Integrating advanced digital technologies in existing lean-based production systems: analysis of paradoxes, imbalances and management strategies

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Abstract

Purpose – The purpose of this paper is to advance the understanding of paradoxes, underlying tensions and potential management strategies when integrating digital technologies into existing lean-based production systems (LPSs), with the aim of achieving synergies and fostering the development of production systems.

Design/methodology/approach – This study adopts a collaborative management research (CMR) approach to identify patterns of organisational tensions and paradoxes and explore management strategies to overcome them. The data were collected through interviews and focus group interviews with experts on lean and/or digital technologies from the companies, from documents and from workshops with the in-case researchers.

Findings – The findings of this paper provide insights into the salient organisational paradoxes embraced in the integration of digital technologies in LPS by identifying different aspects of the performing, organising, learning and belonging paradoxes. Furthermore, the findings demonstrate the intricacies and relatedness between different paradoxes and their resolutions, and more specifically, how a resolution strategy adopted to manage one paradox might unintentionally generate new tensions. This, in turn, calls for either re-contextualising actions to counteract the drift or the adoption of new resolution strategies.

Originality/value – This paper adds perspective to operations management (OM) research through the use of paradox theory, and we (1) provide a fine-grained perspective on why integration sometimes "fails" and label the forces of internal drift as mechanisms of imbalances and (2) provide detailed insights into how different management and resolution strategies are adopted, especially by identifying re-contextualising actions as a key to rebalancing organisational paradoxes in favour of the integration of digital technologies in LPSs.

Keywords Lean production, Industry 4.0 and 5.0, Smart production, Paradox theory, Human-centred technology, Production development, Dynamic equilibrium

Paper type Research paper

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1. Introduction

The advent of advanced digital technologies, typified by Industry 4.0, opens up new and innovative opportunities for manufacturing companies to enhance their production systems through connectivity and intelligence (Calabrese *et al.*, 2020; Xun *et al.*, 2021). In this context, many companies are in the process of transforming their operations to smart production (SP) to achieve sustainable and competitive manufacturing practices (Li, 2020; Sebastian *et al.*, 2017; Sousa-Zomer *et al.*, 2020). To enable SP, the required advanced digital technologies need to be carefully planned and integrated into existing production systems (Fattouh *et al.*, 2023; Frank *et al.*, 2019; Leberruyer *et al.*, 2023). During the last few decades, many production systems have been based on Lean production (LP) principles and now face a new paradigm shift to achieve SP (Alavian *et al.*, 2020). This integration process is often characterised by ad-hoc and fragmentary initiatives (Zangiacomi *et al.*, 2020; Björkdahl, 2020), driven by different organisational functions within the company with varying purposes and motivations or distributed production teams located in various worldwide geographic locations (Ahlskog *et al.*, 2023).

Hence, the difficulty of integration is often not the digital technologies themselves but the challenges in changing from a foundation in the "physical world", to the tensions that arise from interweaving the physical with the digital world (Kane *et al.*, 2015; Saabye *et al.*, 2022). Therefore, to leverage the potential of digital technologies into existing Lean-based production systems (LPSs), manufacturing companies need to redefine and reconfigure organisational strategy, structures, infrastructure, resources and culture (Chirumalla, 2021; Putra *et al.*, 2023). In this regard, recent studies in operations management (OM) have proposed utilising a socio-technical perspective incorporating workers and organisational issues to shape the integration of digital technologies aligned to LP (Marcon *et al.*, 2022; Rosin *et al.*, 2020; Tortorella *et al.*, 2019). According to Buer *et al.*, (2021), the simultaneous use of Lean and digital technologies has a greater complementary effect than the individual effects of each approach. The study suggests that rather than being obsolete, LP is still crucial in effectively utilising emerging digital technologies. Several researchers have also emphasised that LP serves as the foundation for implementing digital technologies (e.g. Rossini *et al.*, 2019; Sony and Naik, 2020). The absence of proper coordination and alignment between the two can lead to multiple tensions during the implementation process (Pozzi *et al.*, 2023; Mokudai *et al.*, 2021), e.g. the tensions between centralised digitalisation of processes vs. decentralised improvement work (Holmemo and Korsen, 2023. Tension in this context refers to conflicts or unease that arise when trying to harmonise disparate elements (Putnam *et al.*, 2016). For example, a tension may arise when LP prioritises minimising waste and keeping processes simple, whilst digital technologies introduce complexity and data-intensive processes.

Paradox theory is well suited to addressing tensions between seemingly contradictory approaches (Smith and Lewis, 2011; Putnam *et al.*, 2016) such as LP and digital technologies because it encourages a balanced, dynamic and learning-oriented perspective (Smith and Lewis, 2011). Rather than attempting to eliminate the tensions, it encourages organisations to harness them as sources of innovation and competitive advantage (Raisch *et al.*, 2009). However, the existing literature provides limited insights into the emerging paradoxes associated with integrating digital technologies into LPS (Holmemo and Korsen, 2023; Putra *et al.*, 2023). Researchers have explored organisational paradoxes, underlying tensions and potential management strategies within the context of LP implementation (Maalouf and Gammelgaard, 2016; Erthal and Marques, 2022) or advanced digital (or industry 4.0) technologies implementation (Dieste *et al.*, 2022; Smith and Beretta, 2021; Mishra *et al.*, 2022; Tóth *et al.*, 2022). Nonetheless, a notable gap exists in respect of research that examines the paradoxical tensions arising from the combination of LP and digital technologies, creating a gap in theory that this study aims to fill. Although studies have emphasised the importance of the interplay between LP and digital technologies (e.g. Rossini *et al.*, 2019; Sony and Naik,

2020; Pozzi *et al.*, 2023), there is a lack of micro-level understanding of paradox resolution strategies enabling their integration, considering factors such as temporality (e.g. Poole and Van de Ven, 1989) or organisational ambidexterity (e.g. Secchi and Camuffo, 2019) and how these factors underlie paradoxical tensions.

Therefore, the purpose of this paper is to advance the understanding of paradoxes, underlying tensions and potential management strategies when integrating digital technologies into existing LPS in a manufacturing industry context, with aim of achieving synergies and fostering the development of LPS. More specifically, two research questions are posed:

RQ1. What tensions and organisational paradoxes are salient in the integration of digital technologies in LPSs?

RQ2. How do managers develop appropriate strategies and cope with tensions and organisational paradoxes in the integration of digital technologies in LPSs?

This study adopts a collaborative management research (CMR) approach involving two global manufacturing companies to gain insights into the paradoxical tensions arising when integrating digital technologies into LPSs. In identifying aspects of performing, organising, learning and belonging paradoxes (Smith and Lewis, 2011), we found that resolving one tension might unintentionally create new ones (Poole and Van de Ven, 1989). For instance, separating LPS- and SP-teams manages the performing paradox but this triggers an internal drift rendering a belonging paradox. Consistent with the dissipative equilibrium model (Weiser and Laamanen, 2022), our findings showcase the tendency of internal drift and the forces that constantly push the organisations towards imbalances, which in worst case tilts the organisation and generates vicious cycles constraining any integration of LP and digital technologies (Smith and Lewis, 2011; Holmemo and Korsen, 2023). Thus, the study highlights the sensitivity and temporality of equilibrium states for all paradoxes (Poole and Van de Ven, 1989), and the findings suggest that maintaining dynamic equilibrium requires new strategies like synthesis (Dieste *et al.*, 2022) and micro-shifts of re-contextualising to rebalance paradoxes. Paradox resolutions are as such context-sensitive and system dependent (Schad and Bansal, 2018). Our study confirms the complementary effects of LP and digital technologies (Buer *et al.*, 2021), however, we also identify contradictions that appear in the practical implementation leading to paradoxical tensions (Maalouf and Gammelgaard, 2016; Dieste *et al.*, 2022; Frank *et al.*, 2019; Smith and Beretta, 2021; Erthal *et al.*, 2021).

2. Theoretical framework

2.1 Tensions in integrating digital technologies and lean production

The integration of digital technologies with LP has emerged as a significant area of interest within OM. When reviewing research on tensions in integrating digital technologies and LP, three clusters of papers emerged as shown in Table 1. The first cluster of papers investigate tensions that arise when implementing LP by utilising a paradox perspective whilst not considering perspectives of any digital technologies (Maalouf and Gammelgaard, 2016; Erthal and Marques, 2022; Secchi and Camuffo, 2019). This small set of papers focussed on case-based research and found that organisational culture and the way of organising Lean practices in the process are critical. The second cluster of papers embrace papers on tensions in implementing I4.0 by utilising a paradox perspective, whilst not considering perspectives of LP (Dieste *et al.*, 2022; Putra *et al.*, 2023; Smith and Beretta, 2021; Mishra *et al.*, 2022). These studies are majorly based on single cases and proposed resolution or coping strategies to manage diverse set of paradoxes. Whilst not using paradox theory explicitly, Holmemo and Korsen's (2023) paper distinguish itself from the other papers by also identifying paradoxical relationships between lean and digitalisation.

