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Letters

# An innovative hybrid architecture to overcome misreporting in supply chain coordination under information asymmetry

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A B S T R A C T

In the modern supply chain landscape, achieving effective coordination is challenging due to information asymmetry and misreporting behaviour. This paper proposes a hybrid architecture combining centralised data management through an Intelligent Mediator with decentralised decision-making. The architecture allows actors to maintain autonomy while promoting truthful information sharing via credibility scoring. By dynamically adjusting for data reliability and aligning individual objectives with overall supply chain goals, the system reduces misinformation impact and builds trust among actors. This framework provides a proactive solution through adaptive feedback loops, fostering stability in complex supply chains.


## 1. Introduction

Effective collaboration is essential to optimise supply chain operations [1–3], but is often hindered by information asymmetry [4,5]. This imbalance promotes misreporting, where actors intentionally distort data—such as underreporting demand or claiming limited capacity—to gain competitive advantages [6,7]. Consequently, such opportunistic behaviour undermines trust and reduces overall supply chain efficiency [8].

Several studies in the literature have proposed coordination mechanisms to improve supply chain performance under information asymmetry. Contract-based approaches and joint decision models typically align incentives through transfer payments, buy-back clauses, or revenue-sharing schemes, and react to opportunistic behaviour by adjusting contractual terms over periods [4,9,6,8]. In most of these works, misreporting is either embedded in parametric uncertainty or addressed ex post through penalties and contract updates, so that distorted reports still influence the operational plan in the period in which they are submitted. Parallel research on trust and digital supply chains shows that trust, reputation, and data sharing are crucial enablers of coordination, and that technologies such as blockchain can improve the integrity and traceability of records, but these contributions generally do not act on the reliability of data at the time of entry into the system [1–3,10].

In contrast, this work does not propose a new coordination mechanism but introduces an innovative hybrid architecture that adds a credibility-based governance layer on top of existing infrastructures. To this end, the system features a self-regulating loop designed to: (i) monitor and mitigate misreporting within the same decision cycle; (ii) translate reliability into an endogenous credibility score that modulates actor influence; and (iii) guide competitive tendencies into a framework where truthful reporting becomes a strategic asset. By making data reliability a prerequisite for gaining bargaining power, this approach enhances operational coordination and boosts overall supply chain efficiency, rather than relying solely on ex post penalties.

## 2. The proposed hybrid architecture

The proposed hybrid architecture for supply chain coordination, illustrated in Fig. 1, integrates centralised data governance with decentralised decision-making. It operates on two distinct levels: the *Intelligent Mediator* (IM), which acts as a credibility-based governance layer, and the *Supply Chain Actors*, who retain operational autonomy. The core innovation lies in a self-regulating loop designed to endogenously modulate the information structure based on actor reliability, as detailed in the following components. The key logical components of the IM are as follows.

- **Data Nexus** (DN): The Data Nexus (DN) acts as a secure, unified repository that consolidates and manages data inputs from all supply chain actors. Operating on blockchain principles, it

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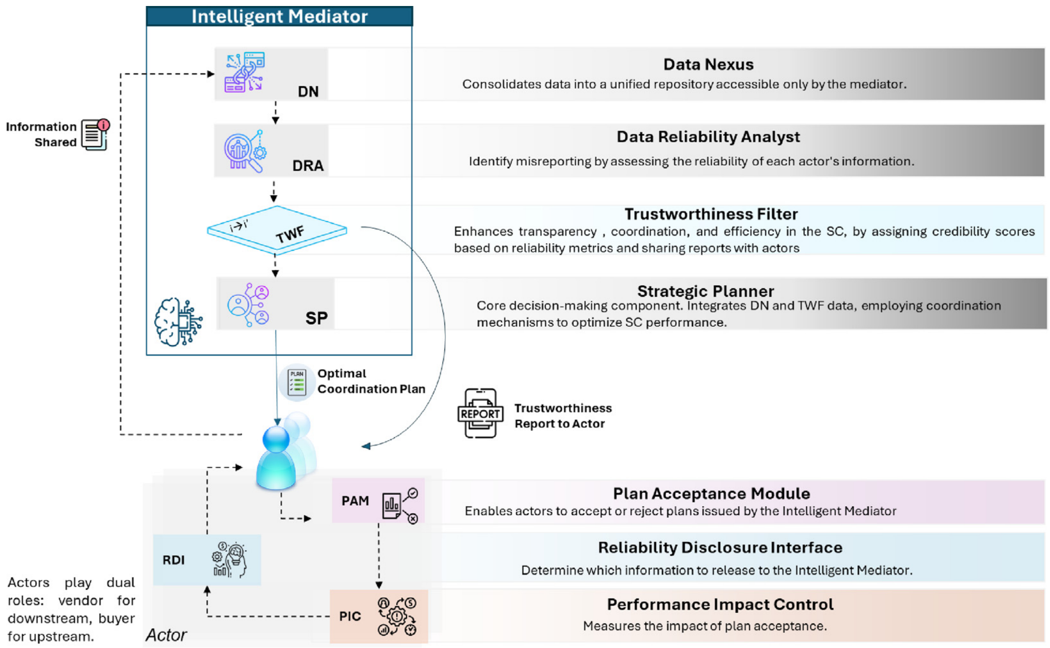


