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DIGITAL INTEGRATION IN LOGISTICS MATURITY RESEARCH: A SYSTEMATIC LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

INTEGRAÇÃO DIGITAL NA PESQUISA SOBRE MATURIDADE LOGÍSTICA: UMA REVISÃO SISTEMÁTICA DA LITERATURA E UM FRAMEWORK CONCEITUAL

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ABSTRACT: Logistics maturity models assess organizational capabilities and support continuous improvement, but they provide limited consideration of digital integration as a capability connecting systems, processes, data, organizational functions, and supply chain actors. This study examines how digital integration has been incorporated into logistics maturity research. A systematic literature review guided by PRISMA 2020 analyzed 92 studies: 78 identified through Scopus and Web of Science searches covering January 1, 2017 to November 30, 2025, and 14 added through citation searching. Bibliometric analyses identified three substantive streams—supply chain and digital capabilities, Industry 4.0 and manufacturing automation, and data analytics and supply chain performance—and one methodological stream related to quantitative assessment. Qualitative synthesis organized digital integration into four dimensions: technological and systems integration, data and information integration, process integration, and organizational and interorganizational integration. The resulting framework positions logistics maturity as the assessment perspective for examining these dimensions. It provides a conceptual basis for future model development, while the proposed assessment elements and relationships with logistics outcomes require operationalization and empirical validation.

KEYWORDS: Logistics Maturity Models; Digital Integration; Industry 4.0; Supply Chain Management; Digital Transformation.

RESUMO: Os modelos de maturidade logística avaliam capacidades organizacionais e apoiam a melhoria contínua, mas consideram de forma limitada a integração digital como uma capacidade que conecta sistemas, processos, dados, funções organizacionais e atores da cadeia de suprimentos. Este estudo examina como a integração digital foi incorporada à pesquisa sobre maturidade logística. Uma revisão sistemática da literatura orientada pelo PRISMA 2020 analisou 92 estudos: 78 identificados em buscas na Scopus e Web of Science, cobrindo o período de 1º de janeiro de 2017 a 30 de novembro de 2025, e 14 adicionados por busca de citações. As análises bibliométricas identificaram três correntes substantivas — cadeia de suprimentos e capacidades digitais, Indústria 4.0 e automação da manufatura, e análise de dados e desempenho da cadeia de suprimentos — e uma corrente metodológica relacionada à avaliação quantitativa. A síntese qualitativa organizou a integração digital em quatro dimensões: integração tecnológica e de sistemas, integração de dados e informações, integração de processos e integração organizacional e interorganizacional. O framework posiciona a maturidade logística como a perspectiva para avaliar essas dimensões. Os elementos de avaliação e suas relações com resultados logísticos ainda requerem operacionalização e validação empírica.

PALAVRAS CHAVE: Modelos de Maturidade Logística; Integração Digital; Indústria 4.0; Gestão da Cadeia de Suprimentos; Transformação Digital.

1. INTRODUCTION

Industry 4.0 has expanded digitalization from isolated automation to the integration of processes, systems, data, and organizational actors. In logistics and supply chain management, technologies such as the Internet of Things, cloud computing, artificial intelligence, cyber-physical systems, and Big Data analytics support information exchange, visibility, traceability, and coordination (Liao et al., 2017; Dalenogare et al., 2018; Ben-Daya et al., 2019; Frank et al., 2019). Digital integration therefore extends beyond technology adoption and refers to the capability to connect logistics processes, information systems, organizational functions, and supply chain partners.

Logistics maturity models support capability assessment, benchmarking, improvement prioritization, and roadmap development (McCormack et al., 2008; Proença & Borbinha, 2016; Kosacka-Olejnik, 2020). Recent models incorporate digital readiness, Industry 4.0 technologies, process integration, and performance measurement (Facchini et al., 2020; Uhlenkamp et al., 2022; Hrouga & Sbihi, 2023). However, these elements are often represented as separate dimensions or indicators, providing limited understanding of digital integration as a transversal capability.

Previous reviews have examined smart manufacturing maturity models and maturity models in logistics and supply chain management (Mittal et al., 2018; Ferraro et al., 2023; Vance et al., 2023; Machado & Rodriguez, 2025). Although these studies connect digitalization, logistics, and maturity assessment, evidence on connectivity, interoperability, data sharing, process integration, real-time visibility, and interorganizational coordination remains distributed across different research streams. Digital integration has not been sufficiently used as the organizing construct for synthesizing these elements within logistics maturity research. This topic is consistent with studies published in the Iberoamerican Journal of Industrial Engineering concerning integrated governance, logistics systems, productive flexibility, and organizational competitiveness (Dos Santos et al, 2024; Kulka et al., 2026; Ferraz dos Santos et al., 2025).

Accordingly, this study asks: How has digital integration been conceptualized and incorporated into logistics maturity research, and which dimensions, capabilities, and assessment elements emerge from the literature? The study aims to systematically map and synthesize this field and develop a conceptual framework and future research agenda. Specifically, it: (1) characterizes the intellectual and thematic structure of the field; (2) identifies and organizes digital integration dimensions, capabilities, and assessment elements; and (3) synthesizes the findings into a conceptual framework and research agenda. The study provides a conceptual synthesis, not an operational maturity model or empirically validated measurement instrument.

2. LITERATURE REVIEW

This section defines the conceptual relationship between digital integration and logistics maturity used to interpret the findings reported in Section 4. It draws on foundational and representative studies and does not constitute the results of the systematic review.

2.1 DIGITAL INTEGRATION IN LOGISTICS

Digital integration in logistics involves four interrelated areas: technological and systems integration, data and information integration, process integration, and organizational and interorganizational integration. Together, they explain how digital resources become embedded in logistics operations rather than remaining isolated technological applications.

Technological and systems integration concerns the connectivity and interoperability of enterprise systems, logistics platforms, sensors, and analytical applications. Data and information integration addresses data availability, quality, standardization, sharing, real-time visibility, traceability, and analytical use. These two areas provide the infrastructure and information flows required for coordinated logistics decisions (Dalenogare et al., 2018; Ben-Daya et al., 2019; Frank et al., 2019; Garay-Rondero et al., 2020).

Process integration connects procurement, production planning, inventory management, warehousing, transportation, and distribution through synchronized workflows and information exchange. Organizational and interorganizational integration extends this coordination across internal functions and supply chain partners through governance, collaboration, aligned responsibilities, and joint decision-making (Wu et al., 2016; Ho et al., 2019; Nasiri et al., 2020; Queiroz et al., 2021).

These areas are complementary. Connected technologies provide limited value without reliable data; reliable data do not ensure coordinated operations when processes remain fragmented; and integrated internal processes are insufficient when supply chain partners cannot share information or coordinate decisions. Digital integration should therefore be examined as a transversal organizational capability rather than as the adoption of individual technologies.

2.2 LOGISTICS MATURITY MODELS

Maturity models represent organizational development through stages that generally progress from fragmented practices to standardized, integrated, measured, and continuously improved processes. They support capability assessment, benchmarking, improvement prioritization, and roadmap development (McCormack et al., 2008; Proença & Borbinha, 2016).

In logistics and supply chain management, maturity models assess different combinations of processes, technologies, organizational practices, performance measures, and relationships with supply chain partners. Recent models have expanded traditional process-oriented approaches by incorporating digital readiness, Industry 4.0 technologies, interoperability, automation, data availability, and real-time monitoring (Werner-Lewandowska & Kosacka-Olejnik, 2019; Facchini et al., 2020; Uhlenkamp et al., 2022).

Maturity assessment involves three related elements. Dimensions define the broad areas being assessed; capabilities describe what an organization should be able to perform; and assessment elements translate these capabilities into observable practices or criteria. However, the inclusion of a technology dimension does not necessarily mean that a model assesses digital integration. A model may record the adoption of IoT, cloud computing, digital twins, or analytical tools without examining whether these technologies exchange consistent data, connect logistics processes, or enable coordination across organizational boundaries (Facchini et al., 2020; Queiroz et al., 2021).

Digital integration and logistics maturity are therefore complementary concepts. Digital integration identifies the capabilities required to connect technologies, data, processes, and actors, while logistics maturity provides the assessment logic for examining how systematically these capabilities have been developed.

2.3 PREVIOUS STUDIES AND RESEARCH GAP

Previous studies connect digitalization, logistics, and maturity assessment from different perspectives. Some focus on the structure and applicability of maturity models, while others examine technology adoption, digital capabilities, logistics processes, or organizational readiness. Table 1 summarizes representative contributions and the gap remaining relative to the present study.

Table 1 – Comparison of previous studies related to digital integration and logistics maturity

Study	Main contribution	Remaining gap relative to the present study
Mittal et al. (2018)	Reviews Industry 4.0 and smart manufacturing maturity models, emphasizing SME requirements.	Focuses on manufacturing readiness rather than digital integration across logistics processes and partners.
Facchini et al. (2020)	Connects Industry 4.0 technologies, logistics activities, and maturity levels.	Assesses technologies within model dimensions but does not use digital integration as the organizing construct.
Queiroz et al. (2021)	Structures Industry 4.0 and digital supply chain capabilities.	Does not organize these capabilities as assessment elements within a logistics maturity perspective.
Ferraro et al. (2023)	Reviews the scope, design, application, and development of logistics and supply chain maturity models.	Does not systematically synthesize digital integration dimensions and capabilities.
Vance et al. (2023)	Reviews smart manufacturing maturity models and their organizational applicability.	Concentrates on manufacturing contexts rather than logistics and interorganizational coordination.
Machado and Rodriguez (2025)	Reviews Logistics/SCM 4.0 maturity models and opportunities for Industry 4.0 technologies.	Emphasizes model development and technology application rather than digital integration as a transversal capability.

Source: Authors' own elaboration.

These studies demonstrate that Industry 4.0, logistics, and maturity assessment are not separate research domains. The remaining gap concerns how digital integration is conceptualized within their intersection. Evidence on connectivity, interoperability, data sharing, process synchronization, real-time visibility, governance, organizational capabilities, and interorganizational coordination remains distributed across studies using technology adoption, maturity-model design, organizational readiness, or model applicability as their main units of analysis.

The present study addresses this gap by using digital integration as the organizing construct for mapping logistics maturity research and synthesizing its dimensions, capabilities, and potential assessment elements. Based on this synthesis, it develops a conceptual framework and future research agenda without claiming to provide a validated maturity assessment instrument.

Figure 1 summarizes this positioning by distinguishing the established research domains, the remaining gap, and the response provided by the present study.