Table 1. Overview of research on tensions and paradoxes in integrating digital technologies and LP

Authors	Focus	Purpose	Research approach	Main findings	Gap related to our study
Maalouf and Gammelgaard (2016)	LP (Lean Production) and Paradoxes	Managing paradoxical tensions in LP implementation	Case study ($n = 3$ companies)	Identified three types of organisational paradoxes in LP implementation: organising, performing and belonging, and suggested managerial actions to address paradoxes	Integrating digital technologies in LP implementation is not studied or not part of the focus
Erthal and Marques (2022)	LP and Paradoxes	Use paradox theory to investigate the interplay of organisational culture and LP implementation	Single case study	Identified four categories of cultural paradoxes (learning, organizing, belonging and performing) that emerged from the clashes between companies' prior organizational culture (OC) and the LP culture. OC acts as antecedent to both defensive mechanisms and managerial actions	
Secchi and Camuffo (2019)	LP and Paradoxes	Explore the determinants of LP implementation failures	Single case study	How LP implementation tasks are allocated between LP specialists and office managers (the degree of structural versus contextual ambidexterity built in the implementation process) led to failure. The way of organizing in the process can generate variation in LP implementation outcomes and create conditions for failure	
Dieste *et al.* (2022)	I4.0 (Industry 4.0) and Paradoxes	Identify main organisational tensions during the I4.0 implementation	Systematic literature review and workshop with experts	Identified 23 tensions and 18 related resolution strategies in I4.0 implementation. The three core domains of resolution strategies are "technological", "managerial-internal" and "managerial-external", and further differentiated into four types of paradox resolution strategies: contextualisation, structural separation (spatial and temporal) and synthesis, where the most prominent strategy used was synthesis	Industry 4.0 context is general, not related to LP practices

(*continued*)

Table 1.

Authors	Focus	Purpose	Research approach	Main findings	Gap related to our study
Putra *et al.* (2023)	I4.0 (digital opportunities) and Paradoxes	Framing exploration of digital opportunities at the interfaces of organisational hierarchy	Single case study	Top management teams (TMTs) adopt a paradoxical framing of exploration, thereby creating a liminal space with unstable boundaries between exploration activities aligned with core resources (i.e. convergent) and those perceived as divergent. Middle management (MMs) role is crucial in (re)defining the boundaries of exploration in order to find a balance between promoting and constraining the exploration of digital opportunities	Explored I4.0 from organizational hierarchy and leadership perspective, but no consideration of LP
Smith and Beretta (2021)	I4.0 (Digital transformation) and Paradoxes	Investigate how incumbent firm organized and managed its digital transformation journey from a micro-level perspective	Longitudinal, exploratory qualitative single case study	The adopted hybrid organizing model by the firm led to the emergence of three paradoxes at the micro- level (paradoxes of organizing, attention, and knowledge sharing). The organizational members, through their coping with these paradoxes, ended up affecting the hybrid organizing model in both positive and negative ways	No consideration of LP-practices in studying the digital innovation in incumbent firm
Mishra *et al.* (2022)	I4.0 (Digital transformation) and Paradoxes	Identify the central paradoxical tensions in developing resilience in organisations and the role of digital transformation in this process	Single case study	Proposed a conceptual framework representing paradoxes (learning, organizing, belonging, performing) in building resilience during the implementation of digitalisation techniques. Proposed five resolution strategies (goal congruence, adaptive culture, revising business plan and strategies, customer relation management, digitalisation) to manage paradoxes associated with resilient operations	No consideration of LP-practices in analysing paradoxes

(*continued*)

Table 1.

Authors	Focus	Purpose	Research approach	Main findings	Gap related to our study
Holmemo and Korsen (2023)	I4.0 (digital tools) and LP	Examine relationship between LP and digitalisation within Industry 4.0	Single case study	Despite agile development, digitalisation is still characterised by *centralisation* and programmatic planning. Lean production is *decentralised*, with long-term and continuous change processes. This creates challenges for coordination between digitalisation and Lean. Also, the findings indicate a *paradoxical relationship between digitalisation and LP and how the two needs to go hand in hand*. Two main explanations of why digital lean tools lag behind lean production are provided: 1) Digitalisation is agile, but centralised and programmatic, and 2) Digital tools are standardised but locally optimised and asynchronous	Utilise a process theory perspective, rather than paradox theory to provide a discussion on the lean-digitalisation paradox and on why digital LP tools stagnate
Rosin *et al.* (2020)	I4.0 and LP	A characterisation of the impacts of I4.0 technologies on LP principles	Conceptual	There is a strong support for I4.0 technologies for Just-in-time and Jidoka, but little or no support for waste reduction and People and Teamwork. *Technologies from I4.0 do not seem to cover the integratedness of Lean principles but can reinforce the efficiency of these principles*. However, I4.0 does not replace Lean management principles, which must be pursued in companies	Identifying paradoxes in I4.0 and LP is not a focus of this study

(*continued*)

Table 1.

Authors	Focus	Purpose	Research approach	Main findings	Gap related to our study
Sanders *et al.* (2017)	I4.0 and LP	Study the influence of lean management tools on I4.0 through interaction plot matrix	Conceptual	There exist numerous synergies between the Lean management (LM) tools and I4.0 design principles. LM tools like TPM, Kanban, production smoothing, autonomation and waste elimination benefit the most by the introduction of I4.0. *Real-time capability, decentralisation and interoperability design principles offer highest support to the LM tools*. The concept of LM is likely to become more important for successful implementation of I4.0	
Tortorella *et al.* (2019)	I4.0 and LP	Examine I4.0 technologies on the relationship between LP and operational performance improvement	Survey (n = 147 manufacturing companies)	I4.0 moderates the effect of Lean practices on operational performance improvement, but *in different directions*. Process-related technologies negatively moderate the effect of low setup practices on performance, whereas product/service-related technologies positively moderate the effect of flow practices on performance	Although cultural aspects mentioned, paradoxes are not explicitly discussed
Tortorella *et al.* (2021)	I4.0 and LP	Identify the *pairwise relationships* between LP-practices and Industry I4.0 technologies	Survey (n = 147 manufacturing companies)	I4.0 technologies are positively correlated with LP-practices A proposed Lean automation framework to guide the integration of I4.0 into LP implementation based on the relationship level between practices and technologies from both approaches. The *framework can potentially overcome traditional barriers and challenges faced in a usual LP implementation*	Identifying paradoxes in I4.0 and LP is not a focus of this study

(*continued*)

Table 1.

Authors	Focus	Purpose	Research approach	Main findings	Gap related to our study
Buer *et al.* (2021)	I4.0 (digitalisation) and LP	Investigate relationships between LP use, factory digitalisation, and operational performance	Survey (n = 75)	Lean manufacturing and factory digitalisation individually contribute to improved operational performance. *When used together, they have a complementary (or synergistic)* effect that is greater than their individual effects combined	Identifying paradoxes in I4.0 and LP is not a focus of this study
Rossini *et al.* (2019)	I4.0 and LP	Examine the impact of the interrelation between I4.0 and LP production practices on the operational performance	Survey (n = 108)	Higher adoption levels of I4.0 may be easier to achieve when Lean production practices are *extensively implemented* in the company. In opposition, when processes are *not robustly designed* and continuous improvement practices are not established, companies' readiness for adopting novel technologies may be lower	
Mokudai *et al.* (2021)	I4.0 (Digital technologies) and LP	Explore how production systems characterised by the LP principle addresses digital transformation	Case studies (n = 7)	Japanese automotive manufacturers selectively adopted digital technologies to enhance the existing Lean production system, labelled as Lean augmentation. There is a potential of digitalisation to limit kaizen, the roles of human involvement and organisational coordination in digitalised manufacturing, and there are potential risks such as *"Lean traps"*	Although some challenges such as Lean traps identified, studying paradoxes is not a focus of this study

(*continued*)

Table 1.

Authors	Focus	Purpose	Research approach	Main findings	Gap related to our study
Kumar *et al.* (2023)	I4.0 and LP	Analyse research works on the integration of LP and I4.0 techniques	Systematic literature review	Identified three clusters of research work: development of conceptual models and frameworks for integrating Lean and I4.0, analysing the *compatibility between the two techniques* for better implementation of one another, and the techniques' combined impact on operational performance	Identifying paradoxes in I4.0 and LP is not a focus of this study
Von Haartman *et al.* (2021)	I4.0 (digital technologies) and LP	Explore the relationship between three types of LP-practices and the digital technologies	Survey (n = 548)	Three types of Lean practices – Lean flow, Lean work organisation and Lean human resource management – are strongly associated with firms' adoption of digital technologies in production by manufacturing firms. *A firm's experience of Lean may act as an absorptive capacity* when adopting digital technologies	
Bittencourt *et al.* (2021)	I4.0 and LP	Identify the synergy between I4.0 approach and the role of LP	Systematic literature review	Lean is seen as an important agent in the implementation I4.0, and Lean concepts such as work standardisation, organisation and transparency are fundamental in supporting the implementation and consolidation of the I4.0. *Management, processes and people are key players in the companies' transformation*	

Source(s): Authors' own creation

The third, and largest cluster of papers, is focussing on the integration of I4.0 and LP, but do not explicitly utilise a paradox perspective (Rosin *et al.*, 2020; Sanders *et al.*, 2017; Tortorella *et al.*, 2019, 2021; Buer *et al.*, 2021; Rossini *et al.*, 2019; Mokudai *et al.*, 2021; Holmemo and Korsen, 2023; Kumar *et al.*, 2023; Von Haartman *et al.*, 2021; Bittencourt *et al.*, 2021). Most of these studies are dominated by survey method, compared to case studies, which is commonly used when exploring paradoxes in the integration of either I4.0 or LP. These survey studies confirmed that there is an interesting synergistic relationship between I4.0 and LP concepts and in combination they have a better effect that can lead to improved operational performance. Moreover, LP is considered as a foundation for successful implementation of I4.0. One plausible explanation to a successful integration of I4.0 and LP is that companies need to have management engagement and improvement processes in place (Bittencourt *et al.*, 2021), which implies the importance of an improvement culture and that improvement initiatives of various kinds, in which digitalisation is one source for improvements, needs to be balanced. Hence, a mature LP approach seems to create a readiness for I4.0 integration (von Haartman *et al.*, 2021). However, there are less tensions or contradictions identified in the survey studies of I4.0 and LP. In the two case studies, contradictions are more salient. For instance, Mokudai *et al.* (2021) describes what they refer to as a lean trap, i.e. when problems and potential digital technology solutions are defined by people operating within the current LPSs, this might limit the view of, and interest in, more radical and disruptive solutions. In a similar vein, Holmemo and Korsen (2023) identify the *lean-digitalisation paradox* providing an explanation for the challenges in integrating I4.0 and LP by asserting that digitalisation is agile, yet centralised and programmatic and that digital tools are standardised yet locally optimised and asynchronous.

