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An implementation model for socio-technical digital tools

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Received 9 June 2023
Revised 7 November 2023
24 January 2024
14 February 2024
Accepted 14 February 2024

Abstract

Purpose – While Digitalisation is gaining momentum among practitioners and the scientific world, there is still a struggle to embark on the digitalisation journey successfully. The struggles are more significant for SMEs compared to large companies. Such transformation could face internal resistance, which evokes the need to put it into a socio-technical perspective such as lean. This paper investigates how SMEs could implement digital tools and technologies in their operations.

Design/methodology/approach – We relied on a multiple case study design in three SME manufacturing companies in Italy. Based on the experience of those companies, the struggles in the implementation and the lessons learned, we formulate an implementation model of digital tools driven by lean thinking.

Findings – Companies tend to implement first digital tools that help with real-time data collection and stress that introducing digital tools becomes challenging without reducing waste in production. The model stresses top management commitment, middle-line involvement and operator training to resist change. All these factors coincide with socio-technical lean bundles developed by seminal works. In addition, the study highlights that financial incentives are not necessarily the common barrier to digital tools implementation in SMEs but rather the cultural aspect.

Originality/value – Our paper enriches the extant body of knowledge by deriving knowledge around digitalisation implementation through lessons learned and corrective actions. It allows managers to benchmark and compare the current state of the implementation process with that of other companies and the one proposed to make corrective actions when necessary.

Keywords Lean, Digital, Implementation model, Industry 4.0, SME

Paper type Research paper

Quick value overview

Interesting because: In the pursuit of digitalisation and keeping up with the pace of technological advancements, companies often jump into the fourth industrial revolution without considering socio-technical aspects coined under the lean paradigm. The research develops a digitalisation implementation model. While models are often created by analysing successful digital implementation, the novelty of the research lies in proposing an implementation model that leverages also on a failed transformation journey.

Theoretical Value: It was found that the digital transformation journey could have two possible starting points. The rivalrous start triggered by financial incentives from I4.0 technology adoption that eventually slows down the digital transformation while the vigorous start driven by socio-technical elements ensures and sustains the journey's success.

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

Journal of Manufacturing Technology Management
Vol. 35 No. 5, 2024
pp. 941-961
© Emerald Publishing Limited
1741-038X
DOI 10.1108/JMTM-06-2023-0230

This is the first step to constructing a middle-range theory about the need for commitment and knowledge of one phenomenon (Lean) for the success of another one (I4.0) based on an empirical study.

Practical Value: In practical terms, managers could refer to the model to understand at which level of digital transformation their operations system is and which social (white and blue collars interaction) and technical criticalities they will face. Accordingly they would be able to pinpoint their progress along the digitalisation journey and learn from the mistakes made and the challenges faced by their peers. Socio-technical aspects shall remain essential for the implementation of any digitalisation initiative.

1. Introduction

Industry 4.0 (I4.0), the fourth industrial revolution, has received growing scientific, academic and managerial attention (Kipper *et al.*, 2020). It utilises advanced digital technologies that allow innovation across all company levels and functions (Koh *et al.*, 2019; Sousa-Zomer *et al.*, 2020). A struggle in implementation accompanies the interest in this revolution (Erol *et al.*, 2016), as companies face barriers during digital technologies implementation (Chauhan *et al.*, 2021). Coping with barriers is a fundamental but exhausting course of action (Dalenogare *et al.*, 2018) that appeared more reasonable to manage by large companies than SME companies (Müller *et al.*, 2018)

SMEs might face more struggles implementing digitalisation because they have additional barriers to face compared to large companies and have fewer resources to invest (Alcácer and Cruz-Machado, 2019).

Several researchers searched for managerial and organisational initiatives to successfully introduce digital technologies (Kagermann *et al.*, 2013; Müller *et al.*, 2018). Extant literature demonstrated that lean management (LM) supports the digital transformation of *t*, the practical empirical evidence is poor, and other authors pointed out the necessity of firms to have a comprehensive framework which can give companies precise guidelines to follow (Frank *et al.*, 2019).The seminal work of Shah and Ward (2007) defines LM as a socio-technical system. This article adopts this definition and attempts to analyse the implementation of I4.0 from that socio-technical perspective that includes human and organisational issues (Marcon *et al.*, 2022).

Our paper attempts to address this gap by investigating the implementation of digital tools integrated into a socio-technical perspective and how synergetic effects between these two types of systems can be achieved to gain a competitive advantage. The resource-based view (RBV) is used as a theoretical lens (Barney, 1991), with a focus on the concept of complementarity where one resource has bidirectional influence over the other to achieve a competitive advantage (Teece, 1986). RBV utilises strategic and valuable resources at the company to drive competitive advantage (Barney, 1991).

This research aims to develop a lean-driven implementation framework for digital tools in SMEs, thus setting the scene for a middle-range theory (Merton, 1968) governing the relationship between a technology-driven paradigm and a socio-technical one for a competitive advantage strategy. To the best of the authors' knowledge, ample room exists to contribute to this topic in the extant literature.

We conducted multilevel case studies in three Italian manufacturing companies, relying on interviews with top management, middle management, operators' insights and site visits. Our research contributes to the body of knowledge by delineating an empirically based digitalisation implementation model.