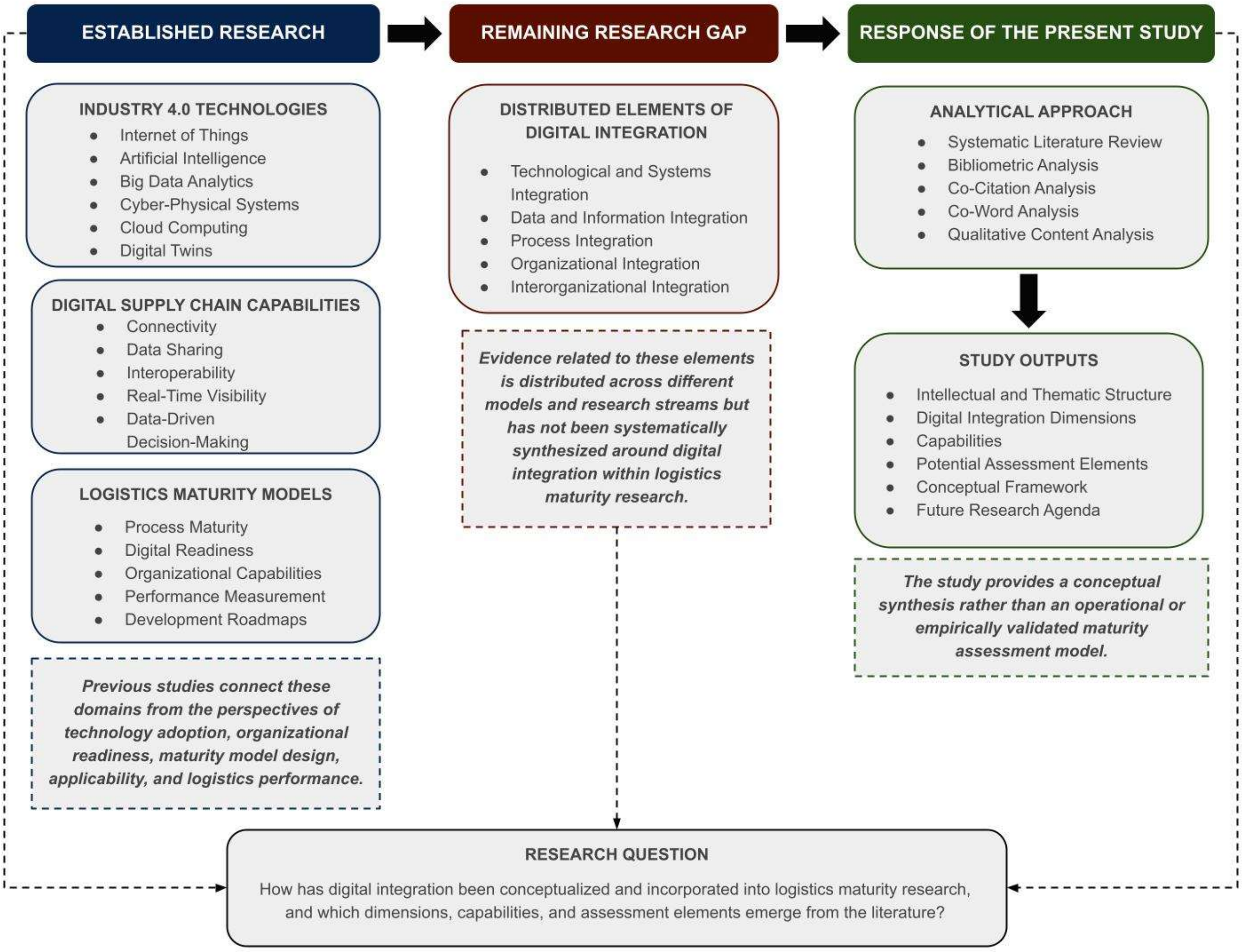


Figure 1 – Conceptual positioning and research gap.
Source: Authors' own elaboration

3. METHODOLOGY

This study combined a systematic literature review, bibliometric analysis, science mapping, and qualitative content analysis to examine how digital integration has been addressed in logistics maturity research. Bibliometric and science-mapping procedures characterized the intellectual and thematic structure of the field, while qualitative content analysis supported the identification of dimensions, capabilities, and potential assessment elements. The results are presented in Section 4.

3.1 RESEARCH DESIGN

The review process and reporting were guided by PRISMA 2020 (Page et al., 2021). The applicable items covered information sources, eligibility criteria, search strategy, record identification, duplicate removal, screening, retrieval, full-text eligibility assessment, reasons for exclusion, and final inclusion.

Because the review did not evaluate interventions, estimate effect sizes, conduct a meta-analysis, or derive study-level causal conclusions, PRISMA items concerning effect measures, statistical synthesis, reporting bias, and certainty of quantitative evidence were not applicable. Methodological assessment instead considered eligibility, thematic relevance, transparency of study objectives and methods, and contribution to the concepts examined.

3.2 ELIGIBILITY CRITERIA

Studies were eligible when they: (1) addressed logistics or supply chain management; (2) examined digital integration, digital transformation, digital capabilities, or related Industry 4.0 applications; (3) considered maturity assessment, maturity models, organizational capabilities, or development levels; (4) were peer-reviewed journal research or review articles; (5) were written in English; and (6) were published between January 1, 2017 and November 30, 2025.

Books, chapters, theses, conference papers, editorials, non-English publications, unavailable full texts, and studies without a relevant connection among logistics, digital integration, and maturity or organizational capabilities were excluded. The publication-period criterion applied to the database search. Studies subsequently identified through citation searching were assessed for theoretical relevance but were not restricted to this period.

3.3 INFORMATION SOURCES AND SEARCH STRATEGY

Scopus and Web of Science were selected because of their multidisciplinary coverage and compatibility with bibliometric analysis. The final searches were conducted on November 30, 2025, and the records were exported with complete bibliographic information and cited references (Echchakoui, 2020).

The search combined three conceptual axes: logistics and supply chain management, digital integration and transformation, and maturity assessment. The database-specific expressions, filters, search date, and retrieved records are reported in Table 2.

Table 2 – Database search strategy and records retrieved

Database	Search field and string	Filters	Search date	Records
Scopus	TITLE-ABS-KEY((logistics OR "supply chain") AND ("digital integration" OR "digital transformation") AND ("maturity model" OR maturity OR model))	English; article or review; 2017-2025	November 30, 2025	228
Web of Science	TS=((logistics OR "supply chain") AND ("digital integration" OR "digital transformation") AND ("maturity model" OR maturity OR model))	English; article or review; 2017–2025	November 30, 2025	317
Total				545

Source: Authors' own elaboration.

3.4 STUDY SELECTION

The searches identified 545 records: 228 from Scopus and 317 from Web of Science. After removing 155 duplicates, 390 records remained for title, abstract, and keyword screening. At this stage, 178 records were excluded because they lacked a substantive logistics or supply chain focus (n = 78), a digital integration or transformation focus (n = 52), or a maturity or capability assessment (n = 31), or had an ineligible document type or language (n = 17).

Of the 212 reports sought for retrieval, 11 were unavailable. Full-text assessment of the remaining 201 reports excluded 123 because they lacked a relevant maturity or capability assessment (n = 45), addressed technology adoption without substantive digital integration (n = 34), had insufficient connection with logistics or supply chain management (n = 23), represented an ineligible publication type (n = 15), or failed another eligibility criterion (n = 6). This process resulted in 78 database-derived studies.

Citation searching based on the reference lists and preliminary co-citation structure of these studies identified 14 theoretically relevant publications. All were retrieved, assessed for thematic relevance, and included, resulting in a final analytical sample of 92 studies. Screening was conducted independently by the co-authors, and disagreements were resolved by consensus. Figure 2 presents the complete selection process.