2.2 A paradox theory perspective

When new elements, such as digital technologies, are intended to be integrated into existing LPSs, differences in intents and priorities generate tensions that can be perceived as contradictory, thus leading to what have been framed as organisational paradoxes, which in one way or the other need to be managed to positively influence organisational development (Putnam *et al.*, 2016; Dieste *et al.*, 2022). Organisational paradoxes are constituted of contradictory yet interconnected elements that exist simultaneously and persist over time (Eisenhardt, 2000; Smith and Lewis, 2011). One example of a well-known paradox in organisations is the one between the two modes of organisational learning exploitation (i.e. activities conducive for short-term efficiency) and exploration (activities conducive for a long-term effectiveness and innovation) (March, 1991).

Smith and Lewis (2011) distinguish between four paradoxes commonly observed in organisations. *Performing paradoxes* arise from the need to meet diverse stakeholder expectations, resulting in competing strategies and goals, concerning the plurality of organisational goals, where stakeholders may have divergent views on what constitutes organisational success, such as financial goals versus social goals. *Organising paradoxes* stem from organisational systems, leading to competing designs, structures and processes, hence, they revolve around different approaches to structuring work, such as centralisation vs. decentralisation or standardisation vs. customisation. *Belonging paradoxes* occur when individuals seek both self-expression and group affiliation, creating tensions between personal identity and collective relationships and involves navigating between the individual and the collective. *Learning paradoxes* highlights the balancing act between existing knowledge (exploitation) and new ideas (exploration) i.e. the need to build upon existing knowledge and practices whilst also embracing innovation (Ozanne *et al.*, 2016).

Apart from the theoretical recognition of organisational paradoxes, these paradoxes also need to be accepted and embraced by actors in an organisation because failing to manage paradoxes can lead to either stagnation or fragmentation (Dooley and Van de Ven, 1999; Raisch *et al.*, 2009). The first step of managing or resolving paradoxes is making sense of and accepting a paradoxical tension, which means to recognise that the two sides/elements are simultaneously conflicting and interconnected and therefore that they require a comprehensive and joint solution. Acceptance also implies an awareness that prioritising one element over the other will create new issues elsewhere or later with possibly increased magnitude and range (Poole and Van de Ven, 1989; Smith and Lewis, 2011). Once a paradox is accepted and embraced, different type of actions and strategies to manage or resolve the paradox need to occur to create or maintain the dynamic equilibrium of the paradoxical tension (Smith and Lewis, 2011; Dieste *et al.*, 2022; Weiser and Laamanen, 2022), which also has been the main focus in theory on organisational ambidexterity, i.e. the organisation's ability to manage the different poles of a paradox simultaneously (Raisch *et al.*, 2009; Secchi and Camuffo, 2019).

Previous research has identified different types of resolutions strategies to manage the juxta-positioned poles of a paradox simultaneously (Dieste *et al.*, 2022). One type is structural separation (cf. structural ambidexterity) and refers to either 1) spatial separation, which means placing the paradoxical elements at distinct places or levels of context, or 2) temporal separation, i.e. allocating them in diverse time periods. Whilst other strategies are aiming for contextualisation as a strategy. Contextualisation is mainly focussed on the cognitive or behavioural aspects (cf. Raisch *et al.*, 2009 on contextual ambidexterity) and helps managers to develop the capability to think paradoxically (Smith and Lewis, 2011; Xiao *et al.*, 2019). because it (1) tries to soften the paradoxical tensions and make them more "workable" and (2) helps in "alleviating tensions by identifying relevant stakeholders as well as their aims and to define how they can be integrated to address the tension" (Dieste *et al.*, 2022, p. 3). To enable contextualisation, the managerial practice of facilitation of learning has proven to be a key factor (Maalouf and Gammelgaard, 2016). A third strategy is synthesis and involves introducing new elements (such as novel organisational procedures and routines or technological solutions) that can reconcile both poles of the paradox (Dieste *et al.*, 2022).

The three types of resolution strategies correspond to what Weiser and Laamanen (2022) frame as "pre-emptive balancing" in their conceptual dissipative equilibrium model, which are the strategies used by management for splitting (i.e. separation strategy) and integrating (contextualising strategy) the poles of the paradox. However, another critical dimension of managing organisational paradoxes advocated by Weiser and Laamanen's (2022, p. 8) model is that "the organisational system is continually pulled out of equilibrium by organisational and human tendencies to drift, as well as by the unintended consequences of interactions between actors". As such, the dissipative equilibrium model also views paradox management also as a continuous process of navigating paradoxical tensions through micro-shifts, requiring apart from the pre-emptive balancing of managers, continuous corrective and proactive actions to maintain organisational balance.

3. Methodology

3.1 Research approach

This study is based on CMR (Shani *et al.*, 2008) involving two global manufacturing companies. The study seeks to highlight the paradoxes, underlying tensions and potential management strategies when integrating digital technologies into existing LPSs, with the aim of achieving synergies and fostering the development of LPS. CMR is well suited for the involvement of multiple perspectives and expertise (Coughlan *et al.*, 2016), which by providing field presence

(Langley and Klag, 2019) and an insider's gaze (Brannick and Coghlan, 2007), is crucial for understanding and addressing the intricacies of this integration. CMR is particularly valuable for both enhancing practical applications and providing valuable contributions to theoretical frameworks in the field of OM and organisation studies (Shani *et al.*, 2012). Further, it enables a holistic and comprehensive understanding of tensions and organisational paradoxes (Shani *et al.*, 2008). Thus, the possibility of obtaining versatile and complementary insights is opened, which is critical since the integration of digital technologies into LPSs is a complex and multifaceted challenge that involves various stakeholders at both the strategical and operational levels.

We applied two cases to collect the relevant data. Based on current practice (Goffin *et al.*, 2019), we opted for theoretical sampling to select cases that would provide insights into the integration of digital technologies into existing LPS. The selection of the cases was informed by the overall CMR approach and the study's purpose, which highlights the following aspects: the relationship between the researchers and the practitioners, the existing LPS and the strategies and organisation for integrating digital technologies.

First, we selected two global manufacturing companies (Table 2), Scania and Volvo Construction Equipment (Volvo CE), each leading within their respective market segments, with which well-established and long-term collaboration between researchers at the university and two managers (PhDs) already existed. The two managers, expected to contribute to the collection of a rich dataset and help in providing valuable insights into industry and indeed they actively contributed to the framing of the research focus and the study design (Shani *et al.*, 2012). All five authors actively participated in the various phases of the study, including data collection, thorough data analysis, collaborative interpretation of the findings and the subsequent identification of potential action steps. The two managers at the companies were engaged as insider-researchers (Brannick and Coghlan, 2007) and as they were "native" to the organisations they were instrumental in helping to identify diverse stakeholders who could provide rich descriptions of the integration of digital technologies into the existing LPS and provide in-depth information about its key activities, supported by documents and background information. This provided the opportunity to contrast various perspectives on the integration of digital technologies into an existing LPS.

Second, we considered it as important to select cases where there was longstanding experience of working with LP. Both companies possess over 2 decades of experience in working with LPS and have been highly successful in their implementation of LP capabilities for improvement of the LPS. Thus, a key selection criterion was the maturity of the companies in their Lean journey.

Third, both companies continuously work with LPS-development and considered it as critical to adopt and integrate advanced digital technologies in finding new competitive and sustainable production approaches. Further, both companies have implemented actions dedicated to digital technologies at both company and factory level with well-defined strategies and organisations and both have high expectations about to be derived from a transformation to SP. Accordingly, both companies had already gained experience in integrating digital technologies into their existing LPS.

3.2 Data collection

With a shared interest in improving comprehension of the encountered challenges, the managers played an active role in both planning and executing the study (Shani *et al.*, 2012). Throughout the process, the team maintained ongoing interaction, including face-to-face and virtual meetings, as well as regular email exchanges. The study, which forms the basis of this paper started in autumn 2022. Data was primarily gathered in in-depth interviews with key respondents, supplemented by case documents, two focus group sessions and regular research team meetings where the expertise of the two managers was drawn upon. This approach was well-founded due to the extensive collaborative history and deep knowledge concerning LP and digital integration within the two companies. This is especially true when working with a relatively focussed and uniform

Table 2. Case description and overview of respondents

Case descriptions	Respondents**	Expertise and background
Scania, is a global manufacturer of heavy trucks and buses, is owned by Volkswagen AG through its subsidiary, Traton SE. The company's main site and headquarters are in Södertälje, Sweden *Lean production teams*: The implementation of Lean production practices at Scania traces back to the 1990s, driven by knowledge sharing and collaboration with Toyota. The concept underwent various iterations and evolved into a company-specific system* known as the Scania Production System (SPS) – referred to as LPS in this paper. The dissemination of the LPS has spread organically through the company and is currently managed through a network of semi- independent teams (offices) ranging in size and responsibility. The global SPS office is responsible for the highest level of abstraction in the system all the way through organisationally specific global offices down to small teams on a factory or division level. In total, worldwide, several hundred personnel work at the SPS teams with the purpose of aligning the organisation and training managers and staff in LPS. *Smart production teams*: To support integration of digital technologies at Scania, a Smart production team has been established and is organised as a physical space – Future factory – and located on one site. It is described as an innovation or prototype arena for digitalisation of operations and is governed by a board including managers representing different units in manufacturing operations. The Smart production team at the Scania case is responsible for exploring, developing knowledge and experience of concepts that hold the potential of later being introduced as part of the LPS and operations. The work is carried out in close collaboration with other units such as Industrial Operations, IT-departments, Digital Office, the unions, universities, and other company brands.	Smart production manager Operations, engaged with Smart production team LPS manager LPS manager 1 follow-up focus group interview with 2 respondents to further explore and validate identified paradoxes with the respondents	Innovation engineer, Background manufacturing Process engineer, Background assembly SPS Manager, Background as manager and Workshop manager of paint shop Business Developer, Background as manager of SPS office in assembly

(*continued*)

Table 2.