The article is structured as follows. After introducing the topic, Section 2 explains the state of the art, while Section 3 presents the methodology. Section 4 presents the study results before the discussion and conclusion in Sections 5 and 6.

2. Theoretical background

2.1 Digitalisation in manufacturing companies

The I4.0 phenomenon refers to a structure of manufacturing assets provided by sensors and facilitated by integrating several digital technologies (Buer *et al.*, 2021; Kagermann *et al.*, 2013). Several manufacturing firms have started introducing their plants to digital technologies. Some authors refer to this phenomenon characterised by a constant and extensive introduction of digital tools in firms as Digitalisation (Buer *et al.*, 2018, 2021). This definition is the one adopted in this article.

These advanced digital tools and technologies completely reshape the production and supply chain environments by improving performance (Raj *et al.*, 2019). Though the advantages are substantial, the path is challenging (Dalenogare *et al.*, 2018; Frank *et al.*, 2019) and has several barriers (Raj *et al.*, 2019)

2.2 Barriers to digitalisation

One of the biggest hurdles in pursuing the digital journey is the absence of a well-defined business strategy, especially when combined with resource scarcity (Raj *et al.*, 2019). There is a need to have a digital strategy shared across all company levels.

Orzes *et al.* (2019) identified six barriers categories: Economic and financial, cultural, competence and resources, legal, technical, and implementation. Stentoft *et al.* (2021) explored three classes: legislation (lack of a common standard); management (lack of resources and understanding of the strategic importance of I4.0) (Lassnig *et al.*, 2021); workforce with resistance to change (Horváth and Szabó, 2019) and lack of qualification and missing knowledge on I4.0 paradigm (Raj *et al.*, 2019).

2.3 Barriers for SMEs

Large companies are favoured by higher preparation for digitalisation and higher financial and technological strength (Sommer, 2015) and exploitation of the first movers advantage while pursuing the path of disruptive technology adoption (Horváth and Szabó, 2019; Sommer, 2015). They can also leverage higher-scale economies and bargaining power toward digital providers (Malekifar *et al.*, 2014). Instead, SMEs have a lower technology level in plant equipment (Mittal *et al.*, 2018) and a low background in I4.0 (Masood and Sonntag, 2020). Thus, these vast investments will make reaching yearly financial targets (e.g. break-even point) even more challenging. Moreover, their common short-term orientation will lead to suspicious and distrusted behaviour towards digitalisation (Masood and Sonntag, 2020).

The holdup in the digital strategy in SMEs makes it crucial to investigate the success factors to help them pursue a successful digital path.

2.4 Digital transformation's influence factors

The need to embrace and adopt digitalisation gained the interest of several researchers. According to the RBV theory, the right combination of resources is necessary for achieving a competitive advantage. It has been argued that one resource alone cannot drive sustainable competitive advantage (Ulrich *et al.*, 1995). Moreover, according to the socio-technical system theory and the competence-based view theory (Imran and Kantola, 2019), technological advancements do not necessarily lead to increased operational performances unless the introduction of digitalisation is coupled with changes in the organisational structure and work practices (Roth and Farahmand, 2023; Schuh *et al.*, 2014). For instance, Tortorella *et al.* (2022) showed how digital technologies increase firms' performance when somewhat integrated in the processes. Many authors recognise the substantial innovation

brought by digitalisation as a huge socio-technical change (Kumar *et al.*, 2022; Lima *et al.*, 2023; Prodi *et al.*, 2022). The changes brought by technologies to the production environment affect all the environment's sub-elements, such as people and processes (Kumar *et al.*, 2022). Among the socio-technical factors that enable a successful digital transformation, the one recognised as pivotal is leadership skill (Colombari and Neirotti, 2023; Tortorella *et al.*, 2023). According to Colombari and Neirotti (2023), companies that can leverage their employees' knowledge and involve them are more likely to use digital technologies and make more informed decisions. The role of employee behaviour and soft managerial practices is recognised to be one of the fundamental pillars of an optimal digital transformation (Alieva and Powell, 2023; Lima *et al.*, 2023), as well as committed top managers (Dinis Carvalho, 2023).

Thus, the factors to consider are many, and the complexity behind firms' digital transformation is apparent. Hence, there is a need to have guidance to address firms' efforts and struggles, not merely to improve performance but to survive in the digital world, where innovation will be mandatory to compete (Ghobakhloo and Fathi, 2020; Somohano-Rodríguez *et al.*, 2020). In particular, this is relevant for SMEs as they are less capable of coping with the challenges of this path (Sommer, 2015).

2.5 The implementation models for digital transformation

Frank *et al.* (2019) developed a model that considers the different adoption patterns of digital technologies and called to focus more on SMEs that have more significant difficulties than larger firms.

Ghobakhloo and Fathi (2020) identified 11 determinants for a successful digital transformation in their exploratory research. However, these need to be confirmed empirically.

Battistoni *et al.* (2023) developed a roadmap for SMEs by comparing Italian enterprises operating in various sectors. They focused on how technology can be an enabler or enhancer of SMEs' digital transformation. They also stressed the importance of adding organisational variables associated with human and managerial resources. One of the main limitations of their work is the lack of focus in this direction. So, an integrated analysis of human, managerial and technological aspects is needed to provide companies with more comprehensive roadmaps.

