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Abstract:	Lean implementations in large and medium-sized organisations are prominent in the literature. However, although small and micro-organisations significantly impact the countries' economy, lean deployments in small and especially micro-firms are uncommon. This research aims to i) explore how micro-manufacturing initiates and develops a successful lean implementation and ii) establish the benefits and barriers from a socio-technical theory perspective. This action research is undertaken in a label manufacturer in the UK, where techniques such as 5S, single-minute exchange of dies, just in time, and total productive maintenance are implemented in sequence over six months to study the social and technical duality of lean. Both qualitative and quantitative data are collected to determine how the micro-organisation implements lean manufacturing and assess the extent to which it improves productivity, reduces lead time, and transforms culture. The results show that both performances are positively impacted and, more importantly, it has changed people's behaviour.

Exploring the impact of a sequential lean implementation within a micro-firm – a socio-technical perspective

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1. Introduction

Lean is a management and manufacturing transformation philosophy, which leads firms to continuously improve and optimise their processes and operations (Bamford et al., 2015; Bhasin, 2013; Möldner et al., 2020). Lean studies are extensive in the literature and empirically evidenced, especially in large firms (Bhasin, 2013; Narasimhan et al., 2006). Shah and Ward (2003) reported 22 lean practices (e.g. pull system, quick changeover techniques, predictive and preventive maintenance, quality management programmes, and self-directed work teams), which they divided into four dimensions: just in time (JIT), total productive maintenance (TPM), total quality management (TQM), and human resource management (HRM). They reported that large manufacturing firms tend to adopt many of these 22 practices across their boundaries to deploy a coherent and impactful lean programme. In this research, we define a lean programme as a deployment that focuses on the selection of certain techniques and practices applied to the most critical manufacturing processes (Bamford et al., 2015). The performance and cultural impact of successful lean deployment are debatable (Bamford et al., 2015; Srinidhi & Tayi, 2004; Yasin et al., 2004); however, it is generally agreed that implementing lean manufacturing, even partially, is challenging and not always persuasive or rewarding for many micro and small firms (Achanga et al., 2006; Hu et al. 2015). Micro-organisations often lack structures, resources, long-term strategies, continuous improvement mechanisms (Cosenz & Bivona, 2020; Haksever, 1996), and expert knowledge and experience in these domains to drive successful implementations (Liberman-Yaconi et al., 2010; Matt & Rauch, 2013). Even implementing common techniques such as SMED (single minute exchange of dies) and 5S (sort, set in order, shine, standardise, and sustain) can prove problematic (Belhadi et al., 2018). In terms of lean implementation, micro and small organisations are less mature than their larger counterparts (Cosenz & Bivona, 2020; Panizzolo et al., 2012). Hence, researchers call for further studies in this specific type of firm to understand the interdependencies and the bidirectional duality between i) lean techniques and operational performance, which belongs mainly to the technical realm (Möldner et al., 2020); and ii) lean practices and the micro-organisation's culture, which belongs to the social realm (Solaimani et al., 2019; Tortorella et al., 2021).

Lean implementation in micro-firms is under-researched; it has also been described as scarce and not prominent (Alkhoraif et al., 2019; Filho et al., 2016; Hu et al., 2015; Yadav et al., 2019). Micro-firms with fewer than ten employees (McGowan, 2019) are the backbone of industrial production (Mittelstaedt et al., 2003) and significantly support employment (Alkhoraif et al., 2019). Since 2013, 95% of the UK's private sector businesses have been micro-firms (Lord Young, 2013; Department for Business, Innovation, and Skills, 2015), contributing to 33% of employment and 18% of the country's turnover (House of Commons, 2015). Hence, there are substantial economic and social incentives to increase the competitiveness of micro-firms. As seen during the COVID-19 pandemic, micro-firms are more vulnerable than their larger counterparts. Therefore, it is even more important to develop successful continuous improvement strategies and deploy methods to ensure competitiveness, agility, and resilience (Liberman-yaconi et al., 2010).

In this context, in addition to the fast-paced technological changes of this approaching fourth industrial revolution (Bibby & Dehe, 2018), we observe that large and global firms increase their competitive gaps in terms of financial and operational performance (e.g. productivity and lead time). This encourages small and micro-firms to further improve their effectiveness, efficiency, and competitiveness, notably, by complying with industry standards and schemes; investing in new technology, machinery, and equipment; and adopting production and supply chain best practices such as lean management (Liu et al., 2018).

Research on lean manufacturing in micro-organisations is limited, and there have been few studies in academic journals in the past 15–20 years (Filho et al., 2016; Hu et al., 2015; Kuratko et al., 2001; Matt & Rauch, 2013; Nwankwo, 2000; Yadav et al., 2019). This research aims to explore how a sequential lean manufacturing programme can be successfully implemented in the context of micro-organisation through the dual perspective of socio-technical system theory. We demonstrate that a micro-organisation can deploy aspects of lean manufacturing to improve productivity and lead time performances, as well as change people's behaviour. We use an action research methodology embedded within a case company, referred to as CL. The data collection relies on eight interviews and a quantitative strand, which analyses 358 performance data points.

This research contributes to lean manufacturing in the micro-organisation body of understanding by providing impactful and valuable knowledge and evidence to micro-firm owners who wish to improve their processes. This is meaningful, as according to Bhasin (2013), less than 10% of lean implementation in SMEs is successful. The study contributes by presenting a roadmap to lean deployment and analysing benefits and barriers from a socio-technical system theory perspective, specifying pragmatic guidance for practitioners. This study also makes a significant contribution by providing evidence of the social and technical duality of lean (Austin & Adebayo, 2021; Knol et al., 2019). We demonstrate how a sequential lean implementation of four techniques (5S, SMED, JIT, and TPM) can improve performance (belonging to the technical system) and transform the culture and behaviours (belonging to the social system) in a micro-firm, after overcoming technical and social barriers (Solaimani et al., 2019).

2. Literature review

2.1.Theoretical perspective: socio-technical systems

In this study, we employ the socio-technical system theory (Trist & Bamforth, 1951) to report how a micro-organisation can implement lean manufacturing practices and assess how a lean implementation improves productivity, reduces lead time, and changes people, culture, and behaviours. This is congruent with Shah and Ward (2007) and Solaimani et al. (2019), who define lean as an integrated socio-technical system that aims to eliminate non-value-added activities, pursue problem-solving (technical system), and generate a culture of continuous improvement (social system). Baxter and Sommerville (2011) define socio-technical theory as ‘an approach that considers human, social, and organisational factors, as well as technical factors in the design of systems and performance’. According to the socio-technical system perspective, organisations consist of two systems: social and technical. The theory suggests that for optimal functioning, both the human and technical systems must be jointly harmonised (Mumford, 2006). The social system relates to the culture, people’s behaviour, and relationships