Case descriptions	Respondents**	Expertise and background
Volvo Construction Equipment (Volvo CE) is a global total solution provider of heavy machinery, solutions, and soft products, including excavators, wheel loaders, road machinery, and articulated haulers. The company operates at 14 production sites and 12 R&D sites worldwide *Lean production teams*: In 2007, Volvo introduced its Volvo Production System* (VPS) – referred to as LPS in this paper – and has since implemented the concept, primarily within its operations division responsible for production. Prior to the launch of LPS, Volvo CE had a long history of applying similar LP concepts, such as Total Productive Maintenance (TPM). Today there is a global LPS-team and local LPS coaches for all sites. The global LPS office is responsible for developing LPS as such, developing methods, tools etc. and supporting all parts of the organisation, including the local LPS coaches. Local LPS coaches are responsible for anchoring and driving LPS principles, methods, and tools locally *Smart production teams*: To support integration of digital technologies, Volvo CE has chosen a network structure of their Smart production team, like the one used for organising the LPS support: One global core Smart production team – the Factory-for-tomorrow – in combination with local Smart production teams at all 14 production sites. All sites' local Smart production teams are cross-functional teams and consist of people from different functions, e.g. manufacturing engineering, IT, logistics, maintenance, and quality, also having different roles in the line organisation	Smart production manager Smart production team Smart production team LPS manager Operations LPS manager 1 follow-up focus group interview with 4 respondents to further explore and validate identified paradoxes with the respondents.	Advanced manufacturing engineering manager, background manufacturing engineering manager Maintenance developer, background maintenance Project leader industrialisation projects, background manufacturing engineering Global VPS coach, background VPS Production leader and operator, background production leader, team leader and operator Local VPS manager, background production manager

Note(s): *cf. company-specific production systems, XPS in Netland (2013)
**Respondents sampled based on their responsibility and engagement in the ongoing work with the integration of digital technologies in LPS
Source(s): Authors' own creation

population that aligns with the study's purpose (Hennink and Kaiser, 2022). The 11 respondents (Table 2), selected in accordance with purposeful sampling principles (Patton, 2002), provided comprehensive insights into both the strategic and operational aspects of LP and digital technologies integration. The in-depth interviews were conducted solely by university researchers, without active manager involvement. To ensure a structured approach for the interviews, an interview guide was developed, focussed on three main themes:

(1) The development process of new technologies and digital services, including questions such as: *How are SP-team organised and who are your stakeholders? Which digital technologies do you usually work with SP-team? Describe the typical development process? What are key stages and decision points (Start/stop/continue)? Which functions are involved in the development process?*

(2) The relationship between digital technologies, SP and LP, including questions such as: *Which, if any, digital technologies seem to be more prominent in enhancing LP? Why? What experience have you gained/what lessons have you learnt from deploying digital technologies in LP?*

(3) The integration and implementation of new technologies within the organisation, including questions such as: *How is the handover of technology to a recipient/another organisation handled? How is existing experience and knowledge preserved/supplanted/amended in the receiving organisation due to the new solution?*

Additionally, two focus groups sessions were organised, one at each company. In total, six respondents participated in the two sessions. The dual aim of the focus group interviews was to gain more detailed understanding and further explore tentative findings derived from the in-depth interviews. In the focus groups interviews the respondents took part of tentative findings and illustrations and in both sessions, there was a strong recognition, i.e. gain face validity, amongst the respondents an indication that we had reached saturation in terms of enough data to underpin our conclusions.

3.3 Data analysis

Data analysis was a collaborative effort involving all authors. Findings were placed in "collective inquiry" where the tensions of the integration of digital technologies were investigated. Inclusion of the two in-case managers, with their first-hand experiences and expertise within the companies, proved invaluable, providing a deep contextual understanding of the respondents' statements and contributing to a more nuanced interpretation of the practical examples shared by the respondents.

Literature analysis commenced using the four paradoxes performing, organising, belonging and learning as preparatory concepts to provide direction in looking for patterns in the data. Consequently, our comprehension and utilisation of the concepts evolved concurrently with data collection and analysis through a structured and deliberate process of bringing together different concepts. These concepts were not explicitly introduced to the respondents but were employed to aid the researchers in theory development. Our data underwent thorough analysis based on the guidelines for thematic data analysis (Miles *et al.*, 2018) encompassing three simultaneous activities: data reduction, data display and conclusion drawing. Initially, the interviews were recorded and transcribed, allowing us to become thoroughly familiar with the data. Each researcher read every transcript repeatedly, identifying interesting phrases that were transferred into a spreadsheet. This process facilitated the identification of common constructs and potential relationships through cross-interview analysis (Eisenhardt and Graebner, 2007).

Subsequently, we applied concepts from the analytical framework (Weiser and Laamanen, 2022) to analyse: characteristics of the integration of digital technologies;

acceptance of organisational paradoxes; searching for tendencies to drift and related tensions; and searching for patterns of corrective and proactive actions/strategies. The analysis resulted in first-order categories of codes that represented respondents' perspectives, expressed in their own words, phrases, or terms (Miles *et al.*, 2018). These provisional codes served to organise subsequent data whilst remaining open to the identification of emerging codes. As a result, the emergence of themes was driven by both theory and data. Next, the analysis focussed on identifying links and patterns by comparing and combining the first-order categories, which lead to the formulation of second-order themes, including a list of initial codes divided into categories and created preliminary drafts illustrating how the categories related to the theoretical themes. This process involved a thorough exploration of the meaning, distinctions and commonalities of codes and categories amongst the authors, culminating in the development of a draft thematic map, representing the different types of tensions involved related to the four paradoxes proposed by Smith and Lewis (2011), Finally, we conducted a comprehensive review of the labelling of codes, categories and themes to ensure their clear definition, designation and alignment.

3.4 Research quality

To enhance the validity of the research, the author team including the two managers had extensive discussions on the initial conceptual framework and subsequent empirical findings. The CMR approach allows for structured exploration and exploitation by practitioners and researchers with the intention of reducing the likelihood of drawing false conclusions from the data collected (Coughlan *et al.*, 2016). To minimise observer bias all interviews were done by at least two of the researchers and the analysis was done jointly (Eisenhardt and Graebner, 2007). Although the main focus of the research has been to identify patterns concerning paradoxical tensions rather than validating them, the topic is rather unexplored and thus the pattern matching was difficult and can have impacted the validity negatively (Denzin and Lincoln, 1994). To mitigate the negative effects of conducting individual interviews, we completed them with focus groups to validate preliminary findings and gain face validity of the identified paradoxical tensions from the individual respondents. Further, to strengthen external validity data were collected from multiple respondents representing different internal functions as well as different sources of evidence aiming to triangulate responses and data. For example, we compared tensions identified from the interviews with governance models (e.g. technology roadmaps) of the respective company. At the start of each interview, we explained the paper's idea, clarified key concepts to minimise the risk of misunderstandings.

4. Empirical results

This study took place in the context of manufacturing operations in two companies: Scania and Volvo CE. Based on the principles of LP and inspired by the Toyota Production System, both companies have over the years gradually developed their own company-specific LPS (see Table 2), which prescribe and standardise the best practices of daily production in manufacturing operations, as well as providing a guide on how to work on short-term (continuous improvements) and long-term production system development.

Over the last five years, a critical issue has been how to increase the utilisation of advanced digital technologies and how the current LPS can be transformed into a SP system. That is, the cases are not about building a Smart factory from scratch, rather it is about finding ways to gradually implement new digital technologies and make them fit with already established production settings to contribute to an overall efficient and effective LPS. Both companies utilising a future strategy when making investments in new machinery by ensuring that they are "IoT ready" for potential future needs, even if currently they have not yet identified the

possibilities or even the needs. At Scania, examples of digital tools already applied or explored are visual aids for the assembly workers such as smart glasses that provide information in real time, digital team boards allowing for better storage and retention of production data enabling better analysis of trends and patterns in operations and enhanced systems for data driven maintenance. All these solutions are intended to increase productivity, enable problems-solving and control variation in the process in line with the intentions of the LPS. At Volvo CE, digital tools and technologies applied or explored are, for example, digital Lean boards to support real-time updates for daily production meetings and to obtain real-time status of the factory. Other technologies are brownfield connectivity to connect old machines/equipment, vision systems to automatise quality control, exoskeletons to support heavy lifts, additive manufacturing for tools and fixtures, XR-technologies to facilitate remote digital collaboration and collaborative robots to remove repetitive tasks for humans.

To support the work on the exploration and implementation of digital technologies in production, both companies have established a type of specialist support function, referred to as a "smart production team" (SP-team), with the aim being to increase the organisational performance in manufacturing operations over the medium to long term based on a set of strategies and technology roadmaps. The SP-teams were created to explore new information about advances in digital technology and develop competence in digitalisation and future manufacturing technologies. When first created, the SP-team at Scania used a top-down approach because they were pushing new digital technologies at production, whilst to begin with, Volvo CE adopted a bottom-up approach in which the objective of exploring and implementing digital technologies was to accelerate the company's LP journey, whilst at the same time adapting to the future by taking advantage of the digital transformation. Later, however, new approaches evolved and now in both cases the mission primarily to inspire the production units and sites and support them in how to apply and utilise digital technologies.

