Toward Lean Service 5.0: evaluation of future perspectives and trends

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Abstract
Embracing the social, resilient, and sustainable dimensions focusing on human-machine cooperation marks the revolution known as X5.0. Combining lean with service 5.0 is the path to enhancing the lean capability of an organisation both at the operational and enterprise level, coining the term 'Lean Services 5.0' (LS5.0). This paper aims to evaluate the managerial implication of LS5.0 to identify opportunities and future research avenues toward Lean Services 5.0 based on the People, Process, Technology (PPT) framework. To achieve this aim, we mapped the current literature via the Systematic Search Flow (SSF) method. We developed the lean service 5.0 PPT framework and identified the 12 principles for an LS5.0 organization. These principles utilise new technologies to foster continuous improvement methods that provide data for value identification and create a reciprocal learning environment.
Keywords: Industry 5.0; Lean Service; Digital innovation; Service 5.0; Continuous Improvement.

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Em direção ao *Lean Service* 5.0: avaliação das tendências e futuras perspectivas

Resumo
Abraçar as dimensões social, resiliente e sustentável com foco na cooperação homem-máquina marca a revolução conhecida como X5.0. Combinar *lean* com serviço 5.0 é o meio para aprimorar a capacidade *lean* de uma organização tanto no nível operacional e estratégico, cunhando o termo '*Lean Services 5.0*' (LS5.0). Este artigo objetiva avaliar as implicações gerenciais do LS5.0 para identificar oportunidades e futuras direções de pesquisa baseado no *framework* que aglutina Pessoas, Processos e Tecnologia (PPT). Para atingir esse objetivo, mapeamos a literatura atual por meio do método *Systematic Search Flow (SSF)*. Desenvolvemos a estrutura LS5.0 PPT e identificamos os 12 princípios para uma organização LS5.0. Estes princípios se utilizam de novas tecnologias para favorecer os métodos de melhoria contínua, fornecendo dados para identificação de valor e criando um ambiente de aprendizado recíproco.
Palavras-chave: Indústria 5.0; Serviço *Lean*; Inovação digital; Serviço 5.0; Melhoria contínua.

Hacia *Lean Service* 5.0: evaluación de tendencias y perspectivas de futuro

Resumen
Adoptar las dimensiones sociales, resilientes y sostenibles con un enfoque en la cooperación hombre-máquina marca la revolución conocida como X5.0. Combinar *lean* con *Service* 5.0 es la forma de mejorar la capacidad *lean* de una organización tanto a nivel operativo como empresarial, acuñando el término '*Lean Services* 5.0' (LS5.0). Este artículo tiene como objetivo evaluar la implicación gerencial de LS5.0 para identificar oportunidades y futuros caminos de investigación hacia LS5.0 basados en el marco de Personas, Procesos y Tecnología (PPT). Para eso, mapeamos la literatura utilizando la metodología *Systematic Search Flow*. Desarrollamos el marco PPT LS5.0 e identificamos los 12 principios para una organización LS5.0. Estos principios utilizan nuevas tecnologías para favorecer los métodos de mejora continua, proporcionando datos para la identificación de valor y creando un ambiente de aprendizaje recíproco.
Palabras clave: Industria 5.0; Servicio *Lean*; Innovación digital; Servicio 5.0; Mejora continua.

1 Introduction

Organisations are experiencing an unprecedented digital revolution marked by a boom in the development of digital technologies, increasing their application in several areas of socio-technical systems (Hamzaoui; Julien, 2022). The rise of digital technologies led to the Fourth Industrial Revolution, also known as Industry 4.0 (I4.0), representing the attempt to apply Artificial Intelligence (AI) and information technