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Assessing Organisational Capabilities for Logistics 4.0 Transition: Case of BOMARE COMPANY

Developed by :
ADJIMI Mouad

Supervised by :
Dr. MOHAMMED AZIZI Yasmine

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ABSTRACT

In the context of accelerated digital transformation, the transition to Logistics 4.0 represents a major strategic challenge for industrial firms in emerging economies. This study aims to assess the Organisational Capabilities of BOMARE COMPANY for this transition, by identifying the capability dimensions that most significantly predict it. Drawing on a positivist quantitative approach and a structured questionnaire administered to employees, analysed through multiple linear regression, the findings confirm that Technological capability is the dominant predictor, followed by Human Capital Capability and the current logistics system state. Organisational capabilities produced no significant direct effect, while Strategic Orientation revealed a perception gap between managerial ambitions and operational reality.

Keywords: Logistics 4.0 , Organisational Capabilities , Digital Transformation , Emerging Economies , BOMARE COMPANY

Résume

Dans un contexte de transformation numérique accélérée, la transition vers la Logistique 4.0 représente un défi stratégique majeur pour les entreprises industrielles des économies émergentes. Cette étude vise à évaluer la préparation organisationnelle de BOMARE COMPANY à cette transition, en identifiant les dimensions de capacités qui la prédisent le plus significativement. En s'appuyant sur une approche quantitative positiviste et un questionnaire structuré administré aux employés, analysé par régression linéaire multiple, les résultats confirment que la préparation technologique constitue le prédicteur dominant, suivi de la préparation humaine et de l'état du système logistique actuel. Les capacités organisationnelles n'ont produit aucun effet direct significatif, tandis que la préparation stratégique a révélé un écart de perception entre les ambitions managériales et la réalité opérationnelle.

Mots-clés : Logistique 4.0 , Préparation organisationnelle , Transformation numérique ,Économies émergentes , BOMARE COMPANY

الملخص

في سياق التحول الرقمي المتسارع، يُمثّل الانتقال نحو اللوجستيك 4.0 تحدياً استراتيجياً بالغ الأهمية للمؤسسات الصناعية في الاقتصادات الناشئة. تسعى هذه الدراسة إلى تقييم مستوى الجاهزية التنظيمية لشركة بومار كمبني **Bomare Company** لهذا الانتقال، من خلال تحديد أبعاد القدرات الأكثر تأثيراً في التنبؤ بها. اعتماداً على منهج كمي وضعي واستبيان منظّم وُزّع على الموظفين وحُلِّل بالانحدار الخطي المتعدد **.** كشفت النتائج أن الجاهزية التكنولوجية تُمثّل المنبئ الأقوى، تليها الجاهزية البشرية وحالة النظام اللوجستي الراهن. في المقابل، لم تُسجّل القدرات التنظيمية أي تأثير مباشر دال، فيما كشفت الجاهزية الاستراتيجية عن فجوة إدراكية بين الطموحات الإدارية والواقع التشغيلي**.**

الكلمات المفتاحية :اللوجستيك 4.0 **,** الجاهزية التنظيمية **,** التحول الرقمي **,** الاقتصادات الناشئة **,** بومار كمبني

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation / Acronym	Meaning
AAPI	Algerian Investment Promotion Agency
AGV	Autonomous Guided Vehicle
AI	Artificial Intelligence
AMR	Autonomous Mobile Robot
ANOVA	Analysis of Variance
APQ	Quality Assurance Department
AS/RS	Automated Storage and Retrieval System
B2B	Business to Business
BSE	BOMARE Solutions Entreprises
CE	European Conformity
CPS	Cyber-Physical Systems
CRM	Customer Relationship Management
DID	Digital Interactive Display
DPI	Industrial Projects Department
DV	Dependent Variable
EDI	Electronic Data Interchange
EMS	Electronic Manufacturing Services
ERP	Enterprise Resource Planning
GPS	Global Positioning System
IaaS	Infrastructure as a Service
IBM	International Business Machines
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IoT	Internet of Things
ISO	International Organisation for standardisation
IT	Information Technology
JIT	Just-In-Time
KPI	Key Performance Indicator
LLC	Limited Liability Company
MAR	Mobile Autonomous Robot
MDZD	Million Algerian Dinars
ML	Machine Learning
NIST	National Institute of Standards and Technology
OBM	Original Brand Manufacturing

OEM	Original Equipment Manufacturing
PaaS	Platform as a Service
PCB	Printed Circuit Board
Q-Q	plot, used in normality testing
R&D	Research and Development
RFID	Radio Frequency Identification
RoHS	Restriction of Hazardous Substances
RPA	Robotic Process Automation
SaaS	Software as a Service
SAP	Systems, Applications, and Products
SARL	Limited Liability Company
SAV	Service Après-Vente (After-Sales Service)
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference
SME	Small and Medium-sized Enterprises
SMT	Surface Mount Technology
TMS	Transportation Management System
TQM	Total Quality Management
UHD	Ultra-High Definition
VIF	Variance Inflation Factor
VMI	Vendor Managed Inventory
WMS	Warehouse Management System
5G	Fifth-Generation Wireless Technology

INTRODUCTION

General Introduction:

The contemporary global economy is undergoing profound and unprecedented transformations, driven by the convergence of digital technologies, the exponential growth of data, and the deep integration between physical and cyber systems. This transformation widely known as Industry 4.0 or the Fourth Industrial Revolution extends far beyond the adoption of individual technologies. It represents a fundamental restructuring of production methods, organisational architectures, and competitive logics. In this new environment, firms no longer compete solely on cost efficiency or product quality; their competitive advantage increasingly rests on their capacity to process real time information, respond swiftly to market changes, and orchestrate complex networks with agility and intelligence (Davenport & Miller, 2022).

Within this evolving landscape, supply chains have undergone a parallel and equally significant transformation. Once viewed primarily as operational and supportive functions, they are now recognised as strategic assets that directly contribute to value creation, resilience, and long term competitiveness. Traditional linear supply chains are progressively giving way to interconnected, intelligent, and data driven networks that integrate suppliers, internal operations, and customers in a seamless and responsive system (Srivastava, 2023).

It is within this context that the concept of Logistics 4.0 has emerged as one of the most significant developments of the current decade. Defined as the application of Industry 4.0 technologies including the Internet of Things (IoT), artificial intelligence, cloud computing, big data analytics, and autonomous robotics to logistics processes such as transportation, warehousing, reverse logistics, and supply chain coordination, Logistics 4.0 aims to build a highly connected, automated, and intelligent logistics system capable of responding dynamically to the demands of a rapidly changing global market (Helo & Hao, 2022).

Research Interest

Despite the growing consensus in academic and managerial literature on the transformative potential of Logistics 4.0, the practical transition towards this new paradigm remains a complex and multidimensional challenge for organisations. The successful adoption of Logistics 4.0 is not solely a matter of acquiring new technologies; it requires the simultaneous development and alignment of several distinct organisational capabilities, including technological infrastructure, human capital, change management competencies, and strategic commitment from top management (Dubey et al., 2023).

In emerging economies such as Algeria, this transition is particularly relevant yet insufficiently studied. Algerian industrial firms are increasingly exposed to international competition and global supply chain disruptions, creating both an urgency and an opportunity to modernise logistics operations. However, the extent to which Algerian organisations currently possess the core capabilities required for a Logistics 4.0 transition remains largely undocumented in the scientific literature (Alshahrani, 2023). This lacuna is all the more significant given that local enterprises, whilst inclined to modernise, confront multiple obstacles: limited digital infrastructure, weak digital culture, budgetary constraints, resistance to change, and scarcity of specialised competencies (Luthra & Mangla, 2018).

This research therefore focuses on the empirical assessment of these core capabilities measuring the degree to which necessary technological, human, organisational, and strategic conditions are present in an Algerian industrial company preparing for the digital transformation of its logistics activities.

Objectives of the Research

The primary objective of this study is to assess the Organisational Capabilities of BOMARE COMPANY for a successful transition to Logistics 4.0. More specifically, this research aims to:

- Identify the current state of the logistics system at BOMARE COMPANY and evaluate its capacity to serve as a foundation for digital transformation;
- Assess the level of technological and infrastructural capabilities available within the company to support Logistics 4.0 adoption;
- Evaluate the level of human capital and digital readiness among employees, including their familiarity with and attitudes towards advanced technologies;
- Analyse the organisational capabilities and strategic management commitment that shape the company's overall preparation for digital transformation;
- Determine whether demographic and professional characteristics significantly influence employees' perceptions of the company's readiness for Logistics 4.0.

Problem Statement

In an era of accelerated digital transformation, the transition to Logistics 4.0 is emerging as a critical strategic imperative for organisations seeking to maintain competitiveness and operational resilience. The logistics function, as the operational backbone of industrial enterprises, finds itself at the centre of this transformation dynamic. However, the gap between strategic ambition and operational reality remains considerable, particularly in emerging economy contexts where the necessary capabilities for such a transition are often only partially developed or poorly aligned.

The central research problem of this thesis can therefore be formulated as follows:

To what extent do the organisational capabilities currently developed within BOMARE COMPANY determine its overall readiness to transition to Logistics 4.0?

This main question reflects the dual objective of the research: on the one hand, to theoretically establish the key capability dimensions that the literature associates with Logistics 4.0 readiness; and on the other, to empirically measure the degree to which these capabilities are present within a specific Algerian industrial company, with a view to providing concrete and actionable insights for its digital transformation strategy.

To operationalise this main question, four secondary questions guide the investigation:

1. To what extent does the current state of BOMARE COMPANY's logistics system support its readiness for a Logistics 4.0 transition?
2. To what extent does BOMARE COMPANY currently possess the technological infrastructure and human capital required to support a transition to Logistics 4.0?
3. To what extent do organisational capabilities and strategic management commitment predict BOMARE COMPANY's overall readiness for Logistics 4.0?
4. Do demographic and professional characteristics such as gender, age, department, and professional experience significantly influence employees' perceptions of the company's readiness for Logistics 4.0?

Hypotheses

In the framework of this quantitative study examining the Organisational Capabilities for Logistics 4.0 transition, we have formulated five research hypotheses that constitute the conceptual backbone of our investigation:

H1: The current level of efficiency and digitalisation of the logistics system significantly affects BOMARE Company’s readiness to transition to Logistics 4.0.

H2: There is a significant effect of technological infrastructure availability and maturity on BOMARE Company’s readiness to transition to Logistics 4.0.

H3: Employees' digital skills and training levels significantly influence BOMARE Company's readiness to transition to Logistics 4.0.

H4: BOMARE Company's organisational capabilities have a significant effect on its readiness to transition to Logistics 4.0.

H5: Management's strategic vision, budget allocation, and communication significantly determine BOMARE Company's readiness to transition to Logistics 4.0.

These theoretical propositions will serve as the guiding thread for our analysis and will be subjected to empirical verification through the collected data and obtained results.

Research Methodology

This research adopts a quantitative approach grounded in the positivist epistemological paradigm. In line with the principles of positivism, social reality is treated as objective and measurable, and knowledge is produced through systematic observation, standardised measurement, and hypothesis testing using statistical procedures (Gavard-Perret et al., 2018).

The primary data collection instrument is a structured questionnaire designed around a five point Likert scale and organised into six thematic axes corresponding to the five independent capability dimensions current logistics system state, technological Capability, Human Capital Capability, Organisational Capabilities, and Strategic Orientation and a sixth axis measuring overall Organisational Capabilities for Logistics 4.0 as the dependent variable. The questionnaire was administered in both paper based and digital formats to a purposive stratified sample of employees at BOMARE COMPANY from departments directly or indirectly involved in logistics related activities.

Data analysis was conducted using multiple linear regression via IBM SPSS Statistics 27 for hypothesis testing, along with descriptive statistics, correlation analysis, and group comparison tests. This approach ensures the robustness and reliability of the empirical findings.

Research Field

The research was conducted within BOMARE COMPANY, an Algerian electronics manufacturer established in 2001 and headquartered in El Biar, Algiers. Over more than two decades of continuous development, the company has grown into one of Algeria's most significant industrial enterprises, with a share capital of 3.2 billion Algerian dinars and a production capacity that spans consumer electronics, household appliances, and high technology systems. The company operates a highly diversified supply chain encompassing international procurement, local purchasing, production, quality assurance, export logistics, and a national after sales service network.

BOMARE COMPANY has demonstrated a clear commitment to technological innovation and digital transformation, as evidenced by the deployment of an SAP ERP system, the establishment of an ISO/IEC 17025 accredited metrology laboratory, the launch of a SMART FABLAB innovation platform, and the commissioning of a highly automated new industrial site in 2024. These characteristics make BOMARE COMPANY an ideal and representative case for this study: it is an organisation already engaged in a digital transformation trajectory, operating precisely the complex logistics functions that Logistics 4.0 seeks to transform, and positioned at a critical diagnostic transition point where readiness assessment is most timely and most actionable.

Structure of the Thesis

In order to address the research problem and answer the sub questions raised above, this thesis is organised into three complementary chapters, each contributing an essential dimension to the investigation.

Chapter I establishes the theoretical foundation of the research by reviewing the literature on three interconnected pillars: Industry 4.0 and its enabling technologies, supply chain management in the digital age, and Logistics 4.0 as the conceptual and operational framework linking the two. This chapter also identifies the core organisational capabilities associated with a successful Logistics 4.0 transition, forming the basis for the conceptual model tested in this study.

Chapter II presents the conceptual and methodological framework of the research. It introduces BOMARE COMPANY as the research field, formulates the research hypotheses and the conceptual model, and details the epistemological positioning, research design, data collection procedure, and analytical methods adopted in this study.

Chapter III presents the empirical results of the study. It includes the descriptive analysis of respondents and capability dimensions, normality and correlation testing, multiple regression analysis for hypothesis testing, group comparison analyses, and a comprehensive discussion of the main findings and their theoretical and managerial implications.

The thesis concludes with a general conclusion that synthesises the main findings, highlights the study's contributions, acknowledges its limitations, and opens perspectives for future research.

This tripartite structure ensures a logical progression from theoretical foundations through methodological development to empirical validation and discussion, thereby establishing a clear link between theory and practice and contributing to both the academic literature on Logistics 4.0 readiness and the practical improvement of logistics processes within BOMARE COMPANY.

CHAPTER I: Theoretical Framework - Industry 4.0 Supply Chain Management and Logistics 4.0

This chapter establishes the theoretical foundation upon which the research model is built. It is organised into three sections. The first traces the historical evolution of industrial revolutions and reviews the core technologies that define Industry 4.0, from big data analytics and artificial intelligence to the Internet of Things, cloud computing, blockchain, and advanced robotics. The second explores the fundamentals of supply chain management in the digital age, examining its key processes, flows, and performance dimensions and how digital transformation is reshaping them. The third section focuses on Logistics 4.0 the concept that applies Industry 4.0 technologies specifically to logistics operations covering its definition, its evolution from traditional logistics, the enabling technologies that underpin it, and the benefits and challenges of its implementation. Together, these three sections provide the conceptual infrastructure required to identify and theoretically justify the five capability dimensions that form the basis of the research model tested in Chapter II.

Section one : Industry 4.0 - Evolution and Key Technologies

The fourth industrial revolution cannot be understood in isolation from the historical context that produced it. Each stage of industrial development carried its own logic of organisation and production, serving as a cumulative foundation for the next. However, Industry 4.0 represents not merely a natural extension of the information age, but a qualitative shift that calls for a fundamental rethinking of established notions of production and technology.

This part briefly traces the historical evolution of the three preceding industrial revolutions, providing an essential foundation for understanding the structural characteristics that distinguish the fourth from its predecessors.

1.1History of Industrial Revolutions

The story of modern industry is, at its core, a story of successive technological disruptions, each of which has profoundly reshaped the way human societies produce, distribute, and consume goods and services. Historians and economists have identified four distinct waves of industrial transformation since the mid eighteenth century, each characterized by a cluster of general purpose technologies that restructured the economy and redefined the boundaries of productive possibility (Perez, 2002; Schwab, 2016). Understanding this historical trajectory is not merely an academic exercise; it provides essential context for situating the current transformation and appreciating why Industry 4.0 represents something qualitatively different from earlier technological changes.

1.1.1The First Industrial Revolution (circa 1760–1840)

The First Industrial Revolution, which unfolded primarily in Britain between approximately 1760 and 1840, marked the transition from agrarian, handicraft economies to manufacturing based systems organised around mechanized production. Its defining technological innovations were the steam engine, the mechanized textile loom, and the coal powered furnace, all of which were transformative not merely in their individual applications but in their cumulative effect on the organisation of labor, capital, and spatial concentration of economic activity (Mokyr, 1990).

The steam engine, developed and refined by James Watt in the 1760s and 1780s, provided a scalable, non site dependent source of mechanical power that could be applied across a wide range of productive activities. This generality of application is precisely what made it a general purpose technology in the sense defined by Bresnahan and Trajtenberg (1995): a technology capable of being deployed across many sectors, with strong complementarities with other innovations, and a pervasive effect on productivity and organisational structure. The mechanized textile industry demonstrated how steam power could be combined with specialised machinery and disciplined factory labor to achieve substantial increases in output per worker (Clark, 2014).

Beyond the factory floor, urbanisation accelerated dramatically as workers migrated from rural areas to industrial towns. The factory system replaced guild and cottage industry structures that had governed production for centuries, introducing new forms of labor discipline, hierarchical management, and time based compensation (Thompson, 1967). The development of canal and, subsequently, railway networks created integrated national markets and allowed industrial production benefits to diffuse geographically. In supply chain terms, this era marked the beginning of organised, larg scale procurement, warehousing, and distribution logistics, even if these activities were not yet conceptualized under that terminology (Christopher, 2016).

1.1.2 The Second Industrial Revolution (circa 1870–1914)

The Second Industrial Revolution, centered roughly on the period from 1870 to the outbreak of World War I, introduced a new cluster of general purpose technologies based on electricity, the internal combustion engine, and industrial chemistry. Unlike the first revolution, which was geographically concentrated in Britain, the second was a more distributed phenomenon, with major centers of innovation in the United States, Germany, and France (Freeman & Louca, 2001; Mowery & Rosenberg, 1989).

Electrification was perhaps the most consequential innovation of this era. The replacement of steam powered mechanical drive trains with electrical motors allowed factories to be reorganised entirely, since power could be delivered flexibly to individual machines. This reorganisation enabled the continuous flow production systems pioneered by Taylor and Ford, which dramatically increased throughput and reduced unit costs (Chandler, 1977). The assembly line, introduced by Ford at the Highland Park plant in 1913, became the emblematic production system of the twentieth century. The Second Industrial Revolution also witnessed the emergence of large vertically integrated corporations with sophisticated managerial hierarchies. From a supply chain perspective, this era produced the first systematic approaches to inventory management, procurement standardisation, and transportation scheduling (Ballou, 2004).

1.1.3 The Third Industrial Revolution (circa 1970s–2000s)

The Third Industrial Revolution, sometimes referred to as the Digital Revolution or the Information Age, began in the early 1970s with the invention of the microprocessor and accelerated through the 1980s, 1990s, and early 2000s with the widespread diffusion of personal computers, enterprise software, and the internet. Its defining characteristic was the digitisation of information and the automation of information processing tasks, which complemented and in many ways superseded the physical automation of earlier revolutions (Castells, 1996; Rifkin, 2011).

The diffusion of enterprise resource planning (ERP) systems, electronic data interchange (EDI), and supply chain management software in the 1980s and 1990s fundamentally transformed firm operations. For the first time, it became feasible to integrate data from procurement, production, inventory, and distribution into a single information system, enabling coordinated planning across the entire value chain (Davenport, 1998). The internet further revolutionised supply chain management by enabling real time communication with suppliers and customers, electronic procurement, and the emergence of e-commerce as a significant distribution channel (Porter, 2001). The globalisation of production networks that accelerated during this period was both enabled by and dependent upon this digital infrastructure, and supply chain management emerged as a distinct managerial discipline with its own professional bodies, academic literature, and graduate programs (Lambert & Cooper, 2000).

1.1.4 The Fourth Industrial Revolution: An overview

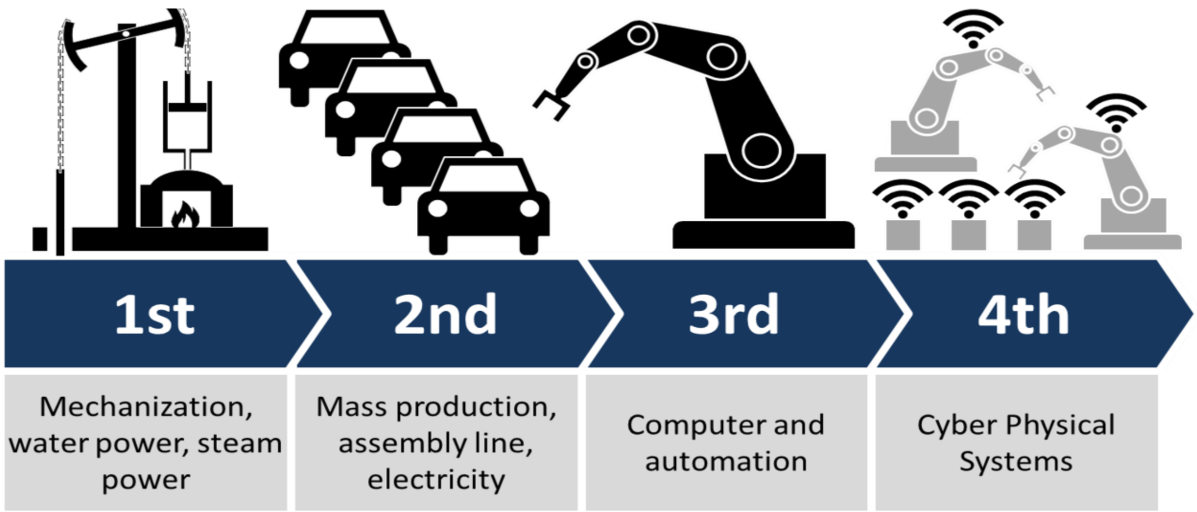
The Fourth Industrial Revolution, a term popularized by Klaus Schwab (2016) through the World Economic Forum, refers to the current wave of technological transformation driven by the fusion of digital, physical, and biological technologies. Unlike the Third Industrial Revolution, which digitalised information, Industry 4.0 enables the intelligent automation of physical processes, blurring the boundary between the digital and physical worlds in ways that have profound implications for production, logistics, and service delivery.

The concept was first formally articulated in Germany, where the term Industrie 4.0 was used to describe a government sponsored strategic initiative announced at the Hannover Fair in 2011, aimed at maintaining German manufacturing competitiveness through the integration of cyber-physical systems into industrial production (Kagermann et al., 2013). Since then, the concept has been adopted and adapted by governments, industry associations, and academic researchers worldwide, sharing a common recognition that the current technological wave represents a discontinuous break from the previous paradigm.

What distinguishes Industry 4.0 from its predecessors is not simply the introduction of new technologies, but the nature of their integration. Big data and analytics, the Internet of Things (IoT), cloud computing and cybersecurity, artificial intelligence (AI) and machine learning, advanced robotics and automation, blockchain, and simulation and digital twins are not independent innovations but form an interconnected ecosystem in which each technology enhances and enables the others (Aksoy & Bulbul, 2025; Ghadge et al., 2020). This systemic integration creates capabilities for real time monitoring, predictive optimisation, and autonomous decision making that were simply not achievable in any previous industrial era. Richnák (2022) notes that Industry 4.0 is already fundamentally transforming logistics processes in enterprises, while Sun and Yu (2021) demonstrate its potential to improve economic efficiency, environmental performance, and social impact simultaneously.

Alongside this industrial transformation, the evolution of the World Wide Web has played a fundamental role in shaping the digital environment in which Industry 4.0 operates. This evolution is typically described in four generations (Aghaei et al., 2012): Web 1.0, a static, read only web for passive information consumption; Web 2.0, a read write web enabling user participation and collaboration; Web 3.0, the Semantic Web, which allows machines to interpret data meaningfully and draw connections automatically; and Web 4.0, an emerging read write execution concurrency web that integrates artificial intelligence, big data, the Internet of Things, and cloud computing into a symbiotic ecosystem where systems can act autonomously on real time information (Ibrahim, 2021). In essence, Web 4.0 serves as the intelligent and autonomous infrastructure that mirrors and supports the cyber physical integration at the heart of Industry 4.0.

Figure 1: The four industrial revolutions



source (Roser, 2015)

1.2 Core Technologies Of Industry 4.0

Industry 4.0 is not reducible to any single technology but rather emerges from the systemic interaction of several complementary technological clusters. Each of these technologies has its own distinct logic of operation, set of applications, and body of literature; yet their transformative power is most fully realised when they are integrated with one another. This section provides a conceptually grounded review of the seven core technologies identified in the literature as most central to the Industry 4.0 paradigm, examining their definitions, mechanisms, and implications for operations and supply chains.

1.2.1 Big Data and Analytics

The concept of big data refers to datasets whose volume, velocity, and variety exceed the processing capabilities of conventional database management systems and analytical tools. The now standard three V characterization, introduced by Laney (2001) and subsequently expanded by various researchers, captures the core technical challenge: data generated by modern industrial systems is produced at high speed, comes in diverse formats (structured and unstructured), and accumulates at a scale that makes exhaustive human analysis impossible (McAfee & Brynjolfsson, 2012). A fourth V, veracity, has been added by some researchers to account for the reliability and consistency problems that arise with large, multi source datasets (Gandomi & Haider, 2015).

In an industrial context, the primary sources of big data include sensor networks embedded in production equipment and logistics assets (notably through the IoT), enterprise information systems (ERP, WMS, TMS), customer facing systems (CRM, e-commerce platforms), social media, and external data providers such as weather services and financial data vendors. The analytical methods applied to these data sources range from descriptive analytics (reporting on past performance), through diagnostic analytics (explaining why something happened), to predictive analytics (forecasting future states) and prescriptive analytics (recommending optimal actions) (Davenport & Harris, 2007; Waller & Fawcett, 2013).

The supply chain applications of big data and analytics are particularly extensive. Demand forecasting has been transformed by the ability to incorporate not just historical sales data but also real time market signals, social media sentiment, and macroeconomic indicators into predictive models (Zhuckovskaya, 2024). Inventory optimisation, supplier risk assessment, route planning, and predictive maintenance are all areas in which advanced analytics have demonstrated measurable performance improvements (Aksoy & Bulbul, 2025; Hrouga & Sbihi, 2023). The integration of big data analytics into supply chain operations contributes significantly to visibility, responsiveness, and the capacity to detect and respond to disruptions before they propagate through the network (Huang et al., 2023).

1.2.2 Artificial Intelligence and Machine Learning

Artificial intelligence, broadly defined as the capacity of computer systems to perform tasks that would typically require human cognitive abilities, has undergone a profound transformation since its theoretical foundations were laid in the 1950s. The current generation of AI applications that are transforming industry are largely driven by machine learning (ML), a subfield of AI in which systems learn to perform tasks by processing training data rather than through explicit programming (Mitchell, 1997; Russell & Norvig, 2020). Within machine learning, deep learning, which utilises multi layered neural networks capable of learning complex, hierarchical representations of data, has proven particularly powerful for applications involving image recognition, natural language processing, and time series forecasting (Lecun et al., 2015). AI also plays an increasingly central role in supply chain planning and optimisation. Reinforcement learning approaches have been applied to inventory management problems, learning optimal replenishment policies through interaction with simulated supply chain environments (Ravshan & Ogunmola, 2025). Natural language processing enables the automated analysis of supplier contracts, shipment documentation, and customer feedback at scale. AI powered route optimisation systems for transportation and last mile delivery incorporate dynamic real time data on traffic, weather, and customer availability to generate routing solutions that minimise cost and time simultaneously.

1.2.3Advanced Robotics and Automation

Robotics has been a component of manufacturing automation since the 1960s, but the robots of Industry 4.0 represent a qualitative advance over their predecessors in terms of flexibility, intelligence, and human robot collaboration capabilities. Traditional industrial robots were designed to perform specific, repetitive tasks in precisely defined environments, required extensive programming for each task, and were physically separated from human workers for safety reasons. By contrast, the advanced robotics systems of Industry 4.0 are characterized by adaptability, sensory richness, learning capabilities, and the ability to operate safely alongside human workers (Hofmann & Rusch, 2017; Suvorova & Glushchenko, 2025). Collaborative robots, or cobots, are designed from the outset to work in close physical proximity with human operators, assisting with tasks that require a combination of human dexterity, judgment, and robotic precision or strength. Mobile autonomous robots (MARs), including autonomous guided vehicles (AGVs) and autonomous mobile robots (AMRs), are transforming warehouse operations by enabling flexible, dynamically routed material handling without fixed infrastructure. Robotic picking systems equipped with computer vision and AI driven manipulation algorithms are extending automation to the previously robot resistant tasks of bin picking and order fulfillment involving diverse product types

(Albrecht & Baier, 2023). The implications of advanced robotics for logistics and supply chains are substantial. In warehousing, robotics enabled fulfillment systems can operate continuously, increase throughput, and reduce error rates compared to manual operations (Winkelhaus & Grosse, 2019). In transportation, autonomous vehicles and drones are in various stages of development and deployment for last mile delivery, potentially transforming the economics of urban freight (Facchini & Oleskow-Szlapka, 2019). The broader automation trajectory also raises significant questions about the changing nature of logistics work, skill requirements, and the distribution of productivity gains between capital and labor.

1.2.4 Simulation and Digital Twins

Simulation has long been used as a tool for analysing complex systems, but the concept of digital twins takes simulation to a qualitatively different level by creating dynamic, real time virtual replicas of physical assets, processes, or systems that are continuously updated with data from their physical counterparts. The concept of the digital twin was first articulated by Grieves (2014) in the context of product lifecycle management, though its broader industrial significance has become apparent as IoT connectivity has made it feasible to create genuinely synchronised virtual representations of physical systems.