In both companies, the integration of digital technologies into the existing LPS has been associated with many competing demands and prerequisites that need to be prioritised. Hence, the work on integrating digital technologies is characterised by a continuous process of negotiation and compromise between the goals, needs and requirements of multiple stakeholders. For example, when innovation engineers responsible for the integration of digital technologies are working on testing and implementing new sensors for real-time monitoring of an assembly line with the long-term goal of reducing disturbances and waste, this presupposes a disruption of the daily production and interference with the day-to-day needs of production managers and operators, who are under pressure to maintain a steady production of goods and who must be ready to manage disturbances to avoid unplanned disruptions. Compared to the work of the LPS-team and SP-teams, the work of managers and operators in production is in general much more short-sighted focussing as it does on operational performance and key performance indicator's (KPI's) related to the day-to-day production. Hence, there is a tension between long-term goals and short-term goals. Furthermore, a key characteristic of both companies, is that the senior production managers have a strong level of autonomy, which means that they can largely avoid or ignore any "push" from the support functions or other instances and decide autonomously when to implement which new ways of working, including new technologies.

Even though it shares the goal of improving the operational performance of the LPS, the integration of digital technologies in the existing LPS is thus characterised by multiple contradictory goals and demands, different time perspectives, changes to requirements, etc. that arise at the intersections between different stakeholder interests, such as between production, SP-team, LPS-team and senior management.

4.1 Acceptance of organisational paradoxes

Previous research provides evidence of the potential synergies between LP and digital technologies for production system development (Buer *et al.*, 2021). In this section we address **RQ1** and by adopting a paradox theory (Smith and Lewis, 2011) perspective, it allows us to a get a more detailed understanding of tensions and related paradoxes (see Figure 1) that first need to be accepted and embraced and then secondly be pre-emptively balanced and work through (Weiser and Laamanen, 2022) to enable the integration of digital technologies in LPS. Illustrating quotes of paradoxes are also presented in Table 3.

4.1.1 Performing paradox. In the analysis, it becomes apparent that the goals and intentions of the different stakeholder interests in manufacturing operations exhibit differences, both in terms of scope and **time horizons,** generating the paradox of **current goals vs. future goals**. For example, the production units, with their decentralised authority, operate under one performing regime with a strong emphasis on optimising day-to-day production of goods, which are at variance with the long-term goals of the SP-team. Additionally, many respondents also point to the "senior management" level, highlighting the need for shared understanding of goals or time horizons between LPS-team, SP-team and production units. This potential disparity between senior management and the other stakeholders establishes a second performing regime.

A second performing paradox concerns **competing but potentially synergetic approaches** to LPS-development. In the interaction between goals related to LP and goals related to digital technologies two distinct performing regimes can be identified, that generate tensions due to contradicting priorities. SP-teams are focussed on exploring new technologies and capabilities, which contrast with the incremental improvement approach of already established production technologies favoured by the LPS. To manage the paradox structural separation into different support structures (LPS-teams and SP-teams) then becomes a solution that allows the companies to withhold focus on both issues and instead build

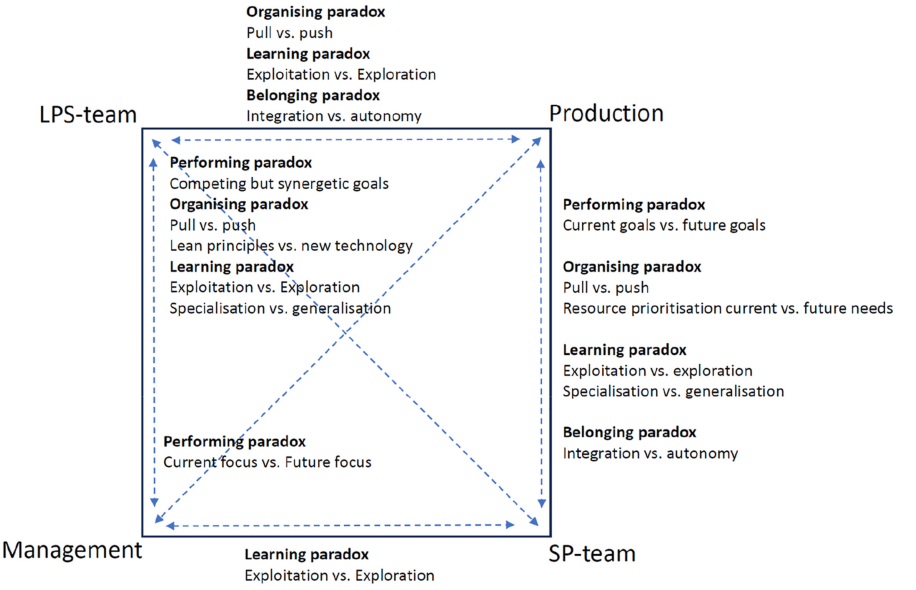


Figure 1.
Organisational paradoxes in the integration of digital technologies in LPS

Source(s): Authors' own creation

Table 3. Overview of acceptance of organisational paradoxes, internal drift and re-contextualising

Acceptance and embracement of organisational paradoxes	Internal drift towards imbalances	Re-contextualising
Performing Paradox *Current goals vs. future goals. Production* vs. s*enior management/SP-team* accepting the dynamics of working towards both short and long-term goals *"I think what management needs to do is to be aware that if an organisation becomes too conservative, we will have a problem in the future. And if an organisation becomes too future focused we will have problem today. . . . As management you have to beware of the organisation ending up in one of these extremes. But where the optimum is I'm not quite sure if anyone ever can say it, and I think it actually shifts, so, I'm not even sure that we should try to find an optimum here. I'm just, I think as a management system, we have to avoid the extremes". (LPS manager, Scania)* *"I think it's a difference in time perspective, smart production looks ahead a number of years and perhaps decades. But within our operations, we're looking at hours or minutes." (Operations, Scania)* *Competing but potentially synergetic goals. LPS-team vs. SP-team* recognising and accepting the complementary effects of digitalisation and the LPS in relation to overarching goals *"It is important for the organisation to recognize that digitalisation and lean can walk hand in hand. You can do lean but if you miss digitalisation, you miss the opportunity to achieve great results. You can do digitalisation itself but miss what is the true problem we aim to solve. We need to recognize a problem first and then reflect about the methods that we have in lean today can solve this problem, but also to look at digitalisation and what it could help to gain even greater results". (Smart production manager, Volvo CE)*	*MYOPIA* Drifting the *performing paradox* when production becomes too short-sighted and prioritise day-to-day production goals and KPI's and neglects future goals *DETACHED* Drifting the *performing paradox* when changes in the organisation and new strategic initiatives is not anchored in the organisation	*Pacing*: Synchronising time horizons *Patching*: Aligning and connecting disparate knowledge elements

(*continued*)

Table 3.

Acceptance and embracement of organisational paradoxes	Internal drift towards imbalances	Re-contextualising
Organising Paradox *Pull based on needs vs. push based on opportunities. Production vs. SP-team/LPS-team* acceptance through being "just-in-time" to the experienced needs in production to alter the perception from a "sense of push" into a "sense of pull" and find the nexus of current and future production needs and digital technology affordances *"If there is need and pull then the chances of a method/technology or whatever it could be used to a higher extent and more successful implementation than if it is a push." (Smart production team, Volvo CE)* *"An example is the exoskeleton to improve ergonomics for staff. We put it down two years ago. Since then, there has been a demand from the logistics side, a person who really seems to be able to find the benefit of it, so all of a sudden there is a pull from the organisation in technology. We tried to push it out two years earlier, then there was no need" (Volvo CE, focus group)* *"And I think at the beginning there were maybe unreasonable expectations thinking that smart factory will change completely how Scania work nowadays. There are more reasonable expectations where they understand that it is a unit to support in development. But they cannot do everything themselves, so we cannot do everything ourselves. We need to all work together." (Smart production manager, Scania)* *Using LP principles vs. implementation of new technology. LPS-team vs. SP-team* anchoring decisions to implement new technologies by using the lean principles and identify root cause needs *"I'm spending lot of money on AGVs but maybe the real solution is reducing the inventory instead of carrying parts from point A to B. "(Smart production manager, Volvo CE)* *"You know, implementing the technology itself, maybe the first thought wouldn't be to follow the lean manufacturing core of push [meaning pull] production. So without LPS, I think we would be unstructured." (Operations, Scania)* *Resource prioritisation current production vs. future smart production needs. Production vs. SP-team/LPS-team* allocate resources to production staff to engage in smart production testing *"Why is it so difficult to do a matchmaking between the needs and the possibilities . . . maybe people need time to work with this, the smart production team have had time, but people outside don't." (Smart production team, Volvo CE)*	*TECHNICAL MONUMENTS* Drifting the *organising paradox* when production experience a sense of push of new promising new technologies that, however, are not aligned with current ways of operating and doing improvement work in production *MYOPIA* Drifting the *organising paradox* when critical resources are not provided to support the possibilities for testing and integrating new technical solutions in production, which in the long run constrain production innovation	*Empowering*: Learning and competence development *Patching*: Aligning and connecting disparate knowledge elements *Pacing*: Synchronising time horizons *Patching*: Aligning and connecting disparate knowledge elements *Pacing*: Synchronising time horizons

(*continued*)