Lastly, in all these models, there is no elaboration on the link and the possible integration with existing managerial theories that may be grounded in the company culture. These theories cannot be neglected since they can influence firms' digital transformation (Ghobakhloo and Fathi, 2020).

2.6 Driving digital transformation: the possible role of lean

LM is a socio-technical system that was born to guide companies from the manufacturing and service sectors to improve their performances (Womack *et al.*, 1991). Lean is a culture of continuous improvement that advocates the contribution of the various stakeholders in the company (Åhlström *et al.*, 2021). Several studies investigated the relationship between LM and implementation of digital tools (Buer *et al.*, 2018). Lean seems to be a promising paradigm for fostering firms' digitalisation process (Buer *et al.*, 2018, 2021; Ciano *et al.*, 2020). The competitive and complex market frontier pushed companies towards implementing and integrating both paradigms in their operations to achieve the promised potential (Rossini *et al.*, 2021). Individually, digitalisation and lean can be considered as homogeneous and imitable resources acquired by industrial competitors and may limit the ability of an organisation to create a competitive advantage when applied in isolation. The concept of complementarity proposed by Teece (1986) explains how one resource might influence and

impact another and how the relationship affects an organisation's competitive positioning or performance. In the context of lean and I4.0, the synergetic effect can generate greater value and improved performance (Frecassetti *et al.*, 2023). However, the study of I4.0 deployment into existing management paradigms is ongoing and necessitates further deepening (Kolberg *et al.*, 2017). However, due to the topic's novelty, academic literature still seeks practical studies to validate propositions and expand the existing knowledge by acquiring empirical evidence from the field. Alieva and Powell (2023) described the fundamental role of the "soft" lean practices and employees' behaviours to avoid digitalisation waste. Dinis Carvalho *et al.* (2023) pointed out the fundamental role of top management commitment in achieving successful digital transformation. However, no study has considered a comprehensive view of a digital tools implementation model encompassing explicitly the facilitating role of Lean. Rossini *et al.* (2021) only describe the different paths adopted by lean and non-lean companies. Thus, what is missing is a model which thoroughly depicts the specific role of lean from a socio-technical perspective in shaping firms' digital transformation path. Aiming to fill this gap, this paper provides a comprehensive implementation model obtained through the analysis of case studies, in which success factors deriving from the lean culture are used and interpreted from a socio-technical perspective.

3. Research method

The empirical description of lean and I4.0 synergy and their role in supporting competitive advantage can be understood using an inductive theory building approach for conducting exploratory case studies based on theoretical replication logic (Eisenhardt, 1989; Barratt *et al.*, 2011). The strength of the case study approach is its ability to offer deep insight and explanation into complex processes that may not be achieved through quantitative methods for data collection. Barratt *et al.* (2011) and Baxter *et al.* (2008) stated that a qualitative case study is the best methodology to study the complex and emerging phenomena that allow researchers to derive holistic and meaningful characteristics of organisations and managerial processes. The case setting of this study is three SME manufacturing companies selected following the theoretical sampling approach and replication logic proposed by Eisenhardt (1989), where each case can be considered as an analytic unit (Steenhuis, 2015) and selected for their fit in having gone through the digitalisation process.

The case study design allows us to triangulate data from different sources and increase the generalisability of our findings (Eisenhardt, 1989) and the possibility to cross-validate data gathered in different realities (Yin, 1984). This methodology aligns with the lean and digitalisation state of research in operations management (Buer *et al.*, 2018) (see Figure 1).

3.1 Research setting and case selection

Although choosing Italian manufacturing companies might reduce the possibility of generalising findings, it assures that confounding variables do not cause variation (Ciano *et al.*, 2020). This research involves companies operating in the manufacturing industries with different levels of implementation and knowledge about LM and I4.0 (see Annex C). The unit of analysis is the tools' implementation and performance with a focus on the shop floor. To ensure abiding by the socio-technical realm, both blue and white collars were involved in the study (socio level), and both interviews and questionnaires aimed at understanding the rationale behind implementing the tools (technical level). The inquiry includes interviews with people in key roles inside the company, from the top management to the production management; Gemba walks on production floors with informal interviews and

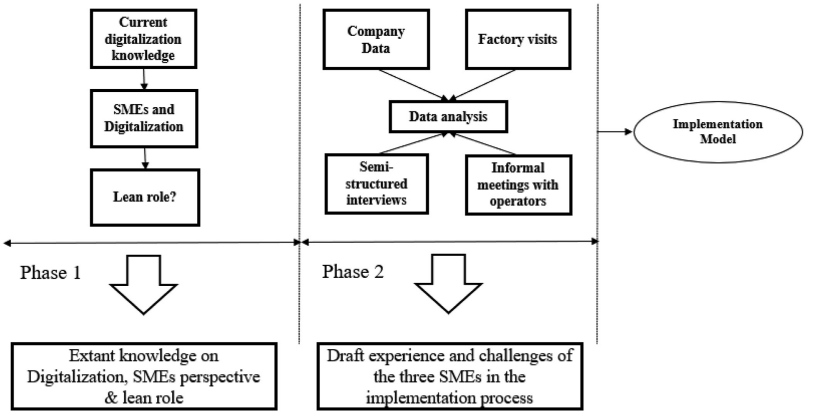

Figure 1.
Research method

Source(s): Di Maddaloni and Davis (2018)

questionnaires to operators interacting with the new digital tools. These data sources are required to triangulate statements and results within and among cases to get reliable insights to contribute to theory and practice. We purposefully selected three SMEs operating in the Italian manufacturing sector. The profile of each company is in Annex A.