**Fig. 1.** Architectural framework of the IM showing core components and their interaction patterns with supply chain actors.

maintains an immutable record of all transactions, with data encrypted using the Mediator's public key to ensure confidentiality and integrity in data management [10].

- **Data Reliability Analyst** (DRA): The DRA implements analytical models to detect and assess potential misreporting behaviours. Processes data stored in the DN, evaluating the reliability of information ($R_t(i)$) at time $t$ by mapping the input $i_t$ to a continuous reliability score within the range $\{0, 1\}$ using a comparative analysis function $r(i_t)$ against historical patterns [11].
- **Trustworthiness Filter** (TWF): This component represents the architecture's primary innovation. Instead of treating information as a static input, the TWF implements a Credibility and Influence Feedback Loop (Fig. 2) that transforms raw reports into effective and credibility-adjusted inputs for coordination.

– *Credibility Building* ([B],[D]): Reliable reporting boosts credibility, directly enhancing the actor's influence on the strategic decision.

– *Strategic Deviation Management* ([A]): To prevent overreacting to isolated anomalies, the system allows occasional deviations from highly credible actors to influence the plan with minimal adjustment, preserving cooperative efficiency.

– *Dynamic Adjustment Mechanism* ([C]): The TWF implements an adaptive distortion factor based on historical credibility. First, the system updates the credibility score $C_t$ as a moving average of verified reliability $R_k$ over an observation window $L$, filtering short-term noise:

$$C_{t+1} = \frac{\sum_{k=t-L+1}^{t} R_k}{L}$$

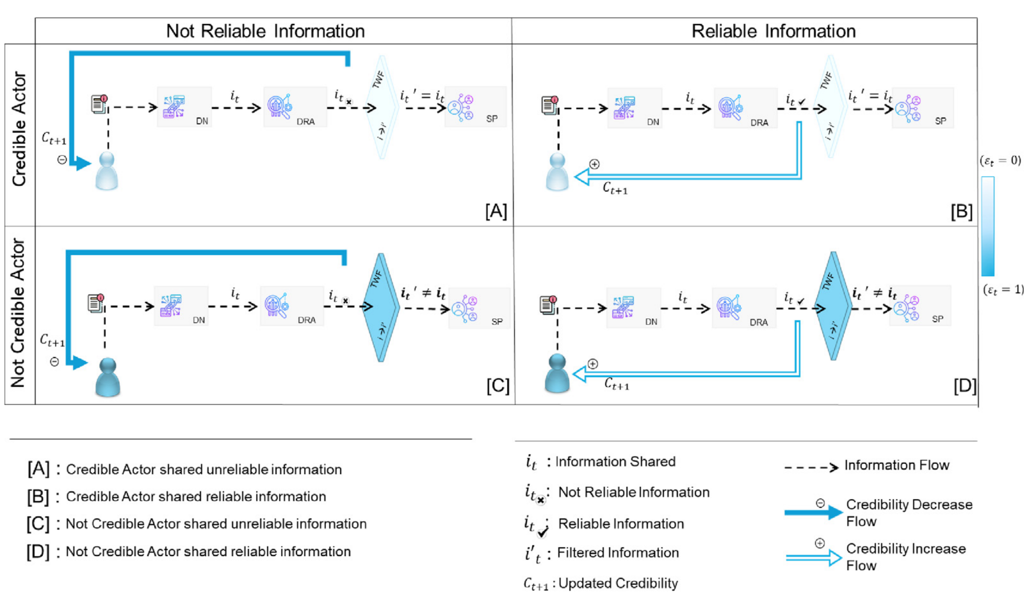


**Fig. 2.** Credibility and Influence Feedback Loop: mechanism for dynamic trust assessment and information adjustment.

This score drives a monotonic distortion factor $\varepsilon_t(C_t) \in [0, 1]$, calculated as:

$$\varepsilon_t(C_t) = \frac{e^{-\alpha C_t} - e^{-\alpha}}{1 - e^{-\alpha}}$$

where $\alpha > 0$ tunes the system's sensitivity (Fig. 3). This mapping ensures that highly credible actors ($C_t \approx 1$) encounter minimal distortion ($\varepsilon_t \approx 0$), while low credibility ($C_t \approx 0$) triggers maximum distortion. The factor is then applied to transform raw reports $i_t$ into credibility-adjusted inputs $\tilde{i}_t = f(i_t, \varepsilon_t)$ (e.g., by scaling or bias correction), which directly feed the coordination step.

