, limiting its decision-making value (Vanhoucke, 2015; Vaseghi & Vanhoucke, 2023). Its inability to reflect stochastic variations further undermines reliability (Creemers et al., 2014b; Cui et al., 2006).

Similarly, the Cruciality Index (CRI) quantifies activity impact on project duration but relies on linear correlation, which may misrepresent risks in complex projects (Raheem et al., 2021; Creemers et al., 2014b). Compared to the more adaptive Schedule Sensitivity Index (SSI), CRI's static nature reduces its effectiveness in dynamic environments (Ballesteros-Pérez et al., 2019).

The SSI is recognized for its superior ability to rank activity sensitivity, enhancing project control by providing proactive risk assessments (Vanhoucke, 2015; Ballesteros-Pérez et al., 2019). However, its inability to account for covariance between activity duration and project completion may introduce estimation errors (Creemers et al., 2014b; Zarghami & Dumrak, 2021).

The Management-Oriented Index (MOI) improves decision-making by integrating risk evolution and network topology, yet its lack of real-time adaptability limits broader applicability (Acebes et al., 2020; Vaseghi & Vanhoucke, 2023; Madadi & Iranmanesh, 2012).

Lastly, the Criticality-Slack Sensitivity Index (CSSI) enhances sensitivity analysis by incorporating float and duration variability, strengthening its predictive capabilities in parallel networks (Acebes et al., 2020; Vaseghi & Vanhoucke, 2023). However, its effectiveness in serial networks remains uncertain, and its static nature restricts long-term applicability (Martens & Vanhoucke, 2019; Song et al., 2021).

Overall, while each index has strengths, no single metric fully captures project sensitivity across all network conditions. A combined approach integrating multiple indices is recommended to enhance decision-making accuracy and risk assessment, with future research focusing on improving adaptability in dynamic project environments (Saffiro, 2023).

4. FUTURE WORK

While current sensitivity indices offer valuable insights, they are all activity-based and often address isolated aspects of project risk. Future research should focus on developing a comprehensive index that integrates the strengths of existing models while mitigating their individual limitations. Such an index would enhance real-time applicability, optimize computational efficiency, and better support decision-making in dynamic construction environments. Moreover, there is a growing need to move beyond activity-level analysis and consider the overall performance of the project schedule. To that end, it would be beneficial to establish a new metric capable of evaluating schedule performance holistically—allowing for meaningful comparisons across projects of similar type and complexity. This dual focus on comprehensive integration and project-level assessment holds promise for advancing risk-aware construction scheduling practices.

5. CONCLUSIONS

This study evaluated six time-sensitivity indices—CI, CRI, SI, SSI, MOI, and CSSI—assessing their implementation ease, computational demands, and clarity in project scheduling. Findings reveal that while CI and SI offer computational efficiency, they lack predictive accuracy in complex networks. CRI and SSI enhance sensitivity analysis through probabilistic modeling but impose high computational costs, limiting large-scale applicability. MOI and CSSI improve risk assessment but require specialized expertise, restricting their adoption. No single index fully captures project sensitivity across diverse conditions, necessitating a hybrid approach that integrates multiple indices to balance accuracy, feasibility, and adaptability. Future research should refine these models to enhance real-time applicability, optimize computational efficiency, and support dynamic project environments, ultimately improving risk assessment and decision-making in construction scheduling.

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