The selection of SMEs aligns with previous research (Cimini *et al.*, 2021; Hoellthaler *et al.*, 2018; Moeuf *et al.*, 2020). We conjecture that to understand the implementation process of digital tools better, SMEs should be the target companies instead of larger firms since simpler processes and less bureaucratic structure characterise them. In addition, the smaller size gives managers more knowledge and more detailed visibility of the processes as they take on more responsibilities, such as overseeing several production lines.

3.2 Interviews

The first step of data gathering starts with an introductory interview. The company's management fills out a questionnaire about the digital tools they implement and shares their thoughts about digitalisation and lean thinking inside their company. An informal discussion is required to set up the entire case based on the tools they implement and their level of knowledge of the topic. Semi-structured interviews were conducted with cross-functional team of executives supporting the implementation of digital tools. Key people inside the organisation were interviewed: the first with the top management of the company, the second with a production manager and the third with a person directly interacting with people on the shop floor.

The interview protocol used during the data collection was informed by previous literature and was customised as per the position of the interviewees. The interviews were recorded after the agreement with the interviewees. The questions protocol has different sub-sections: (1) Organisational structure of the company, (2) Digital tools adoption level, (3) Company's guidelines for the adoption of the tools, (4) Socio and technical obstacles encountered during the implementation process, (5) Impact of tools on operational performances and (6) Insights for future developments. The open-ended questions considered the expertise level and position of the interviewee.

Researchers obtained other data sources during planned trips to the production floor, direct observation of people working on the field, informal interviews with employees in production and a questionnaire given to the operators working to collect their opinions on implementing the digital tools.

3.3 Data analysis

We interpreted the outcomes following a two-step procedure: a within-case analysis and a subsequent cross-case analysis. The within-case analysis describes each case as a stand-alone entity, gaining in-depth knowledge about them to ease the subsequent cross-case analysis (Eisenhardt, 1989). This step allows researchers to delineate the implementation steps of introducing the digital tools by each company, the obstacles faced and the critical success factors of implementation. The cross-case analysis increases the generalisability of results coming from case studies when coupled with within-case analysis (Voss *et al.*, 2002).

3.4 Model creation and revision

The multiple case studies resulted in the shaping of a digital journey implementation model. The model was then discussed and validated with a second round of interviews with all three companies and a senior lean expert with decades of consultancy experience and academic expertise.

4. Results

4.1 Within case analysis

In performing the within-case analysis, it is essential to triangulate all the information sources gathered during the development of the cases. The guidelines for the within-case analysis will be the coding protocol: (1) Digital tools and the contextual factors, (2) Implementation timeline, (3) Implementation process (struggles and problems), (4) Impact on operational performances and (5) Relation between LM and I4.0. Due to length limitation, we report the detailed within-case analysis in Annex B.

4.2 Cross case analysis

Regarding the relationship between the digital tools implementation and the contextual factors, all three participants agree that the CEO and the C-Levels' commitment towards implementing these new technologies must be high and constant to conclude all the related projects successfully. If the commitment of C Levels is not continuous, lower-level employees will become sceptical about the importance of these changes. Conversely, the top management needs support and commitment from the middle-line managers.

> The mentality of the CEO, who is an entrepreneur who is very forward on these things, has always pushed hard to have this (implementation of digital tools) . . . and if it were up to him, all these things could already be operational ten years ago. Unfortunately, suppose you are not supported by collaborators who believe in it, are capable, and know what to do. In that case, everything drags on . . . therefore, in parallel, he had to push the whole structure to growth- Case A, Operations Manager.

Companies A and C, coming from different backgrounds (the former is an MTO while the latter is MTS), agreed that enterprises could leverage the type of production for the introduction of digital tools since enterprises that are capable of performing high volume/low variety productions might have an advantage over firms in which it is necessary to produce high variety items. Moreover, Company B sees size as the introduction's fundamental element, as it might be expensive for small enterprises with restricted budgets. Other contextual factors, such as the type of business (B2B and B2C) and the sector, were not mentioned by the participants.

> In a company like ours, it (introducing digital tools) is facilitated precisely because in terms of the complexity of the production process, together with the number of lines, is limited. (little complexity of the process facilitates tools implementation). So basically, it is easier to plan . . .-Case C, IT Director.

Participants are underlining a possible relation between the type of production and the size, with larger companies with high volume/low variety productions that are advantaged over others in implementing digital tools. Interestingly, Company C fits both of these elements but has no knowledge of lean principles. Thus, the contextual factors might have helped company C achieve implementations regarding I4.0 more easily due to the structural characteristics of its production system.

Coming to the implementation timeline, they all seek data from the field, with the first installed instruments belonging to the real-time data-gathering sphere. They all stated that the first step to improving a system is to have it under control since it is impossible to define the impact of changes without control and measure on point. These tools give them enough reliable material as a foundation for further implementations.

> We implement the digital tools to have real-time data that can be analysed to make decisions about seeking process improvement rather than delivery, delays, order portfolio-Case A, Operations Manager.