A digital twin of a supply chain or logistics network would incorporate real time data feeds from IoT sensors, transportation management systems, weather services, and other relevant sources to maintain a current, accurate model of the physical network. This virtual representation can then be used for several high value purposes: monitoring (detecting anomalies and deviations from expected performance in real time), analysis (understanding the causes of performance problems), prediction (forecasting future states of the system), and optimisation (testing alternative strategies and configurations in the virtual environment before implementing them physically) (Grieves, 2014).

The application of digital twins in logistics and supply chain management is an emerging but rapidly developing area. Vicente et al (2024) . demonstrate through a case study the potential of digital twin technology for supply chain planning, risk management, and responsiveness to demand fluctuations. The ability to simulate the impact of disruptions such as supplier failures, transportation delays, or demand shocks on the virtual replica of the supply chain before they occur in reality, and to develop and test contingency responses, represents a significant advance in supply chain resilience capabilities. The combination of digital twins with AI driven optimisation algorithms creates particularly powerful decision support tools capable of identifying optimal responses to complex, multi-dimensional supply chain challenges (Sun & Yu, 2021; Huang et al., 2023).

1.2.5 Internet of Things (IoT)

The Internet of Things refers to the network of physical objects embedded with sensors, actuators, processors, and communication modules that enable them to collect and exchange data over the internet or other communication networks without requiring direct human intervention (Atzori et al., 2010; Ashton, 2009). The IoT can be understood as the nervous system of Industry 4.0: it provides the physical sensing and actuation layer that connects the digital and physical worlds, enabling real time monitoring and control of physical assets, processes, and environments (Helo & Thai, 2024). In manufacturing, IoT sensors are embedded in machines, tools, and components to enable continuous monitoring of operational parameters such as temperature, vibration, pressure, and energy consumption. This data stream enables predictive maintenance strategies that replace time based preventive maintenance schedules with condition based interventions, typically reducing unplanned downtime and extending asset useful life (Ghadge et al., 2020; Idrissi et al., 2024). In warehousing, IoT devices support automated tracking of inventory location and status, enabling real time visibility into stock levels and supporting autonomous replenishment systems. The logistics applications of IoT are perhaps the most extensively documented in the literature. Smart tracking and tracing systems employing RFID (radio frequency identification), GPS, and cellular communication technologies enable end to end visibility of shipments as they move through global supply chains (Helo & Thai, 2024). This visibility capability addresses one of the most persistent challenges in supply chain management, namely the difficulty of knowing where goods are, in what condition, and when they will arrive, without relying on manual reporting or infrequent carrier updates. Ravshan and Ogunmola (2025) demonstrate that IoT implementation in logistics operations significantly improves operational performance across multiple dimensions including speed, accuracy, and cost efficiency. Vaghani et al. (2022) further analyse security and quality of service considerations in IoTenabled logistics networks, highlighting the importance of cybersecurity design in IoT deployments.

1.2.6 Cloud Computing and Cybersecurity

Cloud computing represents a fundamental shift in the delivery model for computing resources, from ownership of dedicated hardware and software to subscription based access to shared computing infrastructure, platforms, and applications delivered over the internet (Mell & Grance, 2011). The three primary cloud service models are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), each offering different levels of abstraction and different mixes of customer and provider responsibilities. For supply chain management, the significance of cloud computing lies primarily in its ability to provide scalable, accessible, and cost effective computational infrastructure that can support the processing and storage demands of big data analytics, real time IoT data streams, and collaborative information sharing across supply chain networks. Cloud based supply chain platforms enable multi party collaboration across the entire value chain without requiring each participant to maintain expensive dedicated infrastructure, dramatically lowering the barrier to supply chain digitalisation for small and medium sized enterprises (El Hamdi & Abouabdellah, 2022; Zhuckovskaya, 2024). However, the migration of supply chain data and processes to cloud environments introduces significant cybersecurity challenges. Supply chains are increasingly recognised as high value targets for cyberattacks, both because they represent critical infrastructure and because they create complex networks of interconnected organisations with heterogeneous security practices (Hrouga & Sbihi, 2023). The cybersecurity dimensions of Industry 4.0 supply chains encompass not only the protection of cloud platforms and enterprise systems but also the security of IoT device networks, industrial control systems, and inter organisational data exchange protocols (Vaghani et al., 2022). The field of cyber physical security has emerged as a specialised domain at the intersection of information security and operational technology security, addressing the unique vulnerabilities created by the deep integration of digital and physical systems in Industry 4.0 environments.

1.2.7 Blockchain Technology

Blockchain technology, first described in the context of the Bitcoin cryptocurrency system by Nakamoto (2008), is a distributed ledger technology that maintains a continuously growing list of records (blocks) that are linked cryptographically and distributed across a network of nodes such that no single participant can unilaterally modify or delete records without consensus from the network. The key properties of blockchain that make it relevant for supply chain applications are immutability (recorded data cannot be altered without detection), transparency (all participants can view the ledger), decentralisation (no single point of control or failure), and programmability (smart contracts can automatically execute transactions when predefined conditions are met) (Tapscott & Tapscott, 2016; Kshetri, 2018). In supply chain management, blockchain addresses a fundamental challenge that pervades multi party commercial relationships: the need for trusted, verifiable records across organisational boundaries. Traditional approaches to inter organisational information sharing rely on either centralised databases managed by one party (which creates trust and governance issues) or bilateral electronic data interchange (which is costly to implement and difficult to scale). Blockchain offers a technically decentralised alternative that allows all participants to maintain their own copy of a shared record, with cryptographic guarantees of integrity (Lisnevskyi et al., 2023; Idrissi et al., 2024). The supply chain applications of blockchain that have attracted the most research and commercial interest include traceability and provenance verification, financial settlement, and smart contract based automation of logistics processes. Food supply chain traceability systems, exemplified by implementations such as IBM Food Trust on the Hyperledger Fabric platform, enable end to end tracking of products from farm to retailer with cryptographic assurance of record integrity, facilitating rapid identification of contamination sources and supporting anti counterfeiting measures (Hrouga & Sbihi, 2023). Vaghani et al. (2022) analyse blockchain applications in IoT based logistics networks, demonstrating that the combination of blockchain and IoT can significantly improve security and quality of service, though computational resource requirements remain a challenge for resource constrained IoT devices.

Table 1 : New technologies 4.0

Big Data and Analytics	The presence of sensors on machines and products allows the collection of large amounts of data. With appropriate processing and analysis tools, these data help optimise the production chain by precisely identifying problems that occur. They also provide knowledge abou consumer habits and preferences.
Artificial Intelligence	Artificial Intelligence (AI) refers to a broad research field built around an ambitious objective: understanding how human cognition works and reproducing it. In industry, its applications are numerous. It extends data exploitation, supports decision making, anticipates demand, and improves processes
Robots	Today it is possible to develop robots that operate more autonomously, more flexibly, and in greater cooperation with human operators.
Simulation	The 3D simulation of products, materials, or processes can be extended to the entire production chain. The acquisition of real data helps refine and improve these models.
Internet of Things (IoT)	Through sensors installed on machines and objects during manufacturing, machines can access the production history of an item and the corresponding final demand in order to respond automatically or through a central control system. IoT also enables the collection of data during product use to understand which functions are utilised and to identify potential failure modes.
Cloud Computing	Cloud technology is already widely used for managing software and data. The increasing interconnection between production sites

	and company departments requires the sharing of large amounts of data, which is facilitated by cloud solutions.
Additive Manufacturing	This technology raises many expectations. Beyond prototype production, additive manufacturing already enables the small scale production of complex parts, spare parts, and even customised tools. The speed and precision of printing are expected to increase, allowing production on a larger scale.
Augmented Reality	One possible use is to provide maintenance operators with information about repair techniques, for example through augmented reality glasses. This technology can also be used for training purposes or to make design stages less abstract and involve more stakeholders.

Sources :(Kihel, 2021, p. 15)

Section two : Supply Chain Management in the Digital Age

Supply chain management has changed dramatically in the digital age. What used to be a straightforward, linear process moving goods from suppliers to manufacturers to customers has now become something far more complex. Today's supply chains are dynamic networks, powered by real time data and digital technologies. This shift has transformed how companies coordinate their operations, bringing new levels of visibility, flexibility, and responsiveness that were simply not possible before.

This section explores how supply chain management has evolved in response to digital transformation, and how emerging technologies are reshaping the way supply chains are designed and run.

2.1 Fundamentals of Logistics and Supply Chains

This analysis aims to examine the development of the supply chain concept and its management through a chronological review of the various academic and professional definitions that have emerged over time. Such an approach makes it possible to identify the key components, guiding principles, and major transformations that have shaped the current understanding of these concepts.

From the early stages of basic logistics coordination in the 1980s to today’s integrated and collaborative approaches, the supply chain has gradually evolved into a crucial strategic tool for modern organisations. In an environment characterized by globalisation, digital transformation, and increasing sustainability concerns, effective supply chain management has become essential for organisations seeking to remain competitive and adaptable in a rapidly changing business landscape.

2.1.1 Definition of Logistics

The term "logistics" is inherently multidimensional, and its definition has evolved significantly alongside the increasing complexity of global commerce. In its most fundamental sense, logistics refers to the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption to meet customer requirements (Pimor & Fender, 2020). This definition underscores the dual nature of logistics: it is both a physical operation involving the movement of tangible goods and a managerial discipline focused on the strategic alignment of resources.

Modern academic discourse suggests that logistics is far more than a simple operational function; it is a strategic discipline that integrates various activities to create value. Contemporary definitions emphasise the role of logistics in managing both physical flows and information flows. For instance, Helo and Thai (2024) highlight that logistics in the digital era, often termed "Logistics 4.0," relies heavily on smart connected devices to enhance operational efficiency, visibility, and transparency. This shift indicates that logistics is no longer just about moving boxes but about managing data to ensure that the physical movement is optimised for safety, security, and cost effectiveness.

Furthermore, logistics is frequently defined by its core activities. According to Christopher (2016), these include transportation, warehousing, inventory management, material handling, and order fulfillment. The primary goal of these activities is to provide the "right product, in the right quantity, in the right condition, at the right place, at the right time, to the right customer, at the right price" a concept often referred to as the "Seven Rs" of logistics. This holistic perspective ensures that logistics serves as a critical link between production and consumption, directly impacting an organisation's ability to maintain a competitive advantage in a turbulent market (Mentzer et al., 2001).

2.1.2 Evolution of Logistics

The evolution of logistics can be traced through several distinct stages, each marked by technological advancements and shifts in economic priorities. Historically, logistics had its roots in military science, where the primary focus was on the movement and supply of troops. However, its transition into the business world began in the mid 20th century. During the 1950s and 1960s, logistics was largely fragmented, with activities such as transportation and warehousing managed as separate, isolated functions (Christopher, 2016).

The first major shift occurred with the "Physical Distribution" era, where companies began to recognise the importance of coordinating outbound activities to reduce costs and improve customer service. By the 1980s, the concept of "Integrated Logistics" emerged, emphasising the need to link inbound and outbound flows. This period was characterized by the adoption of Information Technology (IT) systems, which allowed for better visibility across the internal supply chain (Hofmann & Rüsch, 2017).

In the 21st century, the evolution has accelerated towards what is now known as "Logistics 4.0." This current stage is defined by the integration of Industry 4.0 technologies such as the Internet of Things (IoT), Big Data analytics, and Artificial Intelligence (AI) into logistics processes. Unlike previous eras, Logistics 4.0 focuses on decentralisation, self regulation, and real time transparency (Winkelhaus & Grosse, 2019).

As noted by Richnák (2022), this transformation is not merely technical but represents a fundamental shift in how enterprises manage maturity and process optimisation to stay competitive in a globalised economy.

Table 2: The major periods in the evolution of logistics

Period	Logistics Approach	Characteristics
War Periods	Military Logistics	- Management of the supply of resources, accommodation, and transportation of military troops. Coordination and control of troop movements. - The works of Antoine Henri Jomini, particularly *Précis de l'art de la guerre*, served as key references for organizing military camps and ensuring the provision of food and other essential supplies.
1950–1975	Fragmented (Separated) Logistics	Demand exceeded supply. - Production focused on large volumes in order to meet market needs. - Activities were divided into separate functions such as production, distribution, and others. - Emphasis on local optimisation, meaning each department tried to minimise its own costs without considering the consequences of its decisions on other departments.

1975–1990	Integrated Logistics	Demand became roughly equal to supply. - Producers began to prioritise product quality and operational flexibility. - The philosophy that the customer is king became central. - Stronger collaboration between different departments inside the organisation. Focus on global optimisation rather than isolated improvements. - Emergence of new managerial concepts such as JIT and TQM, among others.
1990s	Supply Chain Management	- Demand became lower than supply, meaning companies faced a more competitive market. - Development of stronger cooperation and coordination with customers and suppliers in order to improve efficiency across the supply chain. - Emergence of logistics information systems designed to support planning, coordination, and decision making processes. Increasing competition between supply chains rather than only between individual firms.
From 2011 onward	Logistics 4.0	- Digitalisation of the supply chain, enabling more advanced and automated logistics operations. - Integration of the latest information and communication technologies (ICT) within logistics activities. - Establishment of connections between people, machines, equipment, and products through intelligent systems. - These interconnected systems allow real time communication and data exchange, improving coordination, visibility, and operational responsiveness across the supply chain.

Source: (Safae et al., 2024, p. 1306)

2.1.3 Definition of the Supply Chain

While logistics focuses on the flow of goods within and between specific points, the "Supply Chain" represents a broader and more systemic concept than logistics, representing a network of organisations involved in upstream and downstream activities that create value for the final customer (Christopher, 2016). It includes all actors participating in fulfilling customer demand, such as suppliers, manufacturers, transporters, warehouses, retailers, and customers. A key distinction exists between logistics and supply chain management (SCM). While logistics focuses on the movement of goods and information, SCM involves the strategic coordination and integration of all business functions across the entire supply chain (Mentzer et al., 2001). In the modern context, supply chains are increasingly viewed as digital ecosystems. The integration of Industry 4.0 technologies has transformed traditional linear chains into interconnected and responsive networks, enhancing resilience and adaptability to disruptions (Ghadge et al., 2020; Sweeney, 2022). As a result, effective supply chain management plays a critical role in delivering value and ensuring long term organisational performance (Trushkina & Dźwigoł, 2020).

2.2. Supply Chain Processes and Flows

This section focuses on the processes that structure and coordinate supply chain activities. The effectiveness of a supply chain depends not only on resources and technologies, but also on how well these processes are organised and managed across all operational stages. These processes enable coordination between activities and connect all actors within the organisation and with external partners. They ensure the efficient flow of resources and information, maintaining operational continuity and reducing the risk of disruptions.

Since supply chain processes are highly interdependent, the performance of the entire system relies on their integration and coordination. Weaknesses in one process can negatively impact the overall system, highlighting the need for a structured and integrated management approach.

Understanding these processes is essential for improving efficiency, strengthening coordination, and enhancing overall supply chain performance, allowing organisations to respond effectively to market changes and customer expectations.

2.2.1 Main Processes of the Supply Chain

The supply chain is composed of interconnected core processes procurement, production, inventory management, transportation, distribution, and reverse logistics whose performance depends mainly on their coordination and integration.

This section briefly reviews these six processes, focusing on their role within the supply chain and how they are being shaped by the technologies of the Fourth Industrial Revolution.

- **Procurement**

Procurement is the initial process, involving the acquisition of goods and raw materials through strategic supplier selection based on quality, cost, reliability, and sustainability

(Le Moigne, 2017). It includes sourcing strategies such as single and multiple sourcing (Sajadieh & Thorstenson, 2014). With Industry 4.0, procurement becomes more digital and collaborative through real time data sharing and improved coordination (Hofmann & Rüsch, 2017).

- **Production**

Production transforms raw materials into finished goods and can follow different models such as artisanal, line based, and functional systems (Semal, 2017). It also includes strategies like Make-to-Stock, Make-to-Order, and postponement (Le Moigne, 2017). The integration of digital technologies enhances real time monitoring and production performance (Aniba, 2024).

- **Inventory and stock management**

Inventory management controls raw materials, work-in-progress, and finished goods, balancing holding costs and stockout risks (Goldratt & Cox, 2014). It includes different types such as cycle, safety, and anticipated stock (Semal, 2017). Techniques like JIT and VMI optimise inventory, while digital tools enable real time monitoring (Winkelhaus & Grosse, 2019; Saaresto, 2022).

- **Transportation**

Transportation ensures the movement of goods via different modes and represents a major cost factor (Le Moigne, 2017). Technologies such as AI, 5G, and the Physical Internet improve efficiency, optimise routing, and enhance sustainability (Polomoshnov, 2020; Colicchia et al., 2017).

- **Distribution**

Distribution manages the delivery of finished products to customers through different systems such as direct delivery, warehousing, and cross docking (Le Moigne, 2017; Ribas et al., 2019). Strategic choices between centralised and decentralised networks affect both cost and responsiveness (Christopher, 2016).

- **Returns and reverse logistics**

Reverse logistics involves product returns, recycling, and value recovery, becoming increasingly important due to e-commerce and sustainability (Christopher, 2016). It also provides insights for improving product quality and customer satisfaction (Le Moigne, 2017).

2.2.2 Classifying Supply Chain Activities

Supply chain activities can be viewed from four complementary perspectives: traditional logistics functions focused on physical operations, managerial activities concerned with coordination, the core links connecting different actors, and specialised sectors that require tailored approaches.

This section briefly examines each of these dimensions and their evolution in the context of Industry 4.0.

- **Traditional Logistics Ativities**

Traditional logistics activities represent the execution oriented functions of the supply chain, mainly focused on the physical movement and storage of goods. They include transportation, warehousing, inventory management, and material handling, and aim to ensure that products are delivered in the right quantity, condition, and time (Christopher, 2016). Traditionally, these activities were managed in separate silos, where each function optimised its own performance without considering the overall impact on the supply chain. For instance, minimising transportation costs through full truckloads could increase inventory costs or delay deliveries (Pimor & Fender, 2020). Despite their operational nature, these activities remain fundamental to supply chain performance. Even in the Industry 4.0 context, the physical movement of goods continues to be a key challenge, requiring a balance between efficiency and technological innovation (Polomoshnov, 2020). Their effectiveness directly supports the achievement of the “Seven Rs” of logistics (Christopher, 2016).

- **Activities Related to the Management and Coordination of the Supply Chain**

Supply Chain Management (SCM) goes beyond traditional logistics by focusing on the strategic coordination and integration of activities across organisations. It includes demand planning, relationship management, and information sharing, aiming to improve long term performance across the entire supply chain (Mentzer et al., 2001). Such coordination helps reduce the bullwhip effect, where small demand changes lead to large upstream fluctuations.

Effective coordination requires trust and transparency among partners, often supported by digital platforms. In the Logistics 4.0 context, these activities are increasingly data driven, enabling firms to detect market changes and respond quickly (Saaresto, 2022). This transition enhances supply chain agility and responsiveness to disruptions (Sweeney, 2022).

Additionally, SCM involves aligning financial flows and synchronizing production with real demand, shifting from forecast based to demand driven systems (Hofmann & Rüsch, 2017).

- **Activities That Constitute the Links of the Supply Chain**

The supply chain is structured around key links connecting the origin to the final customer, where value is created and information is exchanged. The main links are supplier–manufacturer, manufacturer–distributor, and distributor–customer, each requiring specific management practices and technological support.

The supplier–manufacturer link focuses on sourcing raw materials with an emphasis on quality and reliability. The manufacturer–distributor link manages the flow of finished goods and requires effective inventory strategies. The distributor–customer link, or "last mile," is the most visible and often the most costly stage (Le Moigne, 2017).

In the Industry 4.0 context, these links are increasingly integrated into a digital ecosystem. Technologies such as Blockchain and IoT enhance visibility and coordination across the entire chain (Ghadge et al., 2020), transforming linear supply chains into interconnected and responsive networks capable of adapting to real time changes (Winkelhaus & Grosse, 2019).

- **Specialised Sectors of the Supply Chain**

Although SCM principles are universal, certain sectors require specialised logistics activities due to the nature of their products and constraints. These include cold chain logistics, pharmaceutical supply chains, and humanitarian logistics, each demanding tailored solutions and specific expertise.

For example, cold chains require strict temperature control and real time monitoring to preserve product quality (Christopher, 2016). The pharmaceutical sector emphasises traceability and regulatory compliance due to safety risks. In industrial contexts, the focus is often on precision and advanced technologies such as robotics (Aniba, 2024).

These examples highlight that supply chain management must be adapted to the specific requirements and challenges of each sector rather than applying a uniform approach.

2.2.3 Supply Chain Flows

The effective management of a supply chain is fundamentally dependent on the seamless integration and synchronisation of three primary flows: information, physical, and financial. These flows are not isolated; rather, they are deeply interconnected, with each influencing the performance and efficiency of the others. In the context of the Fourth Industrial Revolution, these flows are undergoing a digital transformation, evolving from linear, sequential processes into highly responsive, hyperconnected networks (Ivanov et al., 2022).

- **Information Flow**

Information flow is the “nervous system” of the supply chain, enabling decision making and coordinating physical and financial movements through the exchange of data such as forecasts, orders, inventory, and delivery status (Christopher, 2016). Its objective is to provide accurate and real time information to reduce uncertainty and limit the bullwhip effect.

With Logistics 4.0, information flow has evolved into integrated digital systems using technologies like IoT, Big Data, and Cloud computing, enhancing visibility and transparency (Hofmann & Rüsch, 2017). Real time tracking enables proactive disruption management and operational optimisation (Helo & Thai, 2024), while digital sensing capabilities strengthen organisational resilience (Saaresto, 2022).

- **Physical Flow**

Physical flow refers to the movement of materials and products across the supply chain, including procurement, production, warehousing, and transportation (Le Moigne, 2017). Its goal is to ensure efficient movement while minimising costs, delays, and waste.

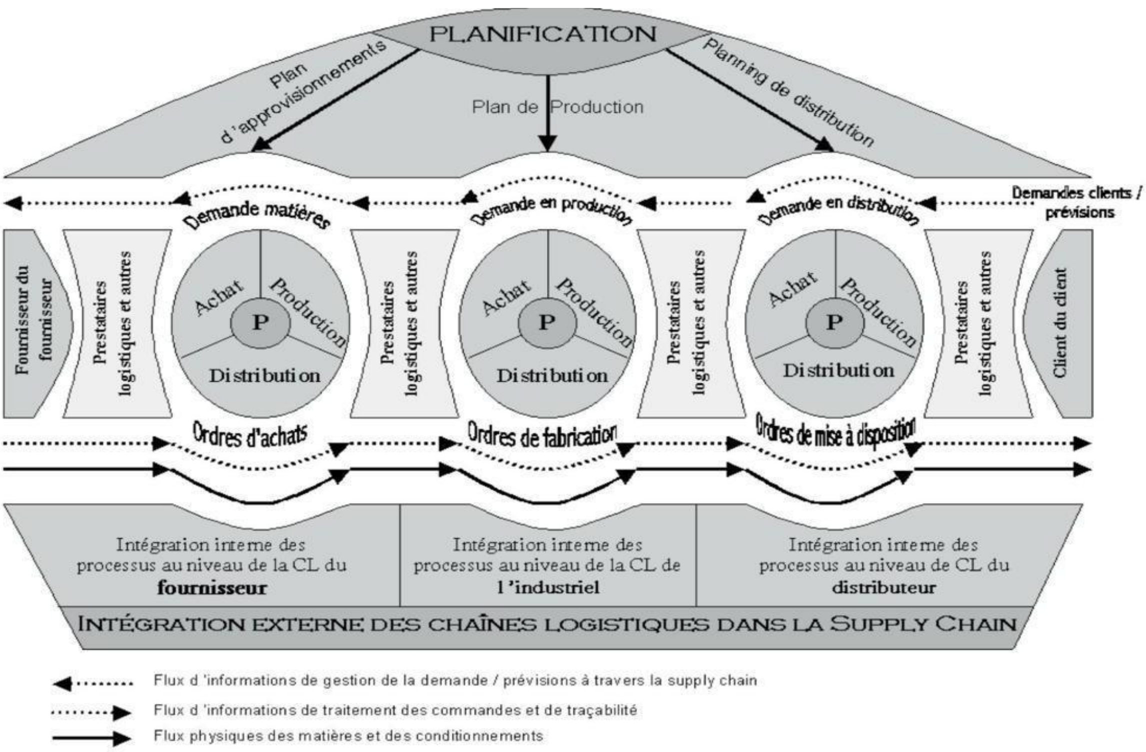
Industry 4.0 technologies improve physical flow management through tools such as Digital Twins for real time control and predictive quality (Aniba, 2024). The Physical Internet concept enhances efficiency and sustainability by optimising transport networks (Polomoshnov, 2020). However, physical flows remain constrained by infrastructure and distance, requiring a balance between digital optimisation and operational reality (Pimor & Fender, 2020).

- **Financial Flow:**

  Financial flow involves the movement of funds within the supply chain, including payments, invoices, and credit terms, and is closely linked to physical and information flows (Comelli et al., 2008). Its efficiency affects liquidity and financial stability.

  Modern SCM integrates financial flows through Supply Chain Finance solutions to optimise working capital. Technologies such as Blockchain enable secure and automated transactions via smart contracts, reducing costs and delays (Ghadge et al., 2020). The alignment of financial, physical, and informational flows is essential for building resilient supply chains, especially in unstable economic environments (Abbasi et al., 2024).

Figure 2: The Extended Enterprise



Source :(Ayadi, 2009, p. 89)

2.3 Supply Chain Management and Performance

Regardless of the size of an organisation or the specific nature of its activities, any economic operation within a company requires the prior availability of material resources and essential production inputs. For this reason, supply chain management can be understood as the coordinated management of a set of activities that include the design, planning, execution, monitoring, and control of operations related to the delivery of products and services. The main objective of these activities is to ensure that goods and services move efficiently from their original sources to the final customer who ultimately consumes them (Iraten, 2014).

2.3.1 Supply Chain Management

Supply Chain Management (SCM) is a strategic and integrated approach to managing the flows of goods, information, and finances from origin to consumption. Unlike traditional logistics, which focuses on physical operations, SCM emphasises the coordination of business processes across multiple organisations to improve overall supply chain performance (Mentzer et al., 2001).

The strategic value of SCM lies in aligning supply chain capabilities with the firm's competitive strategy, whether focused on cost, differentiation, or responsiveness (Christopher, 2016). In today's dynamic environment, SCM has evolved into a critical capability that enables firms to sense market changes and respond effectively through digital integration and collaboration (Saaresto, 2022).

This evolution towards Supply Chain 4.0 relies on Industry 4.0 technologies such as AI, IoT, and Cloud computing, creating interconnected and responsive ecosystems capable of adapting to disruptions in real time (Ivanov et al., 2022; Ghadge et al., 2020).

2.3.2 Supply Chain Performance

- Supply chain performance is a multidimensional concept that assesses how effectively and efficiently the entire network meets customer requirements. It includes all partners and goes beyond cost metrics to a holistic evaluation that balances operational performance and strategic resilience (Özkanlısoy & Akkartal, 2023). Five key dimensions are commonly used: reliability, effectiveness, efficiency, responsiveness, and agility.
- **Reliability:** Reliability refers to the consistency of supply chain operations in delivering correct outcomes, often measured by perfect order fulfillment (Christopher, 2016). It reduces errors and builds customer trust. In Industry 4.0, it is enhanced through real time monitoring and predictive systems (Hofmann & Rüsch, 2017).
- **Effectiveness :** Effectiveness measures the ability of the supply chain to meet its objectives and satisfy customers. It focuses on delivering the right value and aligning operations with strategic goals (Pimor & Fender, 2020; Saleheen et al., 2023).
- **Efficiency:** Efficiency evaluates how well resources are used to produce outputs, focusing

on cost reduction and waste elimination (Le Moigne, 2017). It is essential for competitiveness and is improved through automation and optimisation technologies (Thankkar et al., 2009; Ivanov et al., 2022).

- **Responsiveness :** Responsiveness reflects the speed of delivering products and services, emphasising lead time reduction and synchronisation of flows (El-Garaihy, 2021). It is supported by technologies such as real time tracking and advanced communication systems (Helo & Thai, 2024).
- **Agility :** Agility is the ability to adapt to uncertainty and disruptions by reconfiguring operations and adjusting supply chain activities (Christopher, 2016). It relies on digital capabilities and collaboration, and is enhanced by technologies like AI and simulation tools (Saaresto, 2022; Aniba, 2024; Ghadge et al., 2020).

2.3.3Decision-Making in the Supply Chain

Decision-making in supply chain management is a complex, multi layered process that requires the coordination of various activities across different time horizons and organisational levels. To manage this complexity effectively, decisions are typically categorized into a three level hierarchy: strategic, tactical, and operational. This hierarchical approach ensures that day-to-day activities are aligned with the long term goals of the organisation, thereby enhancing overall supply chain performance and competitiveness (Christopher, 2016; Mentzer et al., 2001).

- **Strategic Level**

  Strategic decisions define the long term structure and direction of the supply chain, involving major investments and network design choices such as facility location, capacity, and partnerships (Christopher, 2016). In the Industry 4.0 context, they increasingly focus on digital transformation and the development of dynamic capabilities through technologies like cloud platforms and advanced analytics (Saaresto, 2022; Ivanov et al., 2022). These decisions establish the foundation for all lower level decisions (Sweeney, 2022).