Acceptance and embracement of organisational paradoxes	Internal drift towards imbalances	Re-contextualising
Learning Paradox *Exploitation vs. Exploration. Production vs. management vs. SP-team vs. LPS-team* maintain continuous learning and competence development to embrace new digital capabilities *"We have daily production meetings and we talk about what happened yesterday, I would prefer that we talk about what happen next week or next of tomorrow and combining data on that. What is coming is disruptive change, that we need to produce our heritage and we need to produce electrical machines and products–that will be disruptive change and it is challenging when people have built same things for 20 years". (Smart production team, Volvo CE)* *"Not all new ideas are good ones, actually. Most new ideas are bad ones, giving the current context, but the context changes so nothing is static, and we still need to evolve." (LPS manager, Scania)* *Specialisation vs. Generalisation. Production vs. SP-team vs. LPS-team* connecting production staff with different specialist functions and knowledge to extend the knowledge base for smart production *"Connecting Smart factory with the processes–it is a sort of dialogue. But it could be much more organized than it is . . . //. . . We need people that serves as bridges and that sort of has a foot in both worlds. Right now, I believe that we are a bit too specialised; you're working either with future development or you're trying to survive in an operation." (LPS manager, Scania)* *"And I have been working in the past three years a little bit like, uh, you would say like a proxy between the smart factory and the production units. So it's a little bit of a mix of" (Smart production, Scania)* *"We have a small lab environment where we can meet . . . that's where the team actually sit and work . . . for us, I think that has been very good . . . Also, we've had good competence in the organisation with it . . . I mean, we've had almost or every competence that we need locally . . . Yeah. So that has also been a good prerequisite that we aren't too dependent on specialists or global support or external support" (Smart production manager, Volvo CE)*	*TECHNICAL MONUMENTS* Drifting the learning paradox when smart production is perceived as "good in itself" and not necessary in any identified need from production *DOGMA* Drifting the *learning paradox* when basic assumptions of lean and the LPS become axiomatic and not seen as principles that continuously needs to be adapted *DETACHED* Drifting the *learning paradox* when senior management does not share the same pace in learning as smart production/LPS and cannot make informed decisions on future investments and implementation of technologies	*Empowering*: Learning and competence development *Leveraging*: Exploring and transforming *Empowering*: Learning and competence development *Patching*: Aligning and connecting disparate knowledge elements

(*continued*)

Table 3.

Table 3.

Acceptance and embracement of organisational paradoxes	Internal drift towards imbalances	Re-contextualising
Belonging Paradox *Integration vs. autonomy. LPS-team vs. production vs. SP-team* sense of being integrated and aligned with shared goals for digitalisation/LPS, vs. sense of autonomy and empowerment in improvement work "*What I would hope for in the future is that you have an exchange of people. People from operations work for a brief time, six months or a year within smart factory, and people from smart factory work for sometimes within the operations itself. Get a network of people you know. They know they can trust you. You can trust them" (LPS manager, Scania)* "F*or maintenance area, no one outside maintenance should push. People from maintenance gets lot of questions from other functions (logistics, quality) etc about if they have heard about predictive maintenance, and of course they have heard about it . . . It needs to come from inside, maintenance are best to drive out waste from maintenance and then they need to see if they can use digital tools" (Smart production team, Volvo CE)*	*TECHNICAL MONUMENTS* Drifting the *belonging paradox* when production operators become alienated and lose a sense of agency in the continuous improvement work	*Patching*: Aligning and connecting disparate knowledge elements

Source(s): Authors' own creation

expertise competence. However, the structural separation triggers an internal drift of the belonging paradox. To achieve synergies between the two perspectives, there is also a need for mutual understanding of one another's goals, approaches and potential benefits, a fact that is illustrated by one of the SP managers at Volvo CE: *"We need to recognize a problem first and then reflect about the methods that we have in Lean today can solve this problem, but also to look at digitalization and what it could help to gain even greater results"*. Cross-functional work across specialist functions and production then becomes a key to the synthesis-resolution strategy. The four performing regimes embody different underlying motivations that are contradictory and generates tensions, yet need to be interconnected as part of the performing paradoxes to positively influence the LPS as a whole.

4.1.2 Organising paradox. Both companies express a concern about incorporating digital technologies in ways that might introduce inflexibility and constrain future improvement work. To avoid built in inflexibility in the integration of new technical solutions the companies try to manage the paradox of ***pull based on needs vs. push based on opportunities***. Both companies emphasise the significance of developing both need and opportunity-based solutions that are easily comprehensible to the users, such as operators and technicians. It is crucial for the end users of these solutions to have confidence in their effectiveness, allowing for their integration into the LPS. This can be achieved through either push or pull mechanisms. According to the respondents, a need-driven pull-approach allows them to address the correct problems with the most suitable short-term solution, whether it be a digital solution or some other form of solution. Adopting a push-approach typically requires a long-term perspective because an increased awareness of possibilities must trigger the will to invest time and resources.

Related to the paradox of pull vs. push, is the paradox of **using LP principles vs. implementation of new technology**. Respondents from Volvo CE have previously highlighted the importance of introducing new technologies and have performed the necessary work to understand the root cause of the situation and, as such, utilise LP principles before subsequently incorporating the relevant digital technologies. For example, it was discovered that in certain cases, the most effective solution lies in waste reduction rather than deploying new technology. This was echoed by respondents at Scania, who suggested that immediate deployment of new technology should not always be the initial solution because the optimal solutions are constantly evolving.

However, when performing production development by integrating digital technologies, it becomes evident for both companies that it triggers the tension of **resource prioritisation between current operations and future SP needs**. The production units are structured to enable control and resource efficiency, whereas the SP-team is organised to support an explorative approach, involving experimentation, variation and risk-taking (March, 1991). A similar dynamic can be observed in the relationship between LPS-teams and production, where the purpose of the LPS-team's is to develop, maintain and disseminate Lean methods and tools. Respondents noted that individuals responsible for implementing solutions require time for this task, but that daily operations take precedence, resulting in less focus on digital transformation. Hence, allocating resources to production staff so that they can become part of the SP-team (or vice versa) is one key to become engage in the testing and development of new and future solutions.

4.1.3 Learning paradox. In previous research, **exploitation vs. exploration**, is perhaps the most well-known example of the learning paradox (cf. March, 1991) and is also salient in the two cases. The importance of exploitation and exploration is expressed by one of the LPS managers at Scania: "*Actually, not all new ideas are good ones. Most new ideas are bad ones, given the current context, but the context changes so nothing is static, and we still need to evolve*". The observations in Scania and Volvo CE highlight the importance of adopting new ideas in response to a changing context. Understanding the system, looking ahead and actively

exploring new solution options appears to be a promising approach in addressing the dual need of exploitation and exploration. However, at both companies' the respondents struggle with competence gaps in terms of not having a wide distribution of expertise or profound understanding of the digital technologies and their potential benefits for future LPS and vice versa. For example, limited technology competence amongst managers impacts the prioritisation of investments in new technology solutions, despite their deep knowledge of production and LP principles. Due to this, it was the experience of one of the respondents at Scania that it was difficult for senior management to answer questions in a qualified way regarding the prioritisation or relative importance of the technology focus.

To avoid competence gaps there are several initiatives to support continuous learning and competence development to enable managers and production operators to acquire new ambidextrous digital capabilities (cf. Secchi and Camuffo, 2019). Related to this is the tension between ***specialisation vs. generalisation*** emphasising the importance of integration of multiple learning perspectives and connecting production staff with different specialist functions and knowledge to extend the knowledge base in respect of the opportunities offered by digital technologies in manufacturing. The necessity to bridge the tension between specialisation vs. generalisation is evident in several statements by the respondents at both Scania and Volvo CE. For example, one of the LPS managers at Scania stated that: "*We need people that serves as bridges and that sort of has a foot in both worlds. Right now, I believe that we are a bit too specialised*" (see Table 3 for extended quote). At Volvo CE, the bridging of knowledge perspectives is partly addressed through creating dual affiliations of staff and creating small SP lab environments in which to meet across knowledge domains, which in turn connects the ways of managing the learning paradox to the belonging paradox.

4.1.4 Belonging paradox. The paradoxes of performing (current goals vs. future goals), organising (resource prioritisation between current operations vs. future SP needs) and learning (specialisation vs. generalisation) are all interconnected with the belonging paradox of **integration vs. autonomy**: The sense of being integrated and aligned with shared goals and ambitions for digitalisation and LPS, on the one hand and sense of autonomy and empowerment in improvement work to adopt new technologies or solutions, on the other hand.

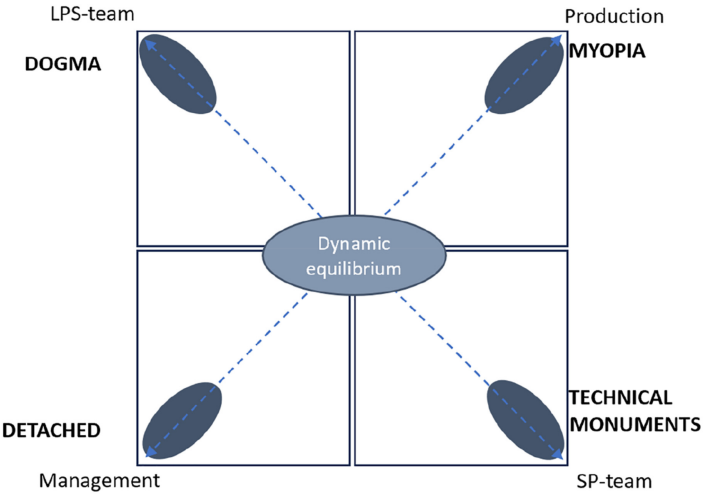
Hence, the actions taken to manage the other paradoxes give rise to new paradoxical tensions related to identity and belonging. At Scania, it was observed that the introduction of new technical solutions affects work roles and identity in several ways. For instance, individuals experienced being disintegrated and a decrease in responsibility over things they previously had control over and some solutions were implemented without considering internal specialist functions or the actual operational needs, aptly illustrated by one of the respondents from operations at Scania: "*We have the specialist functions. They are becoming increasingly frustrated. Why does nobody listen to us?*" At Volvo CE, the learning paradox of specialisation vs. generalisation was managed by having SP-team members divide their time between working in the SP-team and performing various roles in the line organisation. Consequently, they spend part of their time focussing on the exploration of new digital technologies and seizing new opportunities aligned with the shared digitalisation strategy. For the remainder of their time, they returned to daily LPS operations (line organisation), a context that was heavily focussed on daily issues and thus had limited interest in new technologies, often showing resistance. This dual affiliation placed SP-team members in a crossfire of conflicting interests between their ongoing efforts towards the integration of SP goals and the autonomy and loyalty to their colleagues in the line organisation who partly resisted SP ideas. Hence, these dual affiliations result in dual loyalties that need to be balanced, also laying the groundwork for a belonging paradox. A critical issue for acceptance of the paradox then is to acquire a **sense of ownership and relatedness** to the digitalisation and improvement work by building trustful relationships across the organisation.

