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Digital Transformation and Adoption of Industry 4.0: Challenges, Opportunities and Integration Methodology for Moroccan Companies

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Abstract: This article analyzes the specific challenges facing Moroccan companies in their adoption of Industry 4.0, including gaps in technological infrastructure, workforce training, and institutional support. It explores the impact of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and automation in streamlining production processes, improving competitiveness, and reducing costs. By comparing several digital maturity models, the article proposes solutions tailored to Moroccan realities, highlighting the need to adjust approaches to overcome the country's unique obstacles. In addition, the article stresses the importance of investing in digital infrastructure and skills development to maximize the benefits of digital transformation. It presents a structured nine-step methodology to support Moroccan companies in their transition to Industry 4.0, taking into account local specificities. A case study of a Moroccan agri-food SME is also included to demonstrate the practical application of this methodology and the tangible improvements achieved through IoT sensors, real-time monitoring and enterprise resource planning (ERP) integration. This combination of analysis, methodology, and real-world illustration provides practical recommendations for successful digital transformation while optimizing the flexibility, productivity, and competitiveness of Moroccan companies in the global market.

Keywords: Industry 4.0, Digital transformation, IoT, Sensors, Digital maturity models, Moroccan SMEs, Case Study, Integration methodology.

1. Introduction

Context and importance of Industry 4.0

Industry 4.0, often referred to as the "Fourth Industrial Revolution," represents a profound transformation of the manufacturing and industrial sectors through the integration of advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), robotics, data analytics, and additive manufacturing. These advancements enable greater automation and promote extensive interconnectivity between systems, facilitating smoother and smarter operations. Moreover, real-time access to data significantly improves decision-making processes, giving companies the ability to respond quickly and accurately to operational demands [1].

The promise of Industry 4.0 lies in its potential to optimize resource management and operational efficiency. Using advanced data analytics, companies can monitor and refine the use of raw materials, energy and labour, reducing waste and improving sustainability. For example, predictive maintenance,

made possible by IoT sensors and AI algorithms, can detect signs of equipment wear and anticipate breakdowns. This type of preventive maintenance helps to limit costly downtime and minimize repairs, thereby increasing profitability and operational efficiency. Many companies that have already integrated these technologies have seen a marked improvement in performance and a significant reduction in production delays [2].

Challenges and opportunities in the Moroccan context

Adopting Industry 4.0 technologies is a strategic imperative for Moroccan companies aiming to stay competitive in an increasingly dynamic global economy. As digital transformation accelerates across industries worldwide, Moroccan firms must embrace innovation to lower production costs, enhance product quality, and increase the flexibility of their manufacturing systems. These technologies also enable businesses to respond more efficiently to market shifts, customize products to meet customer demands, and integrate more effectively into global value chains [3].

However, the transition to Industry 4.0 in Morocco is not without its challenges. Inadequate digital infrastructure is a major barrier. Deploying advanced technologies requires robust communications networks, such as 5G, to ensure fast and reliable data transfer between connected devices. To date, many parts of the country still lack this infrastructure, limiting the effectiveness of real-time data analysis, remote monitoring and automated processes [4].

A major obstacle to the adoption of Industry 4.0 in Morocco is the skills shortage in the national workforce. The effective use of digital solutions—such as AI, intelligent robotics, and IoT systems—relies heavily on technical know-how, which is often insufficient at the local level. This reality highlights the pressing need to develop continuous education initiatives and specialized training programs to equip both today's workforce and future professionals with the skills required to meet the digital challenges of Industry 4.0.

Problem statement and objectives

Moroccan companies must overcome several critical obstacles to effectively integrate Industry 4.0 technologies. These obstacles include inadequate technological infrastructure, a shortage of digital skills in the workforce, and often limited institutional support. Such limitations hinder the competitiveness of Moroccan firms and compromise their ability to seize opportunities in the global market. There is also a lack of empirical data and case studies documenting how Moroccan enterprises implement Industry 4.0, which makes it challenging to tailor global best practices to the local context.

This article aims to deeply analyze these challenges within the Moroccan context and explore key concepts of Industry 4.0, such as automation, interconnectivity, and data-driven decision-making. It provides a comparative analysis of existing digital maturity models and evaluates their applicability to Moroccan industries. Based on this analysis, a structured nine step methodology is presented, tailored to the specific needs of Moroccan companies. This detailed guide covers each phase of digital transformation, from the initial assessment of digital maturity to the implementation of technologies and the enhancement of employee skills. To give a practical perspective, the study also includes a case study illustrating the application of the proposed methodology in a Moroccan agri-food SME. By adopting the recommendations and approach outlined, Moroccan companies will be able to maximize their competitiveness and sustainability on the global stage.

2. Design Principles of Industry 4.0

According to Nosalska, Industry 4.0 is characterized by the adoption of advanced technologies that promote extensive interconnection between socio-technical systems, leading to significant transformations at the level of machines, individuals, organizations, and industries as a whole [5]. The literature identifies three main perspectives for understanding Industry 4.0:

- **Technological perspective**: Industry 4.0 is seen as a set of enabling technologies—including smart sensors, the Internet of Things (IoT), and robotics—that, once integrated, allow for enhanced connectivity and improved operational performance [1]. These tools strengthen automation, increase the efficiency of industrial processes, and reduce margins for error.
- **Conceptual perspective**: Beyond technology, Industry 4.0 embodies a transformational philosophy leading to organizational and strategic innovations. By integrating digitalization into business models, companies can create new value propositions and achieve a sustainable competitive advantage [6].
- **Networking perspective**: This approach focuses on real-time networks linking machines, individuals, and organizations. It highlights the importance of smooth data flow across all stakeholders in the industrial value chain, enabling optimal coordination and enhanced responsiveness [7].

2.1. Key Features of Industry 4.0

Despite their different angles, these perspectives converge on several fundamental characteristics on Industry 4.0 recognized in the literature:

- **Global connectivity**: Industry 4.0 promotes seamless communication between suppliers, manufactures and customers on a global scale, enhancing transparency and real-time interaction throughout the value chain.
- **Digitization and data-driven decision-making**: By capturing and analyzing data in real-time, digital technologies improve decision-making and optimize

operational performance. Data from sensors and connected devices feed into analytics systems, allowing companies to make informed decisions quickly and accurately.

- **Smart manufacturing**: Cyber-physical systems (CPS) lie at the heart of Industry 4.0, enabling smart factories where physical machinery and digital processes are tightly integrated. This results in highly automated manufacturing environments that can self-monitor and even self-optimize [8].

- **Modularity and flexibility:** Modular system architectures enable quick adaptation to shifting market conditions and customized production requirements. Flexible manufacturing lines can be reconfigured with minimal downtime, which is essential for responding to variable demand and delivering personalized products efficiently [9].

- **Virtualization**: Technologies such as digital twins, simulations, and virtual modeling allow for the design and optimization of production processes in a virtual space. This approach minimizes the risks and costs of physical prototyping and testing, while promoting innovation and greater efficiency in system development [10].