- **Tactical Level**

Tactical decisions translate strategy into medium term actions, focusing on resource allocation and optimisation of flows to balance cost and service levels (Le Moigne, 2017). They include demand forecasting, inventory policies, production planning, and transportation decisions. Industry 4.0 technologies such as AI and Big Data enhance these processes by improving planning accuracy and coordination (Hofmann & Rüsch, 2017; Ghadge et al., 2020). The integration of financial flows is also critical for managing working capital (Comelli et al., 2008).

- **Operational Level**

Operational decisions concern short term execution, ensuring efficient daily operations such as production scheduling, warehousing, and transportation (Christopher, 2016). With Logistics 4.0, these decisions are increasingly automated through technologies like IoT and real time tracking, enabling rapid responses to disruptions (Helo & Thai, 2024). Tools such as Digital Twins and concepts like the Physical Internet further enhance efficiency, responsiveness, and resource optimisation (Aniba, 2024; Polomoshnov, 2020). Effective execution at this level is essential for overall supply chain performance (Pimor & Fender, 2020).

2.4.Challenges and Opportunities in the Supply Chain

The challenges summarised in Table 3 are particularly relevant to the present research context. Among them, three dimensions directly underpin the capability framework tested in this study: technological adaptation, which drives the need for Logistics 4.0 readiness assessment; qualified personnel, which forms the basis of the Human Capital Capability dimension (H3); and supplier relationship management, which reflects the organisational coordination requirements captured in H4. These interconnected challenges confirm that no single capability deficit can be addressed in isolation, and that a holistic, multi dimensional readiness assessment as developed in Chapter II is both necessary and justified.

Table 3: Supply chain challenges and research Axes

Challenges of SC	**Research focus**	**Supply chain issues**	**References**
Customer service / service quality	Supply chain management is primarily driven by customer needs. It aims to deliver the right product, in the right quantity, at the right time, and under appropriate conditions.	Product quality	(Bhakthavatchalam et al.,2015) (Zhao et al.,2019) (Sarkar et al.,2021).
		Operational and managerial quality	Stanley et Wisner,2000) (Anli et al.,2007)

		Service quality	(Stanley et Wisner,2000) (Anli et al.,2007)
		Logistics and transportation quality	(Cheng et al.,2005) (Mada al.,2014)
Cost	Due to economic changes, the costs of raw materials and labor have increased. Organisations must adapt to maintain production while offering quality products at competitive prices.	Labor and raw material costs	(Lans,2018) (Reda et al.,2020) (Petrudi et al.,2020) (Rajeev A et al. 2019) (Tseng et al.,2018) (Schuetz e t Venkatesh,2020) (Arunachalam et al.,2018)
		Operational costs	(Jiang et al.,2017) (Su et Geunes,2012)
Risk management	The diversity of supply sources and market conditions can lead to instability and operational disruptions.	Market changes	(Barmanand (Zhang,2021)(Rasul ,2021)
		Climate and weather changes	(Godde et al.,2021) (Rasul,2021)
Supplier relationships	Strong relationships between partners and suppliers help ensure timely delivery and improve overall performance while maintaining product quality.	Partner relationships	(Lans,2018) (Tseng et al.,2018) (Tseng et al.,2018) (bentahar et benzidia,2018)
Qualified personnel	Employees involved in supply chain activities must be well trained and fully aware of their responsibilities.	Ability to perform tasks effectively	(Lans,2018) (Petrudi et al.2020) (Tseng et al.,2018) (Arunachalam et al.2018)

Unexpected delays	The delivery of raw materials and components is not always on time, leading to uncertainty in operations.	Production delays	(Baccadoro et al.,2006)
		Delivery lead time	(Guo et al.,2020) (Baccadoro et al.,2006)
Technological adaptation to market changes	Technology evolves rapidly, and market conditions change continuously. Companies must remain flexible to adapt to technological advancements and shifting market demands	Technological improvement	(Lans,2018) (Petrudi et al.2020) (Tseng et al.,2018) (Arunachalam et al.2018)

Source :(El Kihel et al., 2023, p. 9)

Section three : Logistics 4.0 Bridging Industry 4.0 and Supply Chain Management

Logistics 4.0 sits at the intersection of Industry 4.0 and Supply Chain Management. It represents the bridge that brings digital technologies into logistics operations, enabling smarter movement, storage, and coordination of goods.

This section briefly explores the concept of Logistics 4.0 and its role in connecting manufacturing transformation with supply chain performance.

3.1.Defining Logistics 4.0

Logistics 4.0 is an integrative concept that represents the application of Industry 4.0 paradigms such as digitalisation, automation, and decentralisation to the field of logistics and supply chain management. It is not merely a collection of new technologies but a fundamental shift in how material and information flows are managed within a global network. According to Winkelhaus and Grosse (2019), Logistics 4.0 can be defined as the logistical system that enables the sustainable and efficient flow of goods through the integration of cyber-physical systems (CPS) and the use of real time data. This definition emphasises that Logistics 4.0 is a "byproduct" of the Fourth Industrial Revolution, where the physical world of logistics is seamlessly connected to a digital counterpart (Symmetry Electronics, 2022).

At its core, Logistics 4.0 aims to create a "smart" supply chain that possesses the ability to automatically perceive, analyse, decide, and execute actions in real time (Westwell, 2025). This transformation is driven by the need for greater transparency, flexibility, and responsiveness in an increasingly complex and volatile market. Unlike traditional logistics, which often relied on manual processes and fragmented information, Logistics 4.0 leverages a hyperconnected ecosystem where machines, products, and systems communicate autonomously to optimise the entire value chain (Demir et al., 2020).

Table 4: Overview of logistics 4.0 definitions and descriptions

Authors and year	**Title**	**Logistics 4.0 description**
Winkelhaus, S., Grosse, E.H. (2020)	Logistics 4.0: a systematic review towards a new logistics system	Logistics 4.0 is distinguished and synthesized by a) the changes of logistics processes that are caused by the use of new digital technologies, b) the implications of the changing production model towards mass customisation, and c) the importance of sustainability and protecting the environment while satisfying all of the above.
Barreto et al., (2017)	Industry 4.0 Implications in logistics: an overview	optimisation of logistics processes that are supported by intelligent systems, embedded in software and databases from which relevant information is provided and shared in order to accomplish a significant automation degree.
Kamble et al., (2018)	Sustainable Industry 4.0 Framework: A Systematic Literature Review Identifying the Current Trends and Future Perspectives	Industry 4.0 technologies make real time data from several logistics domains available, which can be leveraged to create more efficient logistics decisions. Data acquired from products, logistics activities, and manufacturing machinery become easily accessible, bridging the gap between physical and digital worlds.

Tjahjono et al., (2017)	What Does Industry 4.0 Mean to Supply Chain?	the most affected logistics areas by the introduction of Industry 4.0 technologies are order fulfilment and transport logistics. It was also mentioned that implementation of particular Industry 4.0 technologies can have a significant impact in terms of productivity and work improvement on logistics.
Kayikci (2018)	Sustainability Impact of Digitisation in Logistics	digitisation of logistics (i.e., Logistics 4.0) as the enabling of integrated planning and execution systems, logistics visibility, autonomous logistics, and smart warehousing through the implementation of a wide range of digital technologies.
Strandhagen et al., (2017)	Logistics 4.0 and Emerging Sustainable Business Models	Logistics 4.0 was described according to five characteristics: (a) real time big data analytics , (b) reduced storage requirement due to novel manufacturing techniques, (c) autonomous robots and vehicles within warehouses with tracking and decision systems that lead to improved inventory control, (d) real time exchange of information between various actors, and (e) no information disruption due to smart items and cloud supported network

Source: (Fragapane et al., 2021, p. 19)

3.1.1.Evolution From Traditional Logistics to Logistics 4.0

The evolution of logistics has been marked by several distinct phases, each corresponding to a major industrial shift. Traditional logistics, often associated with the first three industrial revolutions, focused primarily on the mechanization of transport, the automation of individual processes, and the introduction of early electronic data interchange (EDI) systems. During these stages, logistics was largely viewed as a supportive, execution oriented function characterized by manual data entry, limited end-to-end visibility, and a "siloed" approach to management (Lizard Global, 2023).

The transition to Logistics 4.0 represents a leap from simple automation to intelligent, networked systems. While "Logistics 3.0" introduced computers and basic robotics to the warehouse, it still lacked the real time connectivity and autonomous decision making capabilities that define the current era. As noted by Cargo Sapiens (2025), the shift towards Logistics 4.0 began in the late 20th century with the rise of the internet and has accelerated with the convergence of technologies like the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI). This evolutionary path has transformed logistics from a reactive "cost center" into a proactive, strategic driver of competitiveness, where the focus has shifted from moving physical boxes to managing the "digital thread" that connects every actor in the supply chain (Paksoy et al., 2021).

3.1.2.Key Characteristics and Principles of Logistics 4.0

Logistics 4.0 is defined by several foundational characteristics and principles that distinguish it from previous logistical models. These principles serve as the guiding framework for designing and implementing modern, smart logistical systems.

•**Interconnection and interoperability:** One of the primary characteristics of Logistics 4.0 is the seamless connection between all entities in the supply chain, including people, machines, and products. This is achieved through the use of IoT and standardised communication protocols, allowing for the real time exchange of data across organisational boundaries (Demir et al., 2020).

•**Decentralisation:** In a Logistics 4.0 environment, decision making is often decentralised. Cyber physical systems are capable of making autonomous decisions based on local data, such as a self driving vehicle rerouting itself to avoid a traffic jam or a smart warehouse system reallocating inventory based on real time demand shifts (Winkelhaus & Grosse, 2019).

•**Real Time capability:** The ability to collect and analyse data in real time is a critical principle. This allows for immediate responsiveness to disruptions and the optimisation of logistical flows based on current conditions rather than historical forecasts (Dexory, 2024).

• **virtualisation and digital Twins:** Logistics 4.0 relies heavily on the creation of virtual models of physical systems. Digital Twins allow organisations to simulate logistical processes, predict potential failures, and test optimisation strategies in a risk free digital environment before implementing them in the physical world (Aniba, 2024).

•**Service orientation:** This principle focuses on the shift from providing physical products to providing logistical "services." Through Cloud based platforms, logistics resources can be shared and accessed as a service (Logistics-as-a-Service), enhancing flexibility and resource utilisation (Ivanov et al., 2022).

•**Transparency and traceability:** The integration of technologies like Blockchain and smart sensors ensures that every movement within the supply chain is recorded and visible to authorized stakeholders. This enhances security, reduces the risk of counterfeit products, and improves overall accountability (Helo & Thai, 2024).

•the principles of Logistics 4.0 interconnection, decentralisation, real time capability, and virtualisation enable the creation of a highly resilient and efficient logistical system. By moving away from the rigid structures of traditional logistics, organisations can achieve the level of agility required to thrive in the digital era (Wilson Sons, 2023).

3.2.The Interplay of Industry 4.0 Technologies in Logistics

The transition from traditional logistical models to the paradigm of Logistics 4.0 is not merely a technological upgrade but a fundamental restructuring of how value is created and delivered. This transformation is driven by a hyperconnected ecosystem where digital technologies converge to create a seamless, intelligent, and responsive supply chain. The following sections provide a deep analysis of the most critical technological enablers: Big Data and Analytics, the Internet of Things (IoT), and Cloud Computing.

3.2.1.Impact of Big Data and Analytics on Logistics Operations

Big Data and advanced analytics act as the core driver of Logistics 4.0, enabling a shift from reactive to predictive management by transforming large volumes of data from multiple sources into actionable insights (Olatunji, 2025).

One of their main impacts is improving demand forecasting through real time data integration, allowing more accurate and dynamic predictions. This helps optimise inventory levels by reducing stockouts and overstocking costs. Additionally, Big Data enhances operational efficiency by optimising logistics activities such as routing and warehouse management (Wolniak, 2024; Venkatasubramanian et al., 2024).

Beyond efficiency, Big Data strengthens supply chain resilience by detecting disruptions early and enabling proactive decisions such as rerouting or supplier adjustment (Rane et al., 2025). Overall, it supports the development of a data driven supply chain that improves decision making, reduces uncertainty, and enhances competitiveness (Mohan, 2025).

3.2.2.Role of IoT in Enhancing Supply Chain Visibility and Tracking

The Internet of Things (IoT) is a key technology in Logistics 4.0, enabling real time data collection through connected physical objects such as vehicles and products. Its main role is to enhance end-to-end visibility and tracking, linking the physical and digital supply chain (Dhiman & Madan, 2025).

IoT improves visibility by monitoring parameters like location, temperature, and humidity, which is essential in sectors such as pharmaceuticals and food logistics to ensure product quality and compliance (Salmi, 2024). It also allows immediate responses to disruptions through real time alerts.

Additionally, IoT enhances operational efficiency in warehouses and transportation by enabling real time inventory tracking and improving fleet management through data on performance and fuel usage (Mohammed, 2025). Overall, IoT transforms supply chains into transparent and interconnected systems, strengthening agility and resilience in a dynamic environment (Hongsakul et al., 2025; Rane et al., 2025).

3.2.3.Cloud Computing For Integrated Logistics Platforms

Cloud computing provides the scalable and flexible infrastructure that supports integration and collaboration in Logistics 4.0 by centralising data storage, processing, and sharing across supply chain partners (Crespo-Aguado et al., 2024). It enables organisations to move from isolated systems to interconnected platforms with real time synchronisation.

Its main advantage is the creation of integrated logistics platforms, allowing all partners to access consistent, real time data, which improves coordination and reduces the bullwhip effect (Ozkan, 2020). It also supports the Logistics as a Service model, giving firms access to advanced technologies without high initial investment, thus benefiting SMEs (Lakhwani, 2025).

Additionally, cloud computing enhances scalability and flexibility by adjusting resources based on demand while ensuring data security through advanced protection mechanisms (Ivanov et al., 2022). Overall, it connects supply chain systems into a unified, responsive, and intelligent digital ecosystem (Rane et al., 2026).

3.2.4.AI and Machine Learning for Predictive Logistics and Optimisation

Artificial Intelligence (AI) and Machine Learning (ML) form the intelligence layer of Logistics 4.0, enabling the shift from rule based systems to self learning and autonomous operations. They support predictive logistics by analysing large datasets to detect patterns and generate accurate forecasts, especially in demand sensing through the integration of external variables (Hidalgo Panez et al., 2025).

Beyond forecasting, AI enhances optimisation by solving complex logistics problems such as routing and warehouse management, reducing costs, delivery times, and resource consumption (Moghaddam & Karimzadeh, 2025). It also enables predictive maintenance by analysing sensor data to anticipate equipment failures, improving reliability and reducing downtime (Morgan, 2025).

Overall, AI and ML transform supply chains into self optimising systems that continuously improve performance, efficiency, and sustainability (Ristvej et al., 2026).

3.2.5 Advanced Robotics and Automation in Warehousing and Transportation

Advanced robotics and automation are key enablers of Logistics 4.0, improving the execution of labo intensive tasks in warehousing and transportation. In warehouses, technologies such as Autonomous Mobile Robots (AMRs), collaborative robots, and Automated Storage and Retrieval Systems (AS/RS) enhance speed, accuracy, and productivity while reducing human error (Anawade & Sharma, 2025).

In transportation, robotics is reflected in autonomous vehicles and drones, particularly for last mile delivery, enabling continuous operations and more efficient navigation (Omar, 2025). These technologies also contribute to improved safety and environmental sustainability.

Additionally, Robotic Process Automation (RPA) optimises administrative tasks such as invoicing and order processing, supporting the efficiency of information flows and overall logistics performance (Anawade & Sharma, 2025).

3.2.6 Blockchain for Supply Chain Transparency and Security

Blockchain provides a secure, decentralised, and transparent system for managing informational and financial flows in Logistics 4.0. It creates immutable records of transactions, enabling all partners to access reliable data and ensuring end-to-end traceability and product authenticity (Rehman, 2025).
It also enhances security by preventing fraud, theft, and counterfeit products through distributed and cryptographically protected data (Bhambri et al., 2026). In addition, smart contracts automate processes such as payments and order validation, reducing administrative costs and accelerating financial flows (Rehman, 2025; IJIRMPS, 2025).

3.2.7 Simulation and Digital Twins for Logistics Planning and Risk Management

Simulation and Digital Twins are key tools for planning and risk management in Logistics 4.0, providing virtual environments to test and optimise logistics strategies. A Digital Twin represents a real system updated with real time data, enabling monitoring and simulation of potential scenarios (Aniba, 2024).

In logistics planning, these tools help optimise layouts and flows before implementation, reducing costs and risks. For risk management, they allow the simulation of disruptions to identify vulnerabilities and develop proactive strategies (Sahal et al., 2021).
When combined with AI and Big Data, Digital Twins enable intelligent simulation, improving decision making, efficiency, and supply chain resilience in dynamic

environments (Rane et al., 2026; Moghaddam & Karimzadeh, 2025).

3.3.Benefits and Challenges of Logistics 4.0 Implementation

In recent years, Logistics 4.0 has transformed supply chains through technologies such as AI, IoT, and data analytics, making logistics more connected, intelligent, and responsive.
However, its adoption remains challenging due to factors such as high costs, lack of technical skills, and data security concerns, highlighting the gap between potential benefits and practical implementation.
This section therefore examines both aspects of Logistics 4.0, focusing on its key advantages such as efficiency, visibility, responsiveness, and sustainability while also addressing the main challenges faced by organisations.

3.3.1.Benefits of Logistics 4.0 Implementation

The adoption of Logistics 4.0 delivers benefits that go far beyond traditional logistics metrics. From real time visibility and operational agility to cost optimisation and environmental sustainability, the advantages span multiple dimensions of supply chain performance.This part briefly presents the key benefits of implementing Logistics 4.0.

- **Enhanced Efficiency and Cost Reduction**

Logistics 4.0 enhances efficiency and reduces costs through interconnected operational, analytical, and network level improvements. At the operational level, automation technologies such as autonomous robots and automated systems replace manual tasks, increasing speed, accuracy, and consistency while lowering labor costs (Albrecht & Baier, 2023; Winkelhaus & Grosse, 2019).
At the planning level, AI driven optimisation improves decision making in routing, scheduling, and inventory management, enabling more efficient resource allocation. These technologies reduce transportation costs through optimised routing and load management, while advanced forecasting and replenishment systems minimise inventory costs and stockouts, improving working capital efficiency (Nguyen & Nguyen, 2025; Aksoy & Bulbul, 2025).
At the network level, enhanced visibility through IoT and cloud platforms improves coordination among supply chain partners, reducing inefficiencies caused by information gaps. This integration helps mitigate the bullwhip effect by ensuring access to shared real time demand data, leading to significant overall cost and efficiency gains (Lee et al., 1997; Winkelhaus & Grosse, 2019).

- **Improved Visibility and Responsiveness**

Logistics 4.0 significantly enhances visibility and responsiveness by enabling real time monitoring of shipments, inventory levels, and network capacities. This shifts supply chain management from reactive analysis of past events to proactive decision making aimed at anticipating and shaping future outcomes (Helo & Thai, 2024; Suvorova & Glushchenko, 2025).

Improved visibility allows for rapid detection of disruptions such as delays, temperature deviations, or supply shortages and immediate managerial response, thereby reducing the detection to action lag, which is a key factor in limiting disruption costs (Huang et al., 2023). At the same time, responsiveness to customer demand is strengthened through the integration of real time data with logistics operations, enabling dynamic adjustments in routing, warehousing, and resource allocation. This enhances service reliability and operational flexibility, particularly under uncertain demand conditions (Dindarik & Fidan, 2025; Vicente et al., 2024).

- **Increased Resilience and Sustainability**

Logistics 4.0 strengthens supply chain resilience by enhancing the ability to anticipate, respond to, and recover from disruptions. This is achieved through real time visibility, digital twin simulations for scenario planning, AI driven rerouting, and distributed decision making that reduces systemic vulnerabilities (Huang et al., 2023; Ghadge et al., 2020).

It also supports sustainability by improving resource efficiency and reducing environmental impact. Technologies such as route optimisation, predictive maintenance, and real time load management lower fuel consumption, emissions, and operational waste, while digital documentation reduces reliance on paper based processes (Kayikci, 2018; Sun & Yu, 2021; Sun & Yu, 2022).

Furthermore, Logistics 4.0 enhances circular economy practices by optimising reverse logistics operations. IoT enables lifecycle tracking of products, while AI improves forecasting and inventory management for refurbished goods, contributing to more efficient and sustainable reverse logistics systems (Sun & Yu, 2022).

3.3.2.Challenges: Investment, Skill Gaps, and Data Security

Despite its significant benefits, the implementation of Logistics 4.0 faces interconnected financial, technical, organisational, and human challenges that limit its full adoption (Facchini & Oleskow-Szlapka, 2019).

From a financial perspective, the adoption of technologies such as IoT, robotics, AI, and digital platforms requires substantial investment, with uncertain and often long term returns. This challenge is particularly critical for SMEs, as well as in rapidly evolving technological environments where obsolescence risk remains high (Richnák, 2022).

Skill gaps represent a major barrier, as Logistics 4.0 requires hybrid competencies combining supply chain expertise with advanced digital skills. The scarcity of such profiles limits organisations' ability to effectively exploit technological investments (El Hamdi & Abouabdellah, 2022).

Finally, data security and privacy issues pose critical risks due to increased connectivity and data sharing. Supply chains are vulnerable to cyberattacks, especially with the expansion of IoT systems and evolving regulatory requirements, making cybersecurity a strategic necessity for successful implementation (Vaghani et al., 2022; Hrouga & Sbihi, 2023).

CONCLUSION

The theoretical framework developed in this chapter establishes the conceptual foundation for the empirical analysis by examining Logistics 4.0 through three complementary perspectives: Industry 4.0, supply chain management, and the technological and organisational dimensions of logistics transformation. First, the analysis of Industry 4.0 demonstrated that it represents a fundamental shift in production and value creation, driven by an interconnected ecosystem of technologies such as IoT, artificial intelligence, big data, cloud computing, robotics, and blockchain, whose combined deployment creates new systemic capabilities. Second, the evolution of supply chain management was highlighted, showing its transition from an operational function to a strategic discipline that directly influences competitiveness, customer value, and resilience, where real time data integration, visibility, and dynamic decision making have become essential requirements. Third, Logistics 4.0 was positioned as the bridge between these technologies and supply chain practices, emphasising that its successful implementation depends not only on technological adoption but also on organisational capabilities, including human skills, process integration, and sustained strategic commitment. Taken together, these insights confirm that assessing

Logistics 4.0 readiness is both necessary and relevant, while identifying the key capability dimensions that underpin the conceptual model developed in subsequent chapters. They also highlight the absence of empirical readiness assessments in the Algerian industrial context, thereby justifying the research focus and methodological approach of this study.

CHAPTER II: Conceptual and Methodological Framework of the Research

Section ONE: Presentation of BOMARE COMPANY

In this section, we provide an overview of the company by presenting its organisational structure and outlining its organisational chart. In addition, we examine the main stages of the production process within the company.

1.1 Presentation of BOMARE COMPANY

BOMARE COMPANY was established in 2001 by the Algerian entrepreneur Ali Boumediene, during a period when Algeria was actively seeking to diversify its economy beyond the hydrocarbon sector. From its inception, the company was driven by a strong and ambitious vision aimed at positioning itself as a key player in the electronics industry.

Over the years, this vision has gradually materialised through continuous growth and development spanning more than two decades. As a result, BOMARE COMPANY has achieved significant progress, marked by the establishment of a new headquarters covering an area of 1,200 m² in El Biar. Furthermore, the company has built a substantial share capital of 3.2 billion Algerian dinars, reflecting its rapid financial and organisational expansion.

Table 5: Identity Sheet of BOMARE COMPANY

Company name	BOMARE COMPANY
Brand name	Stream System (registered in 2003)
Legal form	Limited Liability Company (LLC / SARL)
Sector of activity	Electronics industry (consumer goods, B2B, industrial subcontracting)
Capital	3.2 billion Algerian dinars (3,200 MDZD)
Date of establishment	February 4, 2001
Founder	Mr. Ali Boumediene
Employees	615
Clients	Various types of clients: public and private sectors
Partners	LG, KTC, ALSTOM
Production units	Current plant: total area of 15,000 m² New plant in Blida: 10,750 m²
Total Industrial area	15,000 m² in total (including 10,750 m² for the new facility)
Products	• Televisions (SMART, UHD) • LED strips • Electronic boards: industrial, LED lighting, reverse engineering, customised solutions • Interactive displays (DID) • Interactive whiteboards

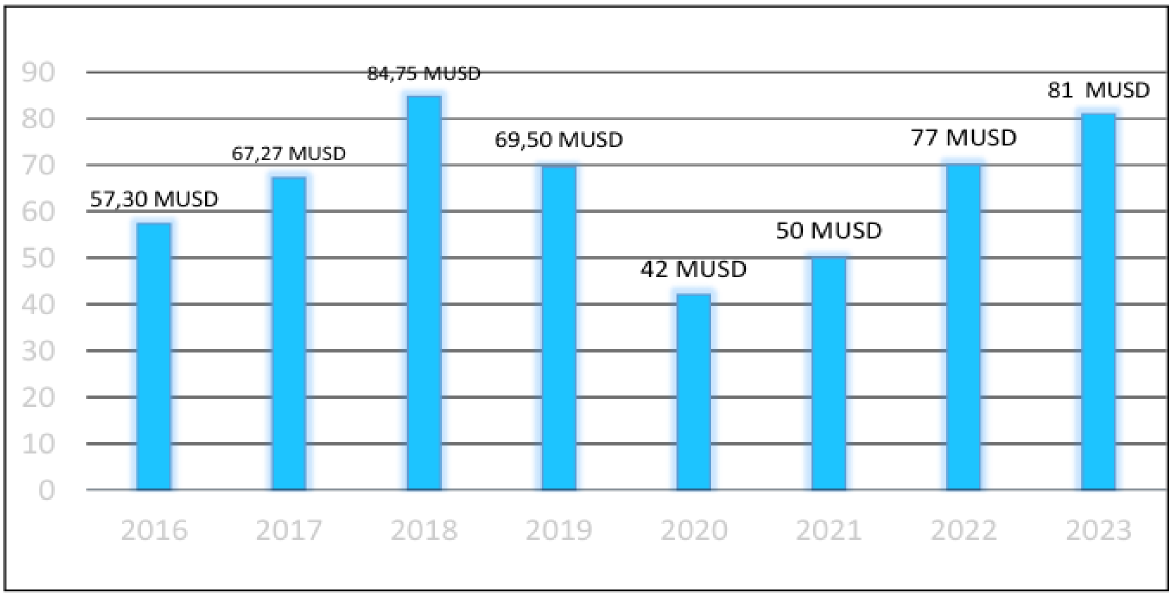
	• Video walls • Surveillance cameras • Various solutions: digital signage, video conferencing, facial recognition, Internet of Things (IoT), digital education (2.0), customised solutions • Software applications and platforms • Automated electronic systems
Export markets	Europe
Certifications	CE, RoHS, ISO 9001:2015, ISO 17025
Head office	26, Rue Mohamed Idir Amellal, El Biar 16406, Algiers
Contact	Tel: +213 (0) 21 79 16 10 Fax: +213 (0) 21 79 25 61 Email: sarlbomare@streamsystem.net Website: www.streamsytem.com

Source: Data provided by BOMARE COMPANY

1.1.1 Revenue Evolution

The figure below illustrates the evolution of BOMARE COMPANY's revenue over the period from 2016 to 2023. It highlights the company's growth trends as well as the most significant fluctuations in its financial performance during this timeframe.

Figure 3: Evolution of BOMARE COMPANY's Revenue from 2016 to 2023



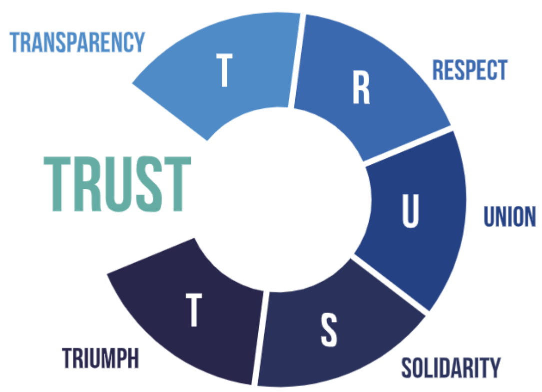
Source: Data provided by BOMARE COMPANY.

An analysis of BOMARE COMPANY's financial performance between 2016 and 2023 reveals a trajectory marked by initial growth, external shocks, and a subsequent strategic recovery. The period began positively, with revenues rising from approximately 58 million Algerian dinars in 2016 to a notable peak of 85 million dinars in 2018, a growth largely driven by strategic industrial partnerships. However, this upward trend was interrupted by a decline beginning in 2019, culminating in a significant drop below 45 million dinars in 2020, primarily due to the disruptive effects of the COVID-19 pandemic on global supply chains. From 2021 onward, the company demonstrated a robust recovery, with revenues progressively increasing to surpass 80 million dinars by 2023. This resurgence is attributed to the successful implementation of new strategic initiatives, including the launch of a high capacity production unit, expansion into European markets, and a strengthened focus on sustainable technologies and research. Ultimately, this performance underscores the company's resilience in navigating external challenges while positioning itself for ambitious growth targets towards 2025.

1.1.2 Company Values

The organisational culture of BOMARE COMPANY is built around the principle of "TRUST," which reflects core values such as transparency, responsibility, and unity. This guiding concept embodies the company's commitment to mutual trust and operational excellence.

Figure 4: Company Values



Source: Data provided by BOMARE COMPANY.

The guiding principles of BOMARE COMPANY reflect a vision focused on excellence and a strong commitment to all stakeholders. The customer occupies a central position, as their satisfaction is not only a priority but also the fundamental objective of all the company's activities. Human capital is considered a key driver of performance, acknowledging that employees are the true source of the company's value.

Moreover, quality is established as a core standard, shaping all internal processes and ensuring a high level of performance. Innovation, on the other hand, serves as a strategic lever that enables the company to remain competitive in a constantly evolving environment. Finally, BOMARE COMPANY views challenges as opportunities for growth and continuous improvement, making adaptability and resilience essential components of its corporate culture.

1.1.3 Institutional Identity and Competitive Positioning

- BOMARE COMPANY stands as a representative example of a successful Algerian enterprise operating in the technology and electronics sector. Over time, it has managed to establish itself not only as a strong local player but also as an exporter of technological products to demanding international markets, particularly within Europe.
- One of the company's key strengths lies in its commercial brand, *Stream*, which has gained significant recognition both domestically and internationally. The brand is widely associated with high quality electronic products offered at competitive prices. It is further distinguished by its ability to provide integrated technological solutions tailored to the needs of both local and global consumers.

1.2 Activities Products and Internal Organisation

BOMARE COMPANY is distinguished by a diversified portfolio ranging from consumer electronics to professional and industrial solutions, supported by a well structured internal organisation and an integrated business model. Through this approach, the company positions itself as a key player in local manufacturing, export activities, and technological innovation.

1.2.1 Product and Service Range

BOMARE COMPANY adopts a deliberate diversification strategy across its production lines, offering a broad array of products and services. Its consumer electronics portfolio includes smart televisions equipped with advanced technologies (SMART TVs), ultra high definition (UHD) televisions, audio systems, home cinema equipment, as well as receivers and decoders. In the professional and industrial segment, the company provides interactive displays (DID), interactive kiosks, and interactive whiteboards designed for educational and institutional use. Additionally, it offers advanced surveillance camera systems and video wall solutions for commercial and public spaces. Beyond finished goods, BOMARE COMPANY manufactures a range of electronic components, including electronic boards, LED strips and lighting systems, and other components intended for industrial applications. From a technical services perspective, the company delivers engineering and design services for electronic products, installation and maintenance services, technical consulting for businesses and institutions, and integrated software solutions tailored to electronic systems.

Figure 5 : Products of BOMARE COMPANY

Source: Developed by the author based on the company's internal data

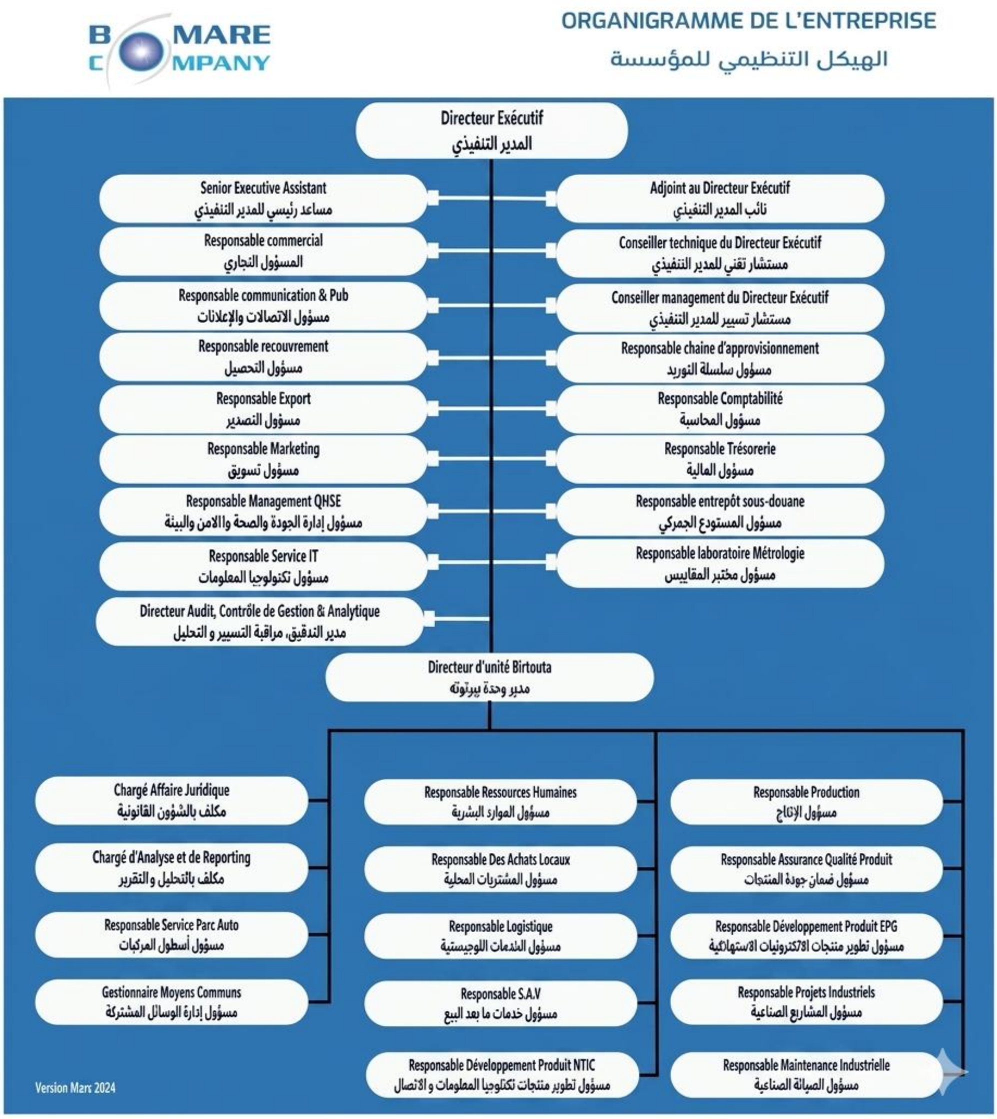
1.2.2 Business Model and Core Activities

BOMARE COMPANY employs an integrated business model encompassing three core manufacturing activities. First, it engages in Original Brand Manufacturing (OBM), producing goods under its own Stream brand for local and international markets. Second, it performs Original Equipment Manufacturing (OEM) for global companies such as LG, demonstrating international trust in its production quality. Third, it offers Electronic Manufacturing Services (EMS) to local and foreign clients, reinforcing its position in the industrial value chain. Additionally, the company prioritises research and development (R&D), investing heavily in technological innovation to bolster competitiveness and ensure long term growth.

1.2.3 Organisational Structure and Subsidiaries

BOMARE COMPANY pursues a diversification strategy through specialised subsidiaries and units. BOMARE SOLUTIONS ENTREPRISES (BSE), established in 2020, serves businesses and institutions by providing digital signage, video conferencing systems, facial recognition security solutions, smart education (2.0) systems, and customised organisational solutions. The Industrial Projects and Subcontracting Department (DPI) strengthens local industrial integration through activities including automated electronic board insertion, reverse engineering of obsolete components, repair of industrial boards, PCB design, testing bench development, and industrial system automation. Additionally, the Metrology Laboratory, accredited under ISO/IEC 17025 standards, offers measurement services for force, dimensions, weighing, temperature, and electrical equipment. Organisationally, the company adopts a functional structure aligned with its activities, centered around general management and an industrial management unit in Birtouta, supported by several operational structures.

Figure 6: Organisational Chart of BOMARE COMPANY



Source : BOMARE COMPANY

1.3 Industrial Capabilities Innovation and Partnerships

BOMARE COMPANY leverages modern industrial infrastructure, strong innovation capabilities, and strategic partnerships to enhance its competitiveness nationally and internationally.

1.3.1 Production Capacity and Infrastructure

BOMARE COMPANY benefits from advanced industrial infrastructure, including a main factory of 15,000 m² organised into three production units, and a new wholly self financed industrial site in Blida spanning 10,750 m² with an investment exceeding 2 billion Algerian dinars, officially registered with AAPI. Production lines feature Surface Mount Technology (SMT) for electronic assembly, quality control units, and a single shift capacity reaching one million televisions annually. Supporting facilities include an ISO/IEC 17025-accredited metrology laboratory, testing units, and R&D infrastructure.

1.3.2 Innovation Research and Development

Innovation and research are central strategic pillars for BOMARE COMPANY. The SMART FABLAB project functions as a fabrication and innovation laboratory equipped with laser cutting and 3D printing, serving as a platform for training, experimentation, and knowledge exchange. Its sustainable business model includes workspace rental, technical solutions, specialised training, and prototype development. The company maintains strong academic collaboration with Saad Dahlab University for student training and joint research projects, supported by a dedicated new product development team committed to continuous improvement.

1.3.3 Strategic Partnerships

BOMARE COMPANY has established a strategic partnership network across multiple domains. Industrially, it has maintained a partnership with LG since 2013 for local television production and collaborates with international component suppliers. In research and academia, it has invested approximately 1.5 million US dollars in partnership with Saad Dahlab University while continuing to develop collaborations with local and international R&D centers. Commercially, the company relies on an extensive network of authorized distributors, agents, wholesalers, and retailers across domestic, European, and African markets.

1.4 Commercial Deployment and Corporate Social Responsibility

BOMARE COMPANY structures its strategy around ambitious commercial expansion and strong commitment to corporate social responsibility .

1.4.1 Export Strategy and International Presence

Export strategy is a key pillar of BOMARE COMPANY's growth, with export activities to Europe beginning in 2007. In 2016, the company secured a five year contract worth 50 million US dollars for Spanish and Portuguese markets, followed by an annual contract valued at 23 million US dollars for Italy in 2019. A major milestone occurred in 2020 with the first export of LG televisions manufactured in Algeria to Europe. Primary targets include Spain, Portugal, and Italy, with planned expansion into Germany and emerging African markets. The export portfolio encompasses televisions, display systems, electronic components, and technical solutions. International recognition includes being named Best Exporter in 2019 by the World Trade Center Algeria and being identified in 2018 by the London Stock Exchange Group as a model of success in the African market.

1.4.2 After Sales Service and Technical Support

BOMARE COMPANY prioritises after sales services as a fundamental component of its quality strategy. Nationally, the company relies on a network of approximately 80 authorized agents across Algeria, supplemented by specialised service centers in major cities. Its development strategy focuses on progressively replacing imported repair components with locally produced ones, optimising regional distribution of service centers, and mobilizing an additional support network of specialised young graduates. Internationally, BOMARE COMPANY plans to establish a service center in Germany to support its exported products. Additionally, it offers a five year warranty on exported STREAM televisions, thereby strengthening customer confidence in Algerian made products.

1.4.3 Corporate Social Responsibility and Economic Impact

BOMARE COMPANY makes significant contributions to Algeria's economic and social development. In employment and training, the company currently provides approximately 1,800 jobs and aims to create 10,550 direct and 30,000 indirect jobs by 2029, while implementing training programs to enhance the skills of young talent. The company actively facilitates technology transfer by promoting the adoption of advanced technologies in Algeria, increasing local industrial integration rates, and fostering a network of collaborating small and medium sized enterprises. Furthermore, BOMARE COMPANY plays a crucial role in economic diversification by supporting the transition of the Algerian economy beyond the hydrocarbon sector, contributing to non-oil export growth, and improving the balance of payments through both import substitution and export development.

Section two: Conceptual Framework and Research Hypotheses

This section builds the conceptual framework of the study by linking the research objective to a set of testable hypotheses. Based on the theoretical foundations discussed previously, the research objective is translated into specific propositions that guide the empirical investigation and structure the analysis of relationships between the key variables.

2.1 From Research Objective to Research Hypotheses

A research hypothesis is a testable and falsifiable statement about the expected relationship between two or more variables, formulated on the basis of existing theory and prior empirical findings (Saunders et al., 2019; Creswell & Creswell, 2018). In a positivist, deductive research design, hypotheses serve as the bridge between the theoretical framework developed in Chapter I and the empirical analysis conducted through the questionnaire.

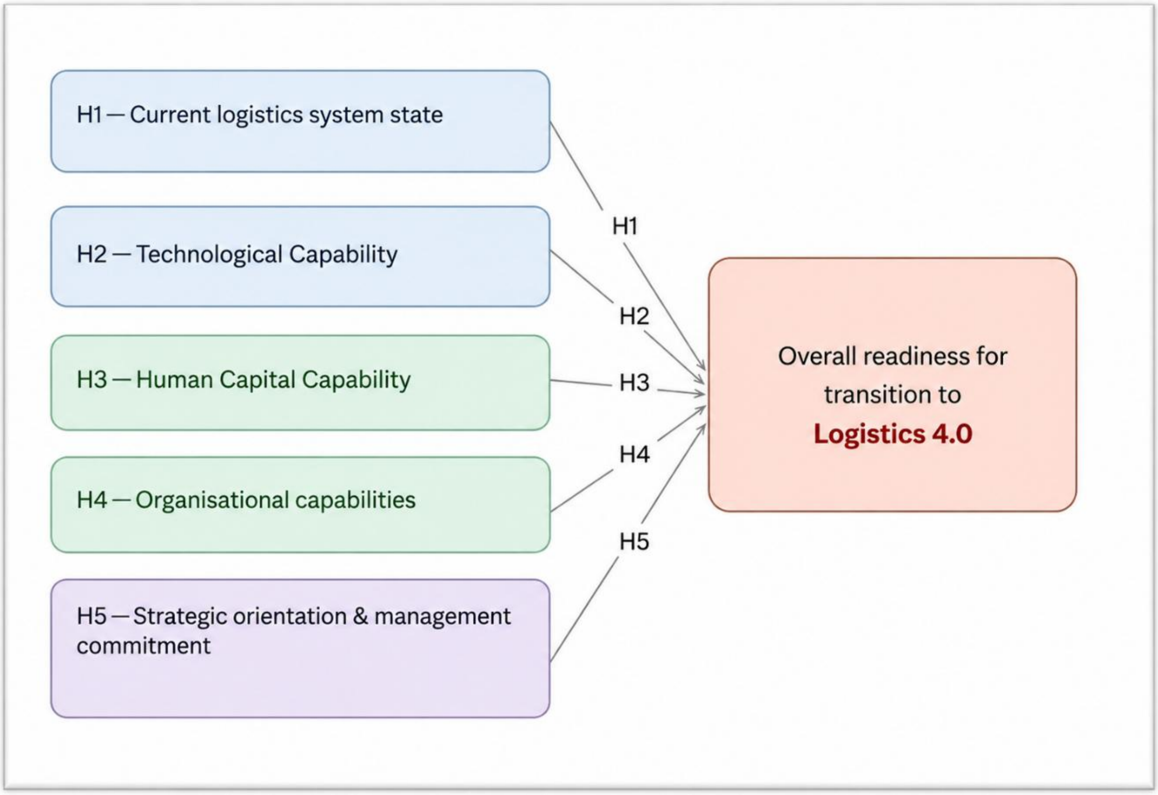
To what extent do the organisational capabilities currently developed within BOMARE COMPANY determine its overall readiness to transition to Logistics 4.0? To operationalise this question, five research hypotheses are formulated, each corresponding to one of the main capability dimensions identified in the theoretical chapter and measured through the questionnaire. These dimensions are:

1. the current state of the logistics system.
2. technological and infrastructural capabilities.
3. human capabilities (employee digital skills) .
4. organisational capabilities (cross functional coordination and change management)
5. strategic orientation and management commitment.

2.2 Conceptual Framework

The conceptual framework below synthesises the theoretical relationships developed in Chapter I into a structured and testable analytical model. It positions the five core capability dimensions as independent variables and maps each to the dependent variable overall readiness for transition to Logistics 4.0 through the five research hypotheses.

Figure 7: Conceptual Framework



Source: Developed by the author

2.3.Statement and Theoretical Justification of Hypotheses

This subsection presents the formulation and theoretical justification of the research hypotheses developed in this study. Each hypothesis is grounded in the existing literature and aligned with the conceptual framework established earlier, ensuring both theoretical coherence and empirical relevance. The following hypothesis focuses on the current state of the logistics system, which constitutes a fundamental basis for understanding the extent of transformation towards Logistics 4.0.

2.3.1 Hypothesis 1 (H1): Current Logistics System State

H1: The current level of efficiency and digitalisation of the logistics system significantly affects BOMARE Company's readiness to transition to Logistics 4.0.

The initial condition of a firm's logistics system represents a critical determinant of its capacity to engage in digital transformation. Organisations that operate with structured, efficient, and partially digitalised logistics processes are generally better positioned to adopt advanced technologies and integrate new digital practices. A higher level of system maturity facilitates data visibility, process coordination, and performance monitoring, all of which are essential prerequisites for Logistics 4.0. In this study, Axis 01 captures key aspects of the current logistics system, including the use of performance indicators, availability of real time information, coordination challenges, and the extent of information fragmentation. These elements collectively reflect the operational maturity of BOMARE’s logistics system and its preparedness for transformation.

2.3.2 Hypothesis 2 (H2): Technological and Infrastructural Capabilities

H2: There is a significant effect of technological infrastructure availability and maturity on BOMARE Company’s readiness to transition to Logistics 4.0.

Technological infrastructure constitutes the fundamental backbone of Logistics 4.0 implementation. The transition towards digitally integrated logistics systems relies on the presence of enabling technologies such as connected devices, automation systems, identification technologies, and data analytics tools.

The absence or immaturity of such infrastructure limits the organisation’s ability to ensure real time tracking, system interoperability, and data driven decision making. Conversely, a well developed technological base enhances operational transparency and supports advanced logistics functionalities.

2.3.3 Hypothesis 3 (H3): Human Capabilities and Digital Skills

H3: Employees' digital skills and training levels significantly influence BOMARE Company’s readiness to transition to Logistics 4.0.

Human resources represent a central pillar in the successful adoption of digital transformation initiatives. The transition to Logistics 4.0 requires not only technological investments but also a workforce capable of understanding, operating, and adapting to digital tools and systems.

A lack of digital competencies and insufficient training can significantly hinder implementation efforts, even in the presence of advanced technologies. In contrast, employees with adequate digital knowledge and continuous training contribute to smoother adoption, reduced resistance to change, and improved system utilisation.

In this study, Axis 03 measure employees’ awareness of digital logistics concepts, their perceived level of digital competence, and the adequacy of training provided, all of which directly impact BOMARE’s readiness.

2.3.4 Hypothesis 4 (H4) : Organisational Capabilities

H4: BOMARE Company's organisational capabilities have a significant effect on its readiness to transition to Logistics 4.0.

The successful transition to Logistics 4.0 is not solely dependent on technological Capability but also on organisational capabilities. Effective coordination between departments, flexible organisational structures, and a culture that supports change are essential for managing the complexity of digital transformation.

Organisations that promote collaboration and adaptability are more capable of aligning processes, integrating systems, and responding to transformation challenges. Conversely, rigid structures and poor communication can delay or even prevent successful implementation.

Axis 04 of the questionnaire assesses these organisational dimensions specifically cross functional collaboration, change management experience, and adaptive culture providing insight into how BOMARE's internal capabilities influence its readiness for Logistics 4.0.

2.3.5 Hypothesis 5 (H5) : Strategic Orientation and Management Commitment

H5: Management's strategic vision, budget allocation, and communication significantly determine BOMARE Company’s readiness to transition to Logistics 4.0.

Strategic direction and top management commitment play a decisive role in shaping the success of digital transformation initiatives. A clearly defined vision provides direction, while adequate financial resources ensure the feasibility of implementation. Additionally, effective communication from management fosters alignment across the organisation and reduces uncertainty among employees.

Without these elements, transformation efforts risk remaining fragmented and lacking coherence. In contrast, strong leadership commitment enhances coordination, motivates employees, and supports long term sustainability of digital initiatives.

In this research, Axis 04 and 05 evaluate management practices related to strategy, communication, and budgeting, and their impact on BOMARE’s readiness to transition to Logistics 4.0.

Table 6: Summary Table of Research Hypotheses

H	Variable Link	Hypothesis Statement
H1	Current Logistics System → Readiness	The current level of efficiency and digitalisation of the logistics system significantly affects BOMARE Company’s readiness to transition to Logistics 4.0.
H2	Technological Capabilities →Readiness	There is a significant effect of technological infrastructure availability and maturity on BOMARE Company’s readiness to transition to Logistics 4.0.
H3	Human Capabilities → Readiness	Employees' digital skills and training levels significantly influence BOMARE Company’s readiness to transition to Logistics 4.0.
H4	Organisational Capabilities → Readiness	BOMARE Company's organisational capabilities have a significant effect on its readiness to transition to Logistics 4.0.
H5	Strategic Orientation	Management's strategic vision, budget allocation, and

	→ Readiness	communication significantly determine BOMARE Company's readiness to transition to Logistics 4.0.

Source : Developed by the author

Section three: Methodological Framework

The next section presents the methodological framework adopted for this study. It outlines the research approach, as well as the tools used to collect and analyse the data.

3.1. Methodological Framework:

Every solid research study rests on a well thought out methodology. It is what gives the work its direction and ensures that the steps taken from collecting data to analysing it are consistent and trustworthy. In practice, the methodological framework acts as a kind of guide. It helps the researcher move from the initial research questions to the choice of specific tools and 5 techniques that are appropriate for what the study is trying to achieve.

3.1.1 Definition of Research

Research is essentially a systematic and disciplined way of asking questions and finding answers. It is not just about collecting information but about building new knowledge, testing existing ideas, or solving practical problems in a structured manner (Fortin & Gagnon, 2016). What makes research different from everyday observation is that it follows a clear process that links theory to what happens in the real world (Chababi & Ouaccerine, 2013).

We define research as a structured and disciplined inquiry driven by scientific questioning about a specific problem. Its purpose is to find answers, propose solutions, or contribute to the development of new theories and knowledge through a rigorous analysis of the subject being studied.

3.1.2 Scientific Methodology

Scientific methodology refers to the set of principles, rules, and procedures that shape how rigorous research is carried out. It provides the structure that ensures findings are coherent, valid, and can be replicated by others. Benhaddouch and Fathaoui (2022) explain that in management research, methodology involves a careful reflection on how researchers access, construct, and validate knowledge. They stress that methodological choices are never random; they are always tied to the epistemological paradigms researchers adopt. (Benhaddouch & Fathaoui, 2022)

3.2 The Quantitative Research Approach

Among the various research approaches available to social science and management researchers, quantitative research holds a central and well established place. It is defined by its focus on collecting and analysing numerical data, testing hypotheses drawn from theory, and producing findings that can be generalised across different populations and settings. Creswell and Creswell (2018) describe quantitative research as an approach used to test objective theories by examining relationships among variables. These variables are typically measured using standardised instruments so that the numerical data can be analysed statistically. This emphasis on measurability, objectivity, and statistical rigor is what sets quantitative research apart from qualitative or interpretive approaches, which tend to prioritise depth, context, and meaning. (Creswell & Creswell, 2018)

The choice of a quantitative approach in this study is not arbitrary, but a deliberate methodological decision grounded in the specific characteristics of the research problem. This thesis aims to assess the Organisational Capabilities of BOMARE COMPANY for a transition to Logistics 4.0 by measuring five distinct capability dimensions across a sample of 67 employees. Such an objective requires instruments capable of producing numerical, comparable, and statistically analysable data. The structured questionnaire built around a five point Likert scale translates theoretical constructs into measurable variables, and multiple linear regression allows the relationships among these variables to be tested rigorously (Hair et al., 2019). Furthermore, the deductive logic of this study moving from a theoretical framework to operationalised hypotheses to empirical testing is inherently aligned with the quantitative tradition. The objective nature of the research questions, the need for generalisable findings across departments and employee profiles, and the requirement to test causal relationships all make a quantitative design the most appropriate and scientifically defensible choice for this investigation (Creswell & Creswell, 2018; Fortin & Gagnon, 2016).

3.3 EPISTEMOLOGY AND RESEARCH PARADIGMS

Epistemology is essentially the philosophical study of knowledge what it is, where it comes from, what its limits are, and how we can claim to know something. Before a researcher can decide on methods, they first need to engage with these foundational questions about what can be known and how. Alharahsheh and Pius (2020) describe epistemology as one of the core philosophical pillars of research, explaining that different epistemological stances lead to different research paradigms, which in turn shape methodological choices and research practices (Alharahsheh & Pius, 2020).

A research paradigm, as defined by Saunders, Lewis, and Thornhill (2019), is a basic set of beliefs and assumptions that guide the researcher's work. It includes assumptions about the nature of reality (ontology), the nature of knowledge (epistemology), and how knowledge can be obtained (methodology). Paradigms function as worldviews that influence everything from how research questions are framed to how findings are interpreted and communicated (Saunders et al., 2019).

In our understanding, epistemology is the philosophical foundation that asks the most basic questions about knowledge: what we can know, how we come to know it, and what the limits of that knowledge might be. Before we can decide how to conduct research, we believe it is essential to reflect on these foundational issues, as the answers we give shape everything that follows.

3.3.1 The Positivist Paradigm

At the heart of positivism lies an objectivist ontology, which holds that social reality exists independently of the researcher and can be studied objectively. It also embraces an empiricist epistemology, meaning that valid knowledge comes only from systematic observation, measurement, and hypothesis testing against empirical data. Positivist researchers also strive for value freedom, working to minimise the influence of personal biases and relying on standardised instruments and replicable procedures to ensure that findings reflect the phenomenon being studied rather than the researcher's own views (Alharahsheh & Pius, 2020).

In our view, the positivist paradigm is defined by four key assumptions: ontological realism (reality exists independently of observers), epistemological empiricism (reality can be known through observation and measurement), methodological quantitativism (numerical data and statistical analysis are the primary means of generating knowledge), and value neutrality (the researcher maintains independence throughout the process). Together, these assumptions provide the philosophical foundation for the methodological choices we have made in this study.

3.3.2 Choice of the Positivist Paradigm

The decision to adopt the positivist paradigm in this study was not made lightly or arbitrarily. It reflects a deliberate alignment between the epistemological foundations of positivism and the specific nature of the research problem I am investigating. Several factors, drawn from both the internal logic of positivism and the characteristics of the research itself, justify this choice.

The main objective of this thesis is to assess the core capabilities needed for a transition to Logistics 4.0. This objective assumes that there is an objective organisational and technological reality that can be identified, measured, and analysed across a defined population of organisations and practitioners.

The positivist emphasis on systematic measurement, hypothesis testing, and generalisable findings is also well suited to a study that aims to produce empirically grounded and practically useful knowledge. Saunders, Lewis, and Thornhill (2019) argue that positivism is particularly appropriate for research that seeks to identify patterns, establish relationships, and produce findings that can be generalised across organisational populations.

Boukaira and Daamouch (2021) argue that in management sciences, the positivist paradigm is most suitable for research that aims to describe, explain, or predict organisational phenomena through the systematic collection and statistical analysis of quantitative data especially when the goal is to produce findings that are representative of a broader population and comparable across different organisational contexts. These conditions fit the present study well. In addition, the deductive logic that comes with positivism moving from theory to operationalization to empirical testing is directly reflected in the design of this study. Alharahsheh and Pius (2020) describe this deductive process as beginning with theory, moving through measurement, and ending with empirical testing. That is exactly what I have done here: the theoretical framework developed in earlier chapters provides the conceptual foundation for turning core Logistics 4.0 capabilities into measurable variables (Boukaira & Daamouch, 2021; Alharahsheh & Pius, 2020).

Benhaddouch and Fathaoui (2022) further point out that the positivist paradigm offers a clear set of criteria for evaluating the quality and rigor of research. These include the validity and reliability of measurement instruments, the representativeness of the sample, and the appropriateness of the statistical procedures used. These criteria are all addressed in the methodological design of this study. By explicitly adopting the positivist paradigm, I am not only justifying the methodological choices I have made but also providing a philosophically coherent framework within which the quality and rigor of the research can be assessed and communicated to the scientific community (Benhaddouch & Fathaoui, 2022).

3.4 QUESTIONNAIRE DEVELOPMENT

The questionnaire serves as the main data collection tool for this study. It is the instrument through which the theoretical concepts developed in earlier chapters are turned into measurable variables that can be analysed statistically. As a structured and standardised way of gathering information from a sample of respondents, the questionnaire fits well with quantitative research designs that require systematic and comparable measurement of multiple variables across a large number of observations. Oppenheim (1992) noted that while the questionnaire is one of the most powerful and widely used tools in social science research, its apparent simplicity can be misleading. In reality, designing a good questionnaire is a complex process that requires careful thought and attention if the data collected are to be valid and reliable enough to support sound conclusions (Oppenheim, 1992).

Dillman, Smyth, and Christian (2014) developed a comprehensive framework for questionnaire design called the Tailored Design Method. This approach emphasises aligning every aspect of the survey instrument and its administration with the characteristics and expectations of the target respondents. According to this framework, an effective questionnaire must accomplish three related goals: it must clearly communicate to respondents what information is being sought and why; it must motivate respondents to take the task seriously; and it must reduce the cognitive burden on respondents, thereby lowering the risk of response errors, satisficing, and item non response. Saunders, Lewis, and Thornhill (2019) place questionnaire development within the broader context of survey based research, noting that it is not a one step activity but an iterative process of drafting, reviewing, pre testing, and revising (Dillman et al., 2014; Saunders et al., 2019).

3.4.1 Structure and Content of the Questionnaire

The structure of a questionnaire how its sections and items are organised and sequenced significantly affects communication clarity, respondent accuracy, and overall data quality. Oppenheim (1992) outlines several key principles, recommending a clear, engaging introduction explaining the study's purpose, the importance of participation, confidentiality protections, and completion instructions. He also suggests grouping items into thematically coherent sections that flow logically, arranging items from simplest to most complex within each section.

Dillman et al. (2014) offer detailed guidance on item wording and presentation, emphasising wording as a critical factor in data quality. They identify common problems causing ambiguity and bias such as technical terms, double barreled questions, leading language, and unclear referents while providing practical strategies to avoid each. They also stress the importance of exhaustive and mutually exclusive response categories, noting that poorly designed options are a frequent source of measurement error.