(Trist, 1981), and the technical system represents the tools, techniques, methods, performance, metrics, and knowledge required to produce goods and services (Pasmore, 1988). Firms must balance and integrate these two systems to enhance their performance (Dabhilkar & Åhlström, 2013; Fox, 1995). The socio-technical theory has been applied in healthcare, computing, information and communication technology, ergonomics, quality management, and lean (Carayon, 2012; Carayon et al., 2015; Hadid & Mansouri, 2014; Hadid et al. 2016; Kleiner et al., 2015; Morgan-Thomas et al., 2020; Shah & Ward, 2007). To be successful, lean manufacturing must consider the implementation of tools and techniques such as 5S, SMED, JIT, and TPM. However, these must be adapted and tailored to the environment and culture of the firm; therefore, they must fit the social fabric and culture of the organisation (Bamford et al., 2015; Rymaszewska, 2014). This shows the duality of lean (Austin and Adebayo, 2021; Knol et al., 2019). For example, to successfully implement lean manufacturing, human resource capabilities (teamwork, training, multi-skilling, and employee flexibility) must be carefully considered (Samson & Terziovski 1999; Wiengarten et al., 2011). Chaudhuri and Jayaram (2019) demonstrate that social considerations have a strong positive effect on technical deployment. Hence, in line with Dabhilkar and Åhlström (2013) and Mohammad and Oduoza (2019), we infer that the socio-technical system is a relevant theory to understand and analyse how a micro-firm can deploy lean manufacturing successfully and to what extent it impacts productivity, lead time, and employee behaviours. Some studies focus on lean implementation from either a technical or cultural perspective in a piecemeal fashion (Agarwal et al., 2013; Bhasin, 2013). It is commonly acknowledged that both systems must be considered and balanced. Social practices and technical components are interdependent and interconnected, and influence firm performance (Bhasin, 2013; Hadid et al., 2016; Shah & Ward, 2003). Failure to consider both systems will ultimately lead organisations to stall their transformation (Yadav et al., 2019).

2.2. Micro-organisations

The characteristics of small and micro-businesses are summarised by Vickers (1990) and consist of i) low-profit margin, ii) limited training and staff development availability, iii) informal quality controls, iv) narrow customer base, v) lack of power over suppliers, vi) lack of long-term plans and strategies, and vii) limited resources and capacities. There are some additional characteristics unique to micro-firms, such as i) limited management and lean skills, ii) high competition, iii) low overheads, and iv) immature systems (Meredith, 2000). Despite these features, owners of micro-organisations possess a high sense of entrepreneurship and can be very innovative (Booyens, 2011). Thus, the ability to compete and survive in the market often comes from owners' managerial competencies and skills (Bianchi et al., 2018). However, scarce resources, environmental pressures, and high competition (Franco & Haase, 2010; Thorgren et al., 2012) prevent micro-organisations from focusing on and developing robust processes and systems (Matt & Rauch, 2013). Liberman-Yaconi et al. (2010) find that owners of micro-organisations rely heavily on personal experience and knowledge, with rare inputs from consultants, universities, or external parties, which could jeopardise successful lean implementation.

2.3. Lean implementation in micro-organisations

Lean manufacturing and total quality management are not just for large manufacturing firms (Shea and Gobeli, 1995). Small firms can also apply most lean and TQM principles (Barrier, 1992; Panizzolo et al., 2012). Crosby (1979) explains that a quality management scheme can be implemented by any business, irrespective of its size or scope. In line with this, Cook et al. (1998) find that micro-firms can apply quality practices, gain just as much profitability as small and medium firms, and gain more employee empowerment.

The quality practices of small and micro-organisations have been mainly linked to TQM and ISO 9000 (McAdam, 1999; Nwankwo 2000; Poksinska et al., 2006), and are briefly associated with JIT (Brown and Inman, 1993; McAdam, 1999), and the Malcome Baldridge award (Stephens et al., 2005). Brown et al. (1998) also report on ISO 9000 and its drawback: the cost of certification is a key barrier to small businesses, even if viewed as a 'necessary evil' for many companies (Fatima, 2014).

Lean is a methodology composed of a set of tools, techniques, systems, and principles that enable a firm to reduce waste and streamline processes and implement continuous improvement to enhance performance (Bhamu & Sangwan, 2014; Bhasin, 2013; Chen et al., 2010; Lander & Liker, 2007; Liu et al., 2018; Panwar et al., 2015; Rawabdeh, 2005; Shah & Ward, 2007; Vlachos, 2015). Numerous academic studies and firms have reported significant improvements in lead time, quality, productivity, customer satisfaction, and profitability after lean implementations (Bamford et al., 2015; Chavez et al., 2015; Liu et al., 2018; Lowe et al., 1997; Sohal & Egglestone, 1994; Melton, 2005; Pearce et al., 2018; Perona et al., 2016). Melton (2005) concludes that lean i) increases the value of the release of working capital, ii) increases supply chain speed, and iii) reduces manufacturing costs. These benefits are achieved by implementing technical practices such as 5S, standardisation, problem-solving, SMED, TPM, JIT, workplace organisation, and visual management (Dombrowski et al., 2010).

Notably, techniques such as small lot sizing, competitive benchmarking, level scheduling, and statistical process control are unpopular tools within SMEs (Alkhoraif et al., 2019). Time and budget constraints (Bhasin, 2013), as well as expertise and know-how (Mathur et al., 2012), are the main barriers. However, Bianchi et al. (2018) suggest that a structured, flexible, and selective approach may fit micro-business entrepreneurs and develop their capabilities.

An organisation can deploy lean in different ways: i) following the wisdom of the so-called gurus, ii) relying on external consultants' inputs, iii) following an excellence framework, or iv) adopting a bottom-up perspective. However, the key question is to define the scope and scale of the implementation. Some scholars argue that only a total and full deployment of lean techniques will lead to successful implementation (Srinidhi & Tayi, 2004; Yasin et al., 2004); while others advocate for a partial deployment, a step-by-step approach, in which tools and techniques are sequentially implemented (Bamford et al., 2015; Papadopoulou & Özbayrak, 2005). However, unlike large companies, micro-organisations lack the structure, ability, and resources to accommodate the multi-stage models and the long-term strategic planning needed to deploy a total and full lean programme (Alaskari et al., 2016; Matt & Rauch, 2013). Moreover, they do lack the knowledge and skills required to identify the most appropriate methods and, therefore, often fail to successfully implement lean into their businesses (Dombrowski et al., 2010).

2.4.Lean from a predominant technical system perspective: 5S, SMED, JIT, TPM

Lean implementation requires knowledge, skills, competencies, resources, and time (Hines et al., 2004). Most reported implementations demonstrate the impact of lean on flow improvement, production cost reduction, and quality improvement in large and medium organisations (Filho et al., 2016; Liu et al., 2018). Fundamental lean techniques include 5S (Jiménez et al., 2015), SMED (Moxham & Greatbanks, 2001), JIT (Sandanayake et al., 2008), and TPM (Sharma et al., 2006).

5S is commonly translated in English as 'sort, set in order, shine, standardise, and sustain'. It was originally developed in the 1980s on Japanese manufacturing shop floors. Many firms practise this lean fundamental technique to develop a culture of discipline. It is often used in combination with other techniques such as TPM or SMED and within kaizen events

(Kobayashi et al., 2008). 5S is often used as a groundwork for more complex lean implementations. It is considered a prerequisite for lean management (Bryar & Walsh, 2002; Ho, 1998; Kumar et al., 2007; Warwood & Knowles, 2004).

SMED was a central technique as part of the Toyota Production System (TPS) to reduce the changeover time between batches (Shingo, 1985). It has been implemented in many industries, such as automobiles, robotics, aerospace, and electronics (Patel et al., 2001; Trovinger & Bohn, 2005). Jebaraj et al. (2013) demonstrate that SMED is beneficial in reducing small stops in a manufacturing firm and improves overall equipment effectiveness (OEE). Shingo (1985) suggests a three-stage plan consisting of i) separating the internal and external setup, ii) converting the internal to external setup, and iii) streamlining all aspects of the operation. Stage one is the most important phase, which distinguishes between internal (when the machine is stopped) and external setup (while the machine is still running), which is the passport to achieving SMED (Shingo, 1985). Stage two involves converting the internal setup to an external one by re-examining the operations and finding ways to convert. Stage three streamlines all parts of the process.

