



## METHODOLOGY FOR DIGITAL MONITORING AND COORDINATION OF SUPPLY CHAIN PARTICIPANTS BASED ON INFORMATION AND COMMUNICATION TECHNOLOGIES

<https://doi.org/10.5281/zenodo.21208570>

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**Abstract:** *Digital monitoring and coordination have become a unified managerial contour in contemporary supply chain management, linking data capture, integration, analytics, decision-making, execution, and feedback. The purpose of this article is to develop a methodological framework for digital monitoring and coordination of supply chain participants based on information and communication technologies. The study is based on the systematization of recent literature on supply chain visibility, information integration, cloud analytics, data management, and digital twins, as well as on the analytical synthesis of ICT instruments, performance indicators, barriers, and implementation stages. The results show that digital monitoring creates visibility, while coordination transforms visibility into synchronized action. ICT perform at least five core functions in this process: event capture, data integration, reduction of information asymmetry, synchronization of decisions, and transition from reactive to proactive management. The article identifies a toolkit that includes IoT, GPS and telematics, RFID, ERP, WMS, TMS, cloud platforms, dashboards, and digital twins. A methodological framework is proposed that includes diagnosis of the supply chain, selection of monitoring objects, design of a five-layer ICT architecture, data governance, KPI design, control tower configuration, exception management, predictive analytics, and continuous improvement. The findings indicate that the effectiveness of digital monitoring depends not on the isolated presence of technologies, but on the ability to integrate participant data, standardize events and KPI, ensure shared visibility and trust, and translate monitoring signals into coordinated decisions.*

**Keywords:** *digital monitoring, supply chain coordination, ICT, supply chain visibility, IoT, ERP, WMS, TMS, control tower, digital twin*



## INTRODUCTION

Digital monitoring of the supply chain can be defined as continuous observation of material, informational, and related financial flows on the basis of digital data originating from corporate systems, sensors, telematics devices, and external platforms. Digital coordination is the alignment of decisions and actions among supply chain participants on the basis of shared, timely, and interpretable information. In current research, monitoring and coordination are not treated as separate functions, but as a single contour: data collection, integration, analytics, managerial decision, execution, and feedback [Ahmed et al., 2021; Abourokbah et al., 2026; Stefanović et al., 2025]. The central analytical premise is that digital monitoring creates visibility, whereas coordination converts visibility into synchronized action. Monitoring answers the question of what is happening in the chain, while coordination answers who should react, when, and how. This distinction is essential for understanding the shift from fragmented information management toward end-to-end digital supply chain control. The literature emphasizes that information and communication technologies play a decisive role in event registration, data integration, reduction of information asymmetry, synchronization of decisions, and the transition from reactive to proactive management. Through shared dashboards, alerts, workflow rules, and control tower logic, ICT make it possible

to replan deliveries, reassign transport, redistribute inventory, and accelerate shipments. Advanced forms of this logic appear in digital twins and predictive analytics [Liu, Pan, Ballot, 2024].

At the same time, systematic reviews show that the barriers to visibility and coordination are not purely technological. They also include fragmented data environments, lack of interoperability, delayed information, limited trust in data exchange, insufficient standards, high implementation costs, shortage of competences, and data overload [Diniz et al., 2025; Stefanović et al., 2025; Smina et al., 2026]. These constraints make it necessary to move beyond isolated technology adoption and toward a methodological approach that connects monitoring with coordinated action across organizational boundaries. The purpose of this article is to develop a methodology for digital monitoring and coordination of supply chain participants based on information and communication technologies, with particular attention to conceptual foundations, ICT tools, performance indicators, implementation stages, barriers, and adaptation to different types of enterprises and supply chains.

## Methods

The study is based on analytical synthesis of conceptual and methodological literature on supply chain visibility, supply chain information integration, cloud-based analytics, data management in smart manufacturing supply chains, digital twins in logistics



and supply chain management, and ICT-enabled cold chain monitoring [Ahmed et al., 2021; Abourokbah et al., 2026; Diniz et al., 2025; Stefanović et al., 2025; Liu, Pan, Ballot, 2024; Smina et al., 2026; Cil, Abdurahman, Cil, 2022]. Methodologically, the article uses a process-oriented and systems-based perspective. Monitoring and coordination are treated as components of an integrated socio-technical system rather than as isolated IT functions. This perspective makes it possible to connect technological layers, interorganizational rules, data governance, KPI, decision logic, and response mechanisms within a single analytical framework. The research procedure includes four interconnected steps. First, conceptual positions on digital monitoring, coordination, visibility, and information integration are systematized. Second, the core ICT tools used for tracking flows, exchanging data, and synchronizing actions are grouped according to their functional role in the supply chain. Third, the main groups of monitoring and coordination indicators are structured around visibility, order execution, inventory and warehouse management, transport, sourcing and production, and resilience. Fourth, a practical methodology is synthesized from the reviewed approaches, including principles, stages, architecture, governance logic, and adaptation to different organizational contexts. The article does not introduce external empirical data beyond the cited studies and examples. Its results take the form of

a methodological framework grounded in the reviewed sources and organized for direct application in supply chain management.