Bryman (2016) notes that questionnaire content must be firmly grounded in the study's theoretical framework, with each item designed to measure a specific, well defined construct. He highlights the value of using previously validated instruments from existing literature to reduce the work of developing new items and facilitate comparison with earlier studies.

For this study, the questionnaire is divided into two main parts. The first part collects background information about respondents and their organisations, including sector, organisational size, position, and years of experience. The second part consists of Likert type scale items organised into thematic sections corresponding to the core capability dimensions of the Logistics 4.0 framework developed in the theoretical chapters.

3.4.2 Selection of Questionnaire Questions

The questionnaire was structured around five main dimensions, each capturing a distinct aspect of the core capabilities required for a transition to Logistics 4.0.

The first section collects personal and professional information (gender, age, experience, job position) to profile the sample and enable meaningful cross group comparisons, a practice consistent with methodological guidance emphasising sample profiling to support validity (Gavard-Perret et al., 2018).

The second section assesses the organisation's current logistics maturity, examining digitalisation levels, integration of logistics activities, existing technologies, and operational challenges of traditional systems. This design draws on logistics maturity models (Christopher, 2016) and studies on smart, integrated supply chains.

The third section focuses on technological and infrastructural capabilities, evaluating information systems, automation, IoT, and data analytics tools to identify existing technical resources and gaps needing attention. This section is informed by work on Industry 4.0 (Kagermann et al., 2013) and digital transformation of logistics (Hofmann & Rüsch, 2017).

The fourth section addresses human and organisational capabilities, examining employee skills, organisational culture readiness for digital transformation, training levels, adaptability to change, and leadership's role in supporting Logistics 4.0 initiatives. This draws on research emphasising human capital and leadership as critical to logistics transformation (Bowersox et al., 2013).

The fifth section explores strategic vision and readiness for Logistics 4.0, covering investment plans, strategic priorities, and barriers to technology adoption. This forward looking perspective is based on work identifying strategic alignment and change management as key success factors for Industry 4.0 adoption (Frank et al., 2019).

A correspondence matrix is provided to ensure full transparency regarding the theoretical grounding of each section, linking each axis to its measured variable, role in the research model, key theoretical references, and corresponding hypothesis.

Table 7: Correspondence Matrix Questionnaire Axes,Variables and Hypotheses

Axes / Section	Items Covered	Variable Role	Theoretical Justification	Hypothesis
Section 01 Professional Information	Gender, age, department, seniority, professional experience	Control / profiling variables	Ensures sample diversity and allows subgroup comparison (Hair et al., 2019; Gavard-Perret et al., 2018)	All hypotheses
Axis 01 Current Logistics System	System digital readiness, KPI usage, real time data use, identification of logistics challenges	Current logistics maturity (independent variable)	Provides baseline operational assessment necessary to identify transformation gaps (Christopher, 2016; Winkelhaus & Grosse, 2020)	H1
Axis 02: Technological Capability	IT infrastructure (IoT, RFID), awareness of automation technologies, technical expertise, investment intentions	Technological capability (Independent Variable)	Reflects Industry 4.0 technological enablers and digital infrastructure readiness (Kagermann et al., 2013; Hofmann & Rüsch, 2017)	H2
Axis 03: Human capital capability	Employee digital skills, training availability, adaptability, management support	Human capability (Independent Variable)	Emphasises importance of human capital and digital competencies in transformation (Bowersox et al., 2013)	H3
Axis 04:	Cross functional	Organisational	Highlights role of	H4

Organisational capability	collaboration, change management experience, innovation culture	capability (Independent Variable)	organisational culture and structure in enabling transformation (Bowersox et al., 2013; Frank et al., 2019)	
Axis 05: Strategic Orientation	Vision, budget allocation, communication, integration in strategy	Strategic capability (Independent Variable)	Captures strategic alignment and leadership commitment for Industry 4.0 adoption (Frank et al., 2019; Fragapane et al., 2021)	H5
Axis 06: Overall Organisational Capabilities	Overall readiness, capability sufficiency, ability to initiate projects, preparedness level	Dependent Variable (Outcome)	Measures overall readiness and transition capability towards Logistics 4.0 (Winkelhaus & Grosse, 2020)	Dependent Variable

Source: Developed by the author

3.4.3 Measurement Scales

For this study, we used a five point Likert scale as the main measurement tool to assess participants' attitudes and perceptions. This scale, which has been widely used in social science research since its introduction by Likert (1932), allows respondents to indicate their level of agreement or disagreement with a set of statements along a continuum from 1 to 5, where 1 means "Strongly disagree" and 5 means "Strongly agree." As Dussaix (2009) points out, a five point scale strikes a good balance between capturing meaningful differences in responses and remaining easy for participants to use.

Table 8: Five Point Likert Scale

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5	4	3	2	1

Source: (Likert, 1932).

According to Roussel (2005), this method has the advantage of turning qualitative data into quantitative form, which makes statistical analysis of the results easier. Following the recommendations of Evrard et al. (2009), we made sure the items were clear and concise to minimise any risk of misinterpretation. The reliability of the instrument was assessed by calculating Cronbach's alpha coefficient, which showed satisfactory internal consistency ($\alpha > 0.75$) for all the dimensions measured (Nunnally & Bernstein, 1994).

To ensure a proper evaluation, we determined the intervals for each evaluation criterion by applying the following rule: Interval / Number of categories = 4 / 5 = 0.8. Thus, the distance between each criterion is 0.8. By adding this value successively as we move from one criterion to the next, we obtained the desired intervals.

Table 9: Evaluation Scale

Interpretation		**Evaluation**
[1,1.8[	Between 1 and less than 1.8	Strongly Disagree
[1.8,2.6[	Between 1.8 and less than 2.6	Disagree
[2.6,3.4[	Between 2.6 and less than 3.4	Neutral
[3.4,4.2[	Between 3.4 and less than 4.2	Agree
[4.2, 5]	Between 4.2 and 5	Strongly Agree

Source: Developed by the author from (Likert, 1932).

From a methodological standpoint, it is important to emphasise that this approach will be consistently and rigorously applied to all questions in the questionnaire that are based on measurement scales.

Table 10: Reliability Statistics

Cronbach's Alpha	**Number of Items**
0.869	**24**

Source: Developed by the author using IBM SPSS Statistics 27

3.4.4 Target Population and Sampling Method

Within the framework of this research, which aims to assess the core capabilities required for a successful transition to Logistics 4.0 within **BOMARE COMPANY**, the target population consists of employees who are directly or indirectly involved in logistics related activities. Prior to administering the questionnaire, a preliminary consultation was conducted with the Human Resources department at BOMARE COMPANY in order to accurately determine the size of the target population. This consultation confirmed that 82 employees across the relevant departments including international procurement, local purchasing, production, logistics, export operations, and administration were directly or indirectly involved in logistics related activities and therefore constituted the accessible population for this study. Of these 82 employees, 67 completed and returned the questionnaire, yielding a response rate of 81.7%. This rate is considered high for organisational survey research and reflects both the accessibility of respondents and the support extended by departmental managers during the data collection process.

All selected individuals possess a sufficient educational and professional background to provide relevant and reliable responses to the questionnaire items.

The selection of participants is based on a purposive sampling approach, where respondents are deliberately chosen according to their expertise, experience, and their relevance to the research objectives. This method ensures that the data collected reflects informed perspectives regarding the capabilities needed to support the transition towards Logistics 4.0 (Etikan et al., 2016).

Furthermore, the study adopts a non probability stratified sampling technique, in line with the recommendations of Hair et al. (2019) for organisational research contexts. The stratification process is carried out based on two main criteria: departmental affiliation (such as logistics, production, and purchasing) and hierarchical level (operational, middle management, and strategic levels). This approach allows for the collection of diverse viewpoints on the readiness and capability requirements for Logistics 4.0 implementation. It is also consistent with the methodological principles outlined by Maxwell (2013) for case study research conducted in organisational settings.

The selection of **BOMARE COMPANY** as the study site is justified on four main grounds. First, its industrial complexity and logistics intensity, as its operations cover procurement, production, quality assurance, export logistics, and after sales services, all of which align with the processes targeted by Logistics 4.0. Second, its ongoing digital transformation, reflected in investments in advanced technologies such as SAP ERP and SMT lines, as well as the launch of a highly automated industrial site, placing the company at a critical transition stage. Third, physical accessibility, which facilitated both paper based and digital data collection and improved response rates. Fourth, its representativeness within the Algerian industrial sector, allowing the findings to inform broader discussions on Logistics 4.0 adoption.

3.4.5 Data Collection

Data for this study were collected using a structured questionnaire administered in both paper based and electronic formats to maximise response rates. The paper version was designed with a clear and professional layout, while the electronic version was created using

Google Forms, a widely used and reliable tool in academic research (Wright, 2017). The questionnaire required approximately 15 to 20 minutes to complete, a duration considered suitable for maintaining respondent engagement while ensuring data quality
(Fan & Yan, 2010).

The data collection process followed a systematic approach divided into three main phases. As noted by Babbie (2020), data collection is an organised process aimed at obtaining valid and reliable information about the phenomenon under study.

Step 1: Preparatory Phase The questionnaire was first reviewed by academic and professional experts to ensure content validity (DeVellis, 2016). A pilot test was then conducted with five participants to evaluate clarity and relevance. Based on their feedback, minor adjustments were made to improve the instrument (Malhotra et al., 2017).

Step 2: Questionnaire Administration A hybrid distribution method was used, combining paper based and online formats. Printed questionnaires were distributed during meetings and face to face interactions, while the online version was shared via email with an explanatory note. Reminders were also sent to increase participation. This approach aligns with the Tailored Design Method (Dillman et al., 2014).

Step 3: Monitoring and Closure Responses were continuously monitored to ensure balanced representation across departments. Additional follow ups targeted underrepresented groups. Data collection ended once a sufficient number of responses was obtained, ensuring statistical validity, in line with recommendations by Saunders et al. (2016).

3.5Data Analysis Tools and Methodology

The processing and analysis of the collected data were carried out using a quantitative research approach that combines specialised software tools with rigorous analytical techniques. Three main software programs were employed. First, IBM SPSS Statistics (version 27) was used to perform advanced statistical analyses, including correlations, ANOVA tests, and multiple regression, due to its robustness and accuracy in handling quantitative data (Field, 2018; Pallant, 2020). Second, Microsoft Excel (version 365) was utilised for initial data cleaning, the creation of pivot tables, and preliminary data visualisation, in line with the recommendations of Walkenbach (2016).

The analytical procedure followed a structured sequence of phases. The first phase involved data cleaning and preparation, which included checking for completeness, handling missing values based on the guidelines of Little and Rubin (2019), and coding the responses for analysis. The second phase consisted of descriptive analysis, where frequencies, means, and

standard deviations were calculated and complemented by appropriate graphical representations.
The third phase focused on inferential analysis, incorporating statistical tests such as chi square tests, t-tests, ANOVA, and correlation analyses to examine relationships between variables.

CONCLUSION

Chapter II translated the theoretical framework developed in Chapter I into a structured and operational research design. It was organised around three main components: the empirical context, the conceptual model, and the methodological approach.
First, BOMARE COMPANY was presented as the research field, highlighting its industrial maturity, ongoing digital transformation, and strategic relevance for assessing Logistics 4.0 readiness.
Second, the conceptual framework was formalized through five hypotheses linking key capability dimensions logistics maturity, technological, human, organisational, and strategic capabilities to overall readiness.
Finally, the methodological choices were defined, including a positivist and quantitative approach, a structured questionnaire based on six Axes, and a purposive stratified sample. The use of SPSS ensured rigorous and reliable hypothesis testing.
Overall, this chapter establishes a clear methodological framework linking theory to empirical analysis, ensuring the relevance and credibility of the research findings.

CHAPTER III: Results and Discussion

This chapter presents and analyses the empirical findings related to BOMARE Company's readiness for Logistics 4.0, based on a structured questionnaire administered to employees involved in logistics and supply chain functions.

The main objective is to assess the current maturity of the logistics system and analyse the key factors influencing readiness for digital transformation, with particular attention to technological infrastructure, employees' digital competencies, organisational capabilities, and the strategic orientation of management. It also aims to test the research hypotheses examining the relationships between these variables and overall readiness.

The collected data are structured and analysed across core dimensions, including the performance and digitalisation of the logistics system, the availability and maturity of technological infrastructure, the level of digital skills, organisational capabilities, and managerial support.

Adopting a quantitative approach, the chapter provides a comprehensive understanding of the determinants of Logistics 4.0 readiness and identifies the key drivers that can enhance logistics performance and strengthen competitiveness in a digital environment.

The study is based on a sample of 67 employees from BOMARE COMPANY involved directly or indirectly in logistics activities. Demographic characteristics such as gender, age, department, seniority, and experience are considered to ensure a diverse and representative perspective, supporting the validity of the analysis.

Section one : Sample Description and Instrument Reliability

This section describes the sample and evaluates the reliability of the measurement instrument used in the study.

1.1 Demographic characteristics of respondents

Table 11: Demographic Characteristics of the Respondents

Characteristic	Category	Frequency (N)	Percentage (%)
Gender	Male	25	37.3
	Female	42	62.7
Age	Under 30 years	29	43.3
	30-40 years	28	41.8

	Over 40 years	10	14.9
Department	Logistics Department Production Department Local Purchasing Supply Chain Department SAV Export APQ	10 32 4 10 6 2 3	14.93% 47.76% 5.97% 14.93% 8.96% 2.99% 4.48%
Seniority	Less than 1 year 1 to 3 years 4 to 7 years More than 7 years	1 32 24 10	1.49% 47.76% 35.82% 14.93%
Total experience	Less than 3 years 3 to 5 years 6 to 10 years More than 10 years	4 28 18 16	6.06% 42.42% 27.27% 24.24%

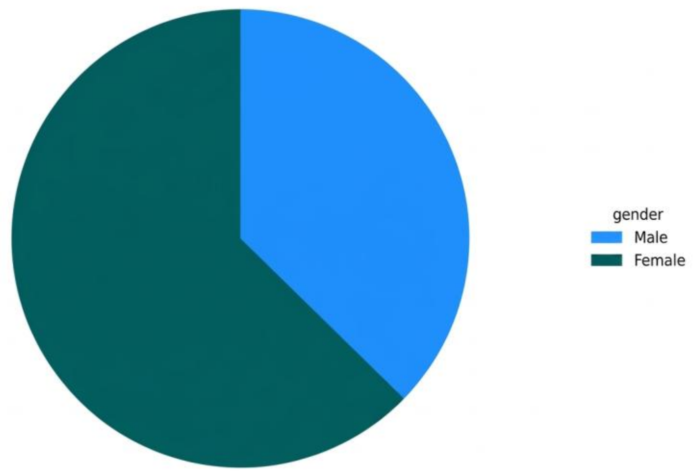
Source: Developed by the author using IBM SPSS Statistics 27

1.1.1 Gender Distribution:

The sample shows a predominance of female respondents, representing 62.69% (around 42 participants), compared to 37.31% male respondents (approximately 25 participants). This reflects a notable presence of women in logistics and supply chain roles within the organisation.

The relatively balanced gender distribution enhances the reliability of the analysis by incorporating diverse perspectives, contributing to a more comprehensive understanding of employees' perceptions regarding the study.

Figure 8: Distribution of Respondents by Gender



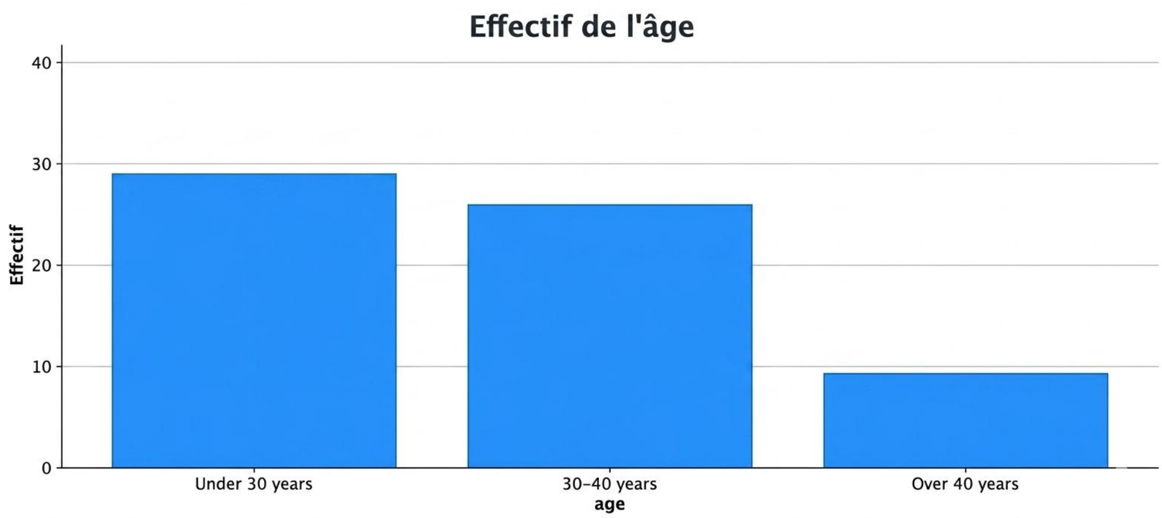
Source: IBM SPSS Statistics 27

1.1.2 Age Distribution:

The age distribution shows a relatively balanced representation between younger and middle aged respondents. Participants under 30 years old form the largest group (43.3%), closely followed by those aged 30–40 (41.8%), while individuals over 40 represent a smaller proportion (14.9%).

Overall, the sample reflects a predominantly young and active workforce, indicating a dynamic organisational environment with employees in the early and mid stages of their careers.

Figure 9: Descriptive Analysis of Respondents' Age



Source: Source: Developed by the author using IBM SPSS Statistics 27

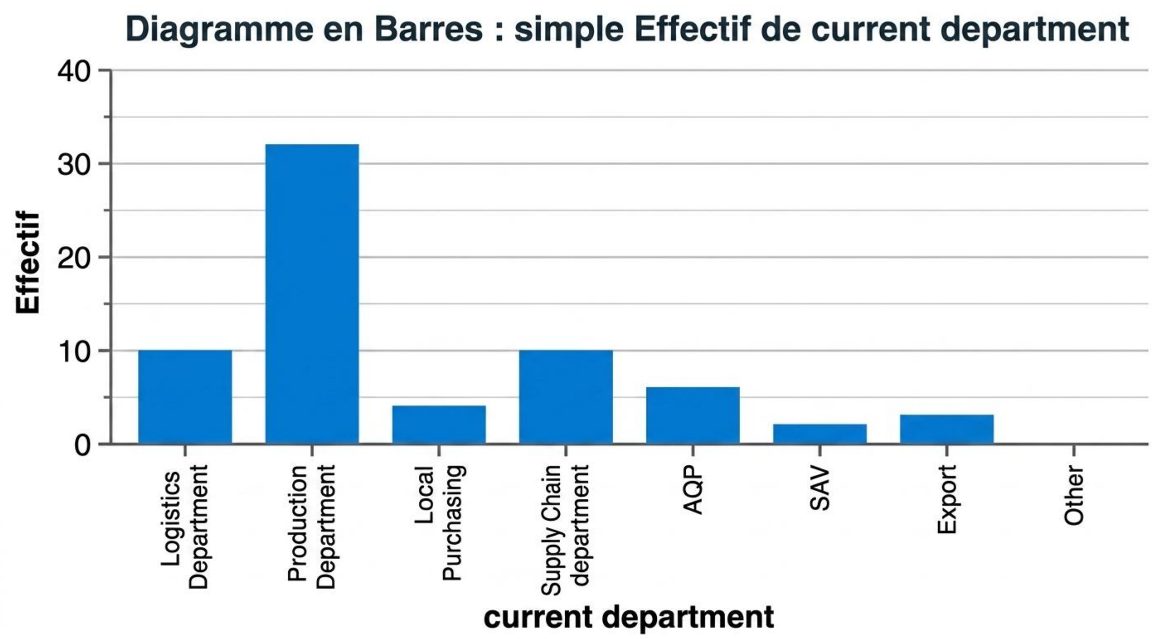
1.1.3 Department Distribution

The distribution of respondents across departments shows participation from multiple functional units, although unevenly represented. The Production Department has the largest share (32 respondents), reflecting its strategic importance and workforce size.

Logistics and Supply Chain departments each include 10 respondents, while After Sales Service (SAV) accounts for 6 and Local Purchasing for 4. In contrast, APQ and Export show lower participation (3 and 2 respondents respectively), likely due to their smaller size and more administrative roles.

Overall, the sample is mainly concentrated in operational departments, which aligns with the study's focus and ensures insights closely reflect the organisation's practical realities.

Figure 10: Distribution of Respondents by Department



Source: Developed by the author using IBM SPSS Statistics 27

The analysis of respondents' departmental affiliation shows a diverse but uneven distribution. The Production Department dominates with 47.8% (32 respondents), reflecting its strategic importance and labor intensive nature.

The Logistics and Supply Chain departments each represent 14.9%, followed by After Sales Service (9%) and Local Purchasing (6%). In contrast, APQ and Export show lower representation (4.5% and 3%) due to their administrative nature and smaller workforce.

Overall, the sample is largely concentrated in operational and production functions, reflecting the organisational structure and enhancing the relevance of the findings, while maintaining a reasonable level of diversity across departments.

1.1.4 Seniority Distribution

The analysis of respondents' seniority shows a diverse distribution of experience levels within the organisation. The majority of participants have 1–3 years of seniority (32 respondents), followed by those with 4–7 years (24 respondents), indicating a workforce mainly composed of relatively recent and moderately experienced employees.

In contrast, only 10 respondents have more than 7 years of seniority, and just 1 has less than one year, reflecting limited representation of highly experienced and newly recruited staff.

Overall, the distribution suggests a workforce largely in the early and intermediate career stages, which may support adaptability to new technologies while still benefiting from the experience of more senior employees.

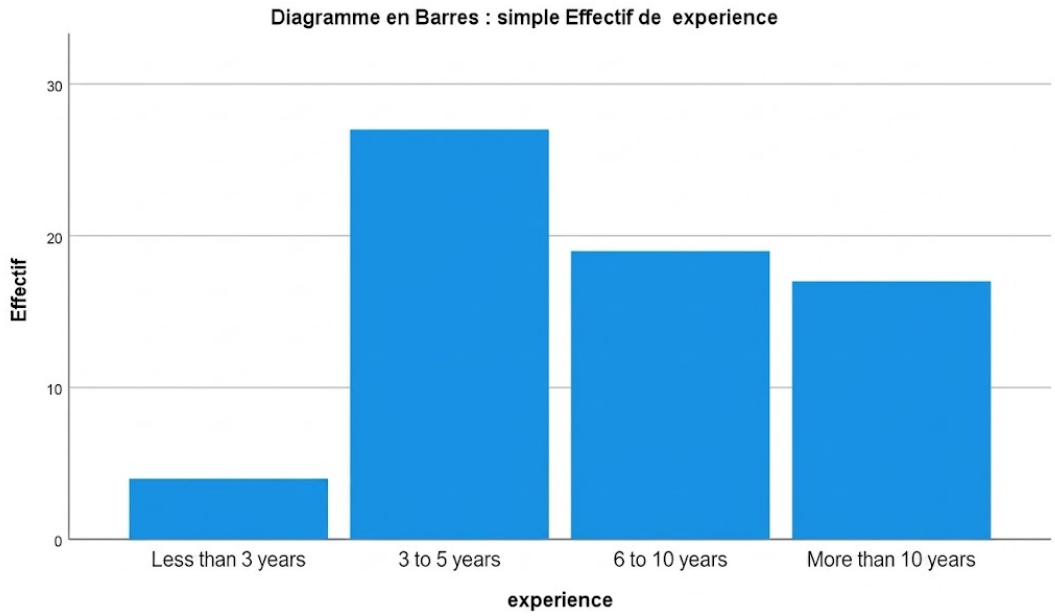
1.1.5 Total Professional Experience

The analysis of total professional experience shows that the largest group of respondents has 3–5 years of experience (28 participants), followed by those with 6–10 years (18 participants), indicating a workforce with developing to moderate expertise.

Additionally, 16 respondents have more than 10 years of experience, reflecting a well experienced segment, while only 4 participants have less than 3 years, making it the least represented group.

Overall, this distribution reflects a balanced mix of moderately and highly experienced employees, enhancing the reliability of the findings by combining diverse perspectives and levels of expertise.

Figure 11: Descriptive Analysis of Respondents' Total Professional Experience



Source: IBM SPSS Statistics 27

1.2 Reliability Analysis of the Measurement Instrument

Before conducting statistical analysis, it is essential to assess the internal consistency of the measurement scales to ensure that items within each axis reliably measure the same construct.

This is evaluated using Cronbach's alpha (α), a widely used reliability indicator (Cronbach, 1951; Nunnally & Bernstein, 1994; Hair et al., 2019). Values range from 0 to 1, with higher values indicating stronger reliability. According to established thresholds, values below 0.60 are unacceptable, 0.60–0.70 acceptable, 0.70–0.80 good, and above 0.80 excellent.

The analysis was conducted for each of the six Axes using all 67 observations, with no missing data affecting the results.

Table 12: Reliability Statistics Cronbach's Alpha by Construct

Axis	Construct	Items	N	α	Assessment
Axis 01	Current Logistics System State (H1)	LS1, LS2, LS3, LS4	4	0.873	Excellent
Axis 02	Technological Capability (H2)	TC1, TC2, TC3, TC4	4	0.867	Excellent
Axis 03	Human Capital Capability (H3)	HC1, HC2, HC3, HC4	4	0.858	Excellent
Axis 04	Organisational Capabilities (H4)	OC1, OC2, OC3, OC4	4	0.868	Excellent

Axis 05	Strategic Orientation (H5)	SO1, SO2, SO3, SO4	4	0.840	Excellent
Axis 06	Overall Readiness Dependent Variable	OR1, OR2, OR3, OR4	4	0.907	Excellent

Source: Developed by the author using IBM SPSS Statistics 27

The reliability analysis shows strong results across all six Axes, with Cronbach's alpha ranging from 0.840 (Axis 05) to 0.907 (Axis 06), all exceeding the 0.80 threshold for excellent reliability.

The dependent variable (Axis 06) demonstrates the highest consistency, supporting the robustness of subsequent regression analysis. Axis 01 also shows strong reliability despite its multidimensional nature, while Axis 05, although the lowest, remains within the excellent range.

Overall, all measurement Axes are highly reliable ($\alpha > 0.80$), confirming the validity of the instrument without the need for item removal.

Section two: Descriptive and Inferential Statistical Analysis

This section presents both descriptive and inferential statistical analyses to examine the data collected from the questionnaire. It begins with a descriptive analysis of each axis to identify general trends, followed by inferential analyses to test the research hypotheses and explore relationships between variables.

2.1 Descriptive Analysis (Axes)

This subsection presents a descriptive analysis of each axis included in the questionnaire. It aims to examine the mean values and standard deviations of the items in order to identify general trends and assess the level of each dimension related to Logistics 4.0 readiness.

2.1.1 Analysis of AXIS 01: Current Logistics System State

The analysis of results by thematic Axes provides a deeper understanding of key dimensions of logistics management within the studied company. AXIS 01 focuses on the current state of the logistics system, particularly the extent to which the existing system is perceived as a foundation for digitalisation, the regular use of performance data for decision making, the company's awareness of real time data importance, and its efforts to address existing logistics problems. These elements are critical for assessing baseline performance and identifying areas where improvements are needed, including through advanced technologies such as artificial intelligence.

Table 13: Descriptive statistics for AXIS 01 – Current logistics system state

Item	Mean	Std. Deviation
The current logistics system is a good base for future digitalisation	2.99	1.052
Performance data is regularly used to make logistics decisions	2.75	1.078
The company understands the importance of real time data and works to improve information sharing	2.76	0.986
The company is aware of its logistics problems and is working to improve them	2.82	1.029
Overall AXIS 01	2.83	1.036

Source: Developed by the author using IBM SPSS Statistics 27

The analysis of Axis 01 indicates a generally low perception of the current logistics system maturity, with an overall composite mean of M = 2.83 (SD = 1.036), placing it below the neutral threshold of 3.00. At the item level, the highest mean (M = 2.99, SD = 1.052) relates to the perceived suitability of the current system as a foundation for digitalisation, whilst the lowest mean (M = 2.75, SD = 1.078) concerns the regular use of performance data to support logistics decision-making, suggesting that data-driven management practices are not yet firmly established. The standard deviations across items range from 0.986 to 1.078, indicating moderate to substantial dispersion of responses around the mean, which implies that employee perceptions are not uniform and that the maturity of the logistics system may be experienced differently across departments. Overall, the results reflect an operational logistics system that is not yet positioned to serve as a solid foundation for Logistics 4.0, underscoring the need to strengthen data utilisation practices and translate strategic awareness of logistics challenges into concrete operational improvement actions.

2.1.2 Analysis of AXIS 02: Technological Capability

AXIS 02 focuses on technological Capability, particularly the company's IT infrastructure capacity to support advanced technologies such as IoT and RFID, awareness of modern automation technologies, access to technical expertise needed for digital logistics, and plans to invest in digital logistics technologies. These elements are essential for evaluating the company's capability to embark on a successful digital transformation journey and identifying technological gaps that need to be addressed.

