

Digital Maturity Trajectories toward Logistics 4.0: Critical Success Factors and Risk Profiles in Morocco

Oumaima ELAAGUIR^{a1}, Youssef AL MERIOUH^b

^{ab} National School of Business and Management of Tangier, Abdelmalek Essaâdi University, Morocco

Article Info	Abstract
Keywords: Logistics 4.0; digital transformation; digital maturity; Industry 4.0; critical success factors; risk management; digital supply chain; organizational capabilities; Morocco. JEL classification: O33; M15; L25; M10 Received: 15 September 2026 Accepted: 30 September 2026 Published: 12 October 2026	This study examines how critical success factors and risk profiles associated with Logistics 4.0 evolve across different levels of organizational digital maturity. An exploratory qualitative multiple-case study was conducted through sixteen semi-structured interviews with logistics, operations and digital transformation managers, as well as executives from Moroccan organizations at different maturity levels. Thematic within-case and cross-case analysis identified four maturity configurations: initial digitalization, structured digitalization, organizational integration, and advanced Logistics 4.0. The findings show that leadership, digital competencies and information-system integration remain important throughout the maturity trajectory, while their roles evolve as digital capabilities deepen. Risk profiles also shift from predominantly human, organizational and financial concerns toward interoperability, cybersecurity, technological dependency and data-governance risks. The study contributes a dynamic perspective on Logistics 4.0 by jointly examining the evolution of critical success factors and risks across maturity configurations. It further suggests that digital maturity should be understood as a cumulative organizational capability rather than a simple measure of technological sophistication.

¹ Corresponding author. E-mail address: elaaguir.oumaima@etu.uae.ac.ma

DOI : <https://doi.org/10.23882/ijdam.26395>

Peer-review under responsibility of the scientific committee of the IJDAM Review

This is an open access article under the license Creative Commons Atribuição-NãoComercial 4.0.



1. Introduction

Digital transformation has increasingly become a fundamental driver of organizational and operational change across industries. The growing adoption of Industry 4.0 technologies, such as the Internet of Things (IoT), artificial intelligence (AI), big-data analytics, cloud computing, cyber-physical systems and advanced automation, is reshaping the way firms manage physical and informational flows and coordinate production and logistics activities (Frank *et al.*, 2019; Vial, 2019). Within supply chains, these technological developments have contributed to the emergence of Logistics 4.0 and digitally enabled supply-chain systems, characterized by greater connectivity, real-time information exchange, automation and data-driven decision making (Büyükoğkan and Göçer, 2018; Winkelhaus and Grosse, 2020).

However, the transition toward Logistics 4.0 cannot be reduced to the implementation of advanced technologies. The value generated by digital solutions depends largely on an organization's ability to integrate them into existing processes, develop the necessary human competencies, align digital initiatives with strategic priorities and transform growing volumes of data into relevant operational and managerial insights. Digital transformation should consequently be viewed as a broader organizational process involving technological, human and managerial changes rather than as a purely technological development (Vial, 2019; Verhoef *et al.*, 2021).

This perspective is particularly important in supply-chain environments, where the presence of digital technologies does not necessarily indicate a high level of digital maturity. Organizations may implement enterprise resource planning (ERP) systems, warehouse management systems (WMS) or other isolated digital applications while maintaining fragmented information systems, limited interfunctional integration and significant reliance on manual processes. At higher levels of maturity, by contrast, organizations increasingly connect internal operations with external supply-chain partners and rely on real-time information, advanced analytics and automation to coordinate increasingly complex logistics ecosystems (Frederico *et al.*, 2020). Digital maturity therefore reflects not only the extent to which technologies are adopted, but also the organization's capacity to integrate and exploit them effectively.

Previous research on Industry 4.0 adoption has identified a broad range of technological, organizational and environmental conditions influencing successful implementation. Among the factors most frequently highlighted are top-management support, digital capabilities, technological readiness, organizational culture, information-system integration, external collaboration and environmental pressures (Sony and Naik, 2020a; Vial, 2019). Studies addressing Industry 4.0 readiness further emphasize that organizational preparedness extends beyond technological infrastructure and requires the development of complementary human and organizational capabilities (Sony and Naik, 2020b). These findings underline the importance of critical success factors (CSFs) in shaping digital transformation outcomes.

Nevertheless, the existing literature has largely approached CSFs as relatively stable determinants of technology adoption or implementation. Less attention has been devoted to their changing role as organizations progress from initial digitalization toward more integrated and intelligent logistics configurations. A factor that is critical at an early stage may acquire a different function as digital capabilities develop. For instance, basic user training may be sufficient when an organization introduces an operational information system, whereas more advanced digital environments require data literacy, analytical capabilities, continuous learning and increasingly sophisticated

decision-making competencies. This suggests that CSFs should be examined dynamically rather than treated as fixed conditions throughout the digital transformation process.

The same issue arises with regard to digital risks. The integration of Industry 4.0 technologies can enhance supply-chain visibility, responsiveness and resilience, but it may simultaneously create new sources of vulnerability associated with interconnected systems, data dependencies, cybersecurity threats and reliance on external technology providers (Spieske and Birkel, 2021; Zouari *et al.*, 2021). Consequently, the relationship between digital maturity and risk cannot necessarily be understood as a simple reduction in exposure. As organizations become more digitally integrated, certain traditional risks may become easier to monitor or control, while new technological, systemic and data-related vulnerabilities may emerge.

Taken together, these observations reveal a need for a more dynamic understanding of Logistics 4.0 maturity that considers the simultaneous evolution of the capabilities required for successful transformation and the risks generated by increasing digital integration. Rather than viewing digital transformation as a one-time adoption decision, this study conceptualizes Logistics 4.0 as a progressive trajectory through which organizations develop and combine technological, organizational and managerial capabilities.

Against this background, the study addresses the following research question:

How do the critical success factors and risks associated with Logistics 4.0 evolve across different levels of organizational digital maturity?

To address this question, an exploratory qualitative multiple-case study was conducted. The empirical investigation is based on sixteen semi-structured interviews with managers and decision-makers from organizations displaying different levels of digital transformation. Within-case and cross-case thematic analyses were used to identify recurring patterns and compare four analytically derived maturity configurations, ranging from initial digitalization to advanced Logistics 4.0 environments.

The study makes three main contributions. First, it advances a dynamic perspective on Logistics 4.0 by conceptualizing digital maturity as a progressive organizational trajectory rather than a discrete technology-adoption event. Second, it demonstrates that CSFs are not static throughout this trajectory: leadership, digital competencies and information-system integration remain important, but their roles and requirements change as organizational maturity increases. Third, it contributes to the discussion of digital risk by showing that increasing maturity does not necessarily eliminate organizational exposure to risk; instead, it transforms the composition and nature of the risk portfolio, with emerging concerns related to interoperability, cybersecurity, technological dependency and data governance.

The remainder of the article is organized as follows. Section 2 reviews the literature on Logistics 4.0, digital maturity, critical success factors and digital risks and develops the theoretical framework. Section 3 presents the qualitative research design and methodology. Section 4 reports the empirical findings. Section 5 discusses the findings through the Technology–Organization–Environment framework, the Resource-Based View and dynamic capabilities theory. Section 6 presents the theoretical and managerial implications, while Section 7 concludes the study.

2. Literature Review and Theoretical Framework

2.1 From Industry 4.0 to Logistics 4.0

Industry 4.0 refers to an industrial transformation in which digital, physical and organizational systems become increasingly interconnected through technologies such as IoT, cloud computing, cyber-physical systems, big-data analytics, AI and automation. Rather than representing isolated technological innovations, Industry 4.0 involves the convergence of multiple digital technologies and their integration into organizational processes (Frank *et al.*, 2019).

In logistics, this transformation has contributed to the development of Logistics 4.0. Winkelhaus and Grosse (2020) describe Logistics 4.0 as a new logistics configuration characterized by digital connectivity, automation, decentralization and data-driven decision making. Similarly, research on digital supply chains highlights how connected technologies facilitate information exchange, process visibility and integration between supply-chain actors (Büyüközkan and Göçer, 2018).

The implications of these technologies extend across logistics activities. IoT devices can collect operational information from products, equipment and infrastructure. ERP and WMS solutions support the integration and coordination of operational activities. Big-data analytics and AI can enhance forecasting and decision making, while automation can reduce manual intervention and improve process consistency. At more advanced stages, these technologies can contribute to real-time monitoring and predictive or anticipatory logistics management (Winkelhaus and Grosse, 2020).

However, technology deployment does not automatically generate transformation. Vial (2019) conceptualizes digital transformation as a process in which digital technologies trigger organizational changes that affect value creation, structures, processes and organizational responses. Similarly, Verhoef *et al.* (2021) distinguish between digitization, digitalization and broader digital transformation, demonstrating that transformation involves changes in organizational resources, structures and capabilities.

Consequently, an organization equipped with several digital technologies should not necessarily be classified as digitally mature. The strategic value of these technologies depends on their integration into processes, the quality of the information generated and the organization's ability to use this information effectively. Logistics 4.0 should thus be analyzed as a socio-technical and organizational configuration rather than as a technological inventory.

2.2 Digital maturity as an evolutionary process

Digital-maturity perspectives provide a useful way of moving beyond binary distinctions between organizations that have or have not adopted digital technologies. Organizations frequently occupy intermediate positions in which some activities are highly digitalized while others remain fragmented or manual.

The maturity perspective is especially relevant in supply chains because digital transformation often unfolds sequentially. Frederico *et al.* (2020) conceptualize Supply Chain 4.0 through maturity levels and argue that transformation involves the gradual development of managerial and capability supporters, technology levers, process-performance requirements and strategic outcomes.

Similarly, implementation research shows that Industry 4.0 technologies do not necessarily diffuse simultaneously. Different technological layers and organizational practices may be adopted according to distinct implementation patterns (Frank *et al.*, 2019). Consequently, digital maturity can be interpreted as an evolving capacity to integrate digital resources, processes, competencies and relationships.

This evolutionary interpretation is also consistent with broader digital-transformation research. Verhoef *et al.* (2021) differentiate digitization from broader stages of digitalization and transformation, while Vial (2019) emphasizes the structural and organizational changes associated with technological transformation. Together, these perspectives suggest that maturity is not simply the accumulation of tools but the development of organizational capabilities required to exploit them.

The maturity perspective therefore introduces an important temporal dimension into Logistics 4.0 research. Capabilities required during early-stage digitalization may differ from those required once systems become integrated and decision processes increasingly depend on real-time data. Consequently, the nature of both success factors and vulnerabilities is expected to evolve throughout the transformation trajectory.

2.3 Critical success factors in digital transformation and Logistics 4.0

The Industry 4.0 literature identifies several recurring factors influencing successful implementation. Top-management support is among the most frequently emphasized. Senior management can influence resource allocation, strategic orientation, employee commitment and the legitimacy assigned to digital-transformation initiatives (Sony and Naik, 2020a).

Human competencies constitute another fundamental factor. Digital transformation modifies work practices and requires employees to acquire technological, analytical and decision-related skills. Digital competence increasingly involves more than operational knowledge of software. As organizations become data-driven, employees need to interpret information, identify anomalies, solve problems and contribute to decisions supported by digital technologies.