## Results

1. Digital monitoring and coordination as an integrated managerial contour

The analysis shows that digital monitoring and coordination should be understood as a unified contour rather than as separate managerial functions. In this contour, data are captured from operational events, integrated across systems and participants, processed analytically, translated into managerial decisions, executed operationally, and fed back into the system. This logic corresponds to current approaches to supply chain visibility, information integration, and cloud-based analytics [Ahmed et al., 2021; Abourokbah et al., 2026; Stefanović et al., 2025]. Within this contour, ICT perform at least five functions. First, they register events related to the location, condition, and movement of raw materials, batches, containers, transport units, orders, and returns. Second, they integrate ERP, WMS, TMS, CRM, IoT sensors, external platforms, EDI/API channels, and cloud storage into a unified informational environment [Smina et al., 2026]. Third, they reduce information asymmetry by allowing suppliers, carriers, warehouses, and focal firms to access the same events, thereby lowering transaction costs, coordination errors, and opportunistic behavior [Abourokbah et al., 2026].



Fourth, they synchronize decisions through shared dashboards, alerts, workflow rules, and control towers. Fifth, they support a shift from reactive control to proactive management through forecasting, optimization, and adaptive response, especially in digital twin environments [Liu, Pan, Ballot, 2024].

## 2. ICT toolkit for monitoring and coordination

The reviewed sources make it possible to identify a structured toolkit for digital monitoring and coordination. IoT provides real-time telemetry related to temperature, humidity, vibration, equipment condition, load, and location, and is treated as a key driver of supply chain visibility [Ahmed et al., 2021]. Its practical value lies in monitoring storage and transport conditions, controlling downtime and equipment condition, and enabling early detection of deviations. GPS and telematics ensure continuous tracking of transport and shipments in transit. When integrated with TMS, mapping tools, and ETA analytics, they support route control, arrival-time forecasting, deviation management, and analysis of delays and dwell times. RFID enables automatic identification and tracking of goods, pallets, containers, and returnable packaging without direct line of sight and with greater speed and accuracy than barcode-based approaches. It is especially valuable in warehousing, logistics, cold chains, and traceability applications. ERP serves as the core of transactional truth, covering procurement, orders, production, invoices,

counterparties, and master data. Its integration with RFID and cloud-based solutions improves process efficiency and consistency. WMS supports monitoring and control of warehouse operations such as receiving, put-away, storage, picking, packing, shipping, and inventory counting, while providing real-time inventory visibility, improved inventory accuracy, picking accuracy, labor management, and integration with ERP and TMS. TMS is responsible for planning, execution, and optimization of transport operations; when integrated with warehouse and transport execution, it reduces manual gaps, improves shipment planning accuracy, decreases dock congestion, and shortens order cycle time. Cloud platforms play a critical role in scalability, integration of heterogeneous data, shared access for participants, event processing, alerts, and deployment of BI and ML models [Stefanović et al., 2025]. Dashboards and analytical systems convert data into visible managerial signals through KPI, drill-down analysis, maps, scorecards, alerts, and collaborative workflows. Digital twins extend the logic from monitoring toward scenario modelling, forecasting, optimization, and adaptive management [Liu, Pan, Ballot, 2024]. Taken together, these tools form not a random technological set, but a layered coordination environment in which event capture, transactional processing, integration, analytics, and coordinated response become interdependent components of supply chain control.



### 3. Indicator system for digital monitoring and coordination

The results of the analysis show that indicators should be structured into six groups. The first group covers visibility and data quality: event data completeness, data latency, location and status accuracy, traceability coverage across supply chain stages, share of integrated partners, and master data consistency. These indicators capture the degree to which visibility is technically and informationally achieved. The second group addresses order execution and service performance: OTIF, perfect order rate, order cycle time, fill rate, frequency of order exceptions, and incident closure time. These indicators link monitoring to customer-relevant outcomes and service reliability. The third group concerns inventory and warehouse performance: inventory accuracy, inventory turnover, days of supply, stockout rate, dock-to-stock time, picking accuracy, and return processing time. The fourth group concerns transport and delivery: ETA accuracy, transit time, dwell time, share of route deviations, transport utilization, transport cost per unit, and percentage of damage or losses. The fifth group captures sourcing and production coordination: supplier on-time delivery, lead time and its variability, defect rate, downtime, OEE, and response time to a supply disruption. The sixth group relates to coordination and resilience: time-to-detect, time-to-respond, recovery time, frequency of uncoordinated decisions, SLA compliance in data exchange, and number

of critical events without an owner of response. Broader KPI reviews suggest that current systems are moving from purely operational measurement toward indicators of systemic integration, technological maturity, resilience, and transparency [Sompong et al., 2026].

