




Original research article

## Digital Transformation in Industrial SMEs: A Holistic Approach to Symbiotic Relationships with Technology

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### ABSTRACT

Digital Transformation (DT) has become crucial to growing and developing small and medium-sized enterprises (SMEs) worldwide. Integrating digital tools and technologies in SMEs will increase efficiency, productivity, and profitability. Adopting digital solutions can help SMEs become more competitive, enter new markets, and internationalize operations. However, in the real world, gaps that limit the ability of SMEs to integrate digital assets are still observed, remarkably in small countries such as Portugal. This article aims to discover and analyze how the managers of industrial SMEs in Northern Portugal face the DT process and modify their SMEs' operations due to the DT process. Through semi-structured interviews and subsequent thematic analysis, this study fills a gap in empirical studies on industrial SMEs passing through DT. It proposes a practical and foundational DT strategy for SME managers. The findings demonstrate an informational deficit among managers and the scientific field, with a need for conceptual clarifications. Nonetheless, the results of digital tool integration and their consequent changes offer clear advantages to SMEs that implement them. Therefore, besides a strategic proposal for SMEs interested in DT, this study raises novel pertinent questions about DT in industrial SMEs.

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## 1. Introduction

Companies must constantly innovate in today's competitive global market to ensure success [1], [2]. The 4th Industrial Revolution, or Industry 4.0 (I4.0), presents new challenges and opportunities, demanding a mindset shift where technology is viewed as an ally

rather than a replacement for human resources, making integrating technology, processes, and people essential [3]-[6]. I4.0 reshapes industrial value chains, driving efficiency, sustainability, safety, and quality improvements while reducing costs [3], [4], [7], [8]. However, many companies struggle with I4.0 adoption due to resistance and resource constraints [3], [9], highlighting the importance of Digital Transformation (DT) [10].

DT is a strategic, ongoing change driven by digital technologies, reshaping organizations to improve performance and redefine value [1], [11]. This shift enhances agility, flexibility, and responsiveness to customer needs [3], [4], [12], [13], impacting all company levels, from production to top management [3], [11]. Small and Medium Enterprises (SMEs), which comprise 90% of businesses and 50% of global employment, have unique DT needs due to their agility [3], [14], [15]. While DT can boost SME sustainability, particularly with Lean integration, empirical studies are needed to understand DT success conditions in SMEs, especially in smaller countries like Portugal [1], [3], [12], [16], [17]. Portuguese SMEs cautiously embrace DT to stay competitive, following trends in other countries [1], [4]-[7], [18], [19]. Although economic challenges have impacted these SMEs, post-pandemic effects still need to be explored [20], [21].

This study investigates how Portuguese industrial SME managers approach DT, filling a research gap and supporting DT planning. Interviews with five SME managers from Northern Portugal revealed potential discrepancies between academic recommendations and management practices, prompting future research and a proposed DT framework.

This paper comprises five sections: Section 2 reviews relevant literature, Section 3 details the methodology, Section 4 analyzes results, and Section 5 concludes and suggests future research.

## 2. Literature Review

Existing research on I4.0 in SMEs has largely focused on technologies, with limited attention to mass customization and the need for a clear implementation methodology [22], [23]. While a solid foundation for I4.0 exists, particularly in quality management (QM), research on Industry 5.0 and its sociotechnical approach still needs to be improved, with few studies utilizing case studies, interviews, conceptual approaches, or reviews [3], [24]. Empirical research in this area is particularly scarce [24].

I4.0 allows SMEs to improve competitiveness and expand market share [25]. However, SMEs face challenges in adapting to I4.0, particularly in selecting appropriate tools and practices [25]. Barriers include a need for more financial resources, digital strategy, I4.0 knowledge, skilled labor, standards, organizational resistance, and digital security [26]. Often, essential prerequisites like initial assessments and preparatory steps are overlooked, resulting in a lack of actionable guidelines. Additionally, the human factor and empir-

ical validation should be more frequently addressed, calling for more comprehensive research [25].