Information-system integration is equally important. The coexistence of several digital tools does not necessarily improve organizational performance if they remain isolated. Digital supply-chain research consistently emphasizes integration and connectivity as mechanisms through which digital technologies improve coordination and visibility (Büyüközkan and Göçer, 2018; Frederico *et al.*, 2020).

Organizational culture and change management are also central. Digital technologies frequently alter routines, professional identities and responsibilities. Organizations therefore require mechanisms supporting experimentation, learning and adaptation. Such mechanisms become especially important when technological change is continuous rather than episodic.

Finally, interorganizational collaboration becomes increasingly important as digitalization extends beyond organizational boundaries. Connected supply chains depend on information exchange, interoperability and coordination between suppliers, customers, logistics providers and technology partners. Digital transformation thus increasingly becomes an ecosystem-level phenomenon rather than an exclusively intra-organizational process.

Although these factors are well documented, they are frequently treated as relatively stable prerequisites. Less attention has been devoted to whether the meaning and relative role of these factors change as organizations mature. This study addresses this issue by considering success factors as potentially dynamic organizational capabilities.

2.4 Risks associated with Logistics 4.0

Digital transformation simultaneously generates opportunities and vulnerabilities. At early stages, organizations may face human resistance, lack of skills, uncertainty regarding return on investment, implementation difficulties and temporary process disruption.

Technology-related investments may also generate financial risk because implementation involves acquisition, training, maintenance and adaptation costs, while expected benefits may be uncertain or delayed. These concerns are particularly important for organizations with constrained resources.

As digital systems become increasingly interconnected, additional risks emerge. Cybersecurity becomes more important because a larger number of connected devices, information flows and external interfaces create additional points of vulnerability. Industry 4.0 research has documented vulnerabilities linked to cyber-attacks, system architecture, communication infrastructure and data sovereignty (Lezzi *et al.*, 2021).

Interoperability presents another challenge. Organizations may deploy technologies developed by different suppliers or based on incompatible standards. When critical processes depend on integration between systems, technical incompatibility can disrupt information flows and reduce expected benefits.

Technological dependency also increases. Organizations increasingly rely on technology providers, cloud infrastructure, software solutions and external technical expertise. Such dependencies may create operational or strategic vulnerability.

Finally, the increasing importance of data introduces risks related to data quality, access, ownership, security and governance. In data-driven logistics environments, poor-quality or compromised information can directly affect operational decisions.

Research on supply-chain resilience illustrates this duality. Digital technologies can improve visibility, anticipation and resilience (Zouari *et al.*, 2021; Spieske and Birkel, 2021), yet interconnected and technology-dependent systems may also create new vulnerabilities. Digital maturity therefore needs to be examined together with the transformation of organizational risk rather than assuming that greater technological sophistication automatically reduces exposure.

2.5 Theoretical foundations

Three complementary theoretical perspectives are mobilized: the Technology–Organization–Environment framework, the Resource-Based View and dynamic capabilities theory.

The Technology–Organization–Environment (TOE) framework proposed by Tornatzky and Fleischer (1990) explains organizational technology adoption through three contexts. The technological context concerns available technologies and existing infrastructure. The organizational context includes resources, managerial structures and organizational characteristics. The environmental context encompasses external actors, competitive pressures and institutional conditions.

TOE is useful for Logistics 4.0 because digital transformation depends simultaneously on technological readiness, organizational capabilities and relationships with external stakeholders. As maturity increases and logistics systems become increasingly interconnected, environmental and ecosystem-level factors may become particularly important.

The Resource-Based View (RBV) complements this perspective by focusing on the resources through which organizations generate sustained competitive advantage (Barney, 1991). From an RBV perspective, digital technologies represent only one category of organizational resources.

Human competencies, process knowledge, information quality, managerial expertise and partner relationships may constitute complementary resources that determine whether technological investment produces organizational value.

Dynamic capabilities theory adds an explicitly evolutionary dimension. Teece *et al.* (1997) conceptualize dynamic capabilities as organizational abilities to integrate, build and reconfigure internal and external competencies in changing environments. Teece (2007) later emphasized the processes of sensing opportunities, seizing them and transforming organizational resources.

This theoretical perspective is especially relevant to digital maturity because technologically advanced organizations cannot rely exclusively on resources accumulated at a particular point in time. Continuous technological evolution requires learning, experimentation, adaptation and capability renewal.

The three frameworks are therefore complementary. TOE identifies the technological, organizational and environmental conditions surrounding transformation. RBV explains how complementary resources can generate value from technology. Dynamic capabilities explain how organizations progressively renew and reconfigure these resources as their digital environment evolves.

3. Methodology

3.1 Research design

This research adopts an exploratory qualitative multiple-case study design. Such a design is appropriate when the objective is to understand organizational processes, mechanisms and contextual differences rather than statistically estimate relationships between predefined variables (Eisenhardt, 1989; Yin, 2018).

The research question focuses on how success factors and risks evolve across digital-maturity configurations. This requires attention to managerial perceptions, organizational practices and the way technological transformation is experienced within different organizational contexts.

A multiple-case logic was therefore adopted to identify recurring patterns across organizations while preserving contextual differences between individual cases. The analytical approach was based on theoretical comparison rather than statistical representativeness.

3.2 Case selection

The empirical material comprises sixteen organizations characterized by different levels of digital transformation. A purposive sampling strategy was adopted to capture variation in digital development and to obtain contrasting organizational configurations rather than to construct a statistically representative sample. The selection process deliberately sought heterogeneity in organizational size, sector and technological deployment, while ensuring that all selected organizations had initiated some form of digital transformation relevant to logistics, operations or supply-chain activities.