### 4. Main barriers to visibility and coordination

The reviewed studies show that the main barriers to digital visibility lie not only in technology, but in the organization of interaction among participants [Diniz et al., 2025]. Information asymmetry remains a central problem because different participants possess different volumes and quality of data. This leads to weak trust, delayed decisions, higher transaction costs, and opportunistic behavior. Data delays are another major barrier. When information arrives in batches or manually rather than in real time, ETA errors increase, reactions to disruptions become late, safety stocks grow, and service-related penalties and losses rise. Multi-tier opacity, especially at second- and third-tier supplier levels, creates difficulties in origin control, quality risk management, sustainability control, and traceability. Data silos remain prevalent across ERP, WMS, TMS, local spreadsheets, and partner platforms [Stefanović et al., 2025; Smina et al., 2026]. Additional obstacles include lack of standards and interoperability, divergent formats and identifiers, distrust toward data exchange due to concerns about loss of control, disclosure of sensitive commercial



information, and cybersecurity risks, as well as high costs and shortage of competences, particularly for SMEs. A further problem is data overload, where large telemetry volumes without adequate filtering and prioritization turn visibility into noise rather than managerial value.

## 5. Proposed methodology for digital monitoring and coordination

The proposed methodology is built on several principles: end-to-end visibility rather than local automation; an event-based model rather than only periodic reporting; a unified data and KPI dictionary for all participants; management by exception; combination of technology and interorganizational rules; scalability and adaptation to enterprise type; and direct linkage between monitoring and coordination rather than visualization alone. The methodology includes nine stages. The first stage is diagnosis of the supply chain, including the identification of chain structure, critical nodes, blind spots, supplier levels, and problematic processes such as procurement, warehousing, transport, returns, or cold logistics. The output is a process map and a risk map. The second stage is selection of monitoring objects. For each supply chain stage, it is necessary to define what is monitored, where control points are located, which events are critical, who owns the data, and who owns the response. Typical objects include orders, batches, pallets, containers, vehicles, warehouse cells, temperature regimes, and carrier SLA. The third stage is design

of ICT architecture. A five-layer architecture is recommended: a data capture layer including IoT, GPS, RFID, barcodes, PLC/MES, and mobile terminals; a transactional systems layer including ERP, WMS, TMS, SRM, and CRM; an integration layer including API, EDI, event bus, data lake, MDM, and cloud platform; an analytics layer including BI, dashboards, alerts, ML, ETA, disruption forecasting, and digital twins; and a coordination layer including control tower, workflow, partner portal, SLA, and escalation rules. This structure is consistent with cloud-based and multilevel analytics models for supply chain management [Stefanović et al., 2025; Smina et al., 2026]. The fourth stage is data standardization and governance. This requires unified reference data, master data management, data quality rules, roles of data owner and process owner, and regulations for access, security, and SLA in data exchange. Without these elements, visibility remains fragmented [Diniz et al., 2025]. The fifth stage is development of the KPI system. Indicators should be process-linked, automatically measurable, comparable across participants, and useful for decisions rather than only for reporting. A practically useful design is a three-level KPI structure combining operational KPI, coordination KPI, and risk KPI.

The sixth stage is configuration of dashboards and alert regimes. The control tower should display the status of orders and deliveries, bottlenecks, deviations in ETA, inventory, temperature, and quality,



the responsible participant, and the recommended action. In this sense, the dashboard should function not as a showcase, but as a coordination interface. The seventh stage is organization of management by exception. For each critical event, a threshold, reaction time, responsible party, escalation route, and decision type should be defined. An example is an ETA deviation greater than six hours, which triggers automatic notification of warehouse and customer, replanning of unloading slots, and a search for alternative transport or inventory reallocation. The eighth stage is predictive and prescriptive analytics. At a more mature level, the system should support delay forecasting, out-of-stock forecasting, predictive maintenance, route optimization, and digital twin scenarios [Liu, Pan, Ballot, 2024]. The ninth stage is continuous improvement and maturity assessment, focusing on completeness of digital coverage, share of automatic decisions, reduction in response time, economic effect, and maturity of partner integration.