4.2 Forcing imbalances of organisational paradoxes

What becomes evident in the data analysis is that even though there is a recognition and acceptance of critical organisational paradoxes that need to be worked through (see Figure 1), there is at the same time a tendency of internal drift that amplify tensions and force imbalances of organisational paradoxes, i.e. disturbing the state of equilibrium, see Figure 2 (Weiser and Laamanen, 2022). Different kind of forces are constantly pushing the organisations towards imbalances and in the worst case they tilt the organisation and generates vicious cycles (Smith and Lewis, 2011) constraining the potential for integration. In the analysis, we discern four different imbalance archetypes where the risk of organisational tilt is high: Myopia, Dogma, Technical Monuments and Detached (Table 3).

Myopia: One of the most pressing issues reported in both companies that constrain the integration of digital technologies in LPS, is the scenario in which production becomes too short-sighted and gets stuck in the day-to-day production routine and becomes protective of the current ways of working, i.e. **Myopia**. A mechanism enabling Myopia is when the short-term goal of production is over-prioritised and generate an imbalance in the performing paradox, i.e. current goals become prioritised over future goals. A potential consequence of prioritising short-term goals is that this also amplifies tensions and triggers an imbalance of the organising paradox because it affects the resource prioritisation between current operations and the future needs of improvement work and digital technologies. When critical resources are not provided to support the opportunity to absorb new technical solutions into production and as a part of the LPS it could eventually constrain production innovation. The SP manager at Scania describes this as follows:

> Production managers have a very good overview of production, but they have very little technology competence. So, it is very difficult for them to really know what to prioritise when it comes to "where should I invest money in a system?
>
> Which will be the absorbing organisation? Also, maybe you need to increase your, you know, employee count or competence early. So, you can absorb it later.



Source(s): Authors' own creation

Figure 2. Illustrations of imbalance archetypes caused by amplified tensions in the work on integrating digital technologies in LPS

Another mechanism enabling drift towards Myopia is the situation in which production operators are consumed by their daily production routines and do not have the energy to look beyond their day-to-day work to carry out any future oriented improvement work, even though there be small windows of free time. Hence, daily production and disruptions in production affect the focus on integration of digital technologies because the daily disruptions are always prioritised, for instance to secure resource availability. In the case of Volvo CE, the biggest challenge in the implementation of digital Lean boards was to have a group that is working on the implementation every day, not just in one cell but in all cells.

Technical Monuments: A second critical issue is when the intention to integrate digital technologies becomes too technology-dominated, which generates an imbalance referred to as **Technical Monuments**. Technical Monuments' was a phrase used by one of the respondents at Scania to describe the situation in which the introduction of new digital technology is imposed on production and, because of competence gaps, restricts the production organisation's ability to absorb and utilise the principles of LP to improve.

> We create a solution, but we can't, we don't understand it. Operators can't use it. This single resource in some faraway part of the organisation is the only person understanding how to programme it. (Operations, Scania)

The drift towards Technical Monuments occurs then as an imbalance of the organising paradox when technical solutions are imposed on production; solutions which are perceived as "good in themselves" by their proponents in the SP-team but which do not necessarily fulfil any need that has been identified by production:

> Some people working with new technologies. They want to run too fast. And they don't understand which problem it is that needs solving. (LPS manager, Scania)

At the same time, there is no "sense of pull" from production or LPS-team because of a competence gap amongst the users (operators) on how to maintain and improve the new machinery. Hence, the absence of proper coordination and alignment amongst stakeholder interests (Pozzi *et al.*, 2023; Mokudai *et al.*, 2021) renders an imbalance of the organising paradoxes, which as a consequence also triggers an imbalance of the belonging paradox as responsibilities changes in production and LPS-team; shifting responsibility for updating and maintaining the technical solution further away from the value adding process, making changes and improvements difficult and time consuming; circumstances which make the new solution inflexible and gradually turns it into a technical monument that suppress LPS-development.

Dogma: A third critical issue, **Dogma**, arises when the basic assumptions of LP and the LPS become axiomatic and not seen as principles that continuously needs to be adapted and as such becomes dogmatic. In the interviews, respondents describe a situation when LP principles are perceived by their proponents as a normative ideology and that "this is right in itself," leading to a dogmatic view favouring the application of current ways of adopting Lean principles, which triggers an imbalance of the learning paradox because it suppresses the exploration of future orientations.

> Same thing with Lean if you are not open to try technology and you get stuck with Lean as a "tool" not a methodology and you believe there is no other way of doing it. Lean could slow down/block the vision with digital transformation. (LPS manager, Volvo CE)

Furthermore, by overly focussing on the exploitation of current production through continuous improvements and elimination of waste, there is also a risk of missing out opportunities for exploration and disruptive change. In the case of Volvo CE, LPS-coaches can sometimes be focussed on "what and why are we going to change" and as such sometimes question the need for exploration.

> We sometimes just try to improve the same type of process to make it better and better, than evaluating a new type of process. (LPS manager, Volvo CE)

The Dogma imbalance resemblances what Mokudai *et al.* (2021) refers to as the "Lean trap" in their study of digital technologies as Lean augmentation. The Lean trap unfolds in a situation when production is strongly rooted in a LPS and this tends to make managers and production engineers only view the potential of digital technologies from the perspective of existing LP practices, and in so doing, they then risk being blind to the potentials of new technologies.

Detached: the data also includes indications of situations when senior management is perceived to not share the same pace of learning as the other stakeholders of the LPS-team, SP-team and production and as such becomes **Detached**. Hence, Detached is partly a consequence of not embracing the learning paradox in the sense that senior management are not up to date in exploring of future opportunities thus generating a competence gap.

> If top management are not involved they might miss the company/site-wide benefit offered by a solution, might be problems with expansion, they maybe don't understand what the team was doing since it was a bottom-up approach. (SP-team, Volvo CE)

> When the Smart factory started some years ago, there was an ambition to have, we called it the Smart factory council and it had representatives from different units sitting there, and the idea was that they would help with prioritization of what type of technologies to focus on. One tension there was that they felt like they didn't have the real competence to answer for like what is more important or not. (LPS manager Scania)

The competence gap might then have spin-off effects because it triggers an imbalance of the performing paradox, as it impacts upon managers' opportunities or abilities to make decisions about new strategic initiatives that are grounded in the organisation.

> Today we have a very good model and strategy for digitalisation, but it is not that well known. (LPS manager, Scania)

4.3 Re-contextualising actions as a rebalancing strategy

In the previous two sections we have learnt about the critical organisational paradoxes embraced in the integration of digital technologies in a LPS and the organisational and human forces amplifying tensions and imbalances of organisational paradoxes and disturbing the state of equilibrium. In this section, we address **RQ2** and focus on the micro-shifts of corrective actions (Weiser and Laamanen, 2022), what here is conceptualised as *re-contextualising*, which seeks to rebalance and conjoin the different poles of a paradox and as such cope with the tendencies of internal drift, whilst offering proper coordination and alignment between LP and SP activities (Pozzi *et al.*, 2023; Mokudai *et al.*, 2021). Based on the data of what contributes to acceptance and embracement of the identified paradoxes and other resolution measures taken in the companies to restore balance and drive change and transformation of manufacturing operations, four types of re-contextualising actions and strategies are identified: Empowering, Patching, Pacing and Leveraging (Table 3).

Empowering: learning paradoxical thinking. To avoid competence gaps within critical domains – such as digital technologies – and the risk of drift from the learning paradox into Dogma or Detached, there are in both companies several initiatives and support structures for *empowering* through continuous learning and competence development to enable managers, production engineers and operators to acquire new critical knowledge, e.g. digital capabilities. Confirming the findings of previous research (Dieste *et al.*, 2022; Smith and Beretta, 2021), both companies emphasise the importance of investments in continuous learning as a key factor for ensuring that staff in production can re-contextualise and manage the complex interdependencies simultaneously and thus manage ambiguities so that they can

make decisions for themselves and in the long run increase the possibilities of the pull effect of new technology to rebalance the organising paradox of pull vs. push. Therefore, empowering people is key to paradoxical thinking (Xiao *et al.*, 2019).

Patching: connecting and converging knowledge elements. The SP-teams have toned down the "push" of new technology and instead emphasise the importance of demonstrating the potential of the digital technology. The shift is a re-contextualising through connecting and converging, i.e. *patching*, different knowledge perspectives, finding a fit between them. Patching can then be described as a rebalancing strategy for all four organisational paradoxes using different LP-practices (Johansson *et al.*, 2022). One example from Scania is where personnel developed and tested a checklist to ensure that different knowledge perspectives and interests are taken into consideration when testing new digital technologies. Another example of activities supporting patching is seconding people between business units so that they gain experience from different parts of the organisation and better understand different stakeholders, e.g. production staff with different specialist functions working within the SP-team. As such, patching is also conducive to generating a sense of ownership and relatedness during integration work by building trust-based relationships across the organisations.