Several studies have used the Resource-Based View (RBV) theory to link Quality Management (QM) with organizational outcomes, such as improved performance through integrating quality and sustainability strategies [9], [24]. RBV suggests that firms gain a competitive advantage by leveraging valuable, rare, and non-substitutable resources [9]. In the context of I4.0, SMEs with such resources and a solid implementation plan are better positioned to advance in I4.0. The ability to internationalize has also been identified as a key resource for achieving a competitive advantage and progressing in I4.0 [9].

Previous studies have emphasized the importance of digital strategies in SMEs' DT, highlighting its multidimensional nature [12]. When combined with the right cultural and capability enablers, these strategies can enhance company performance [12]. Research shows SMEs mainly adopt IoT for monitoring, with limited progress in intervention and optimization [8]. Additionally, most research has focused on initial readiness for DT, with few studies examining actual implementation outcomes [8].

A literature review on I4.0 maturity models found that only seven studies investigated I4.0 maturity or readiness models [1]. The main keywords used in the review were "maturity model," "readiness model," "Industry 4.0," "SME," "Small Medium Enterprise," and "Digital Transformation." [1]. The review concluded that there is a need for a comprehensive model that not only offers more detailed granularity than those presented in the literature, especially in the early stages, while maintaining a holistic approach to the concept, but also considers the obstacles and challenges that SMEs face when implementing I4.0 initiatives [1].

When conducting multiple case studies to validate a smart manufacturing adoption framework for SMEs, researchers ensure construct validity by having SME respondents review the case analysis prepared by the authors [27]. Since the study was not causal in nature, internal validity was not required [27]. Similarly, external validity, which aids in generalization, was verified with the help of literal and theoretical replication during the research design phase [27]. The reliability test was conducted as different team members followed the same procedure and arrived at similar results [27]. Triangulation was ensured by using multiple sources of evidence to obtain data and converge them into similar results [27].

To ensure the reliability of qualitative studies on competency development and DT approaches, re-

searchers must fully document the steps taken during the analysis in a data framework, seeking to achieve theoretical saturation [4]. This includes using a semi-structured approach for workshops, in-person visits to SMEs' facilities for confirmation and triangulation of the collected information, and multiple rounds of coding independently conducted by two authors, which are then reviewed and discussed among all to identify any divergent interpretations and reach consensus on how the data should be interpreted [4].

In conclusion, while existing I4.0 literature provides insights into technology and quality management for SMEs, critical gaps persist in areas like mass customization, human factors, and framework validation. Challenges such as financial constraints, skill shortages, and lack of clear guidelines still need to be addressed. This study explores how industrial SME managers in Northern Portugal navigate DT, proposing a strategic framework to guide SMEs and advance academic and practical understanding.

### 3. Methodology

To describe the realization process of the **qualitative study** presented here, we outline the seven distinct steps of this study below:

**Step I—Literature Search on DT:** An exploratory literature review (LR1) was conducted in Google Scholar in May 2023 to develop the semi-structured interview, while another review (LR2) was done in October 2023 in Scopus, following PRISMA guidelines [28] (Table A.1 in Appendix). The keyword selection aligned with previous research [1] and the PICO Framework [29]. Google Scholar was ideal for LR1 due to its broad coverage, including grey literature and non-traditional publications, which provided diverse and emerging research [30]. With its extensive peer-reviewed journals and citation analysis capabilities, Scopus was more suited for LR2, offering precise and reliable data for a focused review [30]. The LR2 search yielded 72 papers from 2015 to 2024, with 44% published in 2023-2024 (after the interview execution in this study), indicating a growing interest in this topic (Figure A.1 in Appendix).

**Step II—Development of Interview Guide and Framework:** A semi-structured interview guide and a DT Framework for Industrial SMEs were developed based on insights from the LR1 and aligned with the study's objectives. The interview guide was refined through expert review for content validity, and a pilot test with a senior SME manager led to

further adjustments. The final interview guide had the nine open questions presented as subtitles (Q1 - Q10) in the Results and Insights section. Open-ended questions were chosen to allow participants to provide rich, detailed responses that quantitative scales like dichotomous or Likert scales may not capture.

**Step III – Criteria for SME Participation:** The selected SMEs were industrial companies based in Northern Portugal that had already begun their DT (DT) and integrated digital technologies into their value chains. Interviewees were chosen based on their direct involvement in or extensive knowledge of the DT process. Each organization assigned a suitable representative for the interviews. To maintain confidentiality, companies were anonymized as C1 to C5. C1 (industrial adhesives) nominated its commercial director; C2 (uniforms), its operations director; C3 (tools), its operations director; C4 (windows), the CEO assistant; and C5 (robotics), its operations director.