This mechanism treats $C_t$ as an internal measurement rather than relying on an external rating. Unlike traditional models that depend on penalties applied after the fact, credibility is updated within the same decision-making cycle. This enables the system to leverage "trust capital": reliable behaviour immediately minimises input adjustment, directly shaping the effective data seen by the Strategic Planner.

- **Strategic Planner** (SP): As the central decision-making authority, the SP computes a coordinated plan using the credibility-adjusted inputs $\tilde{i}_t$ provided by the TWF. It employs standard (or new generation) coordination mechanisms (e.g., joint lot-sizing, pricing rules) directly on these pre-processed data. Crucially, because the inputs already embed the credibility assessment, the planner automatically shifts between aggressive optimisation (for high credibility) and cautious conservatism (for low credibility) without requiring modifications to the underlying algorithms. This design preserves compatibility with existing supply chain literature while endogenously linking behavioural reliability to the effective data used for coordination.

The IM releases two primary outputs:

- *Optimal coordination plan*: generated by the SP, providing actor-specific negotiation variables aligned with the overall supply chain strategy.
- *Trustworthiness Report*: actor-specific credibility assessments, encrypted with individual public keys to ensure confidentiality.

Within individual actors, three key logical components enable autonomous decision-making while maintaining system coordination:

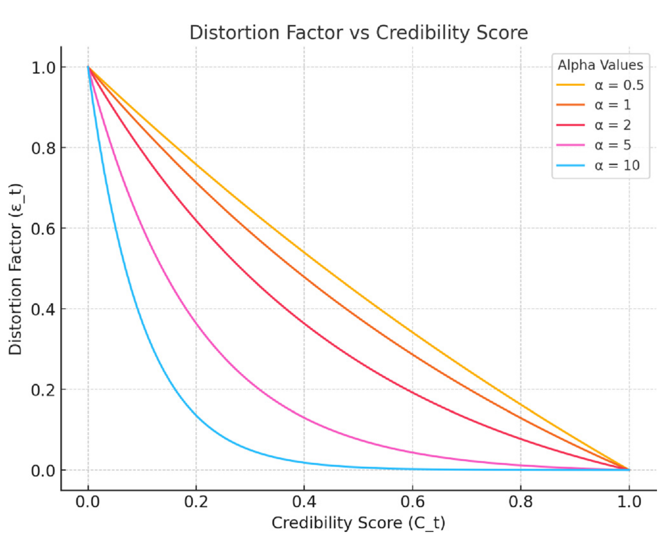


**Fig. 3.** Dependence of the distortion factor $\varepsilon_t$ on credibility $C_t$ for varying sensitivity parameter $\alpha$.

- **Plan Acceptance Module** (PAM): The PAM embodies the decentralised decision-making capability of the architecture, allowing actors to accept or reject the optimal coordination plan. Rejection triggers specific penalties:
  - Credibility Penalty: plan rejection triggers an automatic credibility reduction, as the IM processes it as misreported information in subsequent assessments.
  - Economic Penalty: a financial penalty proportional to the plan's scope. This penalty reflects the impact of rejections on overall coordination efforts.
- **Performance Impact Controller** (PIC): the PIC processes operational outcomes against implemented decisions, generating performance metrics for strategic evaluation. This component integrates established control elements from hybrid manufacturing architectures, such as the KERP mechanism from the Semi-Heterarchical framework in [12].
- **Reliability Disclosure Interface** (RDI): the RDI manages the strategic information disclosure process, allowing actors to calibrate data sharing based on credibility standings and performance impacts. Operating at the intersection of TWF reports and PIC assessments, actors can optimise their strategic position while feeding into the Credibility and Influence Feedback Loop.

This hybrid architecture balances centralised oversight with actor autonomy through the IM's credibility-based coordination mechanism. By incentivising reliable information sharing through direct influence on strategic decisions, the system naturally reduces information asymmetry and strengthens overall supply chain coordination effectiveness.