These design principles underscore how Industry 4.0 technologies and philosophies transform traditional industries by making them more connected, data-driven, and agile. Companies embracing these principles can achieve improvements in productivity, quality, and innovation capacity.

2.2. Sensors and IoT: Pillars of Intelligent Industry

Sensor technologies and IoT networks form a foundational layer of Industry 4.0, enabling the continuous acquisition of operational data, the automation of processes, and enhanced traceability across the value chain. These tools make it possible to supervise industrial environments in real time, evaluate the condition of assets, and anticipate potential breakdowns through early warning signals. Whether used to monitor temperature and humidity in food storage or to track vibrations and energy flows in mechanical equipment, sensors convert passive systems into intelligent, reactive infrastructures.

In the Moroccan context, adoption of these technologies is gradually expanding across key sectors. In the **textile Industry**, for example, IoT sensors are used to track production efficiency, energy consumption, and fabric quality metrics in real time—supporting waste reduction and productivity gains. **Agri-food companies** increasingly rely on sensors to maintain cold-chain integrity and to track inventory and product flow with precision. In **automotive manufacturing zones** like Tangier Med, sensor integration allows for condition-based maintenance and quality assurance.

Through the strategic deployment of connected sensors and IoT platforms, Moroccan companies can significantly improve the transparency and responsiveness of their operations, aligning with global expectations for quality, compliance, and export-readiness.

3. Digital Maturity Models

3.1. Definition

Digital maturity refers to the level of development of an organization in adopting and leveraging digital technologies to achieve its strategic objectives. It reflects an evolutionary process, in which an organization progresses from initial or ad-hoc usage of digital tools to more advanced levels of technological integration and process optimization. According to METTLER (2011), maturity corresponds to a structured progression toward a targeted goal, characterized by continuous improvements and ongoing evolution [11].

Digital maturity is typically assessed across multiple dimensions of an organization's capabilities. In general, digital maturity assessment frameworks focus on three broad areas:

- **Process maturity:** The ability of an organization to define, manage, measure, and optimize its processes to achieve strategic goals. In a highly mature process organization, activities are well-documented, streamlined, and continuously improved, ensuring greater efficiency, better responsiveness to change, and reduced operational risk [11].

- **Technology (Object) maturity**: The sophistication and performance of the technological elements used within the organization, such as machines, software, and systems. Mature technology infrastructure is reliable, efficient, and fully integrated, playing a critical role in enhancing innovation and the quality of products or services [11].

- **People maturity**: The readiness and skill level of employees to adapt to technological changes and continuously improve their digital competencies. A digitally mature workforce is proficient in the use of digital tools and fosters an innovation and problem-solving culture within the organization [12].

As GAMACHE points out, digital performance is a key indicator of digital maturity. It measures the extent to which an organization effectively integrates digital technologies into its operations and strategy, thereby improving efficiency and aligning digital initiatives with broader business objectives [13]. High digital performance implies that investments in technology are translating into tangible business improvements.

3.2. Components of Digital Maturity

Achieving digital maturity depends on several critical components that empower organizations to succeed in a constantly evolving digital landscape:

- **Technological integration**: This involves the effective adoption and seamless implementation of

advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), cloud computing, and data analytics. When properly integrated, these technologies enhance operational efficiency, streamline processes, and support data-driven decision-making across all levels of the organization.

- **Digital culture**: Cultivating a strong digital culture encourages innovation, collaboration, and openness to technological change. Organizations with such a culture experience higher employee engagement and foster an environment where individuals are motivated to embrace new technologies and commit to continuous learning [13].

- **Digital strategy:** A clearly defined digital strategy ensures that technology investments are aligned with business objectives. This strategic framework helps prioritize initiatives and allocate resources effectively, directing digital transformation efforts toward the areas with the greatest impact and long-term value [11].

- **Employee digital skills**: Building and continuously developing the digital capabilities of employees is vital for fully leveraging emerging technologies. This includes targeted upskilling programs that enhance technical proficiency and digital problem-solving skills, ensuring the workforce remains adaptable and competent in a fast-evolving landscape [13].

- **Change management and organizational agility:** The ability to manage change and adapt internal structures and processes is critical. A proactive and agile approach to change management enables organizations to realign workflows and roles efficiently, overcome resistance, and extract maximum value from new technological innovations [14].

Sustained investment in these areas empowers organizations to accelerate digital transformation, respond swiftly to market shifts, and maintain a competitive edge. Ultimately, digital maturity is not a fixed destination but an ongoing process of evolution, adaptation, and continuous improvement.

3.3. Digital Maturity Models

Digital maturity models provide structured frameworks to assess an organization's current state of digital transformation and guide its progression towards advanced integration of digital technologies. These models help identify gaps, prioritize initiatives, and formulate strategic action plans aligned with business objectives [15].

- **The Deloitte model** defines five maturity levels, progressing from an Initial stage—where digital adoption is ad hoc and uncoordinated—to an Optimized stage characterized by continuous innovation and dynamic process improvement [11]. Its stepwise approach offers clarity for planning, though it often requires significant resources, which can be a limitation for Moroccan SMEs.

- **The Gartner model** evaluates digital maturity across four core dimensions: strategic alignment, operational processes, data and information management, and technological capabilities. Its five stages of maturity move organizations from basic awareness of digital potential to a visionary stage where innovation drives ongoing transformation. This model's structured, dimension-based assessment ensures alignment between digital efforts and overall strategy, though it demands robust data availability, which may be challenging in resource-constrained environments.

- **The Forrester model** describes five phases: Explore, Engage, Transform, Optimize, and Differentiate [16]. It emphasizes organizational and cultural adaptation alongside technological integration, highlighting that true maturity requires both process change and cultural readiness. This holistic approach is beneficial for companies seeking sustainable transformation, though it often necessitates strong change management practices, an area needing further development in Moroccan firms.

- **The Capgemini model**, developed with MIT, assesses four dimensions: strategy, customer experience, operations, and organizational culture [17]. It categorizes companies as Digital Beginners, Fashionistas (using innovative tools without strategic coherence), Conservatives (careful adopters prioritizing reliability), or Digital Masters (fully integrating digital into business strategy and operations). While this model underlines the importance of aligning digital investments with strategic goals, achieving the highest maturity level can require extensive diagnostic efforts and substantial resource commitments.

- **The SIRI (Smart Industry Readiness Index)** model, initiated in Singapore, focuses on manufacturing and evaluates readiness in three areas: processes, technologies, and organizational capabilities [18]. Its structured methodology—diagnosis, roadmap design, and implementation—suits manufacturing companies aiming to adopt Industry 4.0 step by step. However, it requires investment in training and advisory support to implement effectively.

- **The RAMI 4.0 (Reference Architecture Model Industry 4.0)** offers a three-dimensional reference architecture guiding companies in designing and integrating Industry 4.0 systems [19]. It maps out layers (from physical devices to business processes), hierarchy levels (from field devices to enterprise systems), and life cycle stages. While technically robust and comprehensive, its complexity can be a barrier without specialized expertise.