**Step IV – Conducting Open-Response Interviews:** Five interviews were conducted at the convenience of the interviewees, either in person or online (C3, C4, C5 chose online). The semi-structured interviews followed a guide with nine questions, developed to align with the study's goals and validated by two academic experts. One researcher conducted the interviews between July and August 2023, each lasting an average of 22 minutes. The longest (C2) was 36 minutes, and the shortest (C3) was 11 minutes. All interviews were recorded.

**Step V – Thematic Analysis of Results:** A primary thematic analysis method was used to identify patterns or "themes" in the interview responses [31]. Thematic saturation and code consistency ensured comprehensive data collection. We tracked saturation through new codes, constant comparison, saturation tables, and sample size guidelines. Code consistency was maintained through codebook development, double coding, regular meetings, and test-retest reliability [31].

**Step VI – Refining the Framework:** The foundational framework for DT was expanded by incorporating interviewees' insights. The resulting framework is presented in the Results and Insights section.

**Step VII – Conclusions and Future Research:** The study concluded with suggestions for future research to address gaps in the literature on the digital DT of industrial SMEs.

## 4. Results

This section is organized in the same order as the questions in the semi-structured interview; here, the summarized analyses of the interviewees' answers are presented.

### 4.1 Q1 - How do you define DT, and how has it been applied in the organization?

In summary, SME managers understand DT as a transformation process from conventional/manual methodologies to digital, whether a total or partial transformation, carried out using digital tools. In other words, they see DT as integrating/converting various processes using digital tools within an organization. However, the literature presents a definition that, although not discordant, goes further, not considering that process conversion is central to the transformation. This conversion is regarded as a "digitalization," not DT, a complex process that aims to change an organization's functioning almost wholly [4, 12]. This is driven by digitalization (i.e., the simple adoption of digital tools) [4, 12].

In practical terms, SMEs have a partial gap in their understanding of a DT, which may have implications at an operational level and is possibly one of the reasons why divergences occur during this process in different companies. These findings follow what was observed by recent studies in the Basque Country, Spain [4], and Canada [3].

### 4.2 Q2 - Why did you decide that DT was the way forward?

In convergence with the literature, DT emerges in the managers' view as a path that aims to meet needs and attenuate valences in different organizations. Not only do companies recognize that DT is part of the future, enhancing growth, helping to solve problems, and presenting a sustainable basis to ensure that they keep up with the market in which they operate [11, 12], but they also use this process and digital tools for pressing needs [12].

### 4.3 Q3 - When did you start the process, and when did it end (how long did it last)?

Some managers define a precise duration of their DT, while others understand DT as a continuous, not finite, process. These divergences are possibly due to how DT is seen, carried out, and idealized by differ-

ent organizations. With this, it is possible to observe that for the initial integration and use of some of the tools that these companies consider to be part of the core of their DT, there is a minimum implementation time of one and a half years and a maximum time of four and a half years. This marked difference may arise from the context in which the organization operates, for example, in what it produces, its size, its resources, and urgency, or the complexity/depth of its DT.

The literature points out various contextual factors that may influence the duration of DT, such as firm sizes. Due to more limited resources, SMEs may adopt a gradual approach and implement DT in stages, extending the process over a longer period [4, 15]. The availability of financial, technological, and human resources directly impacts the speed and scope of DT [4, 7, 15]. Also, the depth of changes, the number of affected processes, and the integration of different technologies influence the time required for implementing DT [4, 15]. Additionally, the need for rapid adaptation to new demands or the pursuit of solutions for specific issues can accelerate the DT [4, 15, 22].

Some companies agree with the literature, considering the DT process as interactive and continuous [14 - 15]. It has a beginning but no defined end, relying on a constant search for tools and changes that improve an organization. However, as this is a central point of DT, the management of SMEs should have it on a relatively basic bottom line.