Prior to the interviews, preliminary information concerning the organizations' digital development was collected through discussions with organizational representatives, including telephone exchanges conducted during the case-selection process. This preliminary assessment considered observable characteristics such as the adoption of Industry 4.0-related technologies, the use and scope of enterprise resource planning (ERP) systems, the degree of information-system integration, the level of automation and the extent of interorganizational digital integration. Organizational size

and sector were also considered in order to ensure variation in the empirical contexts represented in the sample.

A general maturity framework was established prior to data collection to guide the purposive selection of contrasting cases. It was not used as a formal measurement scale or as a statistical classification instrument. Rather, it provided an initial analytical orientation for assessing differences in technological adoption, information-system integration, automation and interorganizational integration. Four organizations were intentionally selected for each broad level of digital development in order to maintain a balanced comparative structure across the sixteen cases.

Importantly, the four maturity configurations reported in this study were not fully defined before the interviews. The preliminary maturity framework was used only to guide case selection and ensure variation in digital development. The final configurations were progressively constructed and refined through the subsequent qualitative analysis of the interview material. The within-case and cross-case analysis enabled the researchers to identify recurring combinations of technological, organizational and integration characteristics and to refine the boundaries between the four configurations.

The organizations were consequently grouped into four analytically derived configurations: initial digitalization, structured digitalization, organizational integration and advanced Logistics 4.0. The classification does not constitute a statistically validated maturity scale. Instead, it represents an empirically grounded analytical typology developed through the combination of an initial case-selection framework and subsequent qualitative comparison. This distinction limits potential circularity because the initial characterization of cases was based on observable digital-development criteria gathered before the thematic analysis of critical success factors and risks, while the final configurations were subsequently refined through systematic comparison of the empirical evidence.

Table 1. Analytical structure of the sample

Maturity configuration	Number of organizations	Dominant digital-development characteristics
Initial digitalization	4	Limited or partial technology adoption; basic ERP use; fragmented information systems; limited automation and interorganizational integration
Structured digitalization	4	More structured ERP/WMS deployment; standardized digital processes; improved operational information visibility; emerging automation
Organizational integration	4	Greater information-system integration; stronger interfunctional information flows; more extensive process digitalization; increasing organizational integration
Advanced Logistics 4.0	4	Advanced technology deployment including IoT, AI and automation; real-time data use; high system integration; extended interorganizational connectivity

The classification should not be interpreted as a statistically validated maturity scale. Rather, it represents an analytical categorization developed to compare contrasting empirical configurations. Individual organizations may also exhibit different maturity levels across specific dimensions. The four configurations therefore represent dominant patterns rather than mutually exclusive organizational states.

This analytical positioning provided the basis for the subsequent qualitative investigation, which examined how critical success factors and risk profiles varied across these contrasting configurations.

3.3 Data collection

The study is based on sixteen semi-structured interviews with logistics managers, operational managers, digital-transformation managers and executives.

The interviews explored technologies currently used, information-system integration, implementation experiences, facilitating factors, perceived obstacles, risks, performance effects, collaboration and innovation practices.

The semi-structured format provided a common analytical structure while allowing respondents to elaborate on issues specific to their organizational context. Particular attention was given not only to technologies deployed but also to the organizational conditions through which these technologies were adopted, integrated and used.

3.4 Data analysis

The qualitative analysis followed a thematic and comparative procedure inspired by established approaches to within-case and cross-case qualitative analysis (Miles *et al.*, 2020; Yin, 2018). Each interview was first examined individually to identify units of meaning and recurring themes. The empirical material was then organized around several analytical dimensions, including Industry 4.0 technologies, information-system integration, critical success factors, risks, performance, collaboration and innovation.

The analysis proceeded through an iterative coding process. Relevant units of meaning were identified and assigned descriptive codes, which were subsequently grouped into broader thematic categories. A structured Excel matrix was used to maintain traceability between interview material, units of meaning, codes, thematic categories and individual cases. Although specialized qualitative analysis software was not used, this structured approach enabled systematic organization and comparison of the empirical material while preserving an explicit analytical trail.

A vertical or within-case analysis was first conducted to develop an understanding of each organizational configuration. This stage was followed by a horizontal cross-case comparison intended to identify similarities, differences and recurring patterns associated with digital maturity. The analytical sequence therefore progressed from individual interview examination and thematic coding toward within-case synthesis and cross-case comparison. The final step consisted of identifying recurrent patterns in critical success factors and risks and organizing them according to analytically derived maturity configurations.

Data collection and analysis were conducted iteratively. Emerging themes were continuously compared with evidence from subsequent interviews in order to assess whether additional interviews generated substantially new categories or primarily confirmed previously identified patterns. As the analysis progressed, the later interviews increasingly reinforced the thematic

structure established from earlier cases without generating substantially new categories relevant to the research question. This pattern was considered indicative of thematic saturation and supported the adequacy of the final sample for the cross-case analysis. Saturation was therefore considered as an analytical criterion rather than as a predetermined numerical threshold.

Analytical credibility was further strengthened through comparison across respondent profiles and organizational contexts. The sample included logistics managers, operational managers, digital transformation managers and executives, allowing the researchers to examine whether emerging themes were supported across different functional and managerial perspectives. The analysis also involved systematic comparison between organizations exhibiting different levels of digital maturity. Convergent patterns were retained as recurring findings, while divergent evidence was preserved to account for contextual differences. The coding framework was repeatedly reviewed against the original interview material throughout the analysis to maintain consistency between empirical evidence and emerging interpretations.