- National initiatives such as **France's "Industry of the Future" program** provide integrated support combining diagnostics, training, strategic guidance, and financial incentives to drive digital transformation in SMEs [20]. Although tailored to the French context, this approach highlights the importance of institutional backing, which remains limited in Morocco.

- Finally, the **Industry 4.0 Maturity Index (IMI)** offers a diagnostic tool to evaluate technological, organizational, and process maturity levels,

identifying improvement areas and recommending targeted actions [21]. Its structured assessment and benchmarking capabilities make it practical for developing clear transformation roadmaps.

4. Comparative Study of Digital Maturity Models

To conduct a comparative study of digital maturity models, described above, several key aspects should be evaluated: the assessment criteria each model considers, the maturity levels or stages defined, the methodologies used for evaluation, and the intended objectives or outcomes of each model. Table 1 provides an overview of important comparison criteria across the models, and the subsections below discuss these dimensions and their implications.

4.1. Comparison Criteria

a) Evaluation dimensions: Most digital maturity models assess an organization's progress across multiple dimensions or domains. Common dimensions include:

- **Strategy**: How well does the model integrate or align with the organization's overall strategic objectives ? A strong model ensures that digital transformation initiatives support the company's long-term vision and competitive strategy.
- **Operations**: How does the model address existing business process and operational efficiency. This looks at whether the model guides improvements in workflows, production processes, supply chain management, and other operational areas.
- **Technology**: Does the model encourage the integration and effective use of emerging technologies (AI, IOT, Cloud computing, etc.)? This dimension evaluates how the model drives technological innovation, enhances productivity through technology, and strengthens the organization's technological capabilities [22].
- **Information/Data**: (Relevant in models like Gartner) How the model handles data management and usage ensuring data is collected, managed, and leveraged for decision-making and responsiveness.

These dimensions give insight into how each model supports digital transformation at the strategic, operational, and technological levels of a business. For example, one model might heavily emphasize strategy and culture, while another is more focused on technological capability.

Table 1 (Part I). Comparison of Key Characteristics across Digital Maturity Models.

Comparison Criteria	Deloitte	Gartner	Forrester	Capgemini
Evaluation Dimensions	Strategy, operations, technology	Business objectives, technology	Technology, organizational culture	Digital transformation, customer experience
Maturity Levels	Initiation, adoption, integration, optimization	Specific maturity stages	Adoption and operational phases	Digital transformation stages
Target Industries	Various sectors	All, sector-specific adaptation	Various sectors	Various sectors
Methodological Approach	Mixed (qualitative and quantitative)	Quantitative, qualitative	Qualitative, quantitative	Mixed (qualitative and quantitative)
Key Benefits	Competitive advantage, digital transformation	Risk reduction, continuous improvement	Competitive advantage, cost reduction	Operational efficiency improvement
Implementation Complexity	Medium to high	Variable depending on context	Medium to high	Variable depending on context
Flexibility and Adaptability	Moderate to high	High	High	High
Methodological Support	Documentation, implementation tools	Guides, specific tools	Available resources	Change management guides and tools
Change Management Approach	Integrated into maturity assessment	Structured approach	Integrated into methodology	Integral part of digital transformation
Performance and Results Measurement	Key performance indicators	Specific metrics	Continuous result evaluation	Operational efficiency measurement
Scalability	Scalability	Adaptation to new challenges	Continuous innovation consideration	Flexibility for the future
Implementation Cost	High	Variable depending on company size	Medium to high	Context-dependent
Organizational Requirements	Strong focus on transformation	Dependent on sector-specific requirements	Culture favorable to change	Adaptation to new technologies

Table 1 (Part II). Comparison of Key Characteristics across Digital Maturity Models.

Comparison Criteria	SIRI	RAMI	Industrie du Futur (France)	Industrie 4.0 Maturity Index
Evaluation Dimensions	Technology, skills, infrastructure	Architecture levels, security	Diagnosis, skills, technologies	Connectivity, prediction, autonomy
Maturity Levels	Preparation, adoption, adaptation, advantage	Interoperability, connectivity	Exploration, structuring, transformation	Connectivity, automation, prediction, autonomy
Target Industries	Manufacturing, services, government	Industrial and manufacturing sectors	All sectors	Manufacturing industries
Methodological Approach	Mixed (qualitative and quantitative)	Structured, prescriptive	Structured diagnostic, supporting guides	Clear steps and advanced digital tools
Key Benefits	Preparation for Industry 4.0, competitiveness	Interoperability, security	Transformation supported by public policies	Adaptability, operational gains
Implementation Complexity	Medium to high	Medium to high	Medium	High
Flexibility and Adaptability	High	High	Medium	High
Methodological Support	Guides, online resources	Documentation, technical guides	Institutional support	Documentation, simulation models
Change Management Approach	Focused on adaptation to change	Focused on interoperability	Public support, change management	Structured and participatory approach
Performance and Results Measurement	Digital skills evaluation	Industrial security measurement	Sector-specific performance indicators	Continuous evaluation, data-driven feedback
Scalability	Adaptability to Industry 4.0	Technological adaptability	Gradual adaptability	Scalability based on digital technologies
Implementation Cost	Medium to high	Medium to high	Variable	High
Organizational Requirements	Readiness for digital innovation	Interoperability standards	Involvement of multiple stakeholders	Technical and organizational expertise needed

b) Maturity levels: Each digital maturity model defines a set of stages or levels that represent progressive advancement in digital transformation. These levels allow organizations to track their progress and understand their current state versus a more advanced state:

- **Initiation/Ad Hoc**: The early stage where organizations have recognized the need for digital transformation but are only beginning to explore digital solutions. Activity is uncoordinated and often experimental.

- **Adoption/Developing**: In this phase, digital technologies start to be integrated into some processes. The transformation is underway but not yet organization-wide; some successes occur, but the company has not fully realized digital benefits.

- **Integration/Defined**: Digital technologies and practices become deeply integrated into key systems and processes. There is alignment between digital initiatives and business processes, and the organization has standard methodologies for implementing new digital solutions [23].

- **Optimization**: The most advanced stage, where organizations continuously improve and innovate using digital technologies. At this level, companies maximize the benefits of digital tools through real-time data-driven optimization and agile adaptation. The goal is sustainable growth and competitive advantage through technology.

These levels (which may have specific names per model, as seen with Deloitte's five levels or Capgemini's categories) enable a company to identify where the stand in their journey spotlight areas for improvement, and plan the next steps in their digital transformation.

c) Targeted sectors: Some maturity models or programs are designed with particular sectors in mind, while others are generic. For instance:

- **Manufacturing-focused models**: Frameworks like SIRI or RAMI 4.0 explicitly target manufacturing and industrial companies, addressing challenges like automation of production lines, quality control, and supply chain integration [23].

- **Services sector models**: Certain models or adaptations focus on sectors like finance, healthcare, or public services, emphasizing digital customer experience, digital service delivery, or e-governance.

- SME vs. large enterprise: Some models consider the scale of the organization. SMEs might require simpler, more flexible models due to resource constraints, whereas large enterprises might implement more complex, multi-phase models.