As these results arise, new questions arise: **"Do SMEs understand DT as a stage?"; "Do companies that understand DT as something circumstantial consider it something to start over and end according to the supply of needs or the existence of resources?"**

In practice, the management of SMEs needs to understand that DT is a continuous and interactive process, which, although it can be divided into projects or stages of finite duration, should, in essence, be considered as something ongoing, a constant search for tools that allow an increase in agility, productivity, assistance in solving problems and supply of needs. Thus ensuring the continuous presence of innovation that enables the creation of foundations for the future and a continuity of competitiveness in the market in which they operate.



#### 4.4 Q4 - Was there any specific methodology/strategy used?

While some companies employed varying levels of planning in executing their DT, none used a specific strategy or methodology. Some sources confirm a lack of maturity models and roadmaps for I4.0 implementation and evaluation, especially for SMEs, pointing to the need for a comprehensive model that considers SMEs' challenges in I4.0 initiatives [1, 15]. Conversely, other sources present methodologies for managing DT in SMEs, proposing specific actions for different stages [3, 9, 15, 22]. For example, one source suggests a six-step I4.0 methodology validated for SMEs [22], while another emphasizes adopting strategies based on tools and goals suited to each company's needs [3]. Additional sources recommend assessing each company individually to tailor the I4.0 strategy accordingly [1, 3, 9, 15], and one describes an I4.0 transformation management methodology validated by experts [15].

The references agree on the importance of adapting DT strategies to each company's unique needs, with proposed frameworks providing tools and steps tailored to SMEs' contexts. This literature gap underscores the need for further research, particularly to develop approaches and tools that help SMEs implement DT effectively. This study concluded that Portuguese manufacturing companies have no introductory DT methodologies, leaving companies guided by their specific needs, resources, and objectives.

With this, it is observed that there is a gap in the academic literature regarding the strategies for the realization of DT in industrial SMEs. To assist, facilitate, and standardize, to a certain extent, the planning of SMEs in the realization of DT, the authors present, therefore, a possible basic strategy that intends to fill this gap but advises the realization of more extensive studies on this specific topic, to find out if this proposition is valid and reliable.

#### 4.5 Q5 - What are the biggest challenges/obstacles during DT?

Managers stated that companies face different challenges during their DT, possibly due to the various contexts in which they operate [1, 3, 4]. Therefore, one of the most frequent challenges is the need for upskilling [4, 14]. The lack of information, resistance to change, the difficulty of obtaining external partnerships [3, 4] and aligning objectives by senior management, department directors, and employees

[15], and the costs associated with starting and carrying out a DT [3] are also factors seen as challenges/obstacles to the process in question.

Contradictory to the literature, respondents did not mention "Lack of Standards and Legislation" and "Information Technology Security Issues" [26] as a pressing concern for their organizations. Another source [21] emphasizes standards, legislation, and data security as significant barriers to implementing I4.0, particularly regarding sustainability. It underscores the role of cybersecurity in DT, explicitly identifying data security as a challenge for I4.0 adoption due to vulnerabilities to attacks and the need to protect information privacy. The discrepancy between the literature and findings may stem from contextual differences among the companies analyzed.

Thus, other questions arise that can be analyzed in future studies regarding the topic: **"How to avoid these obstacles?"**, **"How can we solve or mitigate them?"**, **"How do SMEs obtain or provide information about DT and its challenges?"**

#### 4.6 Q6 - How has digital transformation affected the company at a hierarchical, cultural, organizational, and employee mindset level?

The answers provided show no absolute convergence of results. Only two of the five companies interviewed stated that notable organizational changes were needed, like in [3] and [12]. Only in one company have profound changes been found at the cultural/mindset level, in the hierarchical structure, and the production processes, that is, a holistic transformation, like in [3] and [6].

The managers' views diverge from the literature, which generally emphasizes the need for a holistic transformation, whereas most investigated firms focus on more superficial changes. This gap between theory and practice may stem from academic sources promoting an ideal of DT that does not fully align with SME realities. Most investigated firms show less profound organizational changes, concentrating on digital tools, which may reflect differing definitions of DT among SMEs. This theoretical-practical gap aligns with the literature, suggesting a tendency toward "digitalization" rather than the entire DT [12].