Formal inter-coder reliability statistics and participant member-checking were not employed. Instead, analytical rigor was supported through iterative coding, systematic within-case and cross-case comparison, multiple respondent perspectives, and continuous verification of interpretations against the original interview material. The resulting maturity configurations are therefore interpretive, empirically grounded constructs derived from recurring patterns across the cases rather than statistically validated maturity levels.

4. Findings

4.1 A progressive Logistics 4.0 maturity trajectory

The cross-case analysis reveals an overall progression from operational digitalization toward increasingly integrated, connected and anticipatory logistics environments.

The first configuration, “initial digitalization”, is characterized by the use of selected digital applications, including partial ERP functionalities and specialized tools. Digital technologies are mainly used to improve specific operational activities such as purchasing, inventory management or traceability. Systems remain partially fragmented, information circulation is limited and some processes continue to depend on manual intervention.

The second configuration, “structured digitalization”, reflects a broader use of digital tools. ERP and WMS functionalities cover additional operational processes and organizations develop more standardized procedures. Stock alerts and operational information improve visibility and coordination. However, integration with external partners remains limited and data are still predominantly used to support operational rather than predictive decisions.

The third configuration, “organizational integration”, is characterized by stronger interfunctional integration. Information systems increasingly connect purchasing, operations, finance and logistics activities. Data circulate more easily between functions and performance management becomes more structured. Organizations begin to move from isolated digital applications toward a more coherent organizational information architecture.

The fourth configuration, “advanced Logistics 4.0”, involves more strongly connected digital environments combining integrated systems with IoT, automation, AI or advanced analytics. Real-time information increasingly supports operational supervision, and organizations exhibit greater capacity for anticipation and data-driven decision making.

Table 2. Comparative characteristics of the four maturity configurations

Dimension	Initial digitalization	Structured digitalization	Organizational integration	Advanced Logistics 4.0
Technologies	Partial ERP and isolated tools	ERP/WMS	Integrated ERP	IoT, AI, automation and advanced platforms
IS integration	Low and fragmented	Moderate	Strong, mainly internal	Extended to ecosystem
Processes	Partly manual	Structured	Standardized and integrated	Automated and increasingly real time
Performance management	Limited indicators	Operational KPIs	Integrated KPIs	Predictive/data-driven management
Leadership	Initial impulse	Coordination	Strategic orientation	Transformational orientation
Competencies	Tool use	Operational digital skills	Analytical skills	Analytical and strategic digital capabilities
Collaboration	Limited	Functional	Developed	Increasingly ecosystem-based
Innovation	Limited	Emerging	Structured	Institutionalized

The comparison indicates that maturity does not simply correspond to an increase in the number or sophistication of technologies. Progression involves simultaneous changes in information-system integration, processes, competencies, management practices and interorganizational relationships.

4.2 Leadership as a transversal but evolving factor

Leadership emerges as one of the most consistent success factors across maturity configurations.

During initial digitalization, management primarily plays an initiating role. Managers authorize digital investment, allocate basic resources and encourage employees to use newly introduced technologies. At intermediate levels, leadership becomes more coordinative and strategic. The challenge is no longer limited to introducing a digital tool but increasingly involves ensuring consistency between different technological initiatives and organizational priorities.

At advanced maturity levels, leadership assumes a more transformational role. Managers are expected to support experimentation, continuous learning and organizational adaptation rather than manage isolated implementation projects. Leadership therefore remains relevant throughout the trajectory but changes function. It moves from technology sponsorship to coordination, strategic alignment and ultimately the institutionalization of continuous digital transformation.

4.3 Digital competencies as a condition for technological appropriation

The interviews similarly highlight the importance of human competencies.

At lower maturity levels, capability requirements are primarily operational. Employees need to understand basic system functionalities and incorporate new applications into established work routines.

As system integration increases, competence requirements become more analytical. Employees increasingly need to interpret system-generated information, identify operational anomalies and use data to support decisions.

At advanced maturity levels, digital competence extends beyond technical tool utilization. Analytical reasoning, problem solving, learning ability and data-supported decision making become more important.

These findings indicate that the value of technology depends strongly on employee appropriation. Investment in competencies constitutes an important mechanism through which technological resources are transformed into organizational capabilities.

4.4 Information-system integration as a maturity differentiator

A particularly significant finding concerns system integration.

The analysis indicates that the presence of an ERP does not, by itself, provide a reliable indicator of digital maturity. Organizations using apparently similar technologies can exhibit substantially different levels of integration and information exploitation.

In initial configurations, digital systems often remain fragmented. Individual functions may use separate tools, requiring information to be transferred manually or through intermediate procedures.

At intermediate levels, functional integration improves information circulation and operational visibility.

At higher maturity levels, integration expands across organizational functions and, progressively, across organizational boundaries. Information flows increasingly connect internal operations with external supply-chain partners.

System integration therefore appears to be a critical differentiator between technology adoption and genuine digital transformation. The strategic value of digital technologies lies less in their independent sophistication than in their ability to operate coherently within broader organizational and interorganizational systems.

4.5 Organizational culture and innovation

The cross-case comparison also reveals differences in innovation practices.

At low maturity levels, technological innovation is primarily problem-driven. Organizations introduce digital tools to address immediate operational problems such as errors, lack of traceability or inefficient manual processes.

At intermediate levels, innovation becomes more structured and increasingly associated with process improvement.

In advanced configurations, innovation becomes more institutionalized. Organizations demonstrate greater willingness to experiment, learn and continuously reconsider how technologies can support or redesign business processes.

Digital maturity therefore includes a cultural dimension. The ability to learn from experimentation and continuously adapt organizational practices becomes increasingly important as transformation progresses.