JIT is an essential aspect of lean philosophy for creating flow (Behrouzi & Wong, 2011). It aims to minimise work-in-progress inventory throughout the entire system (Parnaby, 1988). Its benefits are universal, which include work-in-progress reduction, increased flexibility, raw material reduction, increased quality, increased productivity, reduced space requirements, and lower overhead (Voss, 1987). However, Swink et al. (2005) find that JIT has no positive effect on cost performance. Meanwhile, Cua et al. (2001) suggest that multiple approaches are mutually supportive in achieving manufacturing performance improvement and JIT needs to be implemented with other lean techniques.

The TPM is the fourth lean technique reviewed in this study. Kyokai (1996) deploys TPM on the shop floor to maximise equipment effectiveness, focusing on the entire equipment life cycle to establish a system, coordinating all departments, involving everyone, and having a team-based culture to ensure zero losses. Shirose (1992) considers six major losses in TPM: breakdown losses, setup and adjustment losses, idling and minor stoppage losses, reduced speed losses, quality defects and rework, and startup/yield losses. This demonstrates how 5S and SMED are complementary and synergetic with TPM.

2.5. Lean from a predominant social system perspective

Although lean manufacturing is often described from a technical perspective, the role of the people is paramount for successful deployment (Tortorella et al., 2021). Hence, we also need to analyse it from a social perspective (Yadav et al., 2019). Solaimani et al. (2019) argue that lean focuses on people, culture, and leadership to create a positive and proactive attitude towards continuous improvement. Employees and executives play the most important role in leading any business transformation (Hummels and De Leede, 2000). For instance, Alpenberg and Scarbrough (2016) observe that the success of the quality circle technique does not come from its procedures or applications (associated with the technical system); it is rather determined by the facilitators' communication, engagement, and empowerment skills (associated with the social system). In a subsequent study, Alpenberg and Scarbrough (2021) report that lean dispersed practices (associated with the technical system) linked with integrative practices (associated with the social system) will improve productivity and involvement. This corroborates Möldner et al. (2020), who find that besides the technical lean practices, the social practices improve process innovation and performance, inferring the concept of duality.

2.6.Gap analysis and the duality of lean

Although research has explored TQM and ISO 9000 benefits in micro-organisations, further research on micro-firms is considered essential to extend and complement the current body of understanding (Filho et al., 2016; Kuratko et al., 2001; Yadav et al., 2019). Moreover, research on lean and quality management in micro-organisations does not consider the duality aspect between the technical and social systems and their interactions, for example, as in Prasad and Tata (2009), Hodge et al. (2011), and Ramesh and Ravi (2017). Similarly, Gilmore and Smith (1996) conduct action research on SMED but focus essentially on the technical aspect of lean. To the best of our knowledge, only a few academic publications analyse the evolution and impact of lean techniques, such as 5S, SMED, JIT, and TPM, in micro-organisations from both the social (culture and behaviour) and technical (productivity and lead time) viewpoints. Therefore, this research addresses this gap and provides a deeper understanding of the lean manufacturing bidirectional duality phenomenon within micro-enterprises. This is achieved by shedding light on how a micro-firm can successfully manage sequential lean implementation. Two research questions are presented to structure the study: *RQ1: How can a micro-organisation effectively implement lean and overcome the main social and technical barriers? RQ2: To what extent can a lean implementation improve productivity, reduce lead time, and transform the culture?*

3. Methodology

3.1. Research design rationale

Action research was designed with a label micro-manufacturer in the UK, referred to as CL (Minshull & Dehe, 2017). Action research often focuses on improving the system in which the research is being conducted (Vanderstoep & Johnston, 2008; Visintin et al., 2017; Vlachos, 2015), where researchers are directly involved in the study and actively participate in the change implemented (Chen et al., 2010; Prybutok & Ramasesh, 2005). It can be an effective method for problem-solving in an organisation (Quinlan et al., 2015) and is particularly useful in studying organisational and cultural change (Bamford et al., 2015; Johnson et al., 2014). Lo et al. (2020) explain that empirical studies benefit from using multiple methods. Moreover, researchers have called for using mixed methods and action research in lean implementation in SMEs (Alkhoraif et al., 2019). An advantage of action research is the real-world natural setting in which the data are collected, to help understand how and why a phenomenon has occurred instead of simply stating what occurred (Yin, 2012).

3.2.The case company: CL

Similar to Cosenz and Bivona (2020), this research is undertaken within a case company to explore a specific phenomenon: the deployment of lean manufacturing in a micro-organisation. In line with their approach, we analyse and report empirical evidence from our research. The case company is a family-run self-adhesive label manufacturer established in 1985. The micro-firm provides hot foil, flexographic, and thermal transfer printed labels. It has four permanent employees and one part-time employee. Full-time staff include the managing director, sales office manager, production manager, and production worker. The part-time employee is a production worker. The two manufacturing processes in the company were hot foil and flexographic. There are three hot-foil machines, each with different capabilities and a rewind to finish the product, and one flexographic machine with a rewind machine.

3.3. Role of the research team

One of the researchers worked at CL before the start of the project and had direct access to the company's historical data, information, and staff. They collaborated very closely with the MD to design and implement a solution in partnership with the university staff with expertise in lean manufacturing. This project became the foundation for a part-time MPhil. There are no conflicts of interest, and there are no financial interests for the authors because of this study.

3.4. Action research process relying on mixed methods

In this action research, researchers combine both qualitative and quantitative data to build, triangulate, and provide credible findings (Ivankova, 2015). Mixed-methods research enhances the validity of the results based on triangulation mechanisms. It provides a more complete picture of the phenomenon being investigated and can address complex issues. The set of lean practices implemented and investigated in this study are 5S, SMED, JIT, and TPM. Each technique followed a systematic five-week implementation plan and timeline: i) week 1: observing and analysing the current practice and collecting the performance level data; ii) week 2: providing the selected lean technique training by one of the authors to the staff; iii) week 3: focusing on the implementation and experimentation of the lean technique; iv) week 4: adapting and assessing, during which the quantitative performance data are measured; and v) week 5: evaluating and reflecting, including qualitative data collection through interviews with staff. This five-step cycle was replicated for each of the four lean techniques mentioned in the sequence (P1: 5S, P2: SMED, P3: JIT, P4: TPM), resulting in a sequential approach. In total, this implementation programme lasted more than six months, as planned and unplanned gaps between cycles were taken. This process was led and facilitated on-site by one of the authors.

3.5.The qualitative and quantitative strands

As part of this action research, there are qualitative and quantitative strands. The qualitative strand comprises eight semi-structured interviews with staff throughout the programme. The face-to-face interviews aimed to collect data and understand perceptions regarding the implementation and deployment of lean techniques. It provided the opportunity to coach and let the participants reflect on their lean practices as well as the process. The interviews followed a common protocol but allowed diving into a specific, based on the participants' views and interpretations (Matthews and Ross, 2010).

A thematic analysis was then conducted to analyse the interviews. The four emerging themes are: i) lean improves both the social and technical systems; ii) there are key social and technical enablers specific to micro-organisations; iii) there are key social and technical blockers specific to micro-organisations; and iv) lean impacts productivity and lead time. Table 1 provides a sample of the interview protocol showing the data structure, source, and coding.