Therefore, these results raise new questions: **"Is there distancing from DT in theory and practice?"** and **"Are most industrial SMEs in Northern Portugal carrying out a digitalization and not a DT in practice? Does this hap-**

pen in other countries?"; "Is the DT phenomenon necessary in the investigated context?"; "Is there a possibility that the changes in question will arise naturally with integrating digital tools into the value chain?"

Therefore, there is possibly a need to better define DT at a conceptual level, both in practical and theoretical terms and for further conceptual clarification of what DT and digitalization are. This distinction may be necessary in business to carry out a more complete, deep, and conscious DT. With this distinction, there is a possible introduction of information regarding potential and perhaps beneficial organizational changes companies can make during a DT.

#### 4.7 Q7 - What new technologies have you decided to integrate into the organization?

Each company, possibly due to its resources but in particular to its needs, operational context, and what it produces, has integrated different digital tools. With this, there is a point of convergence: they all use data analysis tools. It is also observed that SMEs in Northern Portugal use IoT and robotics and plan to adopt AI, purchase/integrate additive manufacturing, and integrate robotics in CNC milling machines. As observed in the literature [1, 6, 9], these technologies are considered emerging digital tools and are part of I4.0.

However, nearly all companies also use ERP and CRM software. While essential to organizations and I4.0, these tools are not strictly emerging technologies, as their widespread use dates back over two decades. This shift may reflect the evolution of the I4.0 concept; initially focused on disruptive technologies like IoT and AI, it now emphasizes the integration of legacy systems like ERP and CRM for effective DT. This inclusive approach is supported by [9], who advocate for integrating less advanced technologies as an initial step toward I4.0 adoption.

Therefore, questions are raised about using digital tools in SMEs and what is considered an emerging technology: "Are tools such as ERP and CRM still considered emerging technologies depending on the analyzed country?"; "What is the real scale of implementation of digital tools in industrial SMEs?"

These questions make it possible to study the technological priorities of SMEs in Northern Portugal and analyze whether these companies are lagging in IT.

#### 4.8 Q8 - What benefits do you see from digital transformation and adopting the technologies you have decided to integrate?

The managers highlight a very positive view of DT's benefits for organizations, with SMEs noting improvements in information accessibility, agility, flexibility, and control over resources and operations. All SMEs report that information is now more abundant, organized, and accessible in real-time, leading to gains in operational efficiency. Additional benefits include support for predictive maintenance, reduced human error, faster product shipping, and cost savings.

This converges with [12], who argues that digital technologies must be combined with other organizational factors, such as complementary capabilities and digital culture, to create value and improve performance. This view is supported by [4], who emphasizes the importance of workers' skills for successful DT, arguing that digitalization goes beyond merely implementing technologies. However, the sources expand the discussion on the success factors of DT. [11] emphasizes the importance of digital organizational culture while [12] pointing to the need for digital capabilities and well-defined strategies. In turn, [18] highlights the relevance of power dynamics between buyers and suppliers in the digital supply chain, demonstrating that the success of digitalization depends on a complex ecosystem of factors.

However, this raises the question: "Are the perceived benefits found exclusively due to digital tools, or do they result from the entire context of digitalization or DT being implemented?" The alignments between the interviews and sources reinforce the importance of digitalization and DT for industrial SMEs. However, the question of benefit attribution and the lack of a clear distinction between DT and digitalization in the literature indicate the need for further research. Understanding the specific impacts of each phenomenon and the factors that influence their success is essential for SMEs to fully leverage the potential of the digital era.

#### 4.9 Q9 - Do you consider the transformation to have been a success? How do you measure whether it was (why)?

All managers say that the DT they carry out demonstrates positive results and has been successful. However, none of the companies has a tangible results evaluation system regarding the topic in ques-

tion, and some believe that, although the results have been positive so far, it is too early to say that this process is a complete success. These companies should implement qualitative and quantitative measurement systems to measure this process's results, allowing better management.

The sources strongly support the statement that companies lack tangible results evaluation systems. [15], proposing a methodology for managing I4.0 transformation in SMEs, observes that most companies do not have mechanisms to track progress and measure the success of their initiatives. [4], In turn, it is argued that the lack of specific knowledge about innovative technologies hinders the measurement of digitalization results in SMEs.