Adapting a model to the specific needs of a sector ensures relevance. For Morocco, where key sectors include automotive manufacturing, agri-food, textiles, and mining, a chosen model should be flexible enough to address Industry-specific requirements and constraints.

d) Methodological approach: Different models use different methodologies to assess maturity:

- Qualitative assessments: These rely on interviews, surveys, and subjective judgments to gauge maturity. They provide in-depth, contextual insights, capturing unique challenges and perceptions within a company.

- Quantitative assessments: These methods are based on measurable data, such as key performance indicators (KPIs), metrics, and statistical analysis. Quantitative assessments offer objective evaluations based on precise data.

- Mixed methods: Many robust models use a combination of qualitative and quantitative approaches. For example, a company might fill out a numeric survey (quantitative) and also undergo an expert consultation (qualitative) to get a comprehensive evaluation.

Using multiple methodologies can give a more balanced evaluation, combining the objectivity of metrics with the nuance of expert opinion and internal feedback.

e) Key benefits for companies: Adopting a digital maturity models can offer several benefits:

- **Clear vision and roadmap:** The model provides a structured path for digital transformation, preventing ad-hoc or misguided efforts. Companies know what the next level looks like and can plan accordingly.
- **Competitive advantage**: Strategically integrating digital technologies (as guided by the model) can give companies a significant edge in innovation speed, product/service quality, and responsiveness to market change [22]. Early identification of opportunities through maturity assessment can lead to faster adoption of profitable technologies.
- **Cost reduction**: Many digital transformations lead to cost savings by automating repetitive tasks, optimizing resource use, and reducing waste. Maturity models help identify which process improvements or technologies are likely to yield cost reductions, improving operational efficiency and lowering overheads.
- **Improved productivity and quality**: By optimizing processes and leveraging tools like IoT sensors and AI analytics, employees can focus on higher-value tasks while routine monitoring and adjustments are handled by smart systems. This improves productivity and often enhances product quality (e.g., fewer defects through better monitoring and real-time adjustments).
- **Focused investment**: Models help pinpoint where to invest (e.g., upgrading infrastructure vs. training staff). This ensures resources are allocated where they will have the most impact on maturity growth and business performance.

These benefits demonstrate how digital transformation models contribute to long-term growth, operational efficiency, and market positioning for companies.

4.2. Comparison Matrix

To illustrate the differences and overlaps among the discussed maturity models, Table 1 provides a comparison matrix highlighting key criteria. This visual summary presents how each model addresses evaluation dimensions, maturity levels, target industries, and other factors, which can facilitate decision-making for companies deciding which model or framework to follow.

This comparison matrix underscores that while all models share common goals – such as improving competitiveness, efficiency, and innovation – they differ in scope and approach. Some are prescriptive and specific (e.g., SIRI for manufacturing, RAMI as an architecture), whereas others provide broad guidance across industries (Deloitte, Gartner, Forrester, Capgemini). Companies should select or adapt a model that best fits their needs, resources, and sector.

4.3. Analysis of the Models

The comparative analysis of these digital maturity models reveals both commonalities and distinctions in methodology and practical application. On one hand, many models share similar goals: helping organizations harness digital technologies to improve competitiveness, reduce costs, and increase productivity. For example, Deloitte, Gartner, Forrester, Capgemini, SIRI, RAMI and Industrie 4.0 Maturity Index all address critical dimensions such as strategy, operations, and technology integration, albeit with different terminologies and structures.

However, the models exhibit notable differences in their evaluation criteria, structure, and emphasis. Some models (like Deloitte's) adopt a layered multi-level approach focusing on integration of advanced tech at each stage, while others (like Gartner's) structure the evaluation around distinct dimensions and use performance indicators for an objective assessment. Forrester's model blends qualitative phases with business transformation focus, whereas SIRI provides a domain-specific tool for manufacturing contexts.

The methodologies also differ: models such as Deloitte's and Forrester's use a combination of qualitative insights and quantitative metrics (e.g., scoring via surveys plus expert workshops), while Gartner's model often emphasizes measurable

performance indicators for a more data-driven evaluation. SIRI and IMI provide structured assessment kits that yield scores and visualizations, and RAMI offers a reference map rather than a scored assessment.

Despite their advantages, these models are not one-size-fits-all. Each comes with potential limitations or challenges:

- **Flexibility of implementation:** Some models are highly adaptable to different contexts, while others require substantial investment or a certain organizational maturity to even begin. For instance, implementing a comprehensive model might demand significant data collection and analysis capabilities that smaller firms lack.
- **Resource intensity:** Certain models or frameworks could require heavy investment in consulting, software tools, or internal manpower to carry out the assessment and follow through on recommendations. This can be difficult for SMEs with limited budgets.
- **Generality vs specificity:** A number of models are quite general by design, which is a strength for broad applicability but can be a weakness when it comes to sector-specific nuances. Generic recommendations may not fully account for the particularities of each Industry or regional market. For example, a model developed in a Western context might overlook infrastructural or cultural factors unique to Morocco or similar economies.
- **Change management:** All models implicitly or explicitly acknowledge that technology adoption must be accompanied by organizational change. However, companies often face internal resistance to change. Even with a maturity model roadmap, success depends on leadership driving the initiative and employees embracing new processes. If a model doesn't incorporate change management strategies (or if the company doesn't proactively address this), digital initiatives may stall.

In practice, Moroccan companies adopting these models need to tailor them to local realities. An overly rigid application of a global model might not yield the desired results if, for instance, it assumes the presence of stable broadband connectivity, easy access to capital for tech investment, or readily available digital talent – conditions that may be uneven in Morocco.

Therefore, while digital maturity models are invaluable tools for structuring a transformation journey, organizations must adapt them to their scale and environment. The main benefits of using such models include clearer strategic direction, better allocation of resources to digital initiatives, and a way to measure progress over time. Indeed, many Moroccan firms can gain competitive advantages like cost optimization and improved market agility by following a maturity model's guidance. But they should also be mindful of the challenges: making sure the model's recommendations are feasible within their constraints and that the organization is prepared to manage the human factors (skills and culture) alongside the technological changes.

4.4. Challenges of Moroccan Companies in using Maturity Models

Moroccan companies face specific challenges in their transition to Industry 4.0, which in turn affect how digital maturity models should be implemented:

- **Limited technological infrastructure**: A primary challenge is the lack of robust technological infrastructure. Many organizations still operate with outdated IT systems and insufficient connectivity. This limits their ability to integrate new technologies fully. For instance, deploying IoT sensor networks or real-time production monitoring requires reliable internet and network infrastructure, which may be lacking in certain industrial zones. In sectors like automotive, textiles, or agri-food, attempts to implement advanced solutions (e.g., predictive maintenance or automated quality control) can be hampered by network unreliability or legacy equipment that cannot interface with modern platforms. Maturity models often assume a baseline of digital infrastructure; in Morocco, companies may first need to invest in upgrading connectivity (e.g., factory-wide Wi-Fi, fiber optics, industrial IoT gateways) and modernizing equipment to create a foundation for further digitalization.

- **Insufficient digital skills**: Another significant barrier is the shortage of digital and technical skills in the workforce. Employees might lack experience with data analytics, sensor technologies, or the operation of advanced machinery and software. If staff cannot effectively use new systems, the benefits of technologies will not materialize. This skills gap means that any maturity model implementation must be coupled with a strong emphasis on training and education. Companies will need to create or leverage programs to upskill employees (for example, training maintenance staff in using sensor data dashboards or teaching operators how to work alongside collaborative robots). Bridging this skills gap is crucial for innovation and for ensuring that new tools actually improve productivity rather than cause confusion or errors.

- **Weak institutional support**: The level of institutional and governmental support for digital transformation plays a role. While the Moroccan government has initiated strategies and programs to promote digitalization (such as the **"Maroc Digital 2030"** vision and various industrial modernization funds), some reviewers and experts note that these efforts remain insufficient in funding and scope. Companies may find that there are few incentives, grants, or tax breaks accessible to them for investing in Industry 4.0 technologies. In addition, there might be a lack of consulting support or frameworks localized for Morocco. This means Moroccan firms often have to undertake transformation largely with their own resources. A maturity model could recommend significant investments (for instance, in an ERP system or IoT platform) – without external support, SMEs in particular might struggle to follow through. Strengthening public-private partnerships and policy support (such as subsidizing pilot projects or providing

tax credits for digital investments) would greatly aid companies in advancing through maturity stages.

- **Regulatory and policy factors**: The regulatory environment can also pose challenges. New digital processes must comply with local laws on data protection, cybersecurity, and Industry-specific regulations (like food safety for agri-food companies or quality standards for automotive parts). Implementing Industry 4.0 solutions often means gathering and transmitting large amounts of data (potentially even across borders if using global cloud services). Uncertainties or strict regulations around data handling can complicate projects. Moreover, lack of clarity or guidance on standards (for example, which IoT communication protocols are acceptable, or how to certify a manufacturing process enhanced by AI) can slow adoption. Companies need to be aware of and navigate these regulatory requirements – possibly working with authorities to ensure their digital initiatives are compliant. Maturity models typically include governance and compliance as factors, but local legal context must be explicitly considered by Moroccan firms to avoid pitfalls.

For Moroccan companies to fully leverage digital maturity models, local adaptations are essential. The models must be applied in a way that addresses infrastructure upgrades as a first step, includes robust employee development plans, and aligns with the Moroccan institutional landscape. By doing so, businesses can overcome the identified obstacles, improve their competitiveness, and achieve sustainable growth in an increasingly digital global environment.

4.5. Opportunities for Morocco

Despite the challenges, there are significant opportunities that Moroccan companies can exploit in the context of Industry 4.0:

- **Growing technology ecosystem:** Morocco's technology sector has been growing rapidly, especially in tech hubs and free zones such as *Tanger Med* and *Casablanca TechnoPark*. This growth creates opportunities for local companies to collaborate with technology providers and startups. For example, the presence of IoT solution developers or automation vendors in the country means Moroccan industrial firms can pilot new technologies locally. This ecosystem growth also helps build a talent pool with digital skills. The combination of improving digital infrastructure (e.g., expanding broadband coverage) and a young, tech-savvy workforce is strengthening Morocco's potential to integrate into global value chains as a competitive player in Industry 4.0 [10].

- **Strategic location and export potential:** Morocco's strategic geographic location (gateway to Africa, proximity to Europe) and its free trade agreements provide opportunities for companies to become regional leaders in advanced manufacturing. Embracing Industry 4.0 can enhance export competitiveness. For instance, by implementing real-time quality control and traceability (using sensors and data systems), an agri-food company can meet stringent European standards and access new markets. Industry 4.0 solutions can also reduce production costs, making Moroccan exports more price-competitive globally. In sectors like automotive parts or aerospace components (where Morocco has growing industries), adopting advanced manufacturing technologies could attract more foreign investment and partnership, as global firms seek efficient and digitally capable suppliers.

- **Government initiatives and public-private partnerships:** The Moroccan government's focus on digital transformation (e.g., the national industrial acceleration plans, digital government programs, and sector-specific modernization initiatives) indicates opportunities for companies to receive support. New strategies like *"Maroc Digital 2030"* and programs by the Ministry of Industry and Trade aim to encourage the adoption of Industry 4.0 practices. Firms that proactively engage with these initiatives — for example by participating in government-subsidized pilot projects or innovation competitions — can benefit from funding and expertise. There is an opportunity for more robust public-private partnerships to emerge, where academic institutions and research labs work with industries on Industry 4.0 solutions tailored to local needs (such as precision agriculture technologies, smart textiles, or renewable energy management systems). These collaborations can accelerate innovation and help spread successful case studies across the Moroccan business community.

- **Leapfrogging via select technologies:** In some areas, Moroccan companies have the opportunity to leapfrog older industrial development stages by directly adopting advanced technologies. For instance, instead of gradually improving legacy systems, a company might implement an IoT-based monitoring system and cloud analytics in one go, if the cost is manageable, thus rapidly reaching a higher maturity. Technologies like wireless sensors are now relatively affordable; a smaller factory that never had extensive wired sensors might jump straight to a modern wireless IoT sensor network for condition monitoring. Similarly, cloud-based ERP and manufacturing execution systems allow companies to use high-end digital management tools without heavy on-premise infrastructure. By carefully selecting technologies that offer high impact for reasonable investment, Moroccan SMEs can accelerate their digital maturity and differentiate themselves in the market.

Morocco stands at a juncture where; by addressing its challenges and leveraging these opportunities, it can significantly advance its industrial sector. Efforts to strengthen technological infrastructure, support innovation, and develop a specialized digital workforce will allow the country to realize substantial growth potential. Embracing Industry 4.0 not only fosters internal efficiencies but also positions Moroccan companies to collaborate internationally and increase their competitiveness in global markets. The following section proposes a methodology that

takes into account these challenges and opportunities, providing a practical guide for Moroccan companies to integrate Industry 4.0 technologies step by step.

5. Proposal for a Methodology to integrate Industry 4.0 into Moroccan Companies

This section presents a comprehensive and structured methodology for integrating Industry 4.0 into Moroccan companies, based on nine essential steps that range from initial awareness to establishing institutional support and knowledge sharing. The methodology is designed with the Moroccan context in mind, addressing local challenges (like infrastructure and skills gaps) while enabling companies to optimize processes, enhance capabilities, and maximize adoption of advanced technologies. Each step is intended to build on the previous one, ensuring a gradual and sustainable transformation.