Table 1. Interview structure, protocol, and coding

Interview protocol	Sample quotes from participants	Themes extracted
How do you define 'lean manufacturing?	'optimising production process'; 'satisfying the customer'; 'minimizing waste'.	lean improves both the social and technical systems
How are lean principles already encompassed in the company?	'it is not really implemented, but we have a good system in place with extremely high customer satisfaction, our last customer survey came back with a 10/10 score'; 'so why would it be needed?'; 'if it is not broken, don't fix it'.	There are key social and technical enablers specific to micro-organisations there are key social and technical blockers specific to micro-organisations
How would you describe your experience over the past weeks of deploying the selected lean technique (5S, SMED, JIT, TPM), any example?	'I had some knowledge before, I implemented SMED and some other techniques in the company I used to work for, but realising how they can work in my small company has been a real eye opener' [Technical system]; 'for example, the scheduling made it easier for me to know when things we needed for orders were coming in; before if I didn't know, the job would be left and not done or put on the machine to realise I don't have everything I need to make it. Now the plan is in place, I'm more aware and can plan better' [Social system].	Lean improves both the social and technical systems
The literature suggests that lean manufacturing provides a more productive environment with more skilled employees. To what extent do you agree, disagree? Have you gained more skills?	I've learnt new techniques, new ways of doing things and hopefully will be able to improve and implement new things in the future; 'I think it was good that we decided what was going to change if we were just told what to improve I don't think I would have gone with it as much, but because we came up with the ideas it was like it was more important and I needed to go through with it more'.	lean improves both the social and technical systems lean impacts productivity and lead times
Have there been any particular issues during this lean technique implementation?	'We weren't aware of how much we would be doing, like, changing things and working out what is best and what to change on each rotation' [Technical system]. ….... 'it was surprising how much time I had to dedicate to it. I don't think I realised…we had to learn lots of new things too, it was all a bit difficult to digest in such a short space of time' [Technical system].	there are key social and technical blockers specific to micro-organisations

Were you satisfied with the training and deployment plan and happy with your understanding of the lean techniques prior to their implementation?	It was good to go through the process ourselves….as we created it, we know it inside out, and putting together the new process along with the new manufacturing setup really helped me not make any mistakes' [Social system].	lean improves both the social and technical systems there are key social and technical enablers specific to micro-organisations there are key social and technical blockers specific to micro-organisations
Lean techniques have been linked to problem solving and innovation, would you agree? Can you think of any examples in the past couple of weeks?	'working with the office department to work out the scheduling worked [based on JIT principles]. We all know how it works and how to communicate about it to get it right' [Social system]. ….... 'as I'm not in all the time, things have often moved from one time to the next, labelling everything and having all the things we need in the same place every time made it so much easier to pick the right tool or ink, or cylinder each time without second-guessing if it's right or not'.	Lean improves both the social and technical systems lean impacts productivity and lead times
In your opinion, how has lean reduced the changeover times and cycle times at CL?	The 5S implementation was really effective, organising the areas around the machine to suit what we used most really helped. When we did the stoppages recording, there was 5 or 6 I think after we had checked everything on the machine in training and then started production again I think in the past 2 weeks we've had maybe two.	lean improves both the social and technical systems
Various authors suggest that micro organisations cannot implement lean practices successfully due to lack of resources, amount of staff restricting productivity and implementation, lacking managerial skills, managers time-limited due to 'fire-fighting'..... Reflecting on the overall implementation, to what extent do you agree with the above?	'We don't have the money to have very experienced consultants come in to help; it would be so much easier if we had someone to take care of the day-to-day jobs so we could concentrate on lean'	there are key social and technical enablers specific to micro-organisations there are key social and technical blockers specific to micro-organisations
What are the key benefits generated from implementing lean techniques?	Afterwards, the place looked professional, clean, and somewhere you'd want to work instead of a messy shop floor'; 'increase level of awareness'; 'widened our horizons'.	lean improves both the social and technical systems

Have there been any major issues during this implementation period you have experienced?	During the past couple of weeks, I have felt torn between the implementation of the tools, the manufacturing department, the customers, and running the business as a whole. It was difficult when I had so many things to do each day to dedicate the time the attention needed… the SMED was delayed, and as was the 5S implementation due to things I needed to do and had to postpone [Technical system].	there are key social and technical blockers specific to micro-organisations
Are there any final remarks, comments, or questions you have?	'eye-opener'; 'the manufacturing process is simpler', 'items are easier to find'; 'production is more effective'.	lean improves both the social and technical systems

The quantitative strand of action research is based on an analysis of the performance data of the firm during the research. The data collected are the volume produced, number of jobs, productivity (as a ratio), and lead time (in days). The means and standard deviations of productivity and lead time are analysed. Productivity is calculated as an integer based on the throughput accounting formula for simplicity (Bragg, 2012):

$$\text{Productivity (P)} = \text{Throughput (T)}/\text{Operating Expenses (OE)}.$$

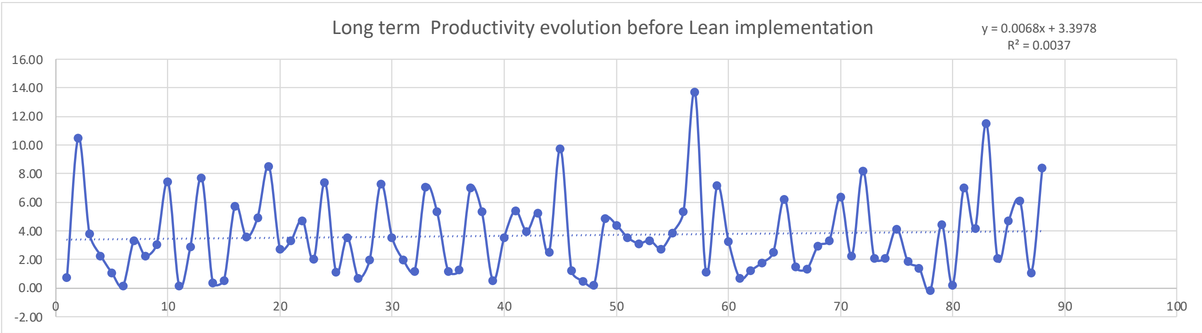
The throughput (T) is the rate at which customer sales generate less truly variable costs, and the operating expenses (OE) are the additional money spent to create throughput, other than truly variable costs. The lead time (LT) is the number of days from start to finish, as recorded in the company system. This set of data enables us to measure the extent to which the lean implementation of the 5S, SMED, JIT, and TPM affected firm performance and tracked the evolution of productivity and lead time over time. First, a baseline assessment is established based on a random sample of 88 measurements of six-month historical data to analyse the long-term productivity and lead time performance before any intervention. Then, an additional 91 data points are analysed for both productivity and lead time throughout the sequential implementation. Appendix 1 provides a sample of the data collection for P0: Pre-lean, P1: Post 5S, and P2: Post SMED. In total, the analysis employs 358 data points (179 data points each for productivity and lead time), enabling the establishment of the trend, significance, and variation created by the lean implementation. The p-values of the two-tailed distribution t-tests are reported in the findings to evaluate the difference between each stage of the sequential deployment.