The sources also support the idea that it is still too early to declare DT a complete success. In analyzing the implementation of I4.0 in a robotic packaging systems company [22], favorable results were obtained in the initial phases. Still, the full adoption of the strategy was recognized as a long-term process. [27] also emphasizes the need for a careful analysis of the benefits and challenges of DT, especially for SMEs still in the early stages of adoption.

Research supports the need for qualitative and quantitative measurement systems to evaluate DT outcomes in SMEs. [3] highlights that effective DT management, including monitoring and evaluation systems, is key to success. [18] notes that measurement systems improve strategic decision-making by clarifying digitalization's impacts on supply chains. [21] advocates for a holistic approach to I4.0, suggesting that using diverse metrics can capture DT's effects on culture, processes, customer relationships, and sustainability, enabling SMEs to manage better and adapt their DT efforts.

These results allow us to ask new questions: **“Even though I consider DT a success, there are negative points; which ones?”**; **“What measurement systems/methodologies should/can be used to measure DT outcomes/success?”**; **“Since DT is, in theory, a continuous process, should its success be measured, also in a general and continuous way, or continuous, but associated with specific projects/implementation or both?”**

These questions potentially allow the study and creation of methodologies for analyzing specific results for SMEs related to their respective DTs. In addition, they raise the question of whether this process has negative aspects, even if, in general, it is a success/beneficial, and ways to mitigate them if they exist.

#### 4.10 Strategical DT Framework for SMEs

The basic framework presented was developed using the managers' answer categories and the managers' feedback and suggestions for improvement. It is formulated using bullet points to improve reading and understanding. It is built circularly with double arrows, demonstrating the process's continuous and iterative character. Organizations that wish to use this fundamental framework should adapt and expand it.

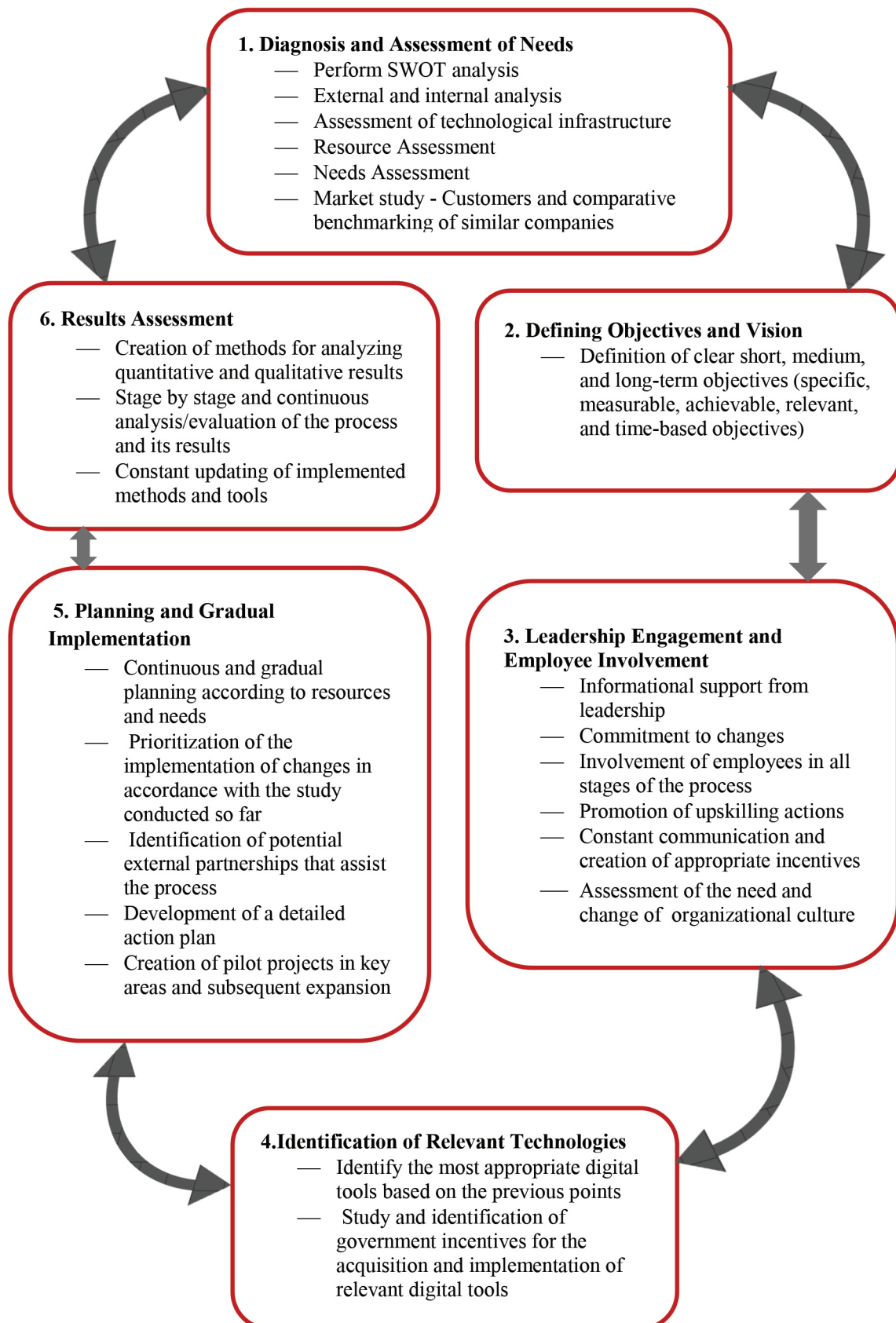
The proposed framework (Figure 1) starts with an **initial assessment** phase, where SMEs assess their digital readiness and identify gaps in technology, human resources, and culture. Next is **strategy development**, aligning digital goals with business objectives and integrating digital tools into value chains. The **implementation phase** follows, integrating digital solutions with necessary training and change management to address resistance. Lastly, **continuous evaluation and adaptation** ensure SMEs monitor performance, optimize processes, and stay agile, enabling them to sustain DT and remain competitive. The framework is **flexible, scalable**, and applicable across industries, addressing SMEs' specific challenges.