Step 1: Awareness and training - *Building understanding of Industry 4.0:* The first step is to raise awareness at all levels of the organization about the concepts and benefits of Industry 4.0. This involves strong communication and educational initiatives. Companies should organize interactive workshops, seminars, or demonstration sessions to explain what digital transformation entails and how technologies such as IoT sensors, real-time data analytics, and AI-driven automation can improve business outcomes. For instance, presenting a case study of a company that successfully transitioned to Industry 4.0 can illustrate the productivity gains achieved through automation and smart systems [19]. Engaging presentations, testimonials from Industry leaders, and even visuals like videos or live demos of IoT devices can make these concepts more accessible and compelling to employees across the organization [24]. In parallel, it's crucial to assess current skill levels and implement targeted employee training programs. Continuous training – focusing on key Industry 4.0 technologies (IoT platforms, industrial automation software, data analytics tools, etc.) – will equip employees with the necessary skills to operate in a digital environment [25]. By investing early in awareness and education, a company creates a receptive culture and prepares its workforce to actively participate in the transformation.

Step 2: Capacity and needs assessment – *Evaluating current capabilities and identifying gaps:* Before jumping into new technologies, the company should conduct a thorough analysis of its internal processes and capabilities. This assessment has two main components:

- **Evaluation of current infrastructure and processes:** Review existing production systems, IT infrastructure, and workflows to determine their strengths and weaknesses. For example, is the current machinery capable of being retrofitted with sensors or connected to networks? Are there any digital systems (like an ERP or basic automation) already in place that can be built upon? This step might reveal that some equipment is too outdated to connect to IoT networks, or that the company lacks a centralized database for operations.
- **Identification of specific needs and opportunities:** Engage various departments (production, maintenance, quality, supply chain, etc.) to gather input on pain points and improvement areas. Each department might have unique needs that Industry 4.0 technologies can address. For instance, the maintenance team might identify frequent unexpected machine stoppages – indicating a need for predictive maintenance sensors. The production team might want better real-time monitoring of output and quality – indicating a need for IoT-based production dashboards. It's also valuable to perform market research on Industry trends and benchmark against competitors. This could highlight technologies particularly relevant to the company's sector (e.g., traceability systems in agri-food, or robotics in automotive assembly) [26]. By the end of this step, management should have a clear picture of where the company stands digitally and a prioritized list of needs or problems that digital solutions could tackle. Crucially, this forms the baseline against which future progress will be measured.

Step 3: Strategy Development – *Defining a clear digital transformation Strategy:* With the insights from the needs assessment, the company's leadership can develop a strategic roadmap for the digital transformation. This involves:

- **Defining a vision and goals:** Top management should articulate a clear vision of what the digital transformation aims to achieve, aligned with the company's overall business strategy. For example, a vision might be "to become a data-driven enterprise that doubles production efficiency in five years" or "to achieve zero unplanned downtime through smart maintenance." Setting short-, medium-, and long-term goals helps structure this vision into achievable targets (e.g., short-term: implement pilot IoT monitoring on one line; medium-term: integrate IoT data into the ERP for whole factory; long-term: develop new digital-enabled service offerings) [27].
- **Developing an Action Plan:** With goals in place, a detailed action plan is needed. This plan should outline concrete projects, timelines, required resources (both human and financial), and responsibilities. Key components might include selecting pilot projects, scheduling technology deployments, training programs, and change management initiatives. It's often wise to incorporate pilot phases or proof-of-concept projects, where new technologies are tested on a small scale first [19]. For example, the company might plan to first implement an IoT-based temperature and humidity monitoring system in one production area to ensure it works as expected before scaling up to the entire facility. The strategy should also consider risk mitigation: for each planned technology, what are the potential challenges and how will they be addressed (e.g., cybersecurity for IoT, data privacy, etc.)? By Step 3's conclusion, the company

has a roadmap that aligns digital initiatives with business objectives and clarifies how to proceed.

Step 4: Investment in technologies – *Procuring and developing the right technologies:* With a strategy set, the company can move to the implementation phase, beginning with careful selection and investment in technologies that meet the identified needs.

- **Evaluating technological solutions:** Not all technologies will be equally suitable or cost-effective. The company should research and compare specific solutions for the needs identified. For instance, if the need is for condition monitoring of machines, options might include retrofitting existing equipment with IoT sensor kits versus buying newer "smart" machines with built-in connectivity. Strategic choices should focus on technologies that best fit the company's operational priorities and yield a good return on investment. In a Moroccan context, this may include IoT sensor networks (for real-time monitoring of production conditions), industrial automation systems (like PLCs and robotics for repetitive tasks), data analytics and AI tools (for predictive maintenance or demand forecasting), and modern ERP systems that can integrate shop-floor data with business processes. Special attention should be paid to interoperability – ensuring new tech can integrate with any legacy systems or at least with each other via standard protocols.

- **Budgeting and resource allocation:** Digital transformation can require significant upfront investment, so creating a detailed budget is crucial. This budget should cover costs of technology acquisition (machines, devices, licenses for software platforms), systems integration, and ongoing maintenance. It should also allocate funds for **training** employees on the new technologies and possibly hiring specialist staff or consultants (e.g., a data analyst or IoT engineer) if needed [30]. Companies should explore financial support options here – for example, government grants for technology adoption (if available), or partnerships with tech providers that might offer favorable financing for pilot projects. Since cost is a major concern for many Moroccan SMEs, prioritizing investments that address the most critical pain points first (as identified in Step 2) ensures that early wins can generate savings or added value to help fund subsequent steps. At the end of Step 4, the company should have procured or developed the initial set of technologies and tools needed to start the transformation in targeted areas.

Step 5: Stakeholder engagement – *Mobilizing management and employees:* A successful digital transformation is not just a technical endeavor; it requires people's buy-in and participation at all levels.

- **Leadership involvement:** Senior management must visibly support the transformation. This means committing the necessary resources and demonstrating commitment, for example by regularly communicating the importance of the project, celebrating early successes, and removing obstacles that teams might face. Leadership should establish a governance structure for the transformation (such as a steering committee or task force) that includes key managers who oversee the progress.

- **Employee participation:** Employees should be involved in the process rather than having changes imposed on them with no explanation. Forming multidisciplinary working groups or committees that include shop-floor workers, IT staff, engineers, and others can be very effective. These groups can provide feedback on implementation issues, contribute ideas (workers often have practical insights into process inefficiencies), and serve as champions for change within their departments. Regular communication and feedback sessions are also essential: employees need to be kept informed about what changes are coming, why they are beneficial, and how their work life will be affected. This can be done through town-hall meetings, internal newsletters, or demonstration days where a new system is showcased. It's also important to address fears – for example, some workers might fear that more automation or sensors tracking their work could threaten their jobs or privacy. Management should handle these concerns with transparency, explaining that the goal is to augment human work, improve safety and productivity, and that training/upskilling will be provided for more valuable roles [19].

- **Cultivating a Digital Culture:** Step 5 is also about starting to shift the organizational culture to be more innovation-friendly and data-driven. Recognizing and rewarding teams or individuals who contribute to digital initiatives, and encouraging experimentation (with allowance for failures during pilots) will build a culture in which employees feel ownership of the transformation.

Step 6: Gradual implementation – *Phased rollout of Industry 4.0 solutions:* Rather than attempting a big-bang implementation of new technologies across the entire organization, a phased approach helps manage risk and ensures learning along the way.