## 6. Adaptation and practical application

The methodology can be adapted to different enterprise types and supply chains. For SMEs, implementation should begin with 10–15 basic KPI, cloud SaaS platforms, and phased integration of ERP with light WMS/TMS and BI, without starting from a complex digital twin. For large distributed chains, priority should be given to event-driven architecture, partner portals or control towers, use of

ML and digital twins, and formalized SLA for intercompany data exchange. For manufacturing chains, the methodology should strengthen the MES, IoT, quality, and downtime contour and connect procurement, production, warehousing, and transport while monitoring supplier quality and production continuity. For e-commerce and retail, OTIF, fill rate, inventory accuracy, and last-mile visibility become priority indicators, and integration between WMS and TMS is particularly important. For cold and regulated chains, environmental sensors, traceability logs, alerts, and compliance records are essential, and integration of RFID, IoT, cloud, and BI is especially useful [Cil, Abdurahman, Cil, 2022]. The expected effects of implementation include reduced delays and response times, lower safety stocks, improved ETA accuracy, higher OTIF and inventory accuracy, reduced share of manual coordination, better traceability and compliance, and increased resilience under disruptions. The typical digital solution set includes ERP as a unified transactional base, WMS for warehouse visibility and execution, TMS for transport and ETA, RFID/GPS/IoT for real-time factual events, a cloud platform for integration and scalability, dashboards or control towers for shared situational awareness and coordination, and analytics, ML, and digital twins for forecasting and optimization.

## Discussion

The results indicate that digital monitoring and coordination should be



conceptualized as an interorganizational socio-technical system rather than as a collection of isolated IT instruments. This interpretation is consistent with the reviewed literature on visibility, information integration, cloud analytics, and digital twins. The effectiveness of the system depends not merely on access to more data, but on the ability to transform common data into faster, more accurate, and less costly coordinated decisions. A key implication concerns the relationship between visibility and action. Visibility by itself does not resolve delays, disruptions, or fragmentation unless the chain possesses common rules of interpretation, ownership of reaction, escalation logic, and coordination mechanisms. For that reason, the proposed methodology places equal emphasis on architecture and governance, on data capture and process ownership, and on dashboards and workflow-based reaction. Another important implication is that the barriers to effective monitoring are strongly organizational and interorganizational. Information asymmetry, distrust in data exchange, lack of interoperability, and data silos undermine the very conditions under which visibility can become useful. This means that successful digital monitoring requires unified reference data, master data governance, clearly assigned owners of data and response, and agreed service-level rules for exchange and escalation [Diniz et al., 2025; Stefanović et al., 2025; Smina et al., 2026].

The staged structure of the methodology also suggests that digital maturity in monitoring and coordination develops progressively. Enterprises typically move from diagnosis and visibility gaps toward architecture design, then to rule-based exception management, and later to predictive and prescriptive analytics. In this sequence, digital twins represent a mature capability that extends monitoring into scenario modelling and adaptive management rather than a starting technology [Liu, Pan, Ballot, 2024]. Finally, the differentiated adaptation of the methodology shows that the same conceptual framework can be applied across SMEs, large distributed chains, manufacturing systems, e-commerce, retail, and cold or regulated chains, but with different technological depth, KPI range, and coordination complexity. This supports the conclusion that scalability and contextual adaptation are not optional features but core methodological requirements.

## Conclusion

Digital monitoring and coordination of supply chain participants should be understood as a unified managerial contour that connects data collection, integration, analytics, decision-making, execution, and feedback. Within this contour, digital monitoring creates visibility, while coordination transforms visibility into synchronized action. The study shows that ICT perform five core functions in this process: event capture, data integration, reduction of information



asymmetry, synchronization of decisions, and transition from reactive to proactive management. The practical toolkit of such a system includes IoT, GPS and telematics, RFID, ERP, WMS, TMS, cloud platforms, dashboards, and digital twins. The proposed methodology is based on end-to-end visibility, event-driven logic, unified data and KPI standards, management by exception, and the combination of technologies with interorganizational rules. Its implementation proceeds through diagnosis of the chain, selection of monitoring objects, five-layer architecture design, data governance, KPI formation, control tower and alert configuration,

exception management, predictive analytics, and continuous improvement. The main conclusion is that the effectiveness of digital monitoring and coordination is determined not by the isolated presence of technologies, but by the capacity to integrate data from key stages of the chain, standardize events and indicators, ensure shared visibility and trust, and rapidly convert monitoring signals into coordinated action. A mature system is therefore built not around the question of how to collect more data, but around how shared data can support faster, more precise, and less costly decisions across the supply chain.

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