4. Findings

4.1. CL's background and context with a baseline assessment

Many CL customers are geographically close, and the majority are small- and medium-sized enterprises. The suppliers are more varied, with most being larger companies based elsewhere in the UK and Europe. The main competition for CL arises from digital presses, some of which are only small and cheap, gaining market share and providing a quality product. Companies without these presses must retain their business through other means, which has been to increase the quality of the service and product provided by implementing various programmes, such as lean.

The historical data analysis shows that over time, the company has an established productivity ratio average of 3.70 with a standard deviation of 2.84 (N=88) and an established lead time average of 3.39 days with a standard deviation of 0.92 (N=88) as per Figures 1 and 2. This represents baseline assessment. Importantly, the productivity average seemed to slightly improve before any interventions, as Figure 1's line of fit suggests; however, the trend of the lead time average increases, which is a sign of regression.



Note: productivity is noted as a ratio based on the TOC formula

Figure 1. Established productivity baseline assessment, as a ratio

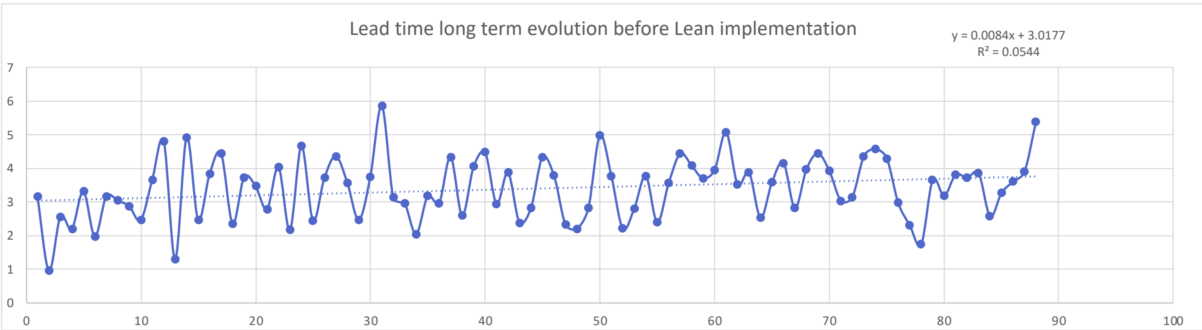


Figure 2. Established lead time baseline assessment, in days

4.2.The sequential implementation

First, 5S is implemented at CL; the employees deploy 5S after the training has been provided, which leads to the production area being cleared, de-cluttered, re-organised, and marked accordingly.

Second, the SMED is implemented at the CL. During its introduction, employees are given an overview of how it could be implemented and benefit the company. During the implementation phase, the staff analyse and separate the internal activities from the external ones and then convert internal activities into external ones to reduce the changes in the bottleneck machine by analysing the footage of the changeover operations.

Subsequently, the JIT is introduced. As CL has a solid and established supplier base, implementing JIT meant that all their deliveries would need to arrive either a day before or on the same day based on the production demand. The scheduling must be improved through a standard communication and a signalling system (i.e. kanban) between the manufacturing and office departments and then between the CL and its main suppliers.

Finally, an autonomous maintenance programme is designed and implemented based on the principles of the TPM. It includes documenting machine inspection points, marking the lubrication points on the machines, providing information on when this was to be carried out (during changeovers or planned stops), creating an autonomous maintenance checklist, and auditing this checklist to ensure relevance and currency.

The sequential approach is powerful for building a knowledge base and confidence of the staff.

4.3.The implementation outcome

Theme 1: Both the social and technical systems improved

The staff reported that lean implementation enabled the improvement of systems and reduced waste. This was a prominent theme of the interviews, providing concurrent evidence that lean techniques helped reduce overproduction, waiting times, inventory, and defects. This was achieved through an '*increase in the level of awareness'*. The participants claim to have expanded their knowledge of lean techniques. They appear to have '*widened their horizons*' on how to improve their manufacturing processes. For example, the MD says, *'I had some knowledge before, I implemented SMED and some other techniques in the company I used to work for, but realising how they can work in my small company has been a real eye-opener, I've learnt new techniques, new ways of doing things and hopefully will be able to improve and* *implement new things in the future'* [attributes predominantly associated with the technical system].

There is also a boost in the realisation that the departments need to work together and synchronise *'with the office department to work out the scheduling really worked [based on JIT principles]. We all [now] know how it works and how to communicate about it to get it right'* [attributes predominantly associated with the social system].

Furthermore, one employee believed that implementing SMED was beneficial and skill broadening in the sense that he learned further about his organisation's manufacturing processes.

Following the implementation of the 5S, the manufacturing area becomes more standardised, health and safety improve, the staff is clearer about where items are stored, and the overall outlook of the production area is improved. *'The 5S implementation was effective, organising the areas around the machine to suit what we used most really helped. […]. Thinking about making tools more accessible made sense. Afterwards, the place looked professional, clean, and somewhere you'd want to work instead of a messy shop floor'.* This shows that physical changes improve the production workspace and allow staff to reduce motion and increase efficiency [attributes predominantly associated with the technical system].

The theme of error reduction emerges following the implementation of 5S and SMED. The participants believe that manufacturing and decision errors were reduced, and the manufacturing area and process became much simpler. Opinions are consistent on this front. One interviewee says, '*As I am not in all the time, things have often moved from one time to the next, labelling everything and having all the things we need in the same place every time made it so much easier to pick the right tool, or ink, or cylinder each time without second-guessing if it's right or not'* [attributes predominantly associated with the technical system]. Another interviewee says, '*It was good to go through the process ourselves…. As we created it, we know* *it inside out, and putting together the new process along with the new manufacturing set-up helped me not make any mistakes'* [attributes predominantly associated with the social system].

Remarkably, the participants seem convinced that production became faster after lean implementation. TPM is mentioned to have improved stoppages '*when we did the stoppages recording there were five or six I think after we had checked everything on the machine in training and then started production again I think in the past 2 weeks we have had maybe two'*, indicating less unplanned stops leading to faster production and fewer delays. The participants become aware of how stocking up on components is important to decrease delays and restore the equipment to keep the machine working under optimal conditions [attributes predominantly associated with the technical system].

It is a fact that the process is shorter after SMED, contributing to faster production, this is mentioned in the interview, along with the notion that 5S had made items quicker and simpler to find, eliminating '*search wor*k'. Delays are also lessened with JIT, *'making it easier for me to know when things we needed for orders were coming in; before, if I did not know, the job would be left and not done or put on the machine to realise I did not have everything I need to make it. Now the plan is in place, I am more aware and can plan better'* [attributes predominantly associated with the social system], which indicates that delays are reduced and production runs more smoothly.

Theme 2: Micro-organisation's social and technical enablers

The results show that the effects occurred rapidly. The participants believe that they were in control of the lean implementation and felt empowered by the fact that they could control these improvements [attributes predominantly associated with the social system]. The interviewees comment on the direct improvements they saw with the implementation of lean practices. These include the improvement of i) the aesthetics of the manufacturing area, ii) the 'smoothness' of the operations, and iii) lead time reduction [attributes predominantly associated with the technical system]. Employees' involvement in training and implementation means that their impact and contribution are direct. This is evidenced by the machine operator, in particular, who says, '*I think it was good that we decided what was going to change, if we were just told what to improve I do not think I would have gone with it as much, but because we came up with the ideas it was like it was more important and I needed to go through with it more'*. This emphasises that the ownership of employees over lean implementation is core to its success [attributes predominantly associated with the social systems].