- **Prioritizing key areas/departments:** Identify which functions or departments will benefit most immediately from Industry 4.0 adoption and are feasible as pilot areas. Common choices are production lines with known bottlenecks, maintenance operations with frequent downtime issues, or logistics/warehouse operations where tracking and efficiency could be improved with IoT. For example, a company might choose to first implement digital solutions in the maintenance department by introducing IoT sensors on critical machinery for predictive maintenance. This department could yield quick wins (downtime reduction) and has clear ROI, making it a good pilot candidate.

- **Pilot projects:** Within the chosen area, implement the selected technologies on a small scale to test their effectiveness under real conditions. Using the maintenance example, a pilot could involve outfitting one production line's machinery with sensors that monitor vibration, temperature, or other health indicators, and using an analytics platform to predict failures. The pilot phase should be closely

monitored and evaluated: Are the sensors providing accurate data? Is the maintenance team responding effectively to alerts? What technical or organizational issues are arising (e.g., network connectivity issues, or confusion about new workflows)? [19] Lessons learned here are invaluable.

- **Scaling up:** If the pilot is successful, the company can then plan to scale the implementation to other machines, production lines, or departments. This might be done in waves, one section at a time, to maintain control. It's important to refine the approach as needed when moving beyond the pilot – for instance, perhaps after the pilot, the company realized it needs a better training module for workers or a different IoT data storage solution; these adjustments can be made in the scaling phase. Gradual implementation ensures that the organization is not overwhelmed and that any unforeseen challenges can be corrected before full-scale rollout. It reduces risk and builds confidence as each phase demonstrates value.

Throughout Step 6, maintaining open communication is important. Share the results of pilot projects company-wide – for example, "Pilot in Department X improved throughput by 15%" – to build momentum and buy-in for subsequent phases.

Step 7: Collaboration with the industrial ecosystem – *Leveraging external networks and expertise:* No company transforms in isolation. Collaboration can significantly accelerate learning and adoption of Industry 4.0 technologies.

- **Participation in Industry events and networks:** Companies should actively engage in specialized conferences, trade shows, and Industry networks related to digital manufacturing and automation. Events such as the **Moroccan Industry 4.0 Conference** or international fairs (if accessible) expose company decision-makers and engineers to the latest sensor technologies, IoT platforms, and success stories. These forums are opportunities to learn best practices and also to meet peers who are on a similar journey. Building connections through these events can lead to knowledge exchange and even partnerships (for example, two non-competing companies might decide to jointly organize a training on IoT for their staff) [19].

- **Academic and research partnerships:** Forming partnerships with universities, technical institutes, and research centers can provide access to cutting-edge research and a pipeline of talent. For instance, collaborating with an engineering university might allow a company to pilot an AI-based quality inspection system developed as part of academic research. Or, a partnership could involve sponsoring student projects or internships focused on real problems the company wants to solve (like optimizing a production process with data science). Some Moroccan universities and engineering schools now have innovation labs or Industry 4.0 programs; tapping into these can be mutually beneficial. The company gains expertise and creative solutions, while the academic side gains practical case studies and potential job placements for their students [25].

- **Engaging with technology providers:** Maintaining close relationships with suppliers of Industry 4.0 technologies (sensor manufacturers, automation solution providers, software vendors) can also foster smoother implementation. These providers often have experience from multiple deployments and can offer guidance on how to adapt solutions to the company's context. Sometimes they might run pilot programs or offer trial periods for new technology at a lower cost to demonstrate value.

- **Benchmarking and best practices sharing:** By collaborating within professional associations or clusters (e.g., a manufacturing association in Morocco), companies can share non-competitive information about what works and what doesn't. For example, a group of factories might share insights on which local service integrators are reliable or how they handled workforce training. This collective knowledge helps each member progress faster and avoid pitfalls.

Such ecosystem collaboration ensures that the company stays informed about state-of-the-art innovations and can continuously update its transformation roadmap with new ideas and technologies, rather than stagnating.

Step 8: Institutional support – *Seeking governmental and institutional assistance:* As noted in the challenges, institutional support can play a significant role. Companies should proactively seek out and utilize any available support from government or Industry bodies for digital transformation.

- **Identifying support programs:** Investigate what programs exist through government ministries (Industry, Trade, Digital Economy) or agencies (like Morocco PME, the Digital Development Agency, or sector-specific funds) that incentivize Industry 4.0 initiatives. There might be grants, co-funding opportunities, or tax incentives for investments in certain technologies or training. For instance, if the government has a subsidy for SMEs adopting renewable energy or energy-efficient equipment, a company could tie an Industry 4.0 upgrade (like installing smart energy meters and IoT controls for machines) into that initiative to get financial aid.

- **Applying for grants or credits:** The company should not hesitate to apply for these supports, even if the process is bureaucratic. Dedicating a team to handle proposals for funding or to liaise with public bodies can yield significant cost relief. For example, some countries have introduced "Industry 4.0 vouchers" for SMEs; if a similar concept appears in Morocco, being early to apply could secure funding.

- **Engaging with Industry associations:** Sometimes support comes in the form of collective initiatives. An Industry association might negotiate bulk deals with a technology provider for its members, or arrange training sessions at subsidized rates. By being active in such associations, a company ensures it doesn't miss out on these opportunities.

- **Policy advocacy:** If certain needed supports are lacking, companies (especially larger ones or

coalitions of SMEs) might engage in dialogue with policymakers to highlight their needs – for example, emphasizing the importance of better tax incentives for digital R&D or easier import of advanced equipment. Active communication can influence the creation of more favorable policies over time.

The goal of Step 8 is to offset some of the initial investment costs and to align the company's transformation efforts with national development goals, creating a win-win situation. Institutional support can also legitimize and bolster the internal case for transformation – showing stakeholders that the company's direction is reinforced by broader economic development strategies [27].

Step 9: Knowledge sharing and continuous improvement _ *Feeding back experience and sustaining momentum:* The final step ensures that the transformation does not have a hard "end" but becomes a cycle of continuous improvement and that the company contributes to and benefits from the wider knowledge base on Industry 4.0.

- Sharing successes and insights: Companies should document their transformation journey – including both successful outcomes and challenges overcome – and consider sharing these through case studies, Industry publications, or conferences. Presenting at events or writing articles (for example, a manufacturing journal or an online platform) about what the company achieved (e.g., "SME X improved OEE by 20% using IoT sensors on legacy machines") not only contributes to the community but also raises the company's profile. It can open opportunities such as partnerships or simply recognition that can be advantageous for business.

- Participating in peer networks: Joining communities of practice or working groups focusing on digital transformation helps keep the momentum. As new technologies emerge (say, Industry 5.0 concepts or AI advances), the company can learn and adapt rather than resting on its laurels. A culture of continuous learning should be cultivated internally too – for example, setting up an internal "Industry 4.0 task force" that continues to meet periodically even after major implementations, tasked with exploring further improvements.