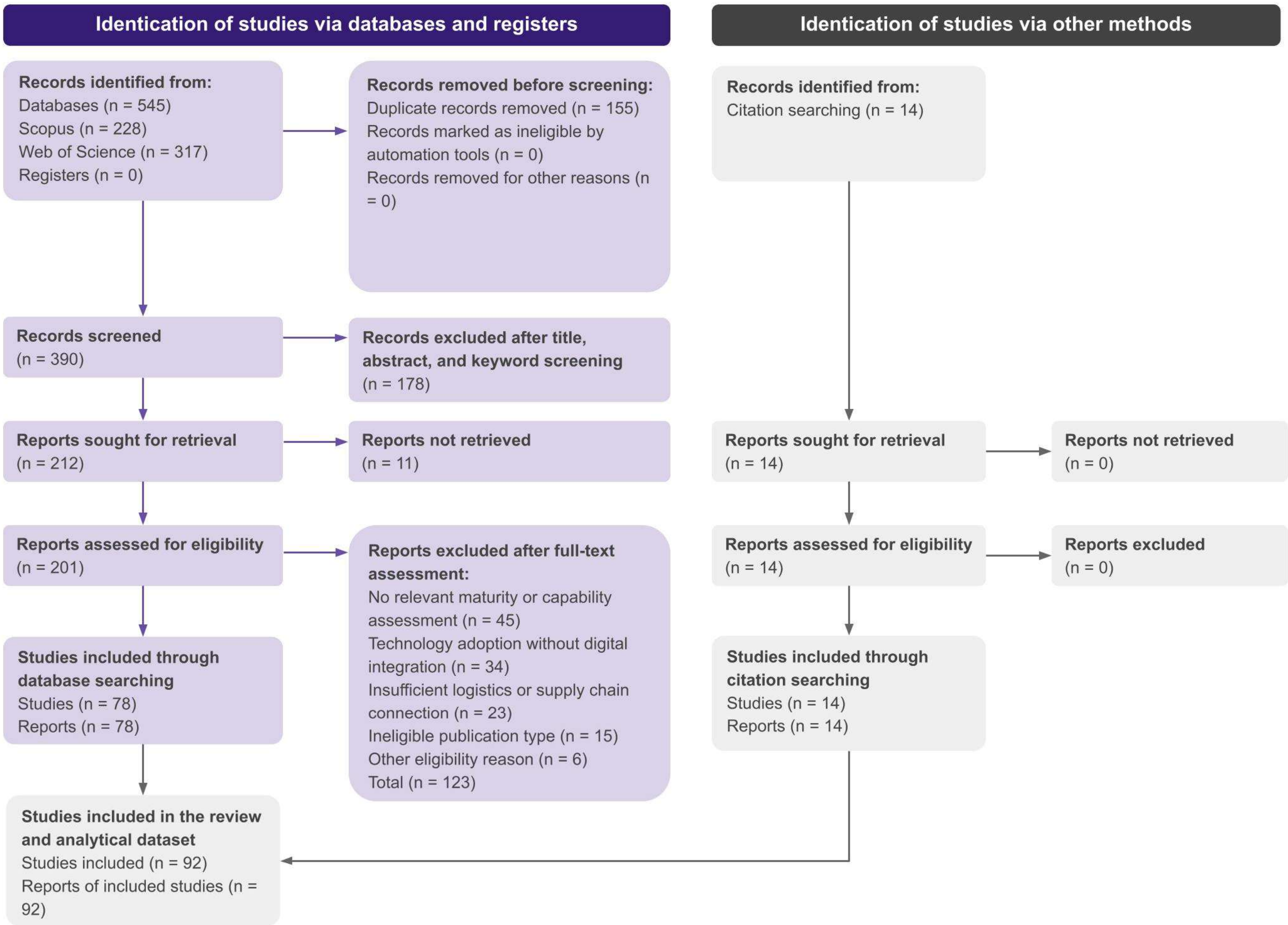


Figure 2 – PRISMA 2020 flow diagram of the study selection process.
Source: Adapted from Page et al. (2021).

3.5 DATA COLLECTION AND ANALYSIS

Bibliographic information from the 92 studies was consolidated in Microsoft Excel 365, including authors, year, title, journal, abstract, keywords, DOI, affiliations, country, and cited references. The spreadsheet also recorded the variables used in the qualitative content analysis.

Bibliometric analysis. The dataset was imported into Biblioshiny to characterize publication patterns and the most influential authors, countries, institutions, journals, and documents (Agbo et al., 2021; Wang et al., 2022).

Co-citation and co-word analyses. VOSviewer was used to construct the co-citation network and identify groups of publications frequently cited together, revealing the intellectual structure of the field (Hjørland, 2013; Rossetto et al., 2018; Donthu et al., 2021). InfraNodus was used to examine relationships among terms and identify thematic patterns through co-word analysis (Paranyushkin, 2019; Donthu et al., 2021).

Qualitative content analysis. The full texts of the 92 studies were examined using a structured extraction form covering study context, logistics processes, technologies and systems, integration mechanisms, maturity dimensions, organizational capabilities, assessment criteria, and reported outcomes. Coding combined deductive categories derived from Section 2 with inductive codes identified during full-text analysis. The codes were compared and grouped by conceptual similarity into dimensions, capabilities, and potential assessment elements. Initial coding was conducted by the first author, reviewed by two co-authors, and disagreements were resolved by consensus. The resulting categories were checked against the source studies to maintain traceability.

4. RESULTS AND DISCUSSION

This section presents the intellectual and thematic structure of the field, the qualitative synthesis of digital integration, the resulting theoretical contributions and conceptual framework, and the practical, societal, and research implications.

4.1 INTELLECTUAL AND THEMATIC STRUCTURE OF THE FIELD

Co-citation and co-word analyses were used as complementary procedures. Co-citation identified groups of publications sharing intellectual foundations, while co-word analysis revealed the concepts associated with these groups.

4.1.1 Co-citation Analysis

The VOSviewer network presented in Figure 3 was constructed from the cited references of the 92 studies. Nodes represent cited publications, links indicate co-citation relationships, and colors identify clusters.

Four clusters were identified: (1) supply chain management and digital capabilities; (2) Industry 4.0 and manufacturing automation; (3) data analytics and supply chain performance; and (4) quantitative assessment methods. The first three represent substantive perspectives on digital transformation in logistics, while the fourth concerns the methods used to examine relationships among capabilities, maturity, and performance.

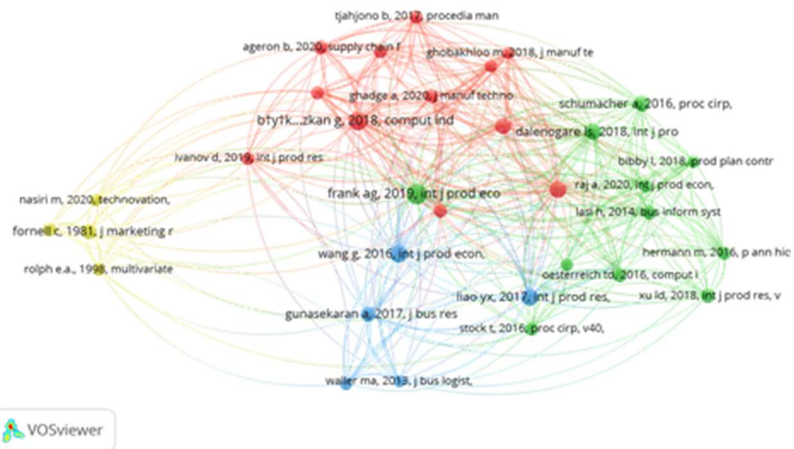


Figure 3 – Co-citation network and intellectual structure of the field.
Source: Authors’ own elaboration based on VOSviewer.

4.1.2 Co-word Analysis

The InfraNodus co-word networks in Figure 4 clarify the thematic content of the four clusters. Panel (a) connects supply chain management with digital technologies, business knowledge, and organizational capabilities. Panel (b) associates Industry 4.0, the Internet of Things, manufacturing automation, and product efficiency. Panel (c) relates Big Data analysis and strategic forecasting to supply chain planning and performance. Panel (d) contains methodological themes such as correlation, effect size, multivariate analysis, and cluster analysis.

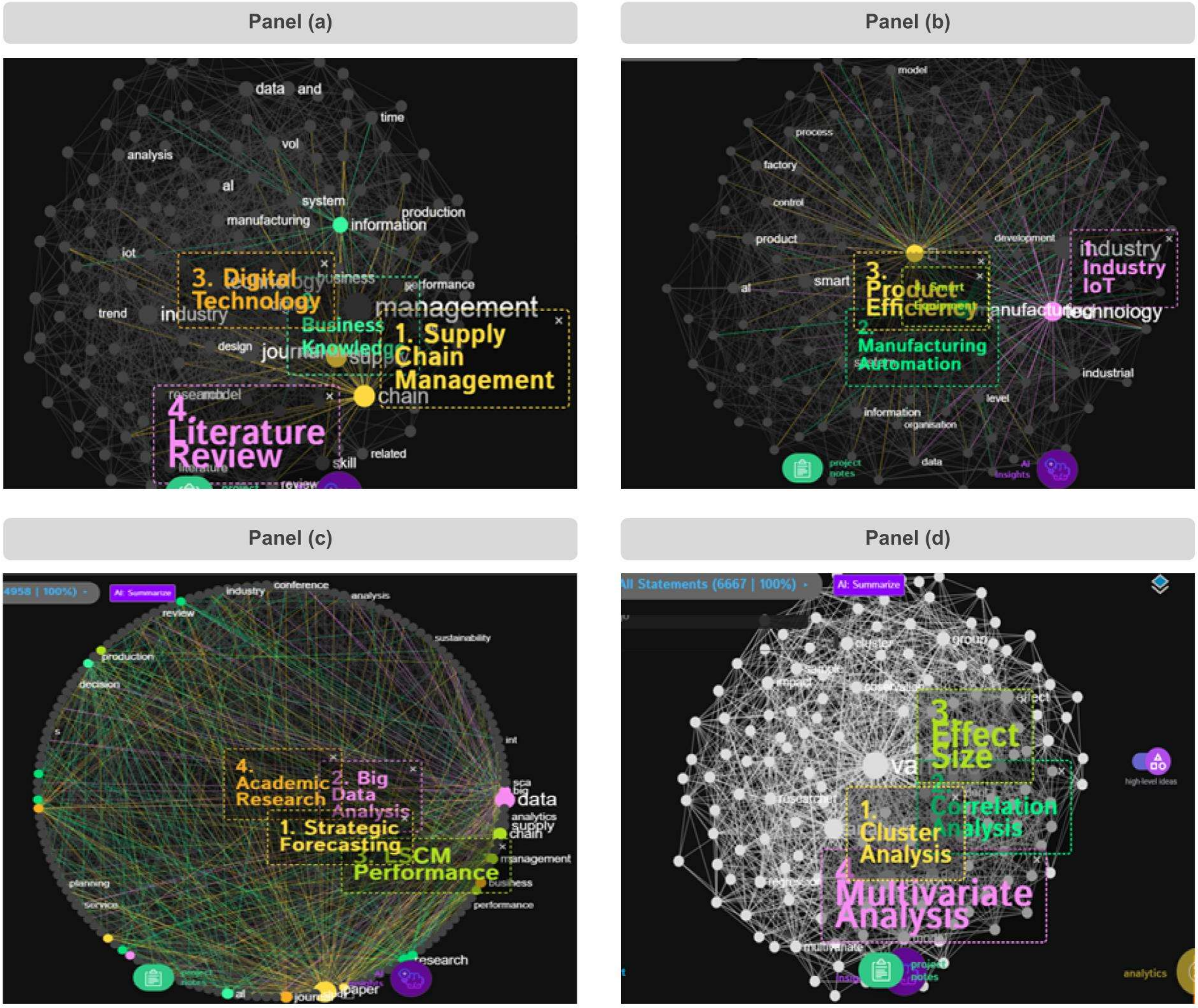


Figure 4 - Co-word networks associated with the four research streams: (a) supply chain management and digital capabilities; (b) Industry 4.0 and manufacturing automation; (c) data analytics and supply chain performance; and (d) quantitative assessment methods.

Source: Authors’ own elaboration based on InfraNodus.

Table 4 summarizes the convergence between the intellectual foundations identified through co-citation and the themes identified through co-word analysis.

Table 4 – Integrated summary of the co-citation and co-word results

Research stream	Representative evidence	Interpretation
Supply chain management and digital capabilities	Ardito et al. (2019); Ben-Daya et al. (2019); Ageron et al. (2020); Garay-Rondero et al. (2020); Queiroz et al. (2021). Themes: supply chain management, digital technology, business, and knowledge.	Organizational capabilities, collaboration, knowledge, and integration across supply chain networks.
Industry 4.0 and manufacturing automation	Dalenogare et al. (2018); Ghobakhloo (2018); Frank et al. (2019); Bai et al. (2020). Themes: manufacturing automation, Industry 4.0, IoT, and product efficiency.	Digital infrastructure, connected technologies, automation, and operational efficiency.
Data analytics and supply chain performance	Waller and Fawcett (2013); Wang et al. (2016); Gunasekaran et al. (2017); Liao et al. (2017). Themes: Big Data analysis, strategic forecasting, and SCM performance.	Data-supported forecasting, planning, decision-making, and performance assessment.
Quantitative assessment methods	Hair et al. (2009); Nasiri et al. (2020); Hanne et al. (2022). Themes: correlation, effect size, multivariate analysis, and cluster analysis.	Methods for evaluating capabilities, maturity, and organizational or supply chain performance.