Following from this control and ownership theme is the notion that employees appear liberated by their ability to control the implementation—not so much for the MD, as he has that control anyway, but for the staff. The fact that personal suggestions and ideas are followed brings about a sense of empowerment among the operators, and it seems as though they are more confident in their job [attributes predominantly associated with the social system].

Theme 3: Micro-organisation's social and technical blockers

The interviews also produce some data suggesting some characteristics of a micro-organisation that hinder lean implementation. The issues within this theme have presented themselves as constant day-to-day concerns for the MD, matters concerning resources, and the perception that the business was just fine before introducing lean, '*so why would it be needed?'*. The day-to-day running of a company is time-consuming; therefore, when lean is introduced, it appears inconvenient at first. This is especially prominent during the SMED implementation: '*many times during the past couple of weeks, I felt torn between the implementation of the tools, the manufacturing department, the customers, and running the business as a whole. It was difficult when I had so many things to do each day to dedicate the time, the attention needed. The SMED was delayed, and so was the 5S implementation due to things I needed to do and had to postpone'* [attributes predominantly associated with the technical system].

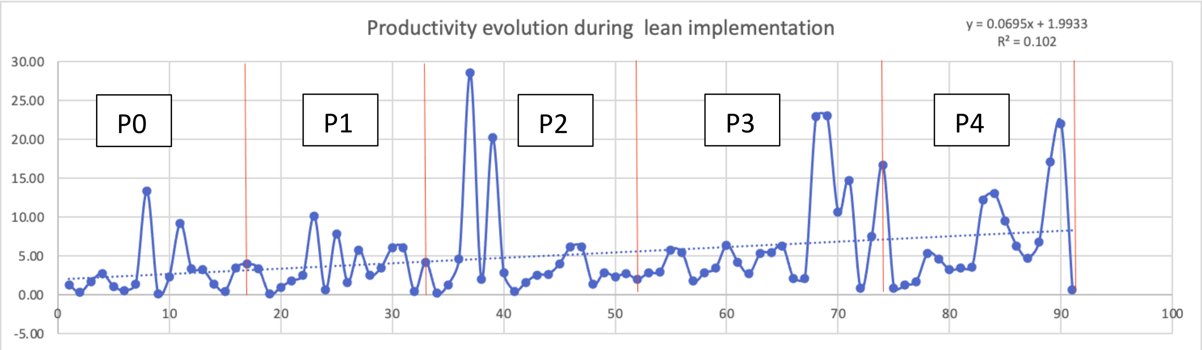
Studies suggest that small and micro-organisations have difficulties implementing lean due to resource scarcity, and this seems to be the case at CL as well. During early interviews, the participants comment on various resource issues, such as '*We do not have the money to have very experienced consultants come in to help; it would be so much easier if we had someone to take care of the day-to-day jobs so we could concentrate on lean'.* The quotes indicate some issues during the introduction of resources or a lack of available resources [attributes predominantly associated with the technical system].

The *'if it is not broken, don't fix it'* mentality also surfaces. CL was treading comfortably before the implementation, so why do they need to go through all the effort if they were fine without lean? During the research and pursuit of ISO9001:2015, the company sent out customer satisfaction surveys. The participants mentioned that many of these surveys came back with a 10/10 score on most of the items, which showed that the customers were extremely satisfied with the service and products they received, creating the perception that lean was not really needed. The participants also mention that they did not think that lean was 'necessary' to implement within CL but were curious about its implementation [attributes predominantly associated with the social system].

Finally, the interviews show that the participants were not fully prepared for implementation to take place. There were instances where no matter how much the researcher tried to coach and train the participants, a pure lack of prior knowledge seems to influence the implementation. The participants mentioned the volume of activity and effort involved was an issue, indicating that *'we weren't aware of how much we would actually be doing, like, changing things and working out what is best and what to change on each rotation'* [attributes predominantly associated with the technical system]. The MD adds: '*It was surprising how much time I had to dedicate to it, I do not think I realised…we had to learn lots of new things* *too, it was all a bit difficult to digest in such a short space of time'* [attributes predominantly associated with the social system].

4.4. The impact on the productivity and lead time: the technical domain

Figure 3 shows the productivity of each job during the data collection period. Overall, the productivity improves after each lean technique is deployed, as shown in Table 2, from a 2.91 ratio to a 6.82 ratio, after the accumulation of 5S, SMED, JIT, and TPM. This trend is illustrated in Figure 3 by the line of fit (y=0.0695x+1.9933). More importantly, productivity significantly improves compared to the baseline assessment from 3.70 to 5.19 (p-value=0.006**). However, productivity experiences much more variation throughout the lean implementation. The standard deviation of the baseline assessment is 2.84, which increases to 5.75 during the lean deployment. After the SMED, the highest variation within productivity is generated with a standard deviation of 7.16, which suggests and confirms the disruption created during the lean implementation. Studying how the different techniques impacted productivity and its variation is insightful, creating significant peaks and valleys.



Note: productivity is noted as a ratio based on the TOC formula

Figure 3. Productivity results at different stages of lean implementation, as a ratio

Table 2. Productivity ratio's mean and standard deviation

Sequential lean implementation	Productivity mean	Productivity std dev
P0: pre-intervention	2.91	3.42
P1: post-5S	3.58	2.90
P2: post-SMED	4.95	7.16
P3: post-JIT	7.06	6.53
P4: post-TPM	6.81	6.06
Total during the programme	**5.19**	**5.75**

Note: productivity is noted as a ratio based on the TOC formula

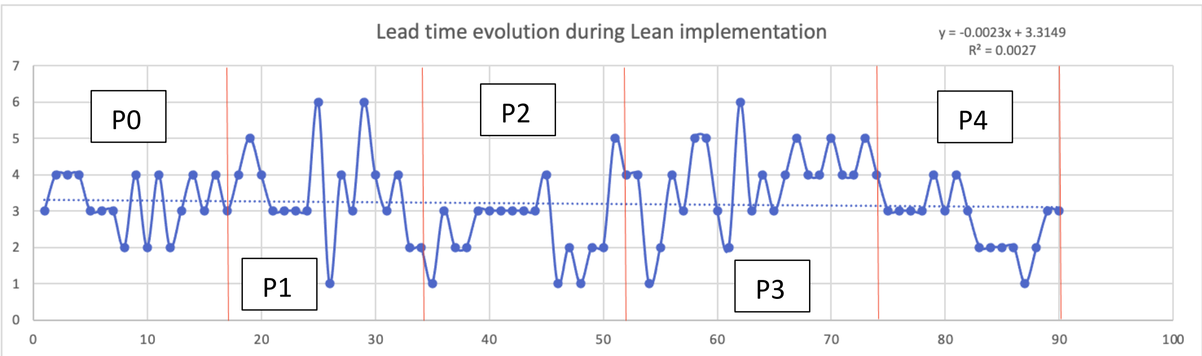
Table 3 reports the significance between each of the implementation phases. Overall, the productivity ratios increase gradually, without evidence of statistical significance between each phase.

Table 3. Productivity ratio's statistical significance values

Hypothesis testing	p-value
H0-1: no difference in Productivity before and after 5S	0.548
H0-2: no difference in Productivity after 5S and after SMED	0.478
H0-3: no difference in Productivity after SMED and after JIT	0.330
H0-4: no difference in Productivity after JIT and after TPM	0.905
H0-5: no difference in productivity before and after the wave lean implementation	0.006**

Note: *p < 0.1; **p < 0.05; ***p < 0.001.