- Iterative assessment: Revisit the digital maturity model or criteria initially used, on a regular basis (e.g., annually). This acts like a feedback loop: measure how far the company has come, identify new gaps or next-level goals, and update the strategy accordingly. For example, after achieving a certain maturity, the company might shift focus to more advanced analytics (like implementing AI for supply chain optimization) as the next frontier. Periodic assessment ensures the company remains aligned with evolving business objectives and technological possibilities [19].

By following this nine-step methodology, Moroccan companies can approach the integration of Industry 4.0 in a **systematic and strategic manner**. The process starts with building awareness and ends with sharing knowledge, reflecting a full transformation journey that not only changes the company internally but also influences its external environment. This approach is designed to overcome local challenges (infrastructure, skills, etc.) through a stepwise progression and by leveraging collective support. Ultimately, it aims for a progressive digital transformation that ensures long-term competitiveness and fosters an innovation-friendly industrial ecosystem in Morocco.

This methodology remains flexible and can be adapted by companies of different sizes and sectors, supporting a phased and sustainable transformation process.

6. Case study: Application of the Industry 4.0 integration Methodology in a Moroccan Agri-food SME

6.1. Company Profile and Context

This case study concerns a **Moroccan SME in the agri-food sector**, located in Meknes, employing approximately 80 people, with an annual turnover of around **30 million dirhams**. The company specializes in the processing and packaging of fruit and vegetables, mainly for the domestic market, with occasional exports to Europe. Its **initial digital maturity level was low (1/5 on the SIRI scale)**, reflecting limited automation, data usage, and system integration. Like many Moroccan SMEs, it faced structural constraints in digital transformation, yet sought to improve competitiveness and resilience.

6.2. Challenges Prior to Transformation

Key challenges identified before adopting Industry 4.0 solutions are included in Table 2.

Table 2. Key challenges.

Challenge	Impact on operations
Supply chain disruptions	Frequent delays in raw material deliveries
Lack of real-time inventory monitoring	Overstocking or stockouts, production delays
Poor interdepartmental communication	Inefficient coordination between production, logistics, and quality
Limited traceability	Difficulties in ensuring product quality and meeting customer standards

6.3. Application of the Nine-Step Methodology

Step 1. Awareness and training

Management initiated the transformation by:

- Organizing **awareness sessions** for executives and operational managers to explain Industry 4.0 concepts and strategic benefits.

- Providing **targeted training** for production, logistics, and quality teams on IoT basics, data analytics, and ERP functionalities.

Step 2. Capacity and needs assessment

A cross-functional team assessed:

- **Infrastructure gaps:** manual inventory processes, non-networked machines, lack of data systems.
- **Specific needs:** real-time monitoring of stock and production lines, predictive maintenance for critical equipment, and integration of operational data into management systems.

Step 3. Strategy development

A clear digital transformation roadmap was created, focusing on:

- **Short-term goals:** pilot IoT-based stock monitoring and ERP integration.
- **Medium-term goals:** partial automation of packaging lines and predictive maintenance deployment.
- **Long-term goals:** full integration of production data with ERP for real-time decision-making.

Step 4. Investment in technologies

Key technological choices are included in Table 3.

Table 3. Key technological choices.

Technology	Purpose
Open-source ERP system	Integrate inventory, production, and sales data
IoT sensors (temperature, humidity, vibration)	Monitor storage conditions and machine health
Planning and analytics software	Optimize production scheduling and resource allocation

The investment strategy prioritized affordable, scalable solutions compatible with the company's financial and human resources.

Step 5. Stakeholder engagement

- **Top management** actively led the initiative, communicating its strategic importance.
- **Employees** were involved through workshops and working groups, fostering ownership and reducing resistance to change.

Step 6. Gradual implementation

A phased rollout was adopted:

1. **Pilot phase:** IoT sensors installed on one production line and storage area.
2. **Evaluation phase:** Monitored results, refined processes, and trained teams.
3. **Scale-up phase:** Deployment extended to remaining lines and full ERP integration.

Step 7. Collaboration with ecosystem

The company engaged with:

- **Local technology providers** for ERP customization and sensor integration.
- **Industry associations and chambers of commerce** for best practice sharing and networking.
- **Academic partners** for training and applied research support.

Step 8. Institutional support

It secured:

- **Regional development grants** for technology acquisition.
- **Training subsidies** through public-private programs supporting digital transformation of SMEs.

Step 9. Knowledge sharing and continuous improvement

Post-implementation activities included:

- Regular **performance reviews** using newly collected data.
- Sharing experience at **sector workshops**, encouraging other SMEs to adopt similar transformation pathways.

6.4. Results and Impact Analysis

- Quantitative improvements (Table 4).

Table 4. Quantitative improvements.

Indicator	Before	After Implementation
Traceability	60%	95%
Stock losses	High	Reduced by 18%
Production time	Baseline	Reduced by 12%

- Qualitative impacts:

- Enhanced resilience through better visibility and responsiveness;
- Improved productivity with partial automation and optimized workflows;
- Strengthened competitiveness, enabling exploration of export opportunities.

6.5 Summary

This case study demonstrates that Moroccan SMEs with low initial digital maturity can successfully integrate Industry 4.0 technologies by following a structured nine-step methodology. The gradual approach ensured sustainable transformation, improved operational performance, and fostered an innovation culture.

7. Conclusion

The examination of various digital maturity models and the practical implementation of Industry 4.0 initiatives in the Moroccan context reveal a diverse

range of approaches to supporting business digital transformation. Models from Deloitte, Gartner, Forrester, Capgemini, SIRI, RAMI, and others all share the common goal of enhancing competitiveness and efficiency through structured digital integration. Yet, they differ significantly in evaluation criteria, defined maturity levels, and sector-specific focus. Each model offers unique insights—ranging from strategic alignment to technological benchmarking—and each comes with distinct strengths and limitations. For Moroccan businesses, which operate within distinct economic, cultural, and technological environments, the direct adoption of global digital transformation models may not produce optimal outcomes. Success depends instead on a strategy of contextual adaptation. Companies must customize these frameworks to reflect local realities, including the level of technological infrastructure, employee skill sets, and regulatory constraints. The case study presented in this paper illustrates this approach: by adapting a structured, step-by-step methodology to its operational context—and by integrating IoT technologies, sensors, and real-time monitoring—the SME was able to effectively engage in its digital transformation. This example demonstrates that while international frameworks offer valuable guidance, they must often be reinterpreted and supplemented with local innovations and support mechanisms to achieve meaningful impact in the Moroccan industrial landscape.

By considering the specific challenges identified—whether related to infrastructure gaps, limited digital skills, or insufficient institutional support—and proactively addressing them, Moroccan companies can not only overcome the hurdles of digital adoption but also accelerate their progress. As shown, investments in sensor technologies and IoT-based monitoring can directly tackle issues like maintenance downtime and product quality control, delivering measurable benefits. Moreover, aligning transformation efforts with national initiatives (such as seeking policy support and engaging in knowledge networks) can amplify the impact and ensure sustainability.

Future research could further explore sector-specific digital maturity assessments and develop localised benchmarks to guide Moroccan companies' transformation pathways.

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