Source: Authors' own elaboration.

The four streams are complementary perspectives rather than stages of a causal sequence. Research on technology addresses connectivity, automation, and digital infrastructure; capability-oriented studies examine knowledge, collaboration, and supply chain coordination; analytics studies focus on data-supported planning and decisions; and the methodological stream provides assessment tools.

Digital integration extends across these perspectives, but its technological, informational, process, and organizational elements remain distributed among them. They are not consistently organized as dimensions, capabilities, and assessment elements within logistics maturity research. This result provides the basis for the qualitative synthesis in Section 4.2.

4.2 QUALITATIVE SYNTHESIS OF DIGITAL INTEGRATION IN LOGISTICS MATURITY RESEARCH

The qualitative content analysis organized digital integration into four interrelated dimensions: technological and systems integration, data and information integration, process integration, and organizational and interorganizational integration. Although the underlying elements appear in the reviewed literature, they are not consistently combined within a single logistics maturity perspective.

4.2.1 Technological and Systems Integration

This dimension concerns the connectivity and interoperability of the digital infrastructure supporting logistics. Dalenogare et al. (2018), Ghobakhloo (2018), and Frank et al. (2019) show that Industry 4.0 depends on coordinated technology implementation rather than isolated applications. Facchini et al. (2020) incorporate Logistics 4.0 technologies into a maturity roadmap, while Uhlenkamp et al. (2022) examine the progressive development of digital twins. Together, these studies indicate that maturity assessment should consider not only technology availability but also connectivity among devices, platforms, enterprise systems, and logistics applications.

4.2.2 Data and Information Integration

Data and information integration involves the collection, standardization, sharing, access, and analytical use of logistics data. Ben-Daya et al. (2019) relate IoT applications to visibility, traceability, and information availability, while Wang et al. (2016) and Gunasekaran et al. (2017) connect Big Data analytics with forecasting, decision-making, and performance. Garay-Rondero et al. (2020) and Queiroz et al. (2021) show that data create value when connected with supply chain processes and organizational capabilities. Accordingly, this dimension includes data quality, standardization, real-time visibility, traceability, analytics, and governance.

4.2.3 Process Integration

Process integration concerns the connection and synchronization of logistics activities. McCormack et al. (2008) associate supply chain maturity with progression from fragmented functions to managed and integrated processes. Werner-Lewandowska and Kosacka-Olejnik (2019) emphasize structured logistics process development, while Facchini et al. (2020), Garay-Rondero et al. (2020), and Hrouga and Sbihi (2023) connect digitalization with logistics activities, information flows, and performance. The combined evidence indicates that process maturity requires integrated workflows linking procurement, planning, inventory, warehousing, transportation, and distribution.

4.2.4 Organizational and Interorganizational Integration

This dimension covers the governance, competencies, collaboration, and relationships required to coordinate digital logistics. Ageron et al. (2020) and Queiroz et al. (2021) identify skills, collaboration, and organizational alignment as central digital supply chain capabilities. Nasiri et al. (2020) show the importance of converting digital investments into coordinated business capabilities, while McCormack et al. (2008) and Ferraro et al. (2023) support the inclusion of cross-functional and interorganizational development in maturity assessment. Digital integration therefore requires strategy, defined responsibilities, workforce capabilities, internal coordination, partner information sharing, and collaborative planning.

4.2.5 Consolidated Dimensions, Capabilities, and Potential Assessment Elements

Table 5 consolidates the dimensions, capabilities, and observable practices identified through the qualitative synthesis. These practices are potential assessment elements for future model development, not validated indicators or measurement scales.

Table 5 – Dimensions, capabilities, and potential assessment elements of digital integration

Dimension	Core capabilities	Potential assessment elements
Technological and systems integration	Connectivity; interoperability; physical–digital integration; platform integration; legacy-system compatibility.	Integration among ERP, WMS, TMS, MES, sensors, and logistics platforms; common interfaces and standards; real-time device communication; cloud–local integration; compatibility with existing systems.
Data and information integration	Data availability, quality, standardization, sharing, visibility, traceability, analytics, and governance.	Data accuracy, consistency, completeness, and timeliness; standardized definitions; shared access; end-to-end tracking; real-time dashboards; analytical use; data access, security, ownership, and governance rules.
Process integration	End-to-end synchronization; integrated workflows; automated information exchange; event-based coordination; cross-functional decisions; performance monitoring.	Digital connection of procurement, planning, inventory, warehousing, transportation, and distribution; automated data transfer; shared workflows; coordinated responses; integrated planning and execution; end-to-end indicators.
Organizational and interorganizational integration	Digital strategy and governance; employee competencies; cross-functional collaboration; partner integration;	Digital logistics roadmap; defined responsibilities; employee training; coordination among logistics, operations, and IT; information sharing with partners; joint planning and performance reviews;

Dimension	Core capabilities	Potential assessment elements
	collaborative planning; continuous improvement.	governance agreements.

Source: Authors' own elaboration based on the qualitative content analysis.

The four dimensions are analytically distinct but operationally interdependent. Connected systems provide limited value without reliable data; data do not ensure integration when logistics processes remain fragmented; and internal integration is insufficient without coordination with supply chain partners. By organizing these elements within a common structure, the synthesis addresses the identified research gap and provides the conceptual basis for the framework presented in Section 4.4. However, the assessment elements require subsequent operationalization and empirical validation.

4.3 THEORETICAL CONTRIBUTIONS

This study contributes to the literature by repositioning digital integration as a transversal logistics capability rather than an isolated technology dimension. It integrates research on Industry 4.0 implementation, digital supply chain capabilities, logistics processes, analytics, and maturity assessment into four interrelated dimensions: technological and systems integration, data and information integration, process integration, and organizational and interorganizational integration. This structure shows that technology adoption alone does not demonstrate integration; systems must exchange reliable data, logistics processes must be synchronized, and organizational actors must coordinate decisions across functional and company boundaries.