Table 14: Descriptive statistics for AXIS 02 – Technological Capability

Item	Mean	Std. Deviation
The company's IT infrastructure can support technologies such as IoT and RFID	3.00	0.953
The company is aware of modern automation technologies in logistics	3.07	1.105
The company has access to the technical expertise needed for digital logistics	3.03	0.937
The company plans to invest in digital logistics technologies	3.13	1.057
Overall AXIS 02	3.06	1.013

Source: Developed by the author using IBM SPSS Statistics 27

The analysis of Axis 02 indicates a moderate level of technological Capability, with an overall composite mean of M = 3.06 (SD = 1.013), reflecting neutral perceptions among employees. At the item level, means range from 3.00 (SD = 0.953) for IT infrastructure support to 3.13 (SD = 1.057) for planned investment in digital logistics technologies. The lowest SD (0.937) is recorded for technical expertise access, suggesting relative consensus on this item, whilst the highest SD (1.105) belongs to awareness of modern automation technologies, indicating more divergent views. Despite the moderate overall mean, the comparatively high standard deviations on several items — particularly automation awareness (SD = 1.105) and planned investment (SD = 1.057) — suggest that perceptions of technological Capability vary considerably across respondents, potentially reflecting differences in role-based exposure to digital tools. Overall, Technological Capability represents neither a clear strength nor a critical weakness, but the combination of neutral means and above-average variability underscores the urgency of targeted investment in IoT, automation, and digital logistics infrastructure.

2.1.3 Analysis of AXIS 03: Human Capital Capability

AXIS 03 focuses on Human Capital Capability, particularly employees' willingness to learn digital skills related to Logistics 4.0, the company's provision or plans to provide training in digital logistics skills, employees' willingness to adapt to new digital tools and ways of working, and management's encouragement for employees to develop digital logistics skills. These elements are essential for evaluating the human capital dimension of digital transformation and identifying areas where workforce development is needed.

Table 15: Descriptive statistics for AXIS 03 – Human Capital Capability

Item	Mean	Std. Deviation
Employees are willing to learn digital skills related to Logistics 4.0	3.18	0.903
The company provides or plans to provide training in digital logistics skills	3.24	0.986
Employees are willing to adapt to new digital tools and ways of working	3.24	0.986
Management encourages employees to develop digital logistics skills	3.21	0.930
Overall AXIS 03	3.22	0.951

Source: Developed by the author using IBM SPSS Statistics 27

The analysis of Axis 03 indicates a moderately positive level of Human Capital Capability, with the highest overall composite mean of the five independent dimensions (M = 3.22, SD = 0.951), reflecting consistently favourable perceptions among employees. At the item level, means range from 3.18 (SD = 0.903) for willingness to learn digital skills to 3.24 (SD = 0.986) for both training provision and adaptability to new digital tools. Standard deviations across all four items remain below 1.00, ranging from 0.903 to 0.986, indicating relatively low dispersion and a high degree of consensus among respondents on this dimension. This convergence of opinion reinforces the reliability of the Human Capital Capability assessment and suggests that employee openness to digital transformation is a genuinely shared organisational characteristic rather than the perception of a specific subgroup. Overall, Human Capital Capability constitutes the strongest capability dimension in the study, with its above-neutral means and low variability identifying it as the most immediately available asset for BOMARE COMPANY's Logistics 4.0 transition.

2.1.4 Analysis of AXIS 04: Organisational Capabilities

The analysis of results by thematic Axis allows for a deeper understanding of various aspects of logistics management within the studied company. AXIS 04 focuses on Organisational Capabilities, particularly the ability of departments to work together to support organisational change, the company's experience in managing change and adapting processes, the organisation's support for cross departmental teams for improvement projects, and the company's encouragement of learning, improvement, and trying new ways of working. These elements are essential for evaluating the organisational culture and structural flexibility required for successful digital transformation.

Table 16: Descriptive statistics for AXIS 04 – Organisational Capabilities

Item	Mean	Std. Deviation
Departments are able to work together to support organisational change	2.99	1.022
The company has experience in managing change and adapting its processes	3.13	1.127
The organisation supports the creation of teams from different departments for improvement projects	2.94	1.113
The company encourages learning, improvement, and trying new ways of working	3.06	1.153
Overall AXIS 04	3.03	1.103

Source: Developed by the author using IBM SPSS Statistics 27

The analysis of Axis 04 indicates a moderate to slightly low level of Organisational Capabilities, with an overall composite mean of M = 3.03 (SD = 1.103). Item means range from 2.94 (SD = 1.113), for organisational support of cross-functional improvement teams, to 3.13 (SD = 1.127), for experience in managing change and adapting processes. Notably, two of the four items fall below the neutral threshold of 3.00, with cross-functional collaboration (M = 2.99, SD = 1.022) and cross-departmental team support (M = 2.94, SD = 1.113) indicating perceived weaknesses in collaborative organisational structures. The standard deviations across all four items range from 1.022 to 1.153 — the highest variability of any independent dimension examined up to this point — suggesting that perceptions of Organisational Capabilities are substantially heterogeneous across the sample. This high dispersion may indicate that collaborative and adaptive practices are applied inconsistently across departments, experienced differently at various hierarchical levels, or contingent on specific project contexts. Overall, Organisational Capabilities requires targeted improvement, particularly in fostering cross-functional collaboration and ensuring that change management capabilities are consistently embedded across the organisation.

2.1.5 Analysis of AXIS 05: Strategic Orientation

The analysis of results by thematic Axis allows for a deeper understanding of various aspects of logistics management within the studied company. AXIS 05 focuses on Strategic Orientation, particularly senior management's clear vision for transitioning to Logistics 4.0, the company's allocation or plans to allocate a budget for digital transformation in logistics, regular communication from management about digital transformation, and the inclusion of Logistics 4.0 in the company's strategic plans. These elements are essential for evaluating the strategic foundation and leadership commitment necessary for successful digital transformation.

Table 17: Descriptive statistics for *AXIS* 05 – Strategic Orientation

Item	Mean	Std. Deviation
Senior management has a clear vision for transitioning to Logistics 4.0	3.13	1.153
The company has allocated or plans to allocate a budget for digital transformation in logistics	3.07	1.271
Management communicates regularly about digital transformation in logistics	3.16	1.163
Logistics 4.0 is included in the company's strategic plans	3.19	1.234
Overall AXIS 05	3.14	1.205

Source: Developed by the author using IBM SPSS Statistics 27

The analysis of Axis 05 indicates a moderate level of Strategic Orientation, with an overall composite mean of M = 3.14 (SD = 1.205). Item means range from 3.07 (SD = 1.271) for budget allocation for digital transformation to 3.19 (SD = 1.234) for the inclusion of Logistics 4.0 in the company's strategic plans. Critically, Axis 05 records the highest standard deviations of any dimension in the study, with all four items exceeding SD = 1.15 (1.153, 1.271, 1.163, and 1.234 respectively). This indicates a high degree of disagreement among respondents regarding management's strategic commitment, suggesting that strategic communication and the visibility of budgetary decisions are not consistently perceived across the organisation. The overall composite SD of 1.205 is particularly noteworthy, as it implies that whilst strategic intent may exist at the managerial level, it has not been uniformly transmitted or credibly demonstrated to employees at the operational level. This divergence between the stated strategic direction and its perceived operational reality constitutes the empirical basis for the perception gap discussed in Section 3.1.6.

2.1.6 Analysis of AXIS 06: Overall Organisational Capabilities for Logistics 4.0

The analysis of Axis 06 indicates a moderate level of overall Organisational Capabilities, with an overall composite mean of M = 3.06 (SD = 0.967). Item means range from 3.04 (SD = 0.944), for confidence that manageable changes can initiate a Logistics 4.0 project, to 3.07 (SD = 0.958), for confidence in a successful transition. Standard deviations are the lowest of any axis in the study, ranging from 0.944 to 0.983, reflecting a relatively high degree of consensus among respondents regarding overall readiness. This convergence of perceptions around the neutral point is analytically significant: it suggests that employees hold a coherent, if cautiously moderate, view of the company's current preparedness. The consistently low variability of this axis also supports the reliability of the composite score as the study's dependent variable, as confirmed by its Cronbach's alpha of 0.907

Table 18 : Descriptive statistics for *AXIS* 06 – Overall Organisational Capabilities for Logistics 4.0

Item	Mean	Std. Deviation
Overall, the company is ready to start its transition to Logistics 4.0	3.06	0.983
The company has the necessary capabilities to move towards Logistics 4.0	3.06	0.983
The company can start a Logistics 4.0 project with manageable changes	3.04	0.944
I am confident the company will successfully transition to Logistics 4.0	3.07	0.958
Overall AXIS 06	3.06	0.967

Source: Developed by the author using IBM SPSS Statistics 27

The analysis of AXIS 06 indicates a moderate level of overall Organisational Capabilities, with mean values slightly above 3.00 (3.04–3.07), reflecting neutral perceptions.

Employees show cautious optimism, with the highest mean (3.07) indicating confidence in a successful transition, despite limitations identified in previous Axis. Perceptions of readiness to start the transition and availability of capabilities (3.06) remain moderate, while the lowest score (3.04) suggests concerns about the extent of changes required.

Overall, readiness is moderate and aligned with earlier findings, highlighting the need to address gaps in infrastructure, collaboration, strategic clarity, and communication to support Logistics 4.0 implementation.

Key finding: All six construct means fall within the neutral range (2.60–3.40). Human Capital Capability (Axis 03, M = 3.22) is the strongest capability dimension, while current logistics system state (Axis 01, M = 2.83) is the weakest. The dependent variable (overall readiness) records M=3.06, confirming that BOMARE COMPANY is at a critical transitional threshold.

2.2 Normality Testing

Before conducting correlation analysis and multiple regression, it is necessary to verify whether the composite mean scores of the six constructs follow a normal distribution. This verification is a prerequisite for the appropriate use of Pearson correlation and parametric regression, which assume that the residuals and predictor variables are approximately normally distributed (Field, 2018). Normality was assessed using the Shapiro Wilk test, which is the most appropriate test for samples of this size (n = 67), as it is more sensitive and powerful than the Kolmogorov Smirnov test when the sample size is below 200 (Razali & Wah, 2011). The null hypothesis of the Shapiro Wilk test states that the data are normally distributed; a p-value above 0.05 leads to the retention of this null hypothesis (i.e., normality is not rejected), while a p-value below 0.05 suggests a significant departure from normality.

Table 19: Shapiro Wilk Normality Tests Composite Mean Scores

Variable	Construct	W statistic	n	Sig. (p)	Distribution	Correlation Test
MOY_AX1	Axis 01 — Current Logistics System State	0.977	67	0.255	Normal	Pearson

MOY_AX2	Axis 02 — Technological Capability	0.961	67	0.234	Normal	Pearson
MOY_AX3	Axis 03 — Human Capital Capability	0.978	67	0.293	Normal	Pearson
MOY_AX4	Axis 04 — Organisational Capabilities	0.979	67	0.329	Normal	Pearson
MOY_AX5	Axis 05 — Strategic Orientation	0.968	67	0.079	Normal	Pearson
MOY_AX6	Axis 06 — Overall Readiness (DV)	0.966	67	0.064	Normal	Pearson

Source: Developed by the author using IBM SPSS Statistics 27

The Shapiro–Wilk test results indicate that normality is fully supported for all six composite mean scores. All constructs MOY_AX1, MOY_AX2, MOY_AX3, MOY_AX4, MOY_AX5, and MOY_AX6 yield p-values greater than 0.05, confirming that the null hypothesis of normality cannot be rejected for any variable. In addition, visual inspection of the Q-Q plots shows that the data points are closely aligned with the diagonal reference line, indicating no significant deviations from normality or presence of extreme outliers. Consequently, the assumption of normality is satisfied across all variables, supporting the use of parametric methods such as Pearson correlation and multiple linear regression in the subsequent analysis.

2.3 Inferential Analyses

This section presents the inferential statistical analyses conducted to examine the relationships between variables and test the research hypotheses. It includes correlation analysis, multiple linear regression, and group comparison tests, providing deeper insights beyond descriptive results.

2.3.1 Pearson Correlation Analysis

The Pearson correlation matrix was computed for the six composite mean scores to examine the bivariate associations among the five independent constructs and the dependent variable before entering them into the regression model. Correlation analysis serves two distinct analytical purposes in this study: it provides preliminary evidence regarding the directionality and strength of the relationships hypothesised in H1 through H5, and it screens for potential multicollinearity among the independent variables a condition that would distort regression coefficients and inflate standard errors (Hair et al., 2019; Field, 2018).

Table 20: Pearson Correlation Matrix — All Six Constructs (n=67)

Variable	AX1 (LS)	AX2 (TC)	AX3 (HC)	AX4 (OC)	AX5 (SO)	AX6 (DV)	n
AX1 — (LS)	—	-.060	-.053	.043	.109	.303*	67
AX2 — (TC)	-.060	—	.017	.000	-.004	.557**	67
AX3 — (HC)	-.053	.017	—	.071	.001	.391**	67
AX4 — (OC)	.043	.000	.071	—	.070	.117	67
AX5 — (SO)	.109	-.004	.001	.070	—	-.107	67
AX6 — (OR/DV)	.303*	.557**	.391**	.117	-.107	—	67

Source: Developed by the author using IBM SPSS Statistics 27

Three of the five independent variables exhibit statistically significant correlations with the dependent variable (MOY_AX6 — Overall Readiness). Technological Capability (MOY_AX2) displays the strongest association ($r = .557$, $p < .001$), indicating a moderate to strong positive correlation. Human Capital Capability (MOY_AX3) follows with $r = .391$ ($p = .001$), and Current Logistics System State (MOY_AX1) demonstrates a significant but weaker association ($r = .303$, $p = .013$). In contrast, Organisational Capabilities (MOY_AX4; $r = .117$, $p = .347$) and Strategic Orientation (MOY_AX5; $r = -.107$, $p = .387$) show no significant bivariate correlations with the dependent variable. Crucially, the inter correlations among the five predictor variables are all near zero (ranging from .000 to .109 in absolute terms), indicating the virtual absence of multicollinearity. This finding is further substantiated by the regression diagnostics presented in the following section.

2.3.2 Multiple Linear Regression Testing Hypotheses H1 Through H5

The central analytical procedure of this study is a multiple linear regression in which overall Organisational Capabilities for Logistics 4.0 (MOY_AX6) is regressed simultaneously on all five independent constructs: Current Logistics System State (MOY_AX1), Technological Capability (MOY_AX2), Human Capital Capability (MOY_AX3), Organisational Capabilities (MOY_AX4), and Strategic Orientation (MOY_AX5). The Enter method was used, meaning all five predictors were entered simultaneously into the model, allowing each predictor's unique contribution to be estimated while controlling for all others. This method is appropriate given that all five predictors are theoretically motivated and derived from established hypotheses rather than exploratory variable selection (Field, 2018). The analysis was conducted on the complete dataset of 67 observations with no missing values, fully satisfying the minimum sample size requirement of at least ten observations per predictor for this five predictor model (Hair et al., 2019).

2.3.2.1 Model Fit R^2 and Overall Significance

This subsection evaluates the overall performance of the regression model by examining the coefficient of determination (R^2) and the statistical significance of the model. It assesses how well the independent variables explain the variation in the dependent variable.

Table 21: Model Summary

R	R^2	R^2 Adjusted	Std. Error of Estimate
0.782	**0.612**	**0.580**	0.583

Source: Developed by the author using IBM SPSS Statistics 27

The regression model achieves a multiple correlation coefficient of R = .782, indicating a strong linear association between the five predictors taken together and the dependent variable. The coefficient of determination $R^2 = .612$ indicates that 61.2% of the variance in overall Organisational Capabilities for Logistics 4.0 is explained by the five capability dimensions collectively. The adjusted $R^2 = .580$ accounts for model parsimony and confirms that this explanatory power is not merely an artefact of the number of predictors. These values represent a substantial explanatory capacity.

Table 22: ANOVA — Overall Model Significance

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	32.637	5	6.527	19.214	0.000
Residual	20.723	61	0.340	—	—
Total	53.360	66	—	—	—

Source: Developed by the author using IBM SPSS Statistics 27

The ANOVA test confirms that the overall regression model is statistically significant: $F(5, 61) = 19.214$, $p < .001$. This result indicates that the combination of the five capability dimensions collectively provides a statistically significant improvement in predicting overall readiness compared to a null model. The regression equation is thus valid and the model fit is strong.

2.3.2.2 Individual Predictor Coefficients and Hypothesis Testing

The following table presents the detailed results of the multiple linear regression analysis, including the unstandardised coefficients, standardised beta values, significance levels, and collinearity statistics for each independent variable. These results allow for the assessment of the individual contribution of each predictor to overall readiness, as well as the testing of the research hypotheses.

Table 23: Regression Coefficients, Standardised Betas, Significance, and Collinearity Statistics

Predictor	H	B	Std. Error	Beta (β)	t	Sig.		Tolerance	VIF
(Constant)	—	-0.894	0.514	—	**-1.739**	0.087		—	—
MOY_AX1 (LS)	**H1**	**0.364**	0.079	**0.371**	**4.607**	**0.000**	***	0.980	1.020
MOY_AX2 (TC)	**H2**	**0.573**	0.080	**0.572**	**7.157**	**0.000**	***	0.996	1.004
MOY_AX3 (HC)	**H3**	**0.418**	0.085	**0.395**	**4.926**	**0.000**	***	0.992	1.008
MOY_AX4 (OC)	**H4**	**0.079**	0.075	**0.084**	**1.042**	0.301	**ns**	0.989	1.012
MOY_AX5 (SO)	**H5**	**-0.132**	0.070	**-0.152**	**-1.890**	0.063	**ns**	0.984	1.017

Source: Developed by the author using IBM SPSS Statistics 27

- **Hypothesis 1 (H1): Current Logistics System State Overall Readiness**

  Result: MOY_AX1 produces a standardised beta coefficient of $\beta = 0.371$, with an unstandardised coefficient of $B = 0.364$ ($SE = 0.079$), $t(61) = 4.607$, $p < 0.001$.

  H1 is **supported**. The current state of the logistics system exerts a significant positive effect on overall readiness ($\beta = 0.371$, $B = 0.364$, $SE = 0.079$, $t(61) = 4.607$, $p < 0.001$). This result confirms that a more mature operational logistics foundation is a significant prerequisite for digital transformation, consistent with the theoretical reasoning of Christopher (2016) and Winkelhaus & Grosse (2020). For BOMARE COMPANY, investments targeting data driven decision making and real time information sharing   the weakest individual items in this axis   will directly enhance perceived transition readiness.

- **Hypothesis 2 (H2): Technological Capability Overall Readiness**

  Result: MOY_AX2 produces a standardised beta coefficient of $\beta = 0.572$, with $B = 0.573$ ($SE = 0.080$), $t(61) = 7.157$, $p < 0.001$.

  H2 is **supported**. Technological Capability emerges as the strongest predictor in the model, with the highest standardised beta coefficient ($\beta = 0.572$, $B = 0.573$, $SE = 0.080$, $t(61) = 7.157$, $p < 0.001$). This finding aligns with Kagermann et al. (2013) and Hofmann & Rüsch (2017), confirming that Logistics 4.0 is inherently technology dependent. Notably, despite being the most impactful lever, Technological Capability scores only in the neutral range ($M = 3.06$), underscoring the urgency of targeted investment in IoT, automation, RFID, and digital logistics infrastructure at BOMARE COMPANY.

- **Hypothesis 3 (H3): Human Capital Capability Overall Readiness**

  Result: MOY_AX3 produces a standardised beta coefficient of $\beta = 0.395$, with $B = 0.418$ ($SE = 0.085$), $t(61) = 4.926$, $p < 0.001$.

  H3 is **supported**. Human Capital Capability is the second strongest predictor in the model ($\beta = 0.395$, $B = 0.418$, $SE = 0.085$, $t(61) = 4.926$, $p < 0.001$). This result reinforces the argument that employee willingness, training provision, adaptability, and managerial encouragement are indispensable enablers of digital transformation (Frank et al., 2019; Bowersox et al., 2013). Critically, Human Capital Capability is also the highest scoring capability dimension ($M = 3.22$), indicating that BOMARE COMPANY's workforce openness constitutes a strategic asset that can be channelled through structured upskilling programmes.

- **Hypothesis 4 (H4): Organisational Capabilities Overall Readiness**

  Result: MOY_AX4 produces $\beta = 0.084$, $B = 0.079$ ($SE = 0.075$), $t(61) = 1.042$, $p = 0.301$.

  H4 is **not supported**. The coefficient for Organisational Capabilities is small and non significant (β

= 0.084, B = 0.079, SE = 0.075, t(61) = 1.042, p = 0.301). Several interpretations merit consideration. First, high standard deviations (1.022–1.153) suggest substantial variability in perceptions across the sample, potentially suppressing the relationship. Second, organisational capabilities may operate indirectly mediated through Human Capital Capability rather than directly on overall readiness. Third, this construct may be more predictive of implementation success (a longer term outcome) than of current readiness perceptions (Müller et al., 2018).

- **Hypothesis 5 (H5): Strategic Orientation Overall Readiness**

Result: MOY_AX5 produces β = -0.152, B = -0.132 (SE = 0.070), t(61) = -1.890, p = 0.063.

H5 is **not supported**. Strategic Orientation produces a negative and marginally non-significant coefficient (β = -0.152, B = -0.132, SE = 0.070, t(61) = -1.890, p = 0.063). This counterintuitive finding should not be interpreted as evidence that strategic commitment harms readiness. Rather, it suggests a strategic-operational perception gap: operational employees who observe management communicating about Logistics 4.0 may become more acutely aware of the distance between strategic ambition and operational reality, thus reporting lower overall readiness The notably high variance (SD = 1.205, the highest composite SD of all Axes) reflects deep disagreement among respondents regarding the genuineness and sufficiency of management's vision and commitment.

2.3.2.3 Collinearity Diagnostics

All VIF values fall between 1.004 (MOY_AX2) and 1.020 (MOY_AX1), far below the commonly cited threshold of 5 and well within the excellent range. Tolerance values range from 0.980 to 0.996, all approaching unity. These results confirm the absence of any multicollinearity concern in the regression model, consistent with the near zero inter predictor correlations reported in the Pearson correlation analysis (Section 2.3.1 above).The regression coefficients can therefore be interpreted with full confidence that no individual predictor's coefficient is artificially inflated or deflated by shared variance with other predictors.

2.3.2.4 Synthesis Hypothesis Testing Results

This subsection provides a concise summary of the hypothesis testing results, indicating which hypotheses are supported or rejected based on the statistical analysis. It highlights the overall pattern of relationships between the independent variables and the dependent variable, offering a clear synthesis of the main findings.

Table 24: Summary of Hypothesis Testing Results

H	Hypothesis Path	Axes	β	Sig. (p)	Decision
H1	Current Logistics System State	Axis 01	**β=0.371**	**p=0.000**	**Supported**
H2	Technological Capability	Axis 02	**β=0.572**	**p=0.000**	**Supported**
H3	Human Capital Capability	Axis 03	**β=0.395**	**p=0.000**	**Supported**
H4	Organisational	Axis 04	**β=0.084**	**p=0.301**	**Not Supported**
H5	Strategic Orientation	Axis 05	**β=-0.152**	**p=0.063**	**Not Supported**

Source: Developed by the author using IBM SPSS Statistics 27

Three of the five research hypotheses are statistically supported at the $p < 0.001$ level. The overall model explains 58.0% of the variance in overall readiness (adjusted $R^2 = 0.580$), with Technological Capability (β = 0.572) as the dominant predictor, followed by Human Capital Capability (β = 0.395) and logistics system state (β = 0.371). Organisational and Strategic Orientation do not emerge as significant predictors in this sample, though the reasons for these non significant results are theoretically interpretable and discussed above.

Therefore, H1, H2, and H3 are fully supported (all $p < 0.001$). H4 (organisational capabilities) and H5 (Strategic Orientation) are not statistically supported. The model explains 58.0% of variance in overall readiness. Technological Capability is the single strongest predictor. These results are globally coherent with the pattern established in the correlation analysis.

2.4 Group Comparison Analyses (ANOVA)

T-test by gender and ANOVA by department, age, and experience

Table 25: Group Comparison Results

Grouping Variable	Construct	Group Means	Statistic	df	Sig. (p)	Significant?	Decision
By Gender (T-Test)	**MOY_AX1 (LS)**	M=3.01 / F=2.65	**t=1.579**	df=65	p=0.119	**No**	H0 retained
	MOY_AX2 (TC)	M=3.03 / F=3.04	**t=-0.051**	df=65	p=0.959	**No**	H0 retained

	MOY_AX3 (HC)	M=2.96 / F=3.30	**t=-1.621**	df=65	p=0.110	**No**	H0 retained
	MOY_AX4 (OC)	M=2.95 / F=3.04	**t=-0.377**	df=65	p=0.707	**No**	H0 retained
	MOY_AX5 (SO)	M=2.98 / F=3.14	**t=-0.599**	df=65	p=0.551	**No**	H0 retained
	MOY_AX6 (OR)	M=3.04 / F=3.00	**t=0.175**	df=65	p=0.862	**No**	H0 retained
By Department (ANOVA)	**MOY_AX1 (LS)**	—	**F=0.304**	df=5,61	p=0.909	**No**	H0 retained
	MOY_AX2 (TC)	—	**F=0.896**	df=5,61	p=0.490	**No**	H0 retained
	MOY_AX3 (HC)	—	**F=0.367**	df=5,61	p=0.869	**No**	H0 retained
	MOY_AX4 (OC)	—	**F=0.652**	df=5,61	p=0.661	**No**	H0 retained
	MOY_AX5 (SO)	—	**F=1.300**	df=5,61	p=0.276	**No**	H0 retained
	MOY_AX6 (OR)	—	**F=0.432**	df=5,61	p=0.825	**No**	H0 retained
By Age Group (ANOVA)	**MOY_AX1 (LS)**	—	**F=1.137**	df=2,64	p=0.327	**No**	H0 retained
	MOY_AX6 (OR)	—	**F=0.103**	df=2,64	p=0.902	**No**	H0 retained
By Experience (ANOVA)	**MOY_AX1 (LS)**	—	**F=0.472**	df=3,63	p=0.703	**No**	H0 retained
	MOY_AX5 (SO)	—	**F=2.534**	df=3,63	p=0.065	**No**	H0 retained
	MOY_AX6 (OR)	—	**F=0.412**	df=3,63	p=0.745	**No**	H0 retained

Source: Developed by the author using IBM SPSS Statistics 27

The results, presented in Table 25, indicate no statistically significant gender-based differences for any of the six axes. The largest observed T-statistic relates to Human Capital Capability, where female respondents (M = 3.30) scored marginally higher than male respondents (M = 2.96), yet this difference did not reach statistical significance: $t(65) = -1.621$, $p = 0.110$. For Technological Capability, perceptions were virtually identical across gender groups (Male: M = 3.03; Female: M = 3.04; $t(65) = -0.051$, $p = 0.959$). Overall readiness perceptions were likewise consistent: $t(65) = 0.175$, $p = 0.862$ (Male: M = 3.04; Female: M = 3.00). The null hypothesis of equal means is retained for all six constructs, confirming that gender does not constitute a significant source of variation in readiness perceptions within this sample. This result suggests that the neutral readiness profile documented in the descriptive analysis is shared uniformly across gender groups, irrespective of the predominance of female respondents (62.7%) in the sample.

2.4.1 Comparison by Department (One-Way ANOVA)

The one-way ANOVA shows no statistically significant differences across departments for any of the six constructs, with all p-values above 0.05. This indicates that employees across all departments share similar perceptions of the company's readiness.

This uniformity suggests that the neutral readiness levels identified are consistent across the organisation and not limited to specific departments, confirming that the results reflect an overall organisational condition rather than departmental differences.

2.4.2 Comparison by Age Group (One-Way ANOVA)

The one-way ANOVA by age group shows no statistically significant differences across all constructs ($p > 0.05$). Although minor variations appear in descriptive means, they are not significant.

This indicates that employees of different age groups share similar perceptions of the company's readiness, reflecting a consistent view across generations.

2.4.3 Comparison by Professional Experience (One-Way ANOVA)

The one-way ANOVA by total professional experience shows no statistically significant differences across all constructs. Although MOY_AX5 approaches significance ($p = 0.065$), it remains above the threshold.

Overall, perceptions of readiness are consistent across all groups, reinforcing the validity of the regression results by confirming the absence of group based bias.

As a Key we can confirm that no statistically significant differences in readiness perceptions were found across gender, department, age group, or professional experience.

The neutral range readiness assessment is a company wide consensus rather than a subgroup specific perception, strengthening the generalisability of the regression findings across the target population.

Section three: Discussion and Implications

This section provides a comprehensive interpretation of the study's empirical results. It first discusses the main findings in relation to the research objectives and theoretical framework, and then explores their theoretical and managerial implications, highlighting their relevance for both academic research and practical application.

3.1 Discussion of Main Findings

The empirical analysis conducted in Chapter III yields a rich and coherent set of findings that collectively shed light on BOMARE COMPANY's current position on the path towards Logistics 4.0. This section interprets those findings in relation to the research hypotheses, the existing theoretical framework, and the specific organisational context of the company.

3.1.1 A Company at the Transitional Threshold

The most overarching finding of this study is that BOMARE COMPANY occupies what can be described as a transitional threshold position: the company is neither clearly ready nor clearly unprepared for Logistics 4.0. All six composite means fall within the neutral range of 2.60 to 3.40, spanning from the current logistics system state as the weakest dimension (M = 2.83) through Organisational Capabilities (M = 3.03), Technological Capability (M = 3.06), and Strategic Orientation (M = 3.14), to Human Capital Capability as the strongest independent dimension (M = 3.22), with overall Organisational Capabilities recording M = 3.06. No dimension approaches either the lower boundary of disagreement (below 2.60) or the upper boundary of clear agreement (above 3.40). This finding is not a sign of stagnation; rather, it reflects a company that has initiated a digital journey as evidenced by investments in SAP ERP, automated production lines, and the SMART FABLAB but has not yet developed the full spectrum of capabilities required for a complete and coherent transition to Logistics 4.0.