4.6 The evolution of risk profiles

A major finding concerns the transformation of risk profiles across maturity configurations.

At early stages, risks are predominantly human, organizational and financial. Resistance to change, insufficient competence, difficulty using digital tools and disruption of established routines constitute important implementation challenges. Financial constraints related to technological acquisition, maintenance and training are also significant.

As digitalization progresses, some of these problems can be reduced through accumulated experience, training and organizational learning. However, increasing system interconnection introduces new vulnerabilities.

Organizations at more advanced maturity levels face greater exposure to system failure, interoperability problems, technology-provider dependency, cybersecurity threats and data-governance issues.

Table 3. Evolution of dominant risk profiles

Maturity configuration	Dominant risks	Main management priorities
Initial digitalization	Resistance, skills deficiencies, investment costs	Training, communication and change support
Structured digitalization	Process disruption, tool dependency and coordination difficulties	Standardization, technical support and change management
Organizational integration	System interdependence, data quality and provider dependency	IS governance, data control and maintenance
Advanced Logistics 4.0	Cybersecurity, interoperability, technological dependency and systemic risks	Data governance, security, continuity and resilience

The key finding is therefore not that maturity eliminates risk but that it progressively changes its nature. Human and organizational risks remain relevant but their relative importance may decline as technological and systemic exposure increases.

Digital transformation should consequently be viewed not as a linear risk-reduction process but as a process in which the organization's risk portfolio is continuously reconfigured.

4.7 An integrated maturity trajectory

The empirical findings can be synthesized into four maturity configurations.

Table 4. Synthetic Logistics 4.0 maturity trajectory

Level	Dominant logic	Key characteristics
Level 1 – Initial digitalization	Digitalize	Isolated tools, partial ERP, limited automation and basic performance monitoring
Level 2 – Structured digitalization	Structure	Standardized processes, ERP/WMS, improved operational visibility and KPIs
Level 3 – Organizational integration	Integrate	Interconnected systems, interfunctional coordination and data-supported management
Level 4 – Advanced Logistics 4.0	Anticipate	IoT, AI, real-time information, analytics, automation and connected ecosystem

The trajectory should not be understood as a rigid or universal sequence. Organizations can progress at different speeds and may display uneven maturity across dimensions.

Rather, the four configurations provide an analytical framework for understanding how organizational capabilities become progressively more complex. Initial digitalization creates technological resources; structured digitalization improves process organization; organizational integration enhances information circulation and data-based coordination; and advanced environments increasingly develop anticipatory, automated and adaptive capabilities.

5. Discussion

5.1 Logistics 4.0 as an organizational maturation process

The first contribution of the study concerns the conceptualization of Logistics 4.0 as an evolutionary organizational process. Existing research already recognizes that Supply Chain 4.0 can be interpreted through maturity stages rather than solely through individual technology adoption (Frederico *et al.*, 2020). The present findings extend this perspective empirically by showing that organizations do not transition directly from traditional logistics to fully connected and intelligent systems. Digital transformation instead develops through the progressive accumulation and integration of technological and organizational capabilities.

This interpretation is consistent with Vial's (2019) argument that digital transformation involves changes to organizational structures and value-creation processes rather than the mere introduction of technologies. It is also compatible with Verhoef *et al.*'s (2021) distinction between digitization, digitalization and broader digital transformation. The findings suggest that an ERP, WMS or AI tool represents a resource or technological component rather than a sufficient indicator of maturity. The organizational capacity to integrate these technologies, develop human competencies and use information in decision processes is more important. Logistics 4.0 maturity therefore appears to reflect a learning trajectory rather than a technological threshold.

5.2 Interpretation through the TOE framework

The results can first be interpreted through the Technology–Organization–Environment framework. The technological context is visible in the movement from isolated operational technologies toward integrated systems, IoT, advanced analytics and automation. However, technological resources alone do not explain differences in maturity. The organizational dimension

is reflected in leadership, skills, culture, change management and information governance. Cases characterized by greater maturity combine technological sophistication with stronger organizational capabilities.

The environmental dimension becomes increasingly visible as maturity progresses. Advanced digital environments involve greater interaction with external partners, service providers and technology ecosystems. This finding is especially relevant for digital supply chains, since information-system integration increasingly extends beyond organizational boundaries.

The results therefore support the idea that technological, organizational and environmental conditions are interdependent. Technological investment may generate limited value when organizational competencies or ecosystem relationships remain underdeveloped.

5.3 Interpretation through the Resource-Based View

The findings also support an RBV interpretation. Technology constitutes an important resource, but the value derived from digital technology depends on complementary organizational resources. Because many technological solutions can be purchased by competing organizations, ownership of technology alone does not necessarily create sustained differentiation.

The cross-case evidence indicates that digital competencies, process knowledge, information-system integration, data quality and governance practices play a major role in translating technologies into operational capabilities. This observation is consistent with the RBV proposition that competitive value results from how resources are combined rather than from the presence of isolated assets (Barney, 1991). The maturity differences observed between organizations can therefore be interpreted as differences in resource orchestration. Two organizations may possess similar technologies but exhibit different levels of maturity because their ability to integrate and exploit these resources differs.

5.4 The role of dynamic capabilities

Dynamic capabilities provide an additional explanation of the maturity trajectory.

The most advanced configurations do not merely possess more digital resources. They display greater capacity for learning, experimentation and adaptation.

Continuous training, organizational learning and innovation become more important as maturity increases. These findings correspond to the dynamic-capability argument that organizations must continually reconfigure their resources as technologies and environments change (Teece *et al.*, 1997; Teece, 2007).