Unfortunately, concerning the impact on operational performances provided by the digital tools, the inquiry did not bring detailed results regarding specific tools but just an aggregate analysis with overall remarks about performances in general. The most satisfying tools have been the ones related to real-time data collection.

Regarding the motive for implementing digital tools, Company A mentioned the possibility of gathering more reliable and higher-quality data that could be accessible in real time. This would serve as a way to accurately map processes, a technical lean practice (Hadid *et al.*, 2016). The information could create a more reliable foundation for future decisions, though those tools are not initially economically convenient. In this sense, fiscal incentives helped the company decide on the adoption when unsure. Company A also stated the improvements brought to the accounting office as well. Company B, instead, talked about the necessity to streamline the process, simplify the tasks for the operators, increase efficiency using more control over production and reduce WIP and stocks along the production activities. Due to its lean culture, it never used fiscal incentives as leverage to introduce these digital technologies. Data collection tasks are instead the top priority for company C to make the correct analyses and improve the performance of its system. Company C was motivated by financial incentives overlooking the strategic implementation plan, which eventually caused it to incur a financial burden by collaborating with a consultancy company.

Regarding the correlation between LM and I4.0, Company A and B were already experienced in applying lean principles, while Company C was unaware of its existence. The latter see Lean practices as fundamental for implementing digital tools and must be used to improve processes before introducing digital tools. Otherwise, the risk of automatising waste in production increases noticeably.

On the other hand, Company C states that I4.0 can exist as a stand-alone concept inside the organisation, helping to improve performance and increase visibility inside the production system. It could be seen as a rivalrous explanation that contradicts the other two companies. For the actual implementation, they exploited consultants' help to leverage the opportunities coming from the field at best, but most importantly, to adopt an approach that might unknowingly be Lean.

Table 1 continues the cross-case analysis by highlighting all three companies' challenges and corrective actions. The companies stressed that cooperation between the various functions is necessary for reducing resistance to change.

> The fortune of our company is this, 90% of the workers are young, so they are already inclined towards technology. The other percentage is still causing us problems . . . so we are training them internally-Case A, Production Director

Table 1. Cross-case analysis and success factors

Success factor	Challenges and pitfalls	Corrective actions
Change of mentality and personal knowledge	Company A's top management often changed ideas about introducing lean concepts in the company. These changes made the operators and the middle management feel uncomfortable and thus hostile to the paradigm	Company A relies on a new COO knowledgeable about lean concepts. The company is trying to educate and convince the other managers about the importance of the paradigm to be all committed to the same purpose
	Company C's top management was not educated about Lean and I4.0 concepts; thus, it was hard to draft a strategic plan for the implementations	Company C managed this situation by hiring consultants that helped introduce the tools. Since it was not enough, the new COO is now trying to bring the lean culture inside the organisation
Freedom in decision-making by middle management and people involvement	Company A's middle management was feeling controlled by the new digital lean installations	Company A solved the issue by explaining to the Middle Management and the operators the importance of the new digital installations, rewarding those who came up with new ideas and suggestions
	Company A's operators were feeling substituted by installations such as the collaborative robot	
	Company B's resistance level was low for the middle management and the operators	Company B did not have resistance problems since the Lean culture is highly spread inside the organisation
	Company C's operators saw in the last year an increase in the automation of the systems and started to wonder about their future in the organisation	Company C is still struggling to understand the importance of the lean digital transformation since the lean culture is not spread inside the organisation. They started now to involve consultants for the purpose
Supplier relationship	Company A based its installations on the experience of the COO, who contacted suppliers he already knew for tailored installations. Integrating these installations, such as the real-time monitoring software, is ongoing	Company A is now exploring the supplier network, looking for more suitable solutions and flexible suppliers to support them with the product and service
		Company B, which can count on a broad supplier network, did not encounter any problems in the process thanks to a solid awareness of the available solutions: suppliers were wisely selected, and tools were suiting their production line
	Company C, to implement the Real-time monitoring software, decided to ask for the help of the supplier already providing the warehouse management system. This decision created inefficiencies and problems since the installed sensors were incompatible with the machines	Company C is redefining the assets' needs, introducing a new ERP to gather data from the tool's PLCs without constraining the system

(*continued*)

Table 1.

Success factor	Challenges and pitfalls	Corrective actions
Adequate information system	Company A did not connect the tools directly to the ERP, but ad-hoc interfaces introduce complexity and errors, which must be manually solved	All the companies suggested how crucial it is to have an IT department define the most suitable tools based on their integration capability
	Company C managed the integration with external sensors not entirely supported by the machines, generating errors and needing back-end human intervention for corrections	Company C is trying to implement an ERP designed for production to interface directly with the machines
	Both companies, A and C, installations are taking months due to the IT infrastructure that is not developed enough	Both companies, A and B, are trying to improve their IT capabilities to manage installations internally to reduce implementation time The IT department is fundamental before and after installations
	Companies A and C could not fully integrate their tools into the IT systems. They had to wait for months and still have issues with the data coming from the shop floor, which is incomplete and needs to be checked with back-end activities	Companies A and C are now trying to strengthen their IT department to improve their integration capabilities
		Company B has a well-defined strategic plan, knowledge about Lean practices, a vast supplier network, and a developed IT system; these issues were highly mitigated and managed by the organisation
	Company C had problems in analysing processes before the tool's installation. They could not spot wastes based on Lean principles; they just worked to automatise their flows	Company C mitigated their lack of knowledge with the assistance of consultants that helped them analyse the necessity of the production and introduce process-changing tools
	Company C had problems analysing the system after installing the real-time monitoring tools, and they had to ask for external support to introduce the process-changing tools	Company C realised how having Lean competencies is fundamental to clean processes before installing digital tools; they will also use these competencies to analyse the data coming from the field to install better