In parallel, Figure 4 represents the lead time in days for each job. Moreover, Tables 4 and 5 show the mean, standard deviation, and statistical findings during the implementation period for lead time performance. The overall average lead time is 3.21 days for a given job, and the overall standard deviation is 1.15 during the implementation. This improves from 3.39 days with an SD of 0.92. The minimum lead time for a particular job is one day, and the maximum is six days. It is noticed that in pre-lean deployment (P0), production is subject to the smallest variation (SD=0.75), while after the 5S deployment, the largest variation is observed (SD=1.31). SMED directly and significantly impacts the lead time, with an average of 2.58 days (p-value=0.013**). Importantly, we observe that lean changed the direction of the trend. The baseline assessment line of fit initially has a positive slope (y=0.0084x+3.0177). However, the lean implementation reverses this trend, showing a negative slope (y=-0.0023x+3.3149). This indicates that lean enables the overall reduction of lead time, even if the lead time average increases after the JIT deployment to 3.82. It also demonstrates that lean is a disruptive business transformation programme, and it will take some time to adjust and adapt effectively to the environment.



Note: Lead time is noted in days

Figure 4. Lead time results at the different stages of the lean implementation, in days

Table 4. Lead time mean in days and standard deviation

Sequential lean implementation	Lead time mean	Lead time standard deviation
P0: Pre-intervention	3.24	0.75
P1: post-5S	3.63	1.31
P2: post-SMED	2.58	1.07
P3: post-JIT	3.82	1.18
P4: post-TPM	2.68	0.79
Total during the programme	**3.21**	**1.15**

Note: Lead time is noted in days

Table 5. Lead time statistical significance values

Hypothesis testing	p-values
H0-6: no difference in lead time before and after 5S	0.299
H0-7: no difference in lead time after 5S and after SMED	0.013**
H0-8: no difference in lead time after SMED and after JIT	0.001***
H0-9: no difference in lead time after JIT and after TPM	0.002**
H0-10: no difference in lead time before and after the wave lean implementation	0.269

Note: *p < 0.1; **p < 0.05; ***p < 0.001.

5. Discussion

5.1. RQ1: How can a micro-organisation effectively implement lean and overcome the social and technical barriers?

First, the findings suggest that the case company successfully implemented lean manufacturing by balancing the social and technical components. This corroborates the ideas of Shea and Gobeli (1995) that lean can be implemented in micro-organisations and is not just for large firms. This also coincides with the notion that lean can be deployed in all businesses, as suggested by Alaskari et al. (2016) and Rymaszewska (2014), as long as both the social and technical system components are considered. In accordance with Ahuja and Khamba (2008), Bamber et al. (2000), and Tice et al. (2005), the employees at CL claim to have gained more knowledge and skills from the lean implementation [attributes associated with both the social and technical systems]. The participants became more aware of how lean could be used within the company [attributes associated with both the social and technical systems]. By the end of the six-month implementation period, they show some willingness towards any subsequent continuous improvement activities that may occur. The employees seem committed to making new improvements even months after the research. This demonstrates that lean deployment has enabled the transformation of culture and people behaviours [attributes predominantly associated with the social system], as well as productivity and lead time performance. With the new lean knowledge acquired, the workforce is more flexible, which coincides with the findings of Simpson and Power (2005).

It is suggested that the benefits of lean are prominent and can be generated much quicker in smaller businesses than in large firms (Haksever, 1996), which is undeniably the case in this study. Some of the success factors are that employees feel they have greater control and are liberated by the training and implementation process [attributes associated with both the social and technical systems]. The study suggests that because employees are involved in the decision-making right from the start and the training, they feel that they have a greater impact on the results and the improvements of the business, which is in line with Cook et al. (1998) and Rymaszewska (2014) [attributes associated with both the social and technical systems]. This increases their sense of responsibility, ownership, and empowerment and is perceived as a 'liberation of power' by the participants (Marin-Garcia & Bonavia, 2015) [attributes predominantly associated with the social system].

Although the company gains technical expertise and appears to have implemented lean reasonably successfully, the findings suggest that the company was ill-prepared for the rollout.

Employees are held back by the lack of prior knowledge, which inevitably influences the lean implementation process. Perhaps for future lean implementation, participants should have pre-training workshops and external site visits to introduce them to the lean concepts before beginning implementations [attributes associated with both the social and technical systems]. The participants also commented on the amount of work involved in the implementation and that they did not realise the required focus and commitment. They mention struggling to digest the technical aspect in a short period, which indicates that trained employees are beneficial for successfully implementing lean programmes, as suggested by Rymaszewska (2014) [attributes associated with both the social and technical systems]. The causes of these issues can be associated with the training and planning of the deployment, which is vital to the success of the implementation (Chan et al., 2005) [attributes associated with both the social and technical systems]. The intense and condensed preparation of the participants could imply that the employees misunderstood the concepts and potentially misjudged the effort involved (Pingyu & Yu, 2010). However, overcoming these obstacles will undoubtedly come with time, practice, and maturity, as employees continue to deploy lean.

A noticeable barrier emerging from the literature is resource obstruction, which appears to be the case at CL. The resources mentioned in the interviews as inadequate consist of finance, software, and people [attributes associated with both the social and technical systems]. The participants believe that the implementation would have been easier with more resources in these areas. There is evidence of these issues in the literature reviewed: financial resources (Rymaszewska, 2014), staff resources and skills, and general resources (Dombrowski et al., 2010; Franco & Hasse, 2010; Thorgren et al., 2012). From the micro-firm perspective, the cost associated with lean is a key barrier, as also mentioned by Ahuja and Khamba (2008) and Chan et al. (2005), suggesting that there is a perception of a high upfront cost with no immediate payback. However, CL has witnessed an initial and direct improvement due to the lean implementation at no direct extra up-front cost. Collaborating with universities and researchers can be a powerful mechanism to access networks, assimilate new knowledge, and deploy complex techniques at no direct cost [attributes associated with both the social and technical systems].

5.2.RQ2: To what extent can a lean implementation improve productivity, reduce lead time, and transform the culture?

Based on the quantitative findings from the productivity and lead time data, it is suggested that lean implementation at CL leads to improved productivity and reduced lead time performance. Productivity improvement is significant, especially when compared to the state before any intervention. The lead time is also reduced after lean deployment, and the trend is reversed. This coincides with the research finding that lean provides significant improvements in productivity and lead time (Lowe et al., 1997; Sohal & Egglestone, 1994). The most significant results are observed in productivity. Significant improvements are observed after JIT and TPM, in line with Ahuja and Khamba (2008) and Voss (1987), suggesting that TPM and JIT reduce production costs and improve productivity and flows. Of course, the combination of lean practices is synergetic, and it is difficult to predict the influence of each technique individually. The improvement will compound as maturity and knowledge grow. The significance of productivity increases as each technique is implemented, confirming that the combination of techniques is more effective than a stand-alone implementation.

Based on the quantitative data collected on lead time and the qualitative findings, it can be inferred that lead time is reduced mainly by SMED and TPM. It is possible that JIT created too many disruptions. To be effective, JIT requires working within the supply chain, whereas the other techniques have a smaller reach around the manufacturing process. Moreover, when the backlog level is low, JIT may not have an early noticeable impact. In addition to the quantitative data, one of the findings from the qualitative data suggests that the staff were producing faster and had fewer delays. The reduction in lead time during the SMED implementation is due to the shortening of the process changes. The employees also believe that the lead time improved after the JIT implementation, which is a noteworthy result. With a definitive plan in place for production, employees feel more organised and work faster, even if this is not consistently observed in the quantitative analysis. Delays are also reduced by the implementation of the TPM, as suggested by both quantitative and qualitative data. The average lead time in days after TPM is the second lowest (mean =2.69) and has the most significant results.