The distinction is important because technological maturity is inherently temporary. Advanced technologies and data practices continually evolve. Consequently, maturity cannot simply be understood as reaching a final technological state.

An advanced organization is therefore not necessarily the one possessing the highest number of technologies at a given moment, but the one that has developed the capability to integrate, adapt and renew digital resources continuously.

5.5 Critical success factors as dynamic capabilities

A further contribution concerns the evolution of critical success factors.

Existing Industry 4.0 research identifies leadership, competence, technological readiness, culture and organizational support as important success factors (Sony and Naik, 2020b). The present study shows that these factors should not be interpreted as static checklist items.

Leadership remains important throughout the maturity trajectory, but its function develops from initial sponsorship to coordination, strategic alignment and transformational leadership.

Digital competencies similarly move from operational tool use toward analytical and decision-related capabilities.

System integration progresses from basic internal connectivity toward interfunctional and eventually interorganizational integration.

The contribution of the study therefore lies partly in replacing a static logic of “presence or absence of success factors” with a developmental logic. A factor may remain important throughout transformation while its required content changes considerably.

5.6 Digital maturity and the transformation of risk

The relationship between digital maturity and risk represents another important contribution.

Digital-supply-chain research demonstrates that digitalization can improve visibility, anticipation and resilience (Zouari *et al.*, 2021). Industry 4.0 technologies can similarly enhance pre-disruption preparedness and supply-chain resilience, particularly through improved information and visibility (Spieske and Birkel, 2021).

The present study nevertheless suggests that digitalization simultaneously generates new risk dependencies.

At early maturity levels, organizations concentrate primarily on human resistance, competence gaps, implementation costs and organizational disruption.

At more advanced levels, interconnected systems create stronger dependencies on infrastructure, data quality, cybersecurity and external providers.

This pattern is consistent with Industry 4.0 cybersecurity research showing that connected digital infrastructures create vulnerabilities that require continuous technical and organizational governance (Lezzi *et al.*, 2021).

Consequently, digital maturity should not be equated with the disappearance of risk. It should instead be interpreted as a growing organizational ability to identify and control an increasingly complex portfolio of technological and organizational risks.

This distinction has important theoretical implications because it positions risk management as an integral dimension of digital maturity rather than a separate implementation problem.

6. Theoretical and Managerial Implications

6.1 Theoretical implications

The study contributes to the digital-transformation and Logistics 4.0 literature in several ways.

First, it reinforces an evolutionary interpretation of Logistics 4.0. The findings indicate that transformation develops through configurations characterized by progressively stronger integration, information use and organizational capabilities.

Second, the research provides a dynamic interpretation of critical success factors. Leadership, competencies and system integration remain relevant across maturity levels but change in content and organizational function. This suggests that future digital-maturity frameworks should specify not only which capabilities matter but how those capabilities need to evolve across stages.

Third, the study introduces a complementary risk perspective. Whereas maturity models primarily emphasize technological and organizational advancement, the present findings show that progression also changes the organization's vulnerability profile. Maturity involves both capability accumulation and risk reconfiguration.

Fourth, the integration of TOE, RBV and dynamic capabilities provides a complementary theoretical explanation. TOE explains the contexts surrounding transformation, RBV explains the conversion of resources into organizational value and dynamic capabilities explain the continued adaptation of resources and practices over time.

Collectively, these results support the following interpretation:

Logistics 4.0 maturity is the progressive organizational capacity to integrate digital technologies, complementary human and organizational resources, data and interorganizational relationships in

ways that improve operational coordination and anticipation while continuously adapting to emerging technological and organizational risks.

6.2 Managerial implications

The findings have several practical implications for organizations engaged in digital logistics transformation.

Managers should avoid equating digital transformation with technology acquisition. The introduction of AI, IoT or advanced analytics cannot compensate for fragmented information systems, insufficient data quality or limited digital competencies.

Organizations at early maturity levels should therefore prioritize basic digital infrastructure, process standardization, workforce appropriation and information consistency before moving directly toward highly sophisticated technologies.

Human capabilities should similarly be managed according to maturity. Initial training can focus on operational use, whereas more advanced transformation requires data interpretation, problem-solving skills and decision capabilities.

Leadership practices must also evolve. Initial transformation may require sponsorship and resource allocation; more mature configurations require strategic coordination and eventually an organizational culture capable of continuous experimentation and learning.

The findings further suggest that digital-risk management should begin early. Managers focusing exclusively on implementation cost and employee resistance may underestimate risks that become critical once systems are integrated, including interoperability problems, cyber threats, supplier dependency and data governance.

Finally, managers can use the four maturity configurations as a diagnostic rather than prescriptive framework. The objective is not necessarily to move immediately toward the most technologically advanced configuration but to determine whether technological ambition is consistent with organizational capabilities, strategic priorities and acceptable risk exposure.

7. Conclusion

This study examined how critical success factors and risks associated with Logistics 4.0 evolve across different levels of organizational digital maturity.

Based on sixteen semi-structured interviews and a qualitative comparison of contrasting organizational configurations, the findings identify four broad maturity levels: initial digitalization, structured digitalization, organizational integration and advanced Logistics 4.0.

The transition between these configurations involves more than increasing technological sophistication. It is accompanied by changes in information-system integration, human competencies, managerial practices, performance management, collaboration and organizational culture.

The findings further demonstrate that critical success factors are dynamic. Leadership evolves from initial sponsorship toward strategic and transformational roles. Digital competencies move from basic technology use toward analytical and decision-related capabilities. System integration expands from isolated or internal applications toward increasingly interconnected organizational and ecosystem configurations.

A second major result concerns risk. Digital maturity does not automatically reduce organizational exposure. Instead, it transforms the risk profile. Early stages are more strongly associated with human, organizational and financial challenges, while more advanced configurations increasingly face interoperability, cybersecurity, technological dependency and data-governance concerns.

Theoretically, the study demonstrates the usefulness of combining TOE, RBV and dynamic capabilities. TOE explains how technological, organizational and environmental conditions interact; RBV highlights the complementary resources required to generate value from technology; and dynamic capabilities explain the importance of continuous learning and resource reconfiguration.

The central contribution is therefore a conception of Logistics 4.0 maturity as a cumulative organizational capability rather than a technological state.

From a managerial perspective, the proposed trajectory can help organizations diagnose their current configuration, identify capabilities requiring development and anticipate risks likely to become more important as digital integration increases.

The study nevertheless has limitations. Its qualitative design and purposive selection of cases do not allow statistical generalization to the wider population of Moroccan organizations. The four-level categorization should consequently be understood as an analytical framework derived from the cases studied rather than a statistically validated maturity scale.

Future research could test the proposed configurations quantitatively using larger organizational samples. Longitudinal studies would also be particularly valuable because they could directly observe how organizations transition between maturity configurations and determine whether the critical success factors and risk transformations identified here persist over time. Comparative research across sectors and national contexts could further examine the influence of institutional and environmental conditions on Logistics 4.0 maturity trajectories.

Ultimately, the key question in Logistics 4.0 is not simply which digital technologies an organization possesses, but how effectively it can integrate, exploit and continuously adapt them. Digital maturity should therefore be understood less as a technological destination than as an evolving organizational capability.

References

- Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of Management*, Vol. 17 No. 1, pp. 99-120.
- Büyükoçkan, G. and Göçer, F. (2018), "Digital supply chain: literature review and a proposed framework for future research", *Computers in Industry*, Vol. 97, pp. 157-177, doi: 10.1016/j.compind.2018.02.010.
- Eisenhardt, K.M. (1989), "Building theories from case study research", *Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.
- Frank, A.G., Dalenogare, L.S. and Ayala, N.F. (2019), "Industry 4.0 technologies: implementation patterns in manufacturing companies", *International Journal of Production Economics*, Vol. 210, pp. 15-26, doi: 10.1016/j.ijpe.2019.01.004.
- Frederico, G.F., Garza-Reyes, J.A., Anosike, A. and Kumar, V. (2020), "Supply Chain 4.0: concepts, maturity and research agenda", *Supply Chain Management: An International Journal*, Vol. 25 No. 2, pp. 262-282, doi: 10.1108/SCM-09-2018-0339.
- Lezzi, M., Lazoi, M. and Corallo, A. (2021), "Cybersecurity for Industry 4.0 in the current literature: a reference framework", *Computers in Industry*, Vol. 103, pp. 97-110.
- Miles, M.B., Huberman, A.M. and Saldaña, J. (2020), *Qualitative Data Analysis: A Methods Sourcebook*, 4th ed., Sage Publications, Thousand Oaks, CA.
- Sony, M. and Naik, S. (2020a), "Critical factors for the successful implementation of Industry 4.0: a review and future research direction", *Production Planning & Control*, Vol. 31 No. 10, pp. 799-815, doi: 10.1080/09537287.2019.1691278.
- Sony, M. and Naik, S. (2020b), "Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review", *Benchmarking: An International Journal*, Vol. 27 No. 7, pp. 2213-2232, doi: 10.1108/BIJ-09-2018-0284.

- Spieske, A. and Birkel, H. (2021), "Improving supply chain resilience through Industry 4.0: a systematic literature review under the impressions of the COVID-19 pandemic", *Computers & Industrial Engineering*, Vol. 158, 107452, doi: [10.1016/j.cie.2021.107452](https://doi.org/10.1016/j.cie.2021.107452).
- Teece, D.J. (2007), "Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance", *Strategic Management Journal*, Vol. 28 No. 13, pp. 1319-1350.
- Teece, D.J., Pisano, G. and Shuen, A. (1997), "Dynamic capabilities and strategic management", *Strategic Management Journal*, Vol. 18 No. 7, pp. 509-533.
- Tornatzky, L.G. and Fleischer, M. (1990), *The Processes of Technological Innovation*, Lexington Books, Lexington, MA.
- Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N. and Haenlein, M. (2021), "Digital transformation: a multidisciplinary reflection and research agenda", *Journal of Business Research*, Vol. 122, pp. 889-901, doi: [10.1016/j.jbusres.2019.09.022](https://doi.org/10.1016/j.jbusres.2019.09.022).
- Vial, G. (2019), "Understanding digital transformation: a review and a research agenda", *The Journal of Strategic Information Systems*, Vol. 28 No. 2, pp. 118-144, doi: [10.1016/j.jsis.2019.01.003](https://doi.org/10.1016/j.jsis.2019.01.003).
- Winkelhaus, S. and Grosse, E.H. (2020), "Logistics 4.0: a systematic review towards a new logistics system", *International Journal of Production Research*, Vol. 58 No. 1, pp. 18-43, doi: [10.1080/00207543.2019.1612964](https://doi.org/10.1080/00207543.2019.1612964).
- Yin, R.K. (2018), *Case Study Research and Applications: Design and Methods*, 6th ed., Sage Publications, Thousand Oaks, CA.
- Zouari, D., Ruel, S. and Viale, L. (2021), "Does digitalising the supply chain contribute to its resilience?", *International Journal of Physical Distribution & Logistics Management*, Vol. 51 No. 2, pp. 149-180, doi: [10.1108/IJPDLM-01-2020-0038](https://doi.org/10.1108/IJPDLM-01-2020-0038).