The study also distinguishes dimensions, capabilities, and potential assessment elements. Dimensions define the broad areas of digital integration, capabilities describe what an organization should be able to perform, and assessment elements represent observable practices or criteria. This distinction provides a conceptual basis for future maturity-model development. The resulting framework specifies the content that a logistics maturity assessment could operationalize but does not provide maturity levels, measurement scales, weights, validated indicators, or causal estimates.

4.4 CONCEPTUAL FRAMEWORK FOR DIGITAL INTEGRATION IN LOGISTICS MATURITY RESEARCH

Figure 5 integrates the results of the systematic review, bibliometric analyses, and qualitative synthesis. Industry 4.0 technologies are treated as digital enablers, while the four dimensions identified in Section 4.2 represent the capabilities through which these technologies become integrated into logistics systems, data flows, processes, organizational functions, and supply chain relationships.

Logistics maturity provides the assessment perspective for examining how consistently these capabilities are defined, implemented, coordinated, measured, and improved. It is therefore an assessment logic rather than a causal variable positioned after digital integration. This interpretation is consistent with the use of maturity models for capability assessment, benchmarking, prioritization, and roadmap development (McCormack et al., 2008; Proença & Borbinha, 2016; Werner-Lewandowska & Kosacka-Olejnik, 2019; Ferraro et al., 2023).

The framework is summarized through four propositions for future theoretical and empirical examination:

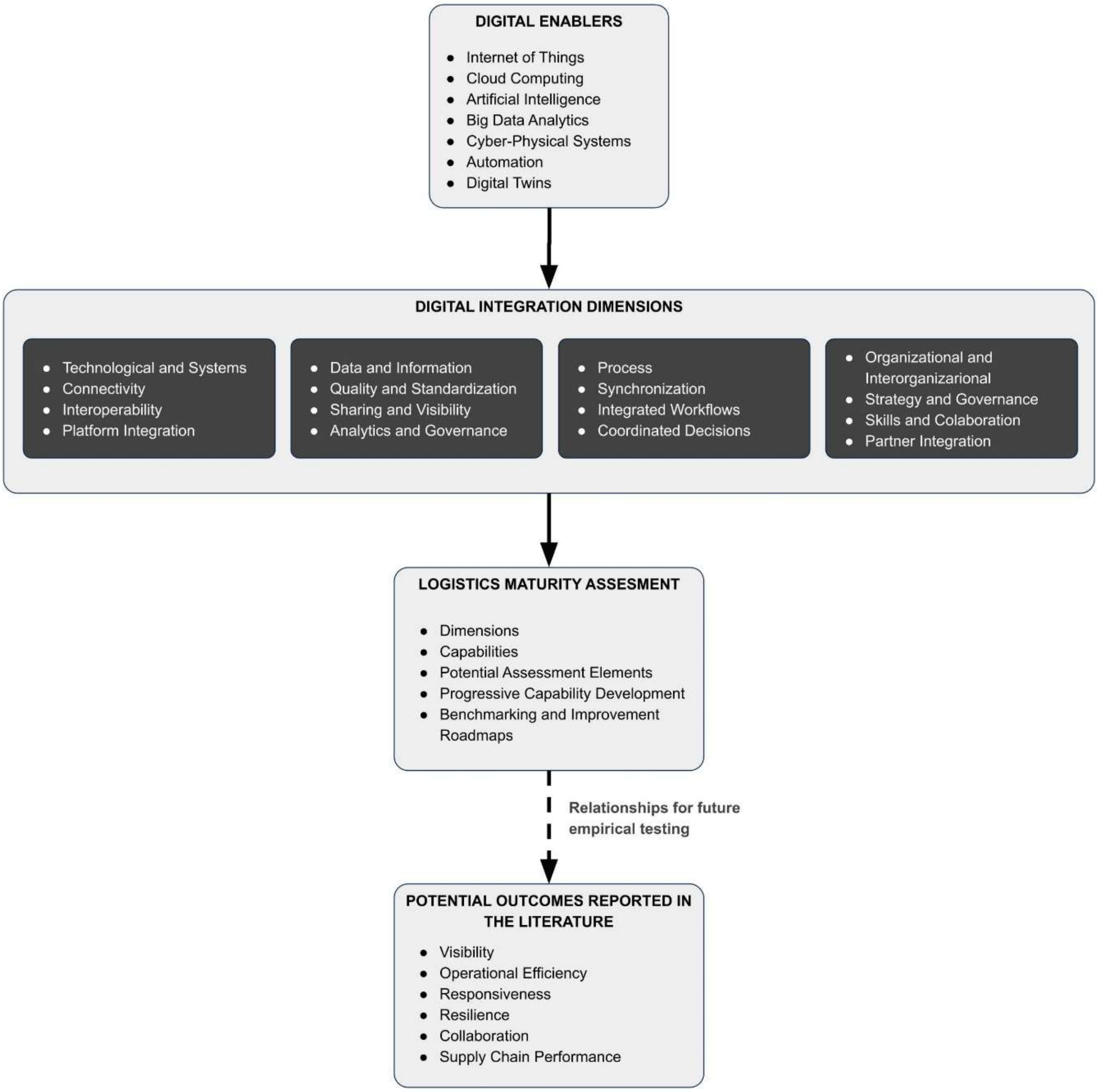
Proposition 1. Digital integration maturity requires connected and interoperable technological systems rather than isolated Industry 4.0 technology adoption (Dalenogare et al., 2018; Ghobakhloo, 2018; Frank et al., 2019; Facchini et al., 2020).

Proposition 2. Data and information integration and process integration are required to translate technological connectivity into logistics visibility, coordinated workflows, and data-supported decisions (Wang et al., 2016; Gunasekaran et al., 2017; Ben-Daya et al., 2019; Garay-Rondero et al., 2020; Queiroz et al., 2021).

Proposition 3. Organizational and interorganizational capabilities are required to sustain digital integration across functional and company boundaries (McCormack et al., 2008; Ageron et al., 2020; Nasiri et al., 2020; Queiroz et al., 2021).

Proposition 4. Logistics maturity assessment should examine the four dimensions as complementary and interdependent areas rather than as separate technological, process, or organizational indicators (Facchini et al., 2020; Queiroz et al., 2021; Ferraro et al., 2023; Machado & Rodriguez, 2025).