This profile is consistent with the maturity model literature, which identifies an intermediate stage often labelled as 'digital awareness' or 'partial adoption' between traditional logistics and fully integrated Logistics 4.0 operations (Christopher, 2016; Winkelhaus & Grosse, 2020). The neutral range profile observed across all dimensions suggests that BOMARE COMPANY has reached this intermediate stage but has not yet succeeded in translating its strategic digital ambitions into a perceptible and uniform operational readiness across the organisation.

3.1.2 Technological Capability: The Dominant Predictor

The most influential finding in this study is the confirmation of H2: Technological Capability is the single strongest predictor of overall Logistics 4.0 readiness, with a standardised beta coefficient of $\beta = 0.572$ ($p < 0.001$), significant at $p < 0.001$.

This finding is strongly aligned with the foundational theoretical arguments of Kagermann et al. (2013) and Hofmann and Rüsch (2017), who position technological infrastructure as the primary enabler of Logistics 4.0. It is also consistent with the correlation analysis, where Technological Capability recorded the highest bivariate correlation with overall readiness ($r = 0.557$, $p < 0.001$).

The critical tension, however, lies in the descriptive findings: Technological Capability itself scores only in the neutral zone ($M = 3.06$), the third lowest mean among all capability dimensions. This creates a paradox with significant managerial implications: the dimension that most determines readiness is also one of the least developed. Employees perceive that the company's IT infrastructure and technical expertise are insufficient to fully support the deployment of IoT, RFID, and advanced automation technologies. This gap between impact and current development level identifies technology investment as the highest priority lever for accelerating BOMARE COMPANY's readiness for Logistics 4.0.

3.1.3 Human Capital Capability: A Strategic Asset Already in Place

The confirmation of H3 ($\beta = 0.395$, $p < 0.001$) establishes Human Capital Capability as the second most impactful predictor of overall readiness, behind only Technological Capability ($\beta = 0.572$) and ahead of the current logistics system state ($\beta = 0.371$). Uniquely among all five capability dimensions, Human Capital Capability is simultaneously a statistically significant predictor and the highest scoring dimension ($M = 3.22$), making it the only construct that is both a strong statistical driver of readiness and already comparatively well developed within the organisation. This combination of predictive power and relative strength makes it the most immediately available asset for the company's transition strategy.

The descriptive data reveal that employees are open to learning digital skills **($M = 3.18$)**, willing to adapt to new digital tools ($M = 3.24$), and perceive management encouragement of digital skill development ($M = 3.21$).These results are consistent with Frank et al.'s (2019) and Bowersox et al.'s (2013) arguments that attitudinal and behavioural readiness among employees is an indispensable enabler of digital transformation one that cannot be manufactured through financial investment alone and typically takes considerable time to develop.

The fact that BOMARE COMPANY's workforce already exhibits this openness is a significant competitive advantage in the transition process. However, the translation of this willingness into actual digital competence depends on the provision of structured, sustained, and targeted training programmes an investment that is far less costly and more rapidly deployable than large scale technological infrastructure upgrades.

3.1.4 Current Logistics System State: Foundation Matters

H1 is also confirmed ($\beta = 0.371$, $p < 0.001$), establishing that the maturity of the current logistics system is the strongest third predictor. This finding aligns with Christopher's (2016) argument that digital transformation does not begin in a vacuum: organisations with a stronger operational logistics foundation one based on standardised processes, performance measurement, and integrated information flows are better positioned to absorb and exploit Logistics 4.0 technologies.

At BOMARE COMPANY, the current logistics system state records the weakest composite mean of all five independent capability dimensions (M = **2.83**, SD = 1.036), placing it at the lower boundary of the neutral range. Within this axis, the item 'performance data is regularly used to make logistics decisions' recorded the lowest individual mean (M = 2.75, SD = 1.078), pointing to a specific and structurally important gap: data driven logistics management is not yet routine. Since Logistics 4.0 is fundamentally built upon the continuous generation, sharing, and exploitation of real time data, this gap represents a foundational constraint that must be addressed before more advanced digital logistics initiatives can be successfully deployed.

3.1.5 Organisational Capabilities: An Indirect or Contextual Enabler

H4 is not statistically supported ($\beta = 0.084$, $p = 0.301$). The Cohen's f^2 effect size computed from the regression output confirms a negligible practical effect ($f^2 = 0.029$, well below the 0.15 threshold for a small effect). Organisational Capabilities which captures cross functional collaboration, change management experience, and adaptive culture does not emerge as a significant direct predictor of overall readiness. This finding is somewhat surprising given the theoretical importance attributed to organisational capabilities in the Logistics 4.0 literature (Müller et al., 2018).

Several interpretations are worth considering. First, the high internal variability of this dimension (standard deviations ranging from 1.022 to 1.153) suggests that organisational practices are experienced very differently across departments, which may dilute its apparent relationship with overall readiness at the aggregate level. Second, organisational capabilities may operate indirectly mediating or moderating the relationship between technological investment and operational outcomes rather than directly predicting readiness perceptions. Third, this dimension may be more strongly predictive of Logistics 4.0 implementation success (a longer term outcome) than of the current readiness perceptions measured in this study. Future research employing longitudinal or mediation designs could examine these dynamics more rigorously.

3.1.6 Strategic Orientation: The Perception Gap

H5 is not statistically supported, and its coefficient is negative in the analytical model (SPSS: $\beta = -0.152$, $p = 0.063$). While result did not cross the significance threshold.

This result should not be interpreted as evidence that strategic management commitment is counterproductive a conclusion that would be both theoretically implausible and statistically unsupported. Rather, the most plausible explanation is the existence of a strategic operational perception gap: employees who are aware of management's stated commitment to Logistics 4.0 through budget allocations, communications, and strategic plans may simultaneously feel more acutely the distance between this stated ambition and the current operational reality, thus reporting lower overall readiness perceptions. In other words, strategic awareness may heighten the perception of unreadiness rather than counteract it.

This dynamic may be conceptualised as **aspirational dissonance** a condition in which employees' awareness of their organisation's stated digital ambitions paradoxically amplifies rather than reduces the perception of current operational unreadiness. Unlike a simple capability deficit, aspirational dissonance does not reflect an absence of action; it reflects an absence of alignment between strategic communication and operational implementation. When management articulates ambitious digital targets without translating them into visible operational progress, the perceptual distance between where the organisation intends to go and where employees experience it to currently stand widens rather than narrows. This construct differs from established notions of strategic ambiguity or implementation barriers in that it is generated not by a lack of strategy, but by an excess of aspiration relative to demonstrated operational change. Its identification in this study represents a potentially novel contribution to the Logistics 4.0 readiness literature, one which will be revisited in the concluding chapter.

This interpretation is further supported by the professional experience analysis, which revealed a noteworthy (though non-significant) trend: newer employees perceive Strategic Orientation more favourably than the most experienced ones. Longer tenured employees, who have observed the gap between strategic announcements and operational change over time, appear more sceptical of management's Strategic Orientation a finding that reinforces the perception gap hypothesis.

3.1.7 Group Comparison Analyses: A Company-Wide Consensus

The group comparison analyses produced a consistent and analytically significant result: no statistically significant differences in readiness perceptions were found across any of the four grouping variables. For gender, the independent samples T-test showed no significant difference in overall readiness perceptions between male ($M = 3.04$) and female ($M = 3.00$) respondents: $t(65) = 0.175$, $p = 0.862$. For department, the one-way ANOVA confirmed no significant variation across the six functional units: $F(5, 61) = 0.432$, $p = 0.825$ for overall readiness. Age group comparisons yielded similarly negligible differences: $F(2, 64) = 0.103$, $p = 0.902$. The closest result to significance was Strategic Orientation by professional experience: $F(3, 63) = 2.534$, $p = 0.065$, which nonetheless remained above the conventional threshold and the null hypothesis was retained. All other constructs by experience also showed non-significant variation: $F(3, 63) = 0.472$, $p = 0.703$ for the current logistics system state and $F(3, 63) = 0.412$, $p = 0.745$ for overall readiness .

This uniformity strengthens the validity and generalisability of the regression findings in two important ways. First, it confirms that the neutral range readiness profile documented in the descriptive analysis is not a subgroup artifact but a genuine company wide perception shared equally by logistics and production employees, by junior and senior staff, and by male and female respondents. Second, it rules out systematic confounding by demographic or professional factors, giving greater confidence that the relationships identified in the regression model reflect true structural determinants of readiness rather than spurious between group differences.

3.2 Theoretical and Managerial Implications

This section outlines the key implications derived from the empirical findings of the study. It highlights how the results contribute to the existing theoretical framework of Logistics 4.0 readiness and provides practical insights for improving organisational performance. The discussion is structured around two main dimensions: theoretical implications and managerial implications.

3.2.1 Theoretical Implications

This study makes several contributions to the theoretical literature on Logistics 4.0 readiness and digital transformation in industrial organisations.

- **Validation of the Technology Human nexus in Logistics 4.0 Readiness.** The findings provide robust empirical support for the theoretical argument that Logistics 4.0 readiness is primarily shaped by the joint development of technological infrastructure (H2) and human capital (H3), with current logistics system maturity (H1) providing the foundational layer. This empirical confirmation of the technology human nexus long theorised but rarely tested in the Algerian context represents a significant contribution to the field, particularly for emerging economy literature where technological and human capability constraints frequently co-exist.

- **Questioning the Direct Effect of Organisational and Strategic Capabilities.** The non significance of H4 and H5 does not invalidate the study or its findings. Rather, it highlights a potential misalignment between strategic intentions and operational practices within the organisation.

While organisational and strategic capabilities are often theorised as direct predictors of digital readiness (Müller et al., 2018; Frank et al., 2019), this result suggests that what is formally stated by the company may not be fully reflected in day-to-day implementation. In other words, the gap between what is said (strategic discourse) and what is actually done (operational reality) may explain the absence of a significant direct effect.

This interpretation reinforces the need for future research to develop more nuanced models that distinguish between declared capabilities and effectively implemented practices, and to examine how this alignment influences readiness perceptions.

- **The Strategic Operational Perception Gap as a Theoretical Construct.** The negative direction of the Strategic Orientation coefficient introduces a new conceptual insight: the awareness of strategic ambition may paradoxically heighten the perception of current unreadiness. This 'aspirational dissonance' between strategic vision and operational reality constitutes a theoretically interesting phenomenon that has not been extensively explored in the Logistics 4.0 readiness literature. Future research could develop and validate this construct more rigorously, potentially through qualitative or longitudinal designs that capture the temporal dynamics between strategic announcement and perceived operational progress.

- **Methodological Contribution: Convergent Multi method Validation.** The use of multiple linear regression analysis (SPSS) for hypothesis testing provides a rigorous and structured methodological approach for examining relationships between variables in Logistics 4.0 research. This approach offers a clear and reliable framework for quantitative analysis in logistics and supply chain management studies, particularly within the Algerian and North African academic context, where empirical research based on statistical modelling remains relatively limited.

3.2.2 Managerial Implications

Beyond their theoretical contributions, the findings of this study carry concrete and actionable implications for the management of BOMARE COMPANY and, more broadly, for Algerian industrial organisations preparing for the Logistics 4.0 transition.

Priority 1 Prioritise technological investment: Given that Technological Capability is the dominant predictor ($\beta = .572$), investment in IoT infrastructure, RFID systems, advanced analytics platforms, and digital expertise should be treated as the primary lever for accelerating the company's Logistics 4.0 transition.

Priority 2 Leverage the existing human capital asset: The workforce's demonstrated openness to digital adaptation (highest mean; $\beta = .395$) represents an underutilised asset. Structured digital skills development programmes particularly in data analytics, digital logistics tools, and Industry 4.0 platforms would enable the company to capitalise on this receptive base.

Priority 3 Strengthen data driven logistics practices: As the lowest scoring independent construct ($M = 2.83$) and a significant predictor ($\beta = .371$), the current logistics system particularly its data utilisation and real time information sharing capabilities requires targeted improvement prior to, or in parallel with, advanced technology deployment.

Priority 4 Bridge the strategic–operational perception gap: Management should prioritise translating strategic digital transformation commitments into visible operational actions: transparent communication about budgetary allocations, pilot Logistics 4.0 projects with tangible outcomes, and involvement of operational staff in transformation planning, to build credibility and close the perception gap.

In summary, the findings of this study provide BOMARE COMPANY with a concrete and empirically grounded diagnostic map of its readiness for Logistics 4.0. The priority investment areas are clear: technology infrastructure first, structured digital upskilling second, and logistics data foundation third. These must be complemented by deliberate efforts to close the strategic operational perception gap and to embed the transformation within a cross functional organisational framework. The combination of these actions, sequenced appropriately and sustained over time, offers BOMARE COMPANY the most viable path towards a successful transition to Logistics 4.0.

Conclusions

Chapter III presented a structured analysis of data collected from 67 employees at BOMARE COMPANY, using reliability analysis, descriptive statistics, normality testing, correlation analysis, multiple linear regression, and group comparisons.

The results confirmed strong internal consistency ($\alpha > 0.80$) and showed that all constructs fall within a moderate range, indicating that the company is at a transitional stage towards Logistics 4.0. Human Capital Capability recorded the highest descriptive mean ($M = 3.22$), while the current logistics system state was the lowest scoring dimension ($M = 2.83$). In the regression model, Technological Capability emerged as the strongest predictor.

The regression model was significant ($p < 0.001$) and explained 58% of the variance in overall readiness. Three hypotheses were supported (H1, H2, H3), with Technological Capability as the strongest predictor, while H4 and H5 were not supported. The negative coefficient of H5 suggests a gap between strategic intentions and operational reality.

No significant differences were found across demographic groups, confirming the consistency of perceptions.

Overall, the findings highlight that technological investment and human capital are key drivers of readiness, while better alignment between strategy and practice is needed. The robustness of the findings is supported by strong internal consistency ($\alpha > 0.80$ across all constructs) .

CONCLUSION

The accelerating pace of digital transformation at the global level has profoundly reconfigured the competitive landscape of industrial logistics, rendering the transition to Logistics 4.0 not merely a strategic aspiration but an operational imperative. Driven by the systemic convergence of Industry 4.0 technologies — including the Internet of Things, artificial intelligence, big data analytics, cloud computing, blockchain, and advanced robotics — this transition demands far more than technological investment alone. It requires the simultaneous development of a coherent set of organisational capabilities: a mature and data-driven logistics foundation, adequate technological infrastructure, digitally skilled and adaptable human capital, cross-functional organisational coordination, and sustained strategic leadership commitment. Yet in emerging economies such as Algeria, the empirical study of these capability dimensions remains largely underdeveloped, leaving industrial organisations to navigate this complex transformation without the benefit of rigorous, context-specific diagnostic evidence.

To respond to the research problem to what extent do the organisational capabilities currently developed within BOMARE COMPANY determine its overall readiness to transition to Logistics 4.0? this study adopted a positivist, quantitative approach grounded in a theoretically derived multi-dimensional capability framework. Five core dimensions were identified from the literature as the structural determinants of readiness: the current state of the logistics system (H1), technological and infrastructural capabilities (H2), human capital and digital skills (H3), organisational capabilities (H4), and strategic orientation and management commitment (H5). These dimensions were operationalised through a validated structured questionnaire administered to 67 employees of BOMARE COMPANY, an Algerian electronics manufacturer already engaged in a digital transformation trajectory. The data were analysed using multiple linear regression in order to empirically test the five research hypotheses and generate an evidence-based answer to the central research question.

The empirical investigation yielded a coherent and analytically rich set of findings. BOMARE COMPANY was found to occupy what may be described as a transitional threshold position: the company is neither clearly ready nor clearly unprepared for Logistics 4.0, with all capability dimensions registering within the neutral range and overall readiness at a mean of M = 3.06 out of 5. This profile is consistent with a stage of partial digital adoption — a company that has initiated a digital journey, as evidenced by investments in SAP ERP, automated production lines, and the SMART FABLAB but has not yet developed the full and coherent spectrum of capabilities that a successful Logistics 4.0 transition demands. The regression model, which explained 58% of the variance in overall readiness (adjusted $R^2 = 0.580$), confirmed three of the five research hypotheses. Technological Capability emerged as the dominant predictor of overall readiness (H2: $\beta = 0.572$, $p < 0.001$), followed by Human Capital Capability (H3: $\beta = 0.395$, $p < 0.001$) and the current state of the logistics system (H1: $\beta = 0.371$, $p < 0.001$). Organisational Capabilities (H4) did not produce a statistically significant direct effect, while Strategic Orientation (H5) generated a negative coefficient — interpreted not as evidence that strategic commitment is detrimental, but as a manifestation of what this study terms aspirational dissonance: the paradox by which employees' awareness of management's stated digital ambitions heightens, rather than alleviates, their perception of current operational unreadiness. Group comparison analyses further confirmed that this moderate readiness profile constitutes a company-wide consensus, shared uniformly across all departments, age groups, levels of professional experience, and genders, thereby reinforcing both the robustness and the generalisability of the findings.

Main Contributions of the Study

This study generates contributions at three levels. Theoretically, it provides an empirical examination empirical examination of Logistics 4.0 readiness in an Algerian industrial context, aiming at addressing an identified gap in the regional supply chain management literature. It validates the central importance of the technology–human nexus in readiness diagnostics and introduces the notion of aspirational dissonance first identified and defined in Section 3.1.6 of this study as a theoretically novel construct warranting further investigation.

Methodologically, the study provides a replicable and transferable diagnostic model for assessing Logistics 4.0 readiness in Algerian and North African industrial organisations. The questionnaire instrument, structured around six axes and validated through Cronbach's alpha reliability analysis, offers a reliable tool that can be adapted and applied in similar industrial contexts.

Managerially, the study provides BOMARE COMPANY with a concrete, evidence based readiness map and a clear prioritisation framework for its Logistics 4.0 transition. The five managerial priorities identified investing strategically in technological infrastructure, capitalising on existing human capital through structured digital upskilling, strengthening the logistics data foundation, bridging the strategic–operational perception gap through transparent communication, and adopting a cross functional transformation approach collectively constitute an actionable and empirically grounded transition agenda.

Limitations of the Study

This study was conducted with methodological rigour and transparency; however, several limitations should be acknowledged. First, the research was limited to a single company, BOMARE COMPANY, which restricts the generalisability of the findings to other firms within the Algerian electronics sector or beyond. While this single case design is appropriate for the diagnostic and exploratory nature of the study, it does not allow for cross company comparisons or broader sector level conclusions.

Second, the sample size of 67 respondents, although sufficient for the statistical analyses conducted and representative of the target population, remains relatively modest compared to large scale quantitative studies. Future research could benefit from larger and multi company samples to enhance statistical power and enable deeper comparative analysis.

Third, the cros sectional design captures perceptions at a single point in time. Given the dynamic nature of digital transformation, these perceptions may evolve as the company implements new initiatives and technologies. Longitudinal studies would therefore provide a more comprehensive understanding of how Organisational Capabilities develops over time.

Fourth, a mixed-methods approach could have provided deeper insights into Organisational Capabilities. However, due to organisational restrictions, the departments concerned only authorised questionnaire distribution and did not permit interviews or other qualitative methods. As a result, the study was limited to a purely quantitative design, which may have constrained deeper exploration of certain findings.

Future Research Perspectives

The findings and limitations of this study open several promising avenues for future research. A natural extension would be to conduct a multi firm, sector level study of Logistics 4.0 readiness across the Algerian manufacturing sector, allowing for comparative analysis and the identification of sector specific patterns in capability development.

The strategic operational perception gap documented in this study deserves dedicated theoretical and empirical attention. Future research could develop and validate this construct through qualitative methods including in depth interviews and focus groups that capture the nuanced cognitive and emotional dynamics through which employees interpret the relationship between their organisation's stated digital strategy and their daily operational experience.

The indirect and potentially mediated role of organisational capabilities also merits further investigation. Future studies could explore whether Organisational Capabilities influences the effect of technological investment on overall readiness, or mediates the relationship between strategic commitment and operational transformation outcomes. Such designs would provide a more granular understanding of the mechanisms through which different capability dimensions interact and reinforce one another.

Finally, longitudinal research that tracks the evolution of BOMARE COMPANY's readiness profile over time as it implements the prioritised actions identified in this study would provide valuable evidence on the pace, sequence, and effectiveness of Logistics 4.0 capability development in practice, and could serve as a foundation for the development of evidence ased transformation roadmaps applicable to the broader Algerian industrial context.

Closing Remarks

The transition to Logistics 4.0 is neither an automatic process triggered by technology acquisition nor a distant aspiration reserved for firms in developed economies. It is a concrete, achievable, and strategically indispensable transformation that demands deliberate diagnostic work, honest capability assessment, and a coherent, sequenced action agenda. This thesis has attempted to contribute precisely to this need: to provide not only a rigorous academic analysis of readiness, but a practical and evidence grounded foundation from which BOMARE COMPANY and, by extension, Algerian industrial organisations more broadly can build a credible and sustainable path towards the intelligent logistics of tomorrow.

The road to Logistics 4.0 is neither short nor straightforward. But this study demonstrates that BOMARE COMPANY possesses at least one essential ingredient that technology alone cannot provide: a workforce that is willing, open, and ready to learn. In the digital age, that readiness of the human element may well be the most decisive capability of all.

BIBLIOGRAPHY

- Abbasi, S., Vlachos, I., Samadzadeh, A., & Etemadifar, S. (2024). Modelling a logistics and financial supply chain network during the COVID-19 era. *Logistics*. https://doi.org/10.3390/logistics8010032
- Aghaei, S., Nematbakhsh, M. A., & Farsani, H. K. (2012). Evolution of the World Wide Web: From Web 1.0 to Web 4.0. *International Journal of Web & Semantic Technology*, 3(1), 1–10. https://doi.org/10.5121/ijwest.2012.3101
- Aksoy, M. B., & Bulbul, H. (2025). Industry 4.0 and digitalisation: New technological trends in logistics. *Journal of Logistics Research*, 45–67. https://dergipark.org.tr/en/pub/ijephss/article/1681131
- Albrecht, T., Baier, M. S., Gimpel, H., Meierhöfer, S., Röglinger, M., Schlüchtermann, J., & Will, L. (2024). Leveraging digital technologies in logistics 4.0: Insights on affordances from intralogistics processes. *Information Systems Frontiers*, 755–774. https://doi.org/10.1007/s10796-023-10394-6
- Alharahsheh, H. H., & Pius, A. (2020). A review of key paradigms: Positivism vs interpretivism. *Global Academic Journal of Humanities and Social Sciences*, 39–43. https://gajrc.com/media/articles/GAJHSS_23_39-43_VMGJbOK.pdf
- Alshahrani, S. T. (2023). Industry 4.0 in "major emerging markets": A systematic literature review of benefits, use, challenges, and mitigation strategies in supply chain management. *Sustainability*, *15*(20), 14811. https://doi.org/10.3390/su152014811
- Anawade, P., & Sharma, D. (2025). Robotics in supply chain management: Transforming logistics for industry 4.0. *AIP Conference Proceedings*. https://doi.org/10.1063/5.0233931
- Aniba, Y. (2024). *Digital twin for the intelligent control and supervision of an industrial production cell in the industry 4.0 concept* [Doctoral thesis]. http://dspace.univ-djelfa.dz/xmlui/handle/112/7895
- Ashton, K. (2009). That "Internet of Things" thing. *RFID Journal*, 97–114. https://www.rfidjournal.com/expert-views/that-internet-of-things-thing/73881/
- Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, 2787–2805. https://www.sciencedirect.com/science/article/pii/S1389128610001568
- Ayadi, S. (2009). Externalisation et création de valeur au sein de la « Supply Chain » : L'entreprise étendue. *La Revue des Sciences de Gestion*, 85–

93. https://doi.org/10.3917/rsg.236.0085

- Babbie, E. R. (2020). *The practice of social research* (15th ed.). Cengage. https://www.cengage.com/c/the-practice-of-social-research-15e-babbie/9780357360767/
- Ballou, R. H. (2004). *Business logistics/supply chain management: Planning, organizing, and controlling the supply chain* (5th ed.). Pearson Prentice Hall. https://archive.org/details/businesslogistic0000ball_c0g9
- Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: An overview. *Procedia Manufacturing*, 1245–1252. https://doi.org/10.1016/j.promfg.2017.09.045
- Benhaddouch, M., & El Fathaoui, H. (2022). Paradigmes épistémologiques et choix méthodologiques en science de gestion : Revue de littérature. *Revue Française d'Economie et de Gestion*, 3(5), 527–538. https://www.revuefreg.fr/index.php/home/article/view/772
- Bhambri, P., Bajdor, P., & Starostka-Patyk, M. (2026). Blockchain-driven supply chains for smart healthcare: Achieving traceability, transparency, and trust. In *Unlocking the potential of blockchain*. Elsevier. https://doi.org/10.1016/B978-0-443-30192-6.00016-1
- Boukaira, S., & Daamouch, M. (2021). Quel choix épistémologique pour une recherche en sciences économiques et de gestion ? *Revue du contrôle, de la comptabilité et de l'audit*, 5(1), 585–602. https://revues.imist.ma/index.php/RMCG/article/view/28044
- Bowersox, D. J., Closs, D. J., Cooper, M. B., & Bowersox, J. C. (2013). *Supply Chain Logistics Management* (4th ed.). McGraw-Hill Education.
- Bresnahan, T. F., & Trajtenberg, M. (1995). General purpose technologies: "Engines of growth"? *Journal of Econometrics*, 83–108. https://www.sciencedirect.com/science/article/pii/030440769401598T
- Bryman, A. (2016). *Social research methods* (5th ed.). Oxford University Press. https://books.google.com/books/about/Social_Research_Methods.html?id=N2zQCgAAQBAJ
- Cargo Sapiens. (2025, July 2). *Logistics 4.0: What it is and how to apply it to your business*. https://cargosapiens.com/en/blog/logistica-4-0/
- Castells, M. (1996). *The rise of the network society*. Blackwell. https://ucg.ac.me/skladiste/blog_9155/objava_66783/fajlovi/manuel_castells_the_rise_of_the_network_societybookfi_org.pdf

- Chabani, S., & Ouacherine, H. (2012). *Guide de méthodologie de la recherche en sciences sociales*. TalebImpressions. https://bib.hec.dz/opac_css/index.php?lvl=notice_display&id=8137
- Chandler, A. D. (1977). *The visible hand: The managerial revolution in American business*. Harvard University Press. https://dipiufabc.files.wordpress.com/2015/06/alfred-d-chandler_the_visible_hand_managerial_bookzz-org.pdf
- Christopher, M. (2016). *Logistics and supply chain management* (5th ed.). Pearson Education. https://repository.gctu.edu.gh/items/show/1125
- Clark, G. (2014). The industrial revolution. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth* (pp. 217–262). Elsevier. https://econpapers.repec.org/RePEc:eee:grochp:2-217
- Colicchia, C., Creazza, A., & Dallari, F. (2017). Lean and green supply chain management: a synthesis of the literature. *International Journal of Advanced Logistics*, 6(1), 1–10. https://doi.org/10.1080/23277408.2016.1201863
- Comelli, M., Féniès, P., & Tchernev, N. (2008). A combined financial and physical flows evaluation for logistic process and tactical production planning: Application in a company supply chain. *International Journal of Production Economics*, 77–95. https://doi.org/10.1016/j.ijpe.2007.01.012
- Crespo-Aguado, M., Lozano, R., Hernandez-Gobertti, F., et al. (2024). Flexible hyper-distributed IoT–edge–cloud platform for real-time digital twin applications on 6G-intended testbeds for logistics and industry. *Future Internet*, 431. https://doi.org/10.3390/fi16110431
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage. https://edge.sagepub.com/creswellrd5e
- Davenport, T. H. (1998). Putting the enterprise into the enterprise system. *Harvard Business Review*, 121–131. https://hbr.org/1998/07/putting-the-enterprise-into-the-enterprise-system
- Davenport, T. H., & Harris, J. G. (2007). *Competing on analytics: The new science of winning*. Harvard Business School Press. https://hbr.org/1998/07/putting-the-enterprise-into-the-enterprise-system
- Davenport, T. H., & Miller, S. M. (2022). *Working with AI: Real stories of human-machine collaboration*. MIT Press. https://doi.org/10.7551/mitpress/14418.001.0001
- Demir, S., Paksoy, T., & Kochan, C. G. (2020). Logistics 4.0: Digital transformation of

supply chain management. In *Augmented reality in supply chain management*. ResearchGate. https://www.taylorfrancis.com/chapters/edit/10.1201/9780429327636-3

- DeVellis, R. F. (2016). *Scale development: Theory and applications* (4th ed.). SAGE Publications. https://books.google.com/books/about/Scale_Development.html?id=48ACCwAAQBAJ
- Dexory. (2024). *Logistics 4.0: Building resilient supply chains with real-time data*. https://www.dexory.com/insights/moving-towards-the-future-how-logistics-4-0-can-improve-supply-chain-resilience
- Dhiman, T., & Madan, P. (2025). The role of Internet of Things (IoT) in enhancing real-time visibility and efficiency in supply chain 4.0. *Open Access Journal of Management and Research*, (2). https://oajmr.com/May2025/v1i202.pdf
- Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method* (4th ed.). John Wiley & Sons. https://psycnet.apa.org/record/2014-34233-000
- Dindarik, N., & Fidan, E. (2025). The mediating role of innovation orientation in the impact of digital transformation on logistics capabilities. *Journal of Business Logistics*, 112–128. https://www.management-poland.com/pdf-202534-123731?filename=The-Mediating-Role-of-Inn.pdf
- Dubey, R., & Bryde, D. (2023). Dynamic digital capabilities and supply chain resilience: The role of government effectiveness. *International Journal of Production Economics*, 258, 108790. https://doi.org/10.1016/j.ijpe.2023.108790
- El-Garaihy, W. H. (2021). Analysis of supply chain operations reference (SCOR) and balanced scorecard (BSC) in measuring supply chains efficiency using DEMATEL and DEA techniques. *Journal of Global Operations and Strategic Sourcing*, 680–704. https://doi.org/10.1108/JGOSS-05-2020-0023
- El Hamdi, S., & Abouabdellah, A. (2022). Logistics: Impact of Industry 4.0. *Procedia Computer Science*, 537–546. https://www.mdpi.com/2076-3417/12/9/4209
- El Kihel, Y., Zouggar-Amrani, A., & Ducq, Y. (2023, June). *Contribution à la modélisation de la Supply Chain pour le pilotage, l'évaluation de la performance et l'intégration des technologies de l'industrie 4.0: Application au cas automobile de PSA Maroc*. CNRIUT 2023, Saint Pierre - La Réunion. https://hal.science/hal-04364113
- Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), 1–