Pacing: synchronising time horizons. The different pace of changes and new initiatives initiated by the SP-team (long-term), continuous improvements in production (short-term) and the pace of day-to-day production also leads to tensions which act on other activities in the organisation. Thus, initiatives taken in one part of the organisation creates tensions due to the difference of time perspectives which at worst results in Myopia or Technical Monuments. *Pacing* becomes critical in re-contextualising and synchronising time perception between different stakeholders. Hence, by synchronising different time perceptions the nexus of current and future production needs and digital technology affordances can be identified and the receiver side of a new digital technology may alter the perception from a "sense of push" into a "sense of pull" through having new digital technologies available "just-in-time" to meet the needs being experienced.

Leveraging: utilising divergence for exploration. The importance of adopting new ideas in response to a changing context is a key factor in *leveraging*. By understanding the system, looking ahead and actively exploring new solution options, appears to be a promising approach when addressing the learning paradox of exploitation vs. exploration (cf. Secchi and Camuffo, 2019). In leveraging, the companies make use of tensions and the divergence in the organisation as a driver of exploration, which ironically, is partly the same as driving the imbalances of Dogma and Technical Monuments. However, by continuously highlighting tensions, the divergence in the organisation is explicated, which can then be used to re-contextualise and leverage transformation processes. Hence, leveraging is about managing the learning paradox of exploitation vs. exploration as transforming mechanism (March, 1991).

5. Discussion and implications

Previous studies have demonstrated the advantages of incorporating digital technologies into existing LP-management models (Buer *et al.*, 2021; Tortorella *et al.*, 2019), and further studies have utilised a paradox perspective when investigating the implementation of either I4.0 (e.g. Dieste *et al.*, 2022) or LP (e.g. Maalouf and Gammelgaard, 2016), see Table 1. However, there is a gap in research examining paradoxes arising from the attempts to integrate LP and digital technologies (e.g. Holmemo and Korsen, 2023). Hence, this paper aims to advance the understanding of tensions and their paradoxical relationship and potential strategies for manage tensions when integrating digital technologies into existing LPSs. This study only highlights few contradictions between the aims of LP and digital technologies on a conceptual level. The respondents provide evidence of the potential complementary effects between LP and digital technologies, confirming the conclusion of Buer *et al.* (2021) that the simultaneous use of the two has a greater effect than the individual effects of each approach. However, our findings indicates that contradictions appear on a more detailed

practical implementation level as each perspective generates different options and priorities, leading to paradoxical tensions. It is on this microfoundations level the paradoxical tensions need to be understood and managed (Maalouf and Gammelgaard, 2016; Dieste *et al.*, 2022; Frank *et al.*, 2019; Smith and Beretta, 2021; Erthal *et al.*, 2021). More specifically, to gain answers to RQ1, the findings of this paper provide insights into the salient paradoxical tensions embraced in the integration of digital technologies in LPSs, by identifying different aspects of the performing, organising, learning and belonging paradoxes (Smith and Lewis, 2011). When addressing RQ2, the findings show the intricacies and relatedness between different paradoxes and their resolutions and, more specifically, how a resolution strategy adopted to manage one tension, might unintentionally generate new tensions or imbalances (Poole and Van de Ven, 1989). For example, the structural separation of LPS-team and SP-team is adopted to manage the performing paradox of competing but potentially synergetic approaches, on the one hand, which, however, disconnects and trigger an internal drift of the belonging paradox, on the other hand. This in turn calls for either re-contextualising actions to counteract the drift or the adopting of new resolution strategies, e.g. synthesis (Dieste *et al.*, 2022) by organising cross-functional work across specialist functions such as the LPS- and SP-teams and production. In full accordance with the theoretical assumption made in the dissipative equilibrium model (Weiser and Laamanen, 2022), our findings showcase the tendency of internal drift because there are forces that constantly push the organisations towards imbalances, which in worst case tilts the organisation and generates vicious cycles constraining any integration of LP and digital technologies (Smith and Lewis, 2011). By identifying the micro-shifts and forces for the four imbalance archetypes Myopia, Technical Monuments, Dogma and Detached, we also highlight the sensitiveness and temporality (Poole and Van de Ven, 1989; Dooley and Van de Ven, 1999) of the state of equilibrium for all four paradoxes. Well in line with Smith and Lewis (2011) and Weiser and Laamanen (2022, our findings indicates that a dynamic equilibrium is not possibly to maintain without the micro-shifts of re-contextualising seeking to rebalance and conjoin the different poles of the paradoxes. This approach copes with tendencies of internal drift by enabling paradoxical thinking (Xiao *et al.*, 2019) or ambidextrous capabilities (Secchi and Camuffo, 2019). Hence, resolutions and re-contextualising of paradoxes are always contextually sensitive and system dependent (Schad and Bansal, 2018).

Dieste *et al.* (2022) added the perspective of the dynamics and complexity in managing paradoxes in integrating digital technologies by suggesting four paradox resolution strategies: contextualisation, spatial separation, temporal separation and synthesis. Our contribution, based on micro-level analysis (Poole and Van de Ven, 1989) further adds to understanding of this complexity by also identifying the types of pulling apart forces and drift from equilibrium and the related integrating and rebalancing actions here framed as the re-contextualising actions of Empowering, Patching, Pacing and Leveraging. Hence, one key theoretical implication of our findings is that it adds micro-level understanding to previous research by empirically show the interplay between acceptance of paradoxes, pre-emptive balancing and re-contextualising as rebalancing mechanisms (Figure 3) and as such contributes with empirical evidence to the conceptual model of the dissipative equilibrium proposed by Weiser and Laamanen (2022). All in all, our findings shed new lights on how to understand rebalancing and transforming mechanisms to maintain dynamic equilibrium (Smith and Lewis, 2011; Weiser and Laamanen, 2022) and new evidence for the appropriateness of the paradox theory to uncover the complex intricacies and relatedness of the two perspectives.

6. Conclusions and future research

In conclusion, our main contributions to the OM research and practice on LP vs. Industry 4.0 are three folded. *First*, the paper provides a fine-grained perspective on why integration sometimes "fails" and identifies the forces of internal drift as mechanisms of imbalances. By providing insights into critical paradoxes, our findings may help practitioners to understand the underlying

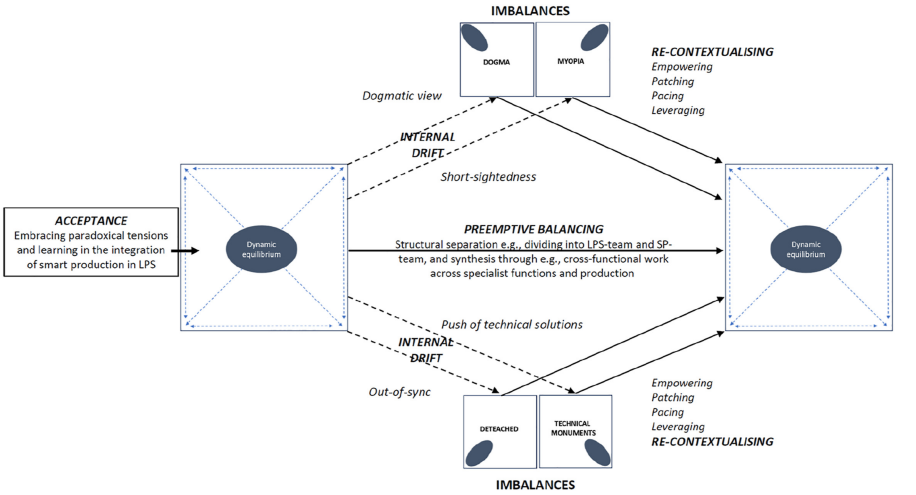


Figure 3.
Model of acceptance, internal drift, and re-contextualising as a rebalancing mechanism

Source(s): Modified from Weiser and Laamanen model of dissipative equilibrium (2022)

reasons and its complexity, the ubiquitous risk of imbalances and create incentives to find a good balanced approach for SP. It may further help practitioners working on the integration of LP and SP to understand each other's perspectives and contribute to create a common base for dialogue. *Second*, the paper provide detailed insights into how different management and resolution strategies are adopted, particularly by identifying re-contextualising actions as a key in rebalancing organisational paradoxes in favour of the integration of digital technologies in a LPS (see Figure 3). A critical issue in companies working on integrating LP and SP, is the constant need of rebalancing and corrective actions avoiding internal drift towards the extremes and to avoid the suppression of either side of organisational paradoxes. Hence, functional management strategies are all about avoiding getting stuck in the extremes. As such, this study has a robust anticipation power, helping managers/coaches responsible for driving LP and digitalisation initiatives in companies to find a balanced approach. Without this type of lens, contradictions and risk of internal drift cannot be anticipated. *Third*, considering that previous research has proven the adequacy of using paradox theory to investigate integration of LP, this study has also proven the usefulness of paradox theory in investigating the micro-level implications of integration of the two perspectives as part of production system development.

Finally, the two companies considered are well established in the LP-paradigm, whilst they have a shorter history of integrating digital technologies. To further elaborate and test the suggested paradoxes, tendencies to drift and management strategies for rebalancing and transforming dynamic equilibrium, future research would benefit from flipping the perspective and investigating companies that have their starting point in the SP paradigm and intent to integrate this with LP. Furthermore, applying the paradox perspective to SP transformation in SMEs would also be useful in providing a different setting where specialist roles and functions are more interwoven because of the size of the companies.

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