(*continued*)

Success factor	Challenges and pitfalls	Corrective actions
Incremental change	Company A implemented an E-Poka-Yoke to exploit the fiscal benefits of amortisation thanks to the presence of the I4.0. Still, this machine is unused and not integrated into the IT system	Company A understood that to maximise the use of a specific asset, it must be part of a more comprehensive strategic plan and be integrated with the system. Incentives should never be the main reason why an installation is pursued
	Company C entered the digital transformation to exploit fiscal benefits and automate its production flows; it failed to integrate the system organically without a strategic plan. Now they are restarting with a strategic plan	Company B, which never leveraged fiscal benefits to select the tools and entered the implementation loop from the left side, did not suffer from these implementation issues
		After entering the implementation loop from the rivalrous start, Company C understood that a strategic plan was necessary to finalise the installations. They are now working on the prerequisites suggested by this model

Table 1.

> We did the first cleaning with the 5s. Operators have gotten into the mindset that the cleaner your workstations, the better. Even the most reluctant workers, with targeted meetings and dialogue, we made it clear that they worked better first. We have produced more and better in less time-Case B, Head of Production.

4.3 The implementation model

We propose an implementation model based on the challenges and corrective actions of the cases (Figure 2). The model has two entrances, highlighted in green (vigorous start) which companies should follow and the red (rivalrous start) that Company C chose and eventually struggled with.

The model has two phases: phase 1 with the prerequisites, while Phase 2 deals with the implementation steps separated by the pivotal box labelled "Knowledge and capabilities for Lean 4.0".

Phase 1 is strongly based on LM and is about developing shared knowledge, strategy, and infrastructure. It all starts with the commitment and education of the top management (TM). TM should have a clear objective to drive resources to these projects and keep subordinates' commitment up as they directly deal with the implementation challenges, as for the Hoshin Kanri practice (Giordani Da Silveira *et al.*, 2013). TM should also work on the spread of LM concepts before introducing I4.0-related technologies; the higher the awareness of LM, the better the understanding, and the higher the commitment to digital transformation.

Moreover, an investment to adapt workers' skills is necessary to embrace the new technological advances, a key point of LM (van Assen, 2018; Marcon *et al.*, 2022).

Also, TM should define a clear strategic plan to achieve their objectives. It implies being aware of the offers available on the market and exploring the supplier network. The last step of the preliminary phase is the development of the IT infrastructure capable of managing both the installation and the maintenance of the digital tools. Initially, companies should integrate the tools with the existing information systems, such as ERP. Otherwise, real-time data sharing becomes challenging.

The knowledge and awareness of the quality of the processes embedded in the system are essential before installing the digital tools.

Phase 2 starts by installing digital tools for real-time data gathering and should be integrated with the IT infrastructure. The middle management is responsible for analysing the data to get valuable decision-making insights. They can then identify and reduce the present waste through corrective actions. There is a need to install process-changing tools to modify the system and improve performance. The model proceeds with a loop in for each tool that has to be installed. The learning curve prevails in guaranteeing a faster implementation, and a continuous improvement culture begins to spread. LM is about standardising the process and allowing I4.0 to be effectively applied, while I4.0, in turn, is boosting LM (Rossini *et al.*, 2021; Tortorella *et al.*, 2019).

Unaware of Lean practices, Company C follows the rivalrous start without the prerequisites and is mainly driven by fiscal incentives. Company C, though, during the inquiry, without explicitly referring to Lean practices, confirmed the importance of the steps on the left of the model: being knowledgeable about the installations before performing them, the need for a plan for installations, and eventually, the need of a well-established IT infrastructure. In highlighting these issues, Company C understood how difficult it was to start implementing digital tools without being prepared, just with the idea of creating a system in which their flow was automated, pushed by the fiscal incentives. These factors led Company C to involve consultancy company in the implementation process that eventually applied LM.