## 3. Dynamic behaviour of the system

Fig. 4 illustrates the dynamic behaviour of the system through a vendor–buyer interaction model, demonstrating how the architecture stabilises influence dynamics through its credibility loop. During normal operations, when both actors maintain consistent information reliability, the system reinforces their credibility scores and strategic influence, establishing a stable coordination pattern that optimises resource allocation across the supply chain.

The architecture's adaptive capabilities become evident when faced with speculative misreporting behaviour. When a previously credible actor introduces misleading information, the system exhibits a controlled response. Initially, due to the actor's established credibility, the system processes the misreported information with minimal distortion. However, this creates a short-term vulnerability window (as depicted in Fig. 4), during which the system's trust mechanism is temporarily exploited. As the architecture identifies this deviation, it triggers a rapid adjustment of the actor's credibility score, leading to an increase in the distortion factor. This feature ensures that continued misreporting leads to increasingly adjustments, as the system progressively amplifies the filtering applied to the actor's inputs. Depending on the sharpness of $\varepsilon_t(C_t)$, this response creates a strong incentive for the actor to return to truthful reporting, effectively stabilising the system through the self-correcting feedback loop. In this way, the Strategic Planner operates on credibility-adjusted inputs and, when an actor's credibility declines, it naturally shifts the coordinated plan that jointly optimises decisions for all $n$ actors towards more conservative choices with respect to that particular actor (for example, by increasing safety margins or reducing the dependence on its declarations).

In conclusion, the proposed architecture, through its adaptive credibility mechanisms, stabilizes the system, which consequently leads to a reduction in variability. This reduced variability enhances overall efficiency and ensures consistent coordination,

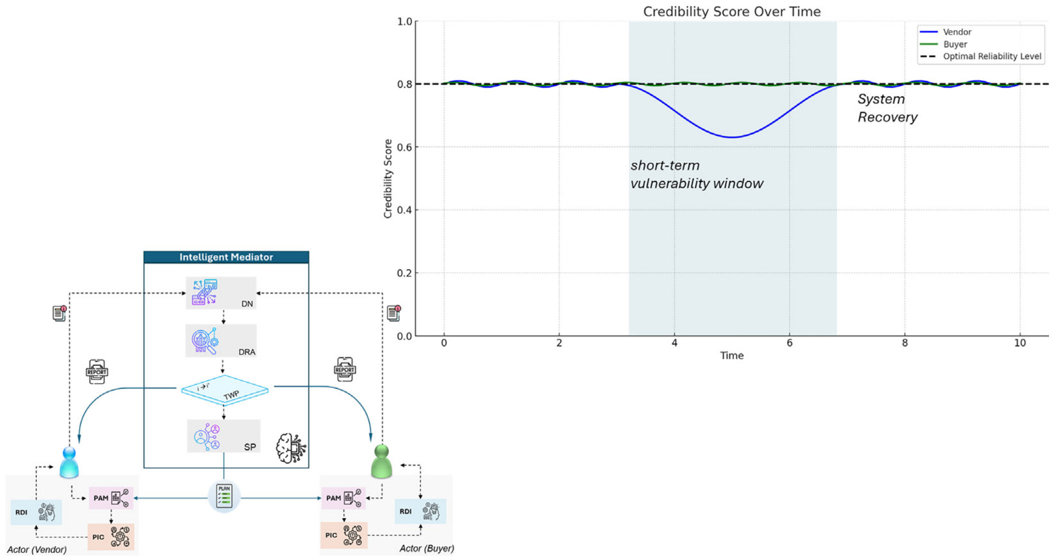


**Fig. 4.** Dynamic interaction patterns and stability mechanisms in the hybrid architecture.

enabling the supply chain to sustain high performance in complex operational environments.

## 4. Conclusions

This paper presents a hybrid architecture designed to enhance supply chain coordination under information asymmetry, leveraging dynamic credibility assessment and adaptive feedback mechanisms. The proposed framework systematically aligns competitive behaviors with coordinated decision-making, while preserving actor autonomy. While the architecture offers scalability across diverse supply chains, further refinements are needed to enhance the robustness of data processing and reliability assessment. As the current landscape continues to evolve, advancing credibility assessment methods will be crucial to ensuring adaptability, stability, and sustained efficiency. This is particularly important as supply chains become more digitalised and reliant on data.

## 5. Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used the Generative AI tool to proofread the manuscript. After using this tool/service, the authors reviewed and edited the content as needed and assume full responsibility for the content of the publication.

## CRediT authorship contribution statement

**Emma Salatiello**: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Silvestro Vespoli**: Writing – review & editing, Supervision, Conceptualization.**Andrea Grassi**: Writing – review & editing, Supervision.**Guido Guizzi**: Supervision.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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