4. https://doi.org/10.11648/j.ajtas.20160501.11

- Evrard, Y., Pras, B., & Roux, E. (2009). *Market: Fondements et méthodes des recherches en marketing* (4e éd.). Dunod. https://www.dunod.com/entreprise-et-economie/market-fondements-et-methodes-recherches-en-marketing
- Facchini, F., & Oleskow-Szlapka, J. (2019). A maturity model for logistics 4.0: An empirical analysis and a roadmap for future research. *Business Logistics in Modern Management*, 223–238. https://www.mdpi.com/2071-1050/12/1/86
- Fan, W., & Yan, Z. (2010). Factors affecting response rates of the web survey: A systematic review. *Computers in Human Behavior*, 26(2), 132–139. https://doi.org/10.1016/j.chb.2009.10.001
- Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). SAGE Publications. https://profandyfield.com/discoverse/dsus/
- Fortin, M.-F., & Gagnon, J. (2016). *Fondements et étapes du processus de recherche: Méthodes quantitatives et qualitatives* (3e éd.). Chenelière Éducation. https://www.cheneliere.ca/en/bundle-fondements-et-etapes-du-processus-de-recherche-4e-ed-9782765073567.html
- Fragapane, G., Ivanov, D., & Panneerselvam, R. (2021). Industry 4.0 technologies and their impact in contemporary logistics. *Sustainability*, 13(21), 11643. https://doi.org/10.3390/su132111643
- Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, 210, 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004
- Freeman, C., & Louca, F. (2001). *As time goes by: From the industrial revolutions to the information revolution*. Oxford University Press. https://vdoc.pub/documents/as-time-goes-by-from-the-industrial-revolutions-to-the-information-revolution-2fb6pcjg1mm0
- Gandomi, A., & Haider, M. (2015). Beyond the hype: Big data concepts, methods, and analytics. *International Journal of Information Management*, 137–144. https://www.sciencedirect.com/science/article/pii/S0268401214001066
- Gavard-Perret, M. L., Gotteland, D., Haon, C., & Jolibert, A. (2018). *Méthodologie de la recherche en sciences de gestion : Réussir son mémoire ou sa thèse* (3e éd.). Pearson France.
- Ghadge, A., Kara, M. E., Moradlou, H., & Goswami, M. (2020). The impact of Industry 4.0 implementation on supply chains. *Journal of Manufacturing Technology*

Management, 669–686. https://doi.org/10.1108/JMTM-10-2019-0368

- Goldratt, E. M., & Cox, J. (2014). *The goal: A process of ongoing improvement* (4th ed.). Routledge. https://www.routledge.com/The-Goal-A-Process-of-Ongoing-Improvement/Goldratt-Cox/p/book/9780566086656
- Grieves, M. (2014). *Digital twin: Manufacturing excellence through virtual factory replication* [White paper]. Florida Institute of Technology. https://theengineer.markallengroup.com/production/content/uploads/2014/12/Digital_Twin_White_Paper_Dr_Grieves.pdf
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate Data Analysis* (8th ed.). Cengage Learning EMEA. https://eli.johogo.com/Class/CCU/SEM/_Multivariate%20Data%20Analysis_Hair.pdf
- Helo, P., & Hao, Y. (2022). Artificial intelligence in operations management and supply chain management: An exploratory case study. *Production Planning & Control*, 33(16), 1573–1590. https://doi.org/10.1080/09537287.2021.1882690
- Helo, P., & Thai, V. V. (2024). Logistics 4.0 – Digital transformation with smart connected tracking and tracing devices. *International Journal of Production Economics*, 109358. https://doi.org/10.1016/j.ijpe.2024.109358
- Hidalgo Panez, K. M., Cuadrado Ramirez, D. B., et al. (2025). Artificial intelligence optimises supply chains in search of predictive and sustainable logistics. *Proceedings of the International Conference on Artificial Intelligence*. https://doi.org/10.1145/3776759.3776806
- Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*, 23–34. https://doi.org/10.1016/j.compind.2017.04.002
- Hongsakul, B., Lalaeng, C., & Ingard, A. (2025). Digital transformation in the logistics industry: An evidence-based synthesis of logistics activity. *TPM–Testing, Psychometric, Methodology in Applied Psychology*. https://tpmap.org/submission/index.php/tpm/article/view/1647
- Hrouga, M., & Sbihi, A. (2023). Logistics 4.0 for supply chain performance: Perspectives from a retailing case study. *Supply Chain Forum: An International Journal*, 352–368. https://www.researchgate.net/publication/373360720_Logistics_40_for_supply_chain_performance_perspectives_from_a_retailing_case_study

- Huang, K., Wang, Z., & Chen, J. (2023). The impact of Industry 4.0 on supply chain capability and supply chain resilience. *International Journal of Production Economics*, 108855. https://www.sciencedirect.com/science/article/pii/S0925527323001457
- Ibrahim, A. K. (2021). Evolution of the Web: From Web 1.0 to 4.0. *Qubahan Academic Journal*, 1(2), 42–51. https://doi.org/10.48161/qaj.v1n2a75
- Idrissi, Z. K., Serghini, M., & El Adnani, J. (2024). Blockchain, IoT and AI in logistics and transportation: A systematic review. *Future Transportation*, 112–134. https://www.sciencedirect.com/science/article/pii/S2949899624000182
- IJIRMPS. (2025). Revolutionizing global trade: Blockchain for transparent and secure supply chains. *International Journal of Innovative Research in Engineering & Management*. https://www.ijirmps.org/papers/2025/6/232830.pdf
- Iraten, S. (2014). La supply chain management un levier pour améliorer la performance de l'entreprise. *Revue des reformes Economique et intégration dans l'économie mondiale*, 135–159. https://asjp.cerist.dz/en/article/43001
- Ivanov, D., Dolgui, A., & Sokolov, B. (2022). Cloud supply chain: Integrating Industry 4.0 and digital platforms in the "Supply Chain-as-a-Service". *Transportation Research Part E: Logistics and Transportation Review*, 102739. https://doi.org/10.1016/j.tre.2022.102739
- Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Recommendations for implementing the strategic initiative Industrie 4.0*. Acatech National Academy of Science and Engineering. https://www.din.de/resource/blob/76902/e8cac883f42bf28536e7e8165993f1fd/recommendations-for-implementing-industry-4-0-data.pdf
- Kayikci, Y. (2018). Sustainability impact of digitisation in logistics. *Procedia Manufacturing*, 782–789. https://www.sciencedirect.com/science/article/pii/S2351978919305372
- Kihel, Y. E. (2021). *Contribution à la modélisation de la Supply Chain pour le pilotage, l'évaluation de la performance et l'intégration des technologies de l'industrie 4.0: Application au cas automobile de PSA Maroc* [Doctoral thesis, Université de Bordeaux & Université Sidi Mohamed ben Abdellah]. HAL. https://theses.hal.science/tel-03916740
- Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, 80–89. https://www.sciencedirect.com/science/article/abs/pii/S0268401217305248
- Lakhwani, T. S. (2025). Integrating 5PL frameworks with drone-based last-mile delivery:

A model for future-ready logistics. *Transportation Development Research*. http://ojs.bilpub.com/index.php/tdr/article/view/449

- Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. *Industrial Marketing Management*, 65–83. https://drdouglaslambert.com/wp-content/uploads/2020/05/Lambert-and-Cooper-Issues-in-Supply-Chain-Management-IMM-2000.pdf
- LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, 521(7553), 436–444. https://doi.org/10.1038/nature14539
- Lee, H. L., Padmanabhan, V., & Whang, S. (1997). Information distortion in a supply chain: The bullwhip effect. *Management Science*, 546–558. https://courses.ie.bilkent.edu.tr/ie460/wp-content/uploads/sites/12/2019/02/Lee-Padmanabhan-Whang-1997-MS.pdf
- Lee, Y., & Shin, D. (2023). The application of chatbot as an L2 writing practice tool. *Language Learning & Technology*, 27(1), 1–19. https://doi.org/10.64152/10125/73541
- Le Moigne, R. (2017). *Supply Chain Management: achat, production, logistique, transport, vente* (2nd ed.). Dunod. https://www.dunod.com/entreprise-et-economie/supply-chain-management-achat-production-logistique-transport-vente-0
- Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, 22(140), 1–55. https://psycnet.apa.org/record/1933-01885-001
- Lisnevskyi, R., Kobets, V., & Veretelnikova, I. (2023). Development of a blockchain platform for logistics order management. *CEUR Workshop Proceedings*, 45–62. https://ceur-ws.org/Vol-3966/W2Paper3.pdf
- Lizard Global. (2023, November 21). *Logistics 4.0: The power of automation in supply chain management*. https://www.lizard.global/blog/logistics-4-the-power-of-automation-in-supply-chain-management
- Luthra, S., & Mangla, S. K. (2018). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection*, *117*, 168–179. https://doi.org/10.1016/j.psep.2018.04.018
- Malhotra, N. K., Nunan, D., & Birks, D. F. (2017). *Marketing research: An applied approach* (5th ed.). Pearson Education. https://dokumen.pub/marketing-research-an-applied-approach-9781292103129-9781292103150-9781292211329-2672682682-1292103124-1292103159.html

- Maxwell, J. A. (2013). *Qualitative research design: An interactive approach* (3rd ed.). SAGE Publications. https://books.google.com/books/about/Qualitative_Research_Design_An_Interactive.html?id=DFZc28cayiUC
- McAfee, A., & Brynjolfsson, E. (2012). Big data: The management revolution. *Harvard Business Review*, 60–68. https://harrt.ucla.edu/wp-content/uploads/2015/12/Big-Data-The-Management-Revolution-.pdf
- Mell, P., & Grance, T. (2011). *The NIST definition of cloud computing* (NIST Special Publication 800-145). National Institute of Standards and Technology. https://csrc.nist.gov/pubs/sp/800/145/final
- Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). Defining supply chain management. *Journal of Business Logistics*, 1–25. https://doi.org/10.1002/j.2158-1592.2001.tb00001.x
- Mitchell, T. M. (1997). *Machine learning*. McGraw-Hill. https://www.cs.cmu.edu/~tom/files/MachineLearningTomMitchell.pdf
- Moghaddam, G. K., & Karimzadeh, M. (2025). AI-driven digital transformation and sustainable logistics: Innovations in global supply chain management. *Research Square*. https://doi.org/10.21203/rs.3.rs-6086101/v1
- Mohammed, I. A. (2025). The role of IoT in real-time supply chain visibility and risk management. *Journal of Management and Social Research*. https://www.researchgate.net/profile/Irshadullah-Asim-Mohammed/publication/396244914
- MOHAMMED AZIZI, Y. (2021). *Facteurs et outils d'accélération du changement organisationnel visant la modernisation administrative Cas : Les organisations publiques Algériennes*. http://dspace.esc-alger.dz:8080/xmlui/handle/123456789/1444
- Mohan, R. (2025). Digital supply chains: The intersection of Artificial Intelligence and logistics. *Global Logistics Review*, 12(1), 45–59.
- Mokyr, J. (1990). *The lever of riches: Technological creativity and economic progress*. Oxford University Press. https://archive.org/details/leverofriches0000moky
- Morgan, M. J. (2025). *The role of digital transformation in enhancing supply chain efficiency: A case of Africa Global Logistics-Rwanda*. Academia.edu. https://www.academia.edu/download/125258640/MORGAN_ARTICLE.pdf

- Mowery, D. C., & Rosenberg, N. (1989). *Technology and the pursuit of economic growth*. Cambridge University Press. https://www.cambridge.org/core/books/technology-and-the-pursuit-of-economic-growth/1CFCDFE6E24A16CB9C6E1D1304507BAD
- Müller, J. M., Kiel, D., & Voigt, K. I. (2018). What drives the implementation of industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability*, 247. https://doi.org/10.3390/su10010247
- Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*. https://bitcoin.org/bitcoin.pdf
- Nguyen, T., & Nguyen, M. (2025). Logistics 4.0 capabilities and performance: The moderating role of digital transformation. *Journal of Business Logistics*, 178–195. https://www.inderscienceonline.com/doi/abs/10.1504/JGBA.2024.149488
- Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.
- Olatunji, A. O. (2025). The role of big data in enhancing operational efficiency. *Journal of Basic and Applied Research International*. https://www.researchgate.net/profile/Aishat-Olatunji-3/publication/388386534
- Omar, A. (2025). *Robotics and automation in warehousing efficiency: Balancing operational gains with workforce impacts* [Master's thesis]. Theseus. https://www.theseus.fi/handle/10024/902800
- Oppenheim, A. N. (1992). *Questionnaire design, interviewing and attitude measurement* (New ed.). Pinter Publishers. https://archive.org/details/questionnairedes0000oppe_i2t6
- Ozkan, N. (2020). *Fostering digital marketplaces in logistics and supply chain: Trends and opportunities*. https://webthesis.biblio.polito.it/14897/1/tesi.pdf
- Özkanlısoy, Ö., & Akkartal, E. (2023). Measuring supply chain performance as SCOR v13.0-based framework. *Logistics*, 65. https://doi.org/10.3390/logistics7030065
- Paksoy, T., Ali, S. S., & Kochan, C. G. (Eds.). (2021). *Logistics 4.0: Digital transformation of supply chain management*. CRC Press. https://www.taylorfrancis.com/books/edit/10.1201/9780429327636/logistics-4-0-turan-paksoy-cigdem-gonul-kochan-sadia-samar-ali
- Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS* (7th ed.). Routledge. https://doi.org/10.4324/9781003117452
- Perez, C. (2002). *Technological revolutions and financial capital: The dynamics of*

bubbles and golden ages. Edward Elgar. https://archive.org/details/technologicalrev00carl

- Pimor, Y., & Fender, M. (2020). *Logistique: Production, Distribution, Soutien* (8th ed.). Dunod. https://bibliotheque.istagmali.com/wp-content/uploads/2024/02/Yves-Pimor-Michel-Fender-Logistique-_-Production-Distribution-Soutien.pdf
- Polomoshnov, N. (2020). *Industry 4.0 impact on physical internet in the scope of trucks transportation*. https://gbsge.com/wp-content/uploads/2023/05/polomoshnov-nikita-2020-industry-4-0-impact-on-physical-internet-in-the-scope-of-trucks-transportation-bba-thesis-ge.pdf
- Porter, M. E. (2001). Strategy and the internet. *Harvard Business Review*, 62–78. https://hbr.org/2001/03/strategy-and-the-internet
- Rane, J., Amol Chaudhari, R., & Rane, N. (2025). Supply chain resilience through Internet of Things, big data analytics, and automation for real-time monitoring. *SSRN Electronic Journal*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5366936
- Rane, N. L., Chika, O. E., & Rane, J. (2026). Business intelligence systems integrating artificial intelligence, big data analytics, machine learning, internet of things, and blockchain. *International Journal of Applied Research in Science and Engineering*. https://deepscipub.com/ijars/article/view/42
- Ravshan, O. N., & Ogunmola, A. (2025). Assessing the role of digital transformation in enhancing logistics operation in Uzbekistan. *Asian Journal of Economics and Business*, 45–62. https://globalresearchnetwork.us/index.php/ajebm/article/view/3259
- Rehman, M. U. (2025). Integrating AI, blockchain, and IoT for sustainable and resilient global supply chains. *Bulletin of Management Review*. http://bulletinofmanagementreview.com/index.php/Journal/article/view/209
- Ribas, I., Leisten, R., & Framinan, J. M. (2019). Review and classification of the demand management in supply chains. *International Journal of Production Research*, 57(15-16), 4987–5004. https://doi.org/10.1080/00207543.2018.1533262
- Richnák, P. (2022). Current trend of Industry 4.0 in logistics and transformation of logistics processes using digital technologies. *Logistics*, 11. https://doi.org/10.3390/logistics6010011
- Rifkin, J. (2011). *The third industrial revolution: How lateral power is transforming energy, the economy, and the world*. Palgrave Macmillan. https://edisciplinas.usp.br/pluginfile.php/8754049/mod_label/intro/epdf.pub

_the-third-industrial-revolution.pdf

- Ristvej, J., Chovanec, D., Kollár, B., & Kubás, J. (2026). *Artificial intelligence in logistics and supply chain*. mwslit.com. https://www.mwslit.com/images/badania_i_rozwoj/2026-02-19-programy_i_materialy/script_artificial_intelligence_in_logistics_and_supply_chain.pdf
- Roser, C. (2015). *Industry 4.0 revolutions*. https://commons.wikimedia.org/wiki/File:Industry_4.0.png
- Roussel, P. (2005). Chapitre 9: Méthodes de développement d'échelles pour questionnaires d'enquête. In P. Roussel & F. Wacheux (Eds.), *Management des ressources humaines: Méthodes de recherche en sciences sociales* (pp. 245–276). De Boeck Supérieur.
- Russell, S., & Norvig, P. (2020). *Artificial intelligence: A modern approach* (4th ed.). Pearson. https://aima.cs.berkeley.edu/
- Saaresto, J. (2022). *Digital transformation in the era of logistics 4.0: Dynamic capabilities view*. Lappeenranta-Lahti University of Technology. https://lutpub.lut.fi/bitstream/handle/10024/164189/masters-thesis-joona_saaresto-1.pdf
- Safae, S., Rahhal, L., & Tamouh, N. (2024). Les fondements de la logistique 4.0: Une exploration générale. *African Scientific Journal*. https://doi.org/10.5281/zenodo.14168700
- Sahal, R., Alsamhi, S. H., Brown, K. N., O'Shea, D., et al. (2021). Blockchain-empowered digital twins collaboration: Smart transportation use case. *Machines*, 193. https://doi.org/10.3390/machines9090193
- Sajadieh, M. S., & Thorstenson, A. (2014). Comparing sourcing strategies in two-echelon supply chains. *Computers & Operations Research*, 45, 108–115. https://doi.org/10.1016/j.cor.2013.12.010
- Saleheen, F., Mirzabeiki, V., & Bourlakis, M. (2023). Embedding attributes towards the supply chain performance measurement: A systematic literature review. *Sustainable Operations and Computers*, 1–15. https://doi.org/10.1016/j.susoc.2022.08.001
- Salmi, V. (2024). *Supply chain visibility for creating more resilient supply chains: How Internet of Things, digital twins and cloud computing can enhance visibility and create more resilient supply chains* [Master's thesis, University of Vaasa]. https://www.doria.fi/handle/10024/189063

- Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (8th ed.). Pearson.
- Schuster Puga, M., & Tancrez, J. S. (2017). A heuristic algorithm for solving large location–inventory problems with demand uncertainty. *European Journal of Operational Research*, 259(2), 413–423. https://doi.org/10.1016/j.ejor.2016.10.059
- Schwab, K. (2016). *The fourth industrial revolution*. World Economic Forum. https://www.weforum.org/stories/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/
- Srivastava, G., Shore, A., & Ram, P. (2023). Examining the role of virtue ethics and big data in enhancing viable, sustainable, and digital supply chain performance. *Technological Forecasting and Social Change*, 186, 122154. https://doi.org/10.1016/j.techfore.2022.122154
- Sun, X., & Yu, H. (2021). The application of Industry 4.0 technologies in sustainable logistics: A systematic literature review. *International Journal of Logistics Research and Applications*, 590–612. https://pmc.ncbi.nlm.nih.gov/articles/PMC8664234/
- Sun, X., & Yu, H. (2022). Towards the smart and sustainable transformation of reverse logistics 4.0: A conceptualization and research agenda. *Transportation Research Part E: Logistics and Transportation Review*, 102757. https://www.sciencedirect.com/science/article/pii/S0925527324001932
- Suvorova, I., & Glushchenko, S. (2025). Transformation of logistics under the influence of digitalisation. *Black Sea Economic Studies*, 92, 20–25. https://doi.org/10.32782/bses.92-3
- Sweeney, E. (2022). Supply chain management: The role of logistics. In *The Palgrave handbook of supply chain management* (pp. 1–22). Palgrave Macmillan. https://www.springerprofessional.de/en/the-palgrave-handbook-of-supply-chain-management/26688722
- Symmetry Electronics. (2022, April 4). *How logistics 4.0 is transforming the digital supply chain*. https://www.symmetryelectronics.com/blog/how-logistics-4-0-is-transforming-the-digital-supply-chain/
- Tapscott, D., & Tapscott, A. (2016). *Blockchain revolution: How the technology behind bitcoin is changing money, business, and the world*. Portfolio/Penguin. https://itig-iq.iq/wp-content/uploads/2019/05/Blockchain_Revolution.pdf
- Thankkar, J., Kanda, A., & Deshmukh, S. G. (2009). Supply chain performance

measurement framework for small and medium scale enterprises. *Benchmarking: An International Journal*, 702–723. https://doi.org/10.1108/14635770910987878

- Thompson, E. P. (1967). Time, work-discipline, and industrial capitalism. *Past and Present*, 56–97. https://academic.oup.com/past/article-pdf/38/1/56/9919167/56.pdf
- Trushkina, N., & Dźwigoł, H. (2020). Development of the Logistics 4.0 concept in the digital economy. *Virtual Economics*, 43–60. https://doi.org/10.34021/ve.2020.03.02(3)
- Vaghani, A., Sahoo, S., & Jha, N. K. (2022). Security and QoS issues in blockchain enabled next-generation smart logistic networks. *UTS ePRESS*. https://opus.lib.uts.edu.au/handle/10453/169443
- Venkatasubramanian, H., Anifa, M., Babu, S., et al. (2024). Leveraging big data analytics for enhancing operational efficiency in IT, manufacturing, and supply chain sectors. *Proceedings of the 6th International Conference on Big Data and Artificial Intelligence*. https://dl.acm.org/doi/abs/10.1145/3745812.3745813
- Vicente, J. J., Martinez, L., & Garcia, F. (2024). The potential of Logistics 4.0 technologies: A case study. *Frontiers in Artificial Intelligence*, 1469958. https://www.frontiersin.org/journals/artificial-intelligence/articles/10.3389/frai.2024.1469958/full
- Waller, M. A., & Fawcett, S. E. (2013). Data science, predictive analytics, and big data: A revolution that will transform supply chain design and management. *Journal of Business Logistics*, 77–84. https://onlinelibrary.wiley.com/doi/full/10.1111/jbl.12010
- Westwell. (2025, December 12). *What is logistics 4.0? From traditional operations to smart supply chains*. https://en.westwell-lab.com/article.html?id=285
- Wilson Sons. (2023, June 27). *Meet logistics 4.0! Concept, features and how it works*. https://wilsonsons.com.br/en/blog/logistics-4-0/
- Winkelhaus, S., & Grosse, E. H. (2019). Logistics 4.0: A systematic review towards a new logistics system. *International Journal of Production Research*, 18–43. https://doi.org/10.1080/00207543.2019.1612964
- Wolniak, R. (2024). Forecasting demand – utilizing business analytics in Industry 4.0 environments. *Silesian University of Technology Scientific Papers*. https://managementpapers.polsl.pl/wp-content/uploads/2024/05/196-Wolniak-3.pdf
- Wright, K. B. (2017). Researching Internet-based populations: Advantages and disadvantages of online survey research, data collection, and administration. *Journal of*

Computer-Mediated Communication, 10(3), JCMC1034. https://doi.org/10.1111/j.1083-6101.2005.tb00259.x

- Zhuckovskaya, I. (2024). Logistics in the context of digital economic transformation. ,1–12. https://orcid.org/0000-0002-2824-0247

APPENDICES LIST

Appendix A: Questionnaire – Logistics 4.0 Readiness

Dear Respondent,

In the context of accelerated digital transformation, the transition towards Logistics 4.0 represents a major strategic challenge for organisations. However, this transition requires a precise assessment of internal capabilities, including technical skills, technological infrastructure, data management, and organisational preparedness.

This questionnaire aims to assess the key capabilities required to successfully transition to Logistics 4.0, based on the experiences and perceptions of professionals in the field. Your contribution is essential to the successful completion of this research.

All information collected will remain strictly confidential and will be used solely for academic research purposes.

Adjimi Mouad, and I am a second-year Master's student at the National Higher School of Management, specialising in Supply Chain Management.

Thank you sincerely for your valuable contribution.

Section 01: General Information

Veuillez cocher la case correspondante :

1.Gender : □ Male □ Female

2.Age Group : □ Under 30 years □ 30–40 years □ Over 40 years

3.Current Department : □ Logistics □ Production □ Local Purchasing □ Supply Chain
□ AQP □ SAV □ Export □ Other : …………………

4.Seniority : □ Less than 1 year □ 1–3 years □ 4–7 years □ More than 7 years

5.Total Professional Experience : □ Less than 3 years □ 3–5 years □ 6–10 years □ More than 10 years

Please indicate your level of agreement with the following statements according to the following scale:

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

AXIS 01: Current Logistics System State

Affirmation	**1**	**2**	**3**	**4**	**5**
The current logistics system provides a good foundation for future digitalisation	◻	◻	◻	◻	◻
Performance data is regularly used to support logistics decision-making	◻	◻	◻	◻	◻
The company recognises the importance of real-time data and works to improve information sharing	◻	◻	◻	◻	◻
The company identifies its logistics challenges and takes actions to improve them	◻	◻	◻	◻	◻

AXIS 02: Technological Capability

Affirmation	**1**	**2**	**3**	**4**	**5**
The company's IT infrastructure can support technologies such as IoT and RFID	◻	◻	◻	◻	◻
The company is aware of modern automation technologies in logistics	◻	◻	◻	◻	◻
The company has access to the technical expertise required for digital logistics	◻	◻	◻	◻	◻
The company plans to invest in digital logistics technologies	◻	◻	◻	◻	◻

AXIS 03: Human Capital Capability

Affirmation	1	2	3	4	5
Employees in the company are willing to develop digital skills related to Logistics 4.0	☐	☐	☐	☐	☐
The company provides or plans to provide training in digital logistics skills	☐	☐	☐	☐	☐
Employees are willing to adapt to new digital tools and ways of working	☐	☐	☐	☐	☐
Management encourages employees to develop digital logistics skills	☐	☐	☐	☐	☐

AXIS 04: Organisational Capabilities

Affirmation	1	2	3	4	5
Departments collaborate effectively to support organisational change	☐	☐	☐	☐	☐
The company has experience in managing change and adapting its processes	☐	☐	☐	☐	☐
The organisation supports cross-functional teams for improvement projects	☐	☐	☐	☐	☐
The company encourages learning, improvement, and innovation in work practices	☐	☐	☐	☐	☐

AXIS 05: Strategic Orientation

Affirmation	**1**	**2**	**3**	**4**	**5**
Senior management has a clear vision for the transition to Logistics 4.0	☐	☐	☐	☐	☐
The company allocates or plans to allocate a budget for digital transformation in logistics	☐	☐	☐	☐	☐
Management communicates regularly about digital transformation in logistics	☐	☐	☐	☐	☐
Logistics 4.0 is integrated into the company's strategic plans	☐	☐	☐	☐	☐

AXIS 06: Overall Readiness

Affirmation	**1**	**2**	**3**	**4**	**5**
The company is ready to transition to Logistics 4.0	☐	☐	☐	☐	☐
The company has the necessary capabilities to support the transition to Logistics 4.0	☐	☐	☐	☐	☐
The company can initiate a Logistics 4.0 project with manageable changes	☐	☐	☐	☐	☐
The company is well-prepared for the transition to Logistics 4.0	☐	☐	☐	☐	☐

Thank you for your valuable contribution to this study, your responses are essential to our research.

Appendix B :GLOBAL QUALITY POLICY

(ISO 9001:2015 / ISO 45001:2018 / ISO/IEC 17025:2017)

Quality Vision

Since its establishment in 2001, Bomare Company has positioned itself as a leading Algerian company in the fields of electronics, electrical appliances, and information technology. The company's quality policy is based on continuous improvement, customer satisfaction, regulatory compliance, environmental responsibility, and sustainable operational excellence.

Core Values

- Innovation and continuous investment in research and development to optimize processes and support sustainable growth.
- Commitment to local production and the development of internal competencies.
- Standardization of activities in accordance with international quality standards.
- Diversification of activities, including manufacturing and technical services.
- Customer satisfaction as the company's highest priority.

Strategic Objectives

- Strengthen customer loyalty and ensure stakeholder satisfaction.
- Develop human capital and promote a strong occupational health and safety culture.
- Reinforce the STREAM brand at both national and international levels.
- Diversify business activities while maintaining technical excellence.
- Ensure continuous improvement and responsible governance.

Top Management Commitments

Top management is committed to:

- Providing the human, technical, and financial resources necessary to achieve strategic objectives.
- Ensuring compliance with all applicable legal and regulatory requirements.

- Considering climate-related impacts in operational and strategic decision-making.
- Maintaining a healthy, safe, and respectful work environment for all employees.
- Promoting a culture of quality, innovation, health, safety, and customer focus.
- Protecting the confidentiality of personal and organizational data.
- Strengthening employee training and professional development.
- Maintaining compliance with international standards and pursuing continuous improvement.

Commitment to Excellence

Bomare Company remains committed to maintaining the effectiveness of its integrated management system and achieving long-term excellence through innovation, responsibility, and customer satisfaction.