The literature associates these capabilities with visibility, efficiency, responsiveness, resilience, collaboration, and supply chain performance. Figure 5 presents them as potential outcomes requiring future empirical testing, not as effects established by this review (Gunasekaran et al., 2017; Ben-Daya et al., 2019; Nasiri et al., 2020; Ivanov & Dolgui, 2021; Hrouga & Sbihi, 2023). Future studies may operationalize the assessment elements in Table 5, define maturity levels and measurement scales, and test their reliability, validity, and relationships with logistics outcomes.



Note: The framework is a conceptual synthesis. It does not provide validated indicators, maturity levels, measurement scales, weights, or tested causal relationships.

Figure 5 – Conceptual framework for assessing digital integration within logistics maturity research
Source: Authors' own elaboration.

4.5 PRACTICAL AND SOCIETAL IMPLICATIONS

The four dimensions in Table 5 provide managers with an initial diagnostic structure for examining digital integration beyond technology acquisition. Before expanding investments in IoT, cloud computing, artificial intelligence, automation, or digital twins, organizations should assess systems interoperability, data quality and governance, process integration, employee competencies, and coordination with supply chain partners. The potential assessment elements can support internal reflection, benchmarking, prioritization, and roadmap development, but should not be used as a formal maturity score, audit, or certification before appropriate indicators, scales, and validation procedures are developed.

Digital integration also requires agreements concerning data access, standards, security, responsibilities, and joint decisions among suppliers, customers, and logistics service providers. This requirement is particularly relevant to small and medium-sized enterprises, which may face resource, infrastructure, knowledge, and bargaining-power constraints when participating in digital supply chains (Mittal et al., 2018; Ageron et al., 2020).

The main societal implications concern workforce development, responsible data use, inclusion, and logistics resilience. Integrated digital systems increase demand for competencies in data analysis, process management, cybersecurity, and cross-organizational collaboration. At the same time, unequal access to digital resources may exclude smaller organizations, while information sharing raises concerns regarding privacy, ownership, transparency, and security. More integrated logistics systems may support visibility, responsiveness, and continuity during disruptions, but these outcomes depend on implementation and governance and should not be assumed as automatic consequences of digitalization.

4.6 Future Research Agenda

Future research should advance from conceptual synthesis toward operationalization, validation, and empirical testing. Table 6 consolidates the main directions arising from the four dimensions, the conceptual propositions, and the limitations of this review.

Table 6 – Future research agenda for digital integration in logistics maturity research

Research direction	Main research question	Suggested methods
Operationalization and validation	Which indicators, scales, maturity levels, and classification rules validly represent the four dimensions?	Delphi studies, expert panels, case studies, factor analysis, PLS-SEM or covariance-based SEM.
Interdependence and capability development	Do the dimensions develop sequentially, jointly, or through alternative maturity pathways?	Longitudinal studies, repeated assessments, action research, configurational analysis.
Organizational and sectoral contingencies	How do company size, industry, infrastructure, logistics complexity, and institutional context affect digital integration maturity?	Multi-group analysis, cross-industry studies, and cross-country comparisons.
Interorganizational integration and governance	How can maturity, secure data sharing, responsibilities, and capability asymmetries be assessed across supply chain partners?	Dyadic and network studies, multi-respondent surveys, governance case studies, stakeholder interviews.
Relationships with logistics outcomes	Under which conditions is digital integration maturity associated with visibility, efficiency, responsiveness, resilience, collaboration, and supply chain performance?	Longitudinal surveys, quasi-experimental designs, mediation and moderation analysis.

Source: Authors' own elaboration.

Operationalization should begin with content validation by academic and industry experts, followed by the definition and statistical validation of indicators, scales, maturity levels, and aggregation rules. Longitudinal and multi-respondent studies are also needed to examine how the four dimensions develop across organizations and supply chain networks and whether the potential outcomes shown in Figure 5 are empirically supported.

5. CONCLUSIONS

This study examined how digital integration has been conceptualized and incorporated into logistics maturity research and which dimensions, capabilities, and assessment elements emerge from the literature. The findings show that digital integration extends beyond individual technology adoption and constitutes a transversal capability connecting technological systems, data and information flows, logistics processes, organizational functions, and supply chain partners.

The first specific objective was achieved by characterizing the field through bibliometric, co-citation, and co-word analyses. The results identified three substantive research streams—supply chain and digital capabilities, Industry 4.0 and manufacturing automation, and data analytics and supply chain performance—and one methodological stream related to quantitative assessment. Their integration showed that relevant evidence remains distributed across technological, organizational, analytical, and maturity perspectives.

The second objective was achieved through qualitative content analysis, which organized digital integration into technological and systems integration, data and information integration, process integration, and organizational and interorganizational integration. The related capabilities and potential assessment elements specify the conceptual content that logistics maturity research should consider when examining digital integration.

The third objective was achieved through the conceptual framework in Figure 5 and the research agenda in Table 6. The framework positions logistics maturity as the assessment perspective for examining the progressive development of the four dimensions, while the agenda identifies priorities for operationalization, validation, longitudinal analysis, interorganizational assessment, governance, and empirical testing of logistics outcomes.

The general objective of mapping and synthesizing digital integration in logistics maturity research was therefore achieved. The study contributes by treating digital integration as a multidimensional capability and distinguishing dimensions, capabilities, and potential assessment elements. However, it does not provide an operational maturity model or validated measurement instrument. The proposed structure requires indicator development, maturity-level definition, organizational application, and empirical validation.

5.1 LIMITATIONS

The review was limited to English-language journal articles retrieved from Scopus and Web of Science for the period from January 1, 2017 to November 30, 2025. Relevant publications from other databases, languages, and document types may therefore have been excluded. Citation searching added 14 theoretically relevant studies but may have favored well-cited publications.

The broad search terms increased coverage but produced a heterogeneous initial dataset and required judgment during screening. Although eligibility decisions were independently reviewed and resolved by consensus, study selection and classification remain partly interpretive. Bibliometric and science-mapping results also depend on database indexing, citation practices, term standardization, software parameters, and network-construction procedures.

Qualitative coding was conducted by the first author and reviewed by two co-authors. This increased consistency and traceability, but alternative classifications of some capabilities and assessment elements remain possible. Finally, the framework has not been empirically validated or applied in organizations. Its assessment elements have not been converted into validated indicators, scales, maturity levels, aggregation rules, or weights, and the proposed relationships with logistics and supply chain outcomes remain to be tested.

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