## 5. Conclusions

Considering its exploratory nature, this article fulfills the proposed objective, helping to fill a gap in the literature and practice on DT in SMEs. Also, it raises pertinent questions on the topic. Given the scarcity of tangible quantitative data, the authors aimed to understand the current state of industrial SMEs in Northern Portugal regarding digital tools' research, adoption, integration, and infrastructure through qualitative analysis. This research identified the necessary changes for the successful implementation of DT and the main challenges observed by SMEs during the realization of the process, allowing for better preparation by similar companies and providing a possible introductory framework for industrial SMEs starting their DT.

Thus, this article defines DT according to the current literature and presents potential emerging technologies and challenges/obstacles in integrating these tools and the whole complex and continuous process that is a DT. The research methodology involves conducting semi-structured interviews with SMEs involved in DT.

The results indicate convergences and divergences with the literature, with positive results from inte-



**Figure 1.** Digital Transformation Introductory Framework for Industrial SMEs

grating and using digital tools and the methodological changes accompanying this process. That said, SMEs have enormous information needs, and there is a lack of conceptual clarification between digitali-

zation and DT. Thus, despite the limitations of the research, especially the sample size, it is considered that the study fulfills the proposed objectives, helping to improve the body of knowledge on the subject.



Future research could expand these qualitative insights by developing quantitative variables for correlation analysis. The findings suggest new research directions to deepen the understanding of DT in industrial SMEs, including quantitative analysis, effective information-sharing strategies, the necessity of DT, gradual digital tool integration, more precise conceptual distinctions between DT and digitalization, the development of DT strategies, framework validation, and further exploration of DT knowledge within SMEs.