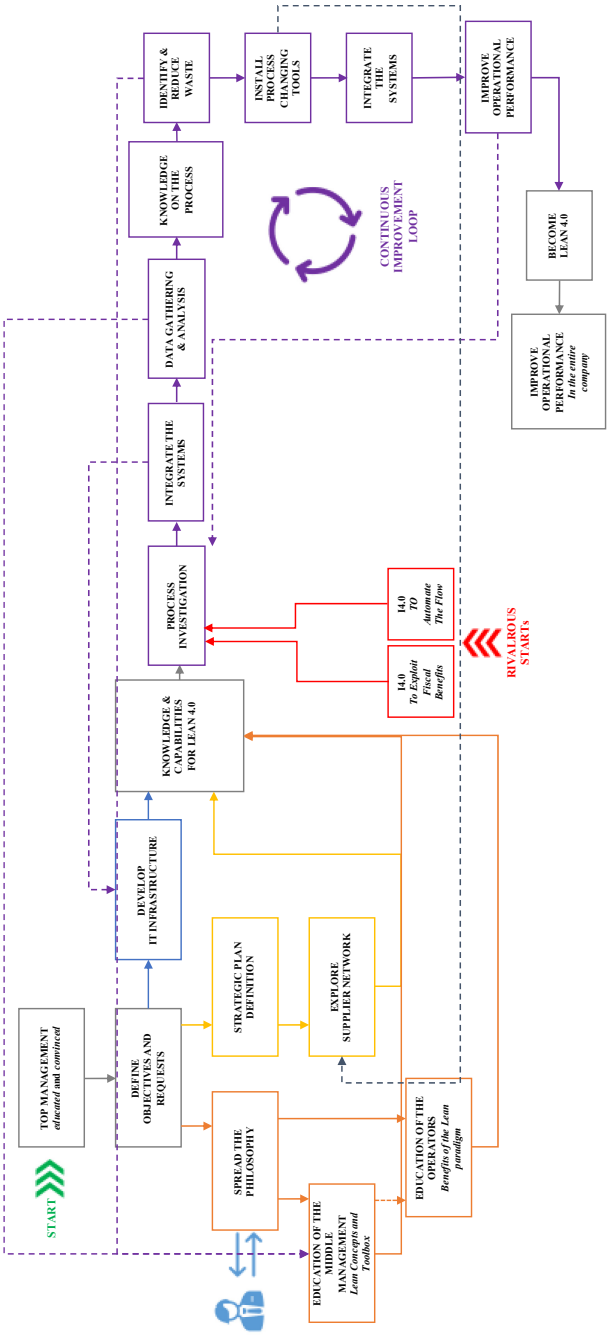

Figure 2.
Implementation model

5. Discussion

The implementation model that emerged from the multiple-case study is presented in Figure 2. The model highlights the implementation path according to the motive of usage of the tools, mainly data visibility followed by process-changing tools.

Compared with existing implementation models in the literature (Frank *et al.*, 2019), the model defines two possible starting points for companies' digital transformation.

LM significantly influences the path of the vigorous start at all organisational levels. It highlights the strong connection between LM and digital transformation (Buer *et al.*, 2018), from the importance of the management's commitment to LM and the need to spread LM throughout training the middle management and operators. The vigorous start leads to a robust implementation of digital tools, confirming the beneficial role of LM in introducing new technologies in the companies (Rossini *et al.*, 2021; Ciano *et al.*, 2020).

The rivalrous start appeared triggered by the financial incentive from I4.0 technology adoption. This path avoids the "preparing phase" of vigorous start and appears faster at first sight. However, it slowed down the digital transformation journey because it generated middle management and operators' lack of commitment and involvement, leading to struggles in integrating I4.0 technologies into operations. This criticality is coherent with other studies in the literature (Bellantuono *et al.*, 2021; Horváth and Szabó, 2019), but it evidences the empirical impact of barriers in the process of technology implementation (Mukhuty *et al.*, 2022).

To tackle those barriers, top management that should adopt a socio-technical system to introduce new changes with a holistic and inclusive perspective (Dinis Carvalho *et al.*, 2023).

Companies using appropriate socio-technical systems such as LM could lead to successful and satisfactory results, as in the case of Companies A and B. Indeed, LM, a socio-technical system, turned out to be a significant factor in positively supporting firms A and B throughout their digital transformation. As depicted in Figure 2, LM strongly influences Path 1 (i.e. vigorous firms like company C can face additional pitfalls and barriers and incur a rivalrous start, which leads to an increasingly complex path. In fact, at first glance, the rivalrous path could seem more manageable and faster. Still, it overlooks many foundational steps, as in the case of Company C, where during the interviews emerged how fundamental the use of the appropriate socio-technical system as LM could have been. Indeed, they had to take remedial actions by hiring a consultancy company to cope with that. Nevertheless, this has led to further inertia in the implementation path, even if the external support and the use of socio-technical systems to support them have improved the situation.

By generalising these findings, it is possible to assume that socio-technical systems, particularly LM, hugely affect how a company embarks on the digitalisation path. However, since the beginning of the transformation, their use yields completely different effects and enhances the results. The case of Company C demonstrates that using socio-technical systems at later stages of the implementation path has a softened impact, which, of course, helps, but in a less effective way. Further, the firm had to appeal to extra financial resources to do that. Thus, the use of LM is encouraged and brings benefits in any of the entrances; however, to get the best out of both paradigms, LM and digital, a rivalrous start is pivotal.

Compared to Rossini *et al.* (2021), this research discusses the success aspect of the digitalisation process. Our research postulates that rivalrous paths may fail in the long run. Even if governmental financial incentives represent a good support (Koh *et al.*, 2019), a technology-driven paradigm is not enough to overcome the tensions that may arise among stakeholders, while a human-centred approach as LM is needed (Cagliano *et al.*, 2019; Dornelles *et al.*, 2022).

The implementation model reinforces the need for LM as a structured approach for an operational, strategic view declined in a change action plan of digital technologies implementation (Romero and Flores, 2019).