Additionally, the qualitative data reveal that employees notice that stoppages and downtime are reduced after TPM. Hence, employees believe that lean leads to a quicker production system, experiencing fewer delays and errors, contributing substantially to lead time improvement. This is especially true following 5S and SMED deployment, corroborating the findings of Pannesi (1995). The employees mentioned in the interviews that following 5S and SMED deployment, i) the manufacturing process is ‘simpler’, ii) items are ‘easier to find’, and iii) production is more effective.

Perhaps an even more critical finding of this study is the bidirectional duality of the lean programme, as it also changes the people and their behaviour, and hence the company culture. This demonstrates that lean routines are a means of generating change (Feldman and Pentland, 2003). Employees now exhibit greater problem-solving abilities and regulate their own work. Consequently, they can enhance their safety and well-being in the workplace, their learning, and ultimately the meaning of their work and its contribution to the organisation (Hummels and De Leeded, 2000). These are key indicators of a successful lean implementation. Transforming culture is one of the hardest tasks for managing directors and executives. We observe here that through the deployment of lean routines, this micro-manufacturing experiences a transformation of its social system, which in turn, is the critical success factor for sustaining lean technical practices. In this study, lean manufacturing techniques have been used as catalysts for behaviour change, illustrating the bidirectional duality of lean between technical and social systems. From this point forward, we believe this micro-firm will be able to sustain a continuous improvement culture on its own, sometimes using traditional lean techniques and sometimes relying on innovative solutions and a problem-solving mindset, which will have become part of the employees' behaviour.

6. Conclusion

6.1. Summary and the importance of the social system

This study documents and demonstrates how implementing lean in sequence can enhance productivity and reduce lead time and transform employees' behaviour in a micro-organisation. We show that the mixed objective performance results associated with the technical system have led to a cultural change associated with the social system. The bottom line is expected to improve in the medium-term following this implementation, as lean practices are sustained. As a result of this deployment, the company has already become more flexible, notably by capitalising on the new knowledge created. The research concludes that the combination and accumulation of lean techniques further increase performance. They must be used in conjunction as opposed to being implemented as stand-alone tools. The study also shows that individual techniques affect different aspects of improvement and should be carefully selected and implemented with purpose and intent. Therefore, the research demonstrates that a micro-organisation can effectively implement lean when both the social and technical systems are integrated. It concludes that lean practices improve employees' skills and can change employees' attitudes and mindsets towards continuous improvement. A key component for successful implementation is the aspect of greater control and liberation for employees, associated with the concepts of ownership and empowerment. The feeling afforded to employees of their importance in the implementation has a great impact on success. Moreover, top management's commitment and support are paramount. Nevertheless, although the implementation is deemed successful, social and technical barriers and roadblocks must be overcome. There are issues where employees are held back by a lack of prior knowledge, which causes misunderstanding. Furthermore, the 'fire-fighting' culture is problematic in deploying lean and can be extremely difficult to overcome for a micro-organisation. This is the largest social factor that limits this implementation.

6.2.Contribution, limitations, and future research

This study is among the first to delve into and analyse the impact of a lean implementation by sequentially deploying 5S, SMED, JIT, and TPM on a micro-organisation's productivity, lead time, and culture. This study contributes to the lean implementation of micro-firms' body of evidence, which has been defined as non-prevalent (Filho et al., 2016; Hu et al., 2015; Yadav et al., 2019). It provides a blueprint methodology to micro-firms' owners who would like to embark on lean manufacturing in terms of managerial contribution. This phenomenon is framed using the socio-technical system theory, which remains limited. Here, we have demonstrated the duality concept of lean, and how the technical and social systems are so interdependent and interact with each other, which form an aspect of our theoretical contribution. Hence, we believe that the findings and analysis make a defined theoretical contribution to the academic literature by applying the socio-technical theory, evidencing that to deploy lean successfully, micro-firms need to integrate and invest in both the social and technical components to realise operational benefits. Moreover, our interpretations reveal that social components significantly impact the adoption of lean technical systems. This corroborates Hadid et al. (2016), who report the importance of implementing lean from a social-technical perspective to improve a firm's operational and financial performance.

The first limitation of this study is the inability to isolate the effect of each technique on productivity and lead time performance. The lean techniques implemented can only be considered together, as they are deployed consecutively in sequence. However, future quantitative research could more precisely measure the isolated impact for each of the techniques: 5S, SMED, JIT, and TPM. Similarly, we acknowledge that the sample collected is relatively small even if the implementation lasted six months, and it employs 358 performance data points and qualitative data. However, as the demand is reasonably constant and stable, we are confident in the reliability of the analysis. It would have been beneficial to collect attribute data to further explain the peaks and valleys. This would have helped us identify whether external factors influence productivity or lead time. The second limitation is the time scale of the implementation of six months. Some studies discuss how lean implementations can take two to three years to influence business performance, especially culture. However, we strongly believe that six months is appropriate for a micro-organisation. Future research should consider a more longitudinal study to explore the long-term effects and evolution of performance throughout different implementation phases. Moreover, the generalisability of this action research study should be taken with caution, and while we strongly believe that our roadmap for lean implementation in sequence can be replicated by other manufacturing micro-firms, we cannot predict the impact it will have on their productivity, lead time, and culture. However, we recommend that scholars and practitioners investigate this quantitatively using a survey methodology on larger scales with micro-organisations. Finally, researchers may utilise socio-technical theory to explore how the lean startup approach (Balocco et al., 2019) can be applied in micro-manufacturing to advance our understanding of the different facets of lean.

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Appendix 1: Sample of the quantitative performance data collection

Phase	Job	Productivity (as a Ratio)	Prod. mean	Prod. SD	Lead time (in days)	LT mean	LT SD
P0: Short Term before implementation	1	1.25			3		
	2	0.29			4		
	3	1.72			4		
	4	2.69			4		
	5	1.08			3		
	6	0.49			3		
	7	1.40			3		
	8	13.30			2		
	9	0.11			4		
	10	2.27			2		
	11	9.15			4		
	12	3.34			2		
	13	3.21			3		
	14	1.40			4		
	15	0.44			3		
	16	3.43			4		
	17	3.91	2.91	3.42	3	3.24	0.75
P1: Data post 5S implementation	18	3.37			4		
	19	0.06			5		
	20	0.93			4		
	21	1.82			3		
	22	2.50			3		
	23	10.13			3		
	24	0.60			3		
	25	7.84			6		
	26	1.61			1		
	27	5.76			4		
	28	2.53			3		
	29	3.48			6		
	30	6.04			4		
	31	6.06			3		
	32	0.43			4		
	33	4.16	3.58	2.90	2	3.63	1.31
P2: Data post SMED implementation	34	0.24			2		
	35	1.27			1		
	36	4.64			3		
	37	28.53			2		

	38	1.98			2		
	39	20.19			3		
	40	2.77			3		
	41	0.44			3		
	42	1.60			3		
	43	2.53			3		
	44	2.63			3		
	45	3.95			4		
	46	6.13			1		
	47	6.11			2		
	48	1.36			1		
	49	2.79			2		
	50	2.32			2		
	51	2.69			5		
	52	1.95	4.95	7.16	4	2.58	1.07