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## Appendices

**Table A.1.** LR Protocol

|   |   |   |
|---|---|---|
| <b>Keywords</b>                                   | PICO framework (Population, Intervention, Comparison, Outcome): "industrial SMEs" or "manufacturing SMEs" (population), "digital transformation" or "Industry 4.0" (intervention), and "management", "roadmap", "strategy" or "framework"   |   |
| <b>Search Strings</b>                             | (TITLE-ABS-KEY ("Digital Transformation" ) OR TITLE-ABS-KEY ( "Industry 4.0" ) ) AND ( TITLE-ABS-KEY ( roadmap ) OR TITLE-ABS-KEY ( strategy ) OR TITLE-ABS-KEY ( framework ) OR TITLE-ABS-KEY ( management ) OR TITLE-ABS-KEY ( path ) ) AND ( TITLE-ABS-KEY ( "Manufacturing SMEs" ) OR TITLE-ABS-KEY ( "Industrial SMEs" ) ) |   |
| <b>Source Selection &amp; Criteria Definition</b> | <b>Studies Language:</b> English<br><b>Source List:</b> Google Scholar (exploratory review) & Scopus (systematic review)<br><b>Source Justification:</b>  |   |
| <b>Studies Type Definition</b>                    | Articles published in journals  |   |
| <b>LR1 &amp; LR2</b>                              | May 2023 & October 2023   |   |
| <b>Studies Quality Evaluation</b>                 | Studies indexed in Chartered Association of Business School (CABS) 2021 list are considered as high-quality and priority in reading   |   |
| <b>Study Selection Criteria</b>                   | <b>Inclusion</b>  | <b>Exclusion</b>  |
|   | - Articles proposed a framework, strategy or roadmap  | - Articles excluded for focusing on a single technology (e.g., AI, additive manufacturing, AAT)<br>- Articles excluded for focusing on a specific type of industrial SME (e.g., high-tech military SMEs in Russia)<br>- Articles out of scope for not encompassing digital transformation |

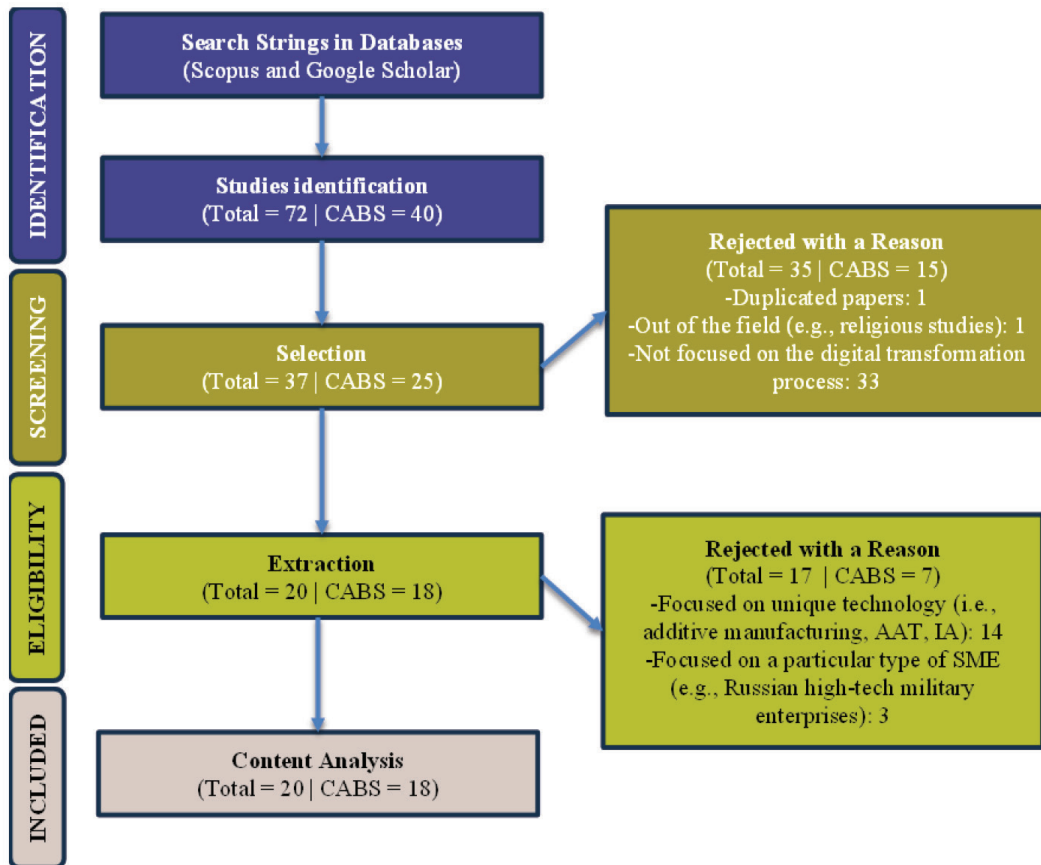


Figure A1. LR Process flow