This change should involve all stakeholders, from top management to operators, and it seems to positively contribute to the digitalisation intensity, as observed by Moeuf *et al.* (2020). This coincides with Employee Involvement, the 10th lean bundle developed by (Shah and Ward, 2007), and adds to it the transparent communication needed to minimise the resistance to change for the operators that emerged from this research. It is, therefore, essential to include and involve operators in the improvement processes regarding active proposals and, most importantly, in terms of explanation (Åhlström *et al.*, 2021). Clearing out the reasons for the introduction and the objectives of the projects helps dramatically in welcoming and building trust in the choices taken at a high level that would be perceived as risks to be substituted by the technology (Dombrowski and Mielke, 2014; Holweg and Maylor, 2018).

Adopting digital projects needs to follow a step-by-step approach to updating the company's infrastructure accordingly, where LM "shapes the way I4.0 technologies are introduced in the operations system: namely, small and incremental changes" (Rossini *et al.*, 2021).

A novelty of the implementation model of this research is an empirical example of how digital tools are a potential enhancer of the capabilities of Lean systems.

A feature of I4.0 is data collection through the installation of digital tools belonging to the real-time data-gathering sphere. Data collection enhanced by digital tools is the watershed between the traditional LM paradigm and the Lean 4.0 one, in which even the conventional Lean practices benefit from the control capabilities of I4.0 technologies (Frank *et al.*, 2019; Rossini *et al.*, 2021). I4.0 could act as a booster for LM since I4.0 could improve continuous improvement activities through the higher amount of available data and ease LM application in complex production systems, such as Make-to-Order (Buer *et al.*, 2018; Rossini *et al.*, 2019a, b).

From the technological point of view, the implementation model stresses the importance of having an IT infrastructure and its integrability and adaptability with the already existing IT systems. Problems in this integration might lead to, in the worst case, make the newly installed tool unusable.

The first three lean bundles developed by Shah and Ward (2007) deal with the suppliers' role. The suppliers are one leading player in onboarding digital tools. Companies should not only rely on them as sourcing stakeholders but also as supportive and active players in the implementation and post-implementation processes (Shah and Ward (2007) Bundle 3-SUPPDEVT). Researchers usually stress the need for training of the workers. In addition, this research adds to Lean 2nd bundle-SUPPFEED as the performance must include the crucial role of the supplier of these tools for training, not just internal company stakeholders.

6. Conclusions

Given the need to increase productivity, governments created technology programs such as I4.0 to enhance digital transformation (Costa *et al.*, 2023; Meindl *et al.*, 2021). Although digital transformation can increase productivity, companies struggle with their technology-driven paradigms to face organisation barriers (Dornelles *et al.*, 2022). Recent studies suggest the relevance of the social perspective of digital transformation as a critical success factor to lead to a fruitful digital transformation (Marcon *et al.*, 2022). On this premise, this paper provides empirical evidence of the positive impact of socio-technical LM practices on success factors of digital tools implementation and – considering three SME cases of actual implementation of digital transformation – to propose a middle-range theory in the form of an implementation model that highlights socio-technical aspects of digital transformation.

The socio-technical aspects of the Lean sphere that sustain the success of a digital transformation in the long period emerged from the case studies and are evident in the implementation model proposed.

In particular, the model extends the literature because it introduces the socio-technical prerequisites necessary to enter the digital transformation, combining elements from the LM and I4.0 paradigms. For example, top management commitment and a better awareness of the digital transformation implementation at all company's hierarchical levels is a socio-technical LM prerequisite in effectively deploying digital transformation. This is in line with previous literature (Colombari and Neirotti, 2023; Tortorella *et al.*, 2023) that recognise the importance of leadership skills and a task-oriented attitude to moderate the relationship between technologies and performances positively. Moreover, the involvement of the people and the education is another socio-technical Lean prerequisite that emerged as fundamental for a successful digital transformation. These two statements regarding lean education and top management involvement and commitment are broad enough to apply to SMEs and all companies but specific enough to test in the context of introducing digitalisation in operations.

Another socio-technical lean practice is cross-functional teams, which emerged from cases by the work of consultancy company that pulled together various perspectives and expertise from departments across the organisation (Fairhurst and Connaughton, 2014). The top-down approach fosters collaborative decision-making while aligning the blue and white collars on the overarching company's objectives (Fairhurst and Connaughton, 2014). This ensures all stakeholders' involvement and ultimately limit resistance to change (Freeman *et al.*, 2010).

This could be considered the first step to constructing a middle-range theory (Merton, 1968) about the need for commitment and knowledge of one phenomenon (lean) for the success of another one (I4.0) based on an empirical study.

Managers could refer to the model to understand at which level of digital transformation their operations system is and which criticalities they will face. Moreover, the model could guide digital transformation from greenfield to drive investments and plan digital transformation timings, contributing to practice.

Future research could be directed towards the dissemination of the model and in the enhancement of its statistical validation. Future research could consider a more comprehensive number of industry professionals contributing to the model's creation and validation phase. A limitation of the model is the simplification of the "entrance point" for the digital transformation. This research highlights two points that are at two extreme situations that are useful to understand the differences of the two patterns. However, the entrance point is not a full black-white decision, but is a grey scale, so it could happens that companies decide to start in different points that are in the middle of the model (as in the middle of a lean transformation or with an IT infrastructure that is partial and not completed). Another possible limitation is the Italian context, which might hinder the model's generalisability and extend it to other national contexts. Furthermore, the model stems from SME's experience but could eventually be generalised to all sizes as lean thinking is innate and logical.

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Further reading

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Annex

The supplementary material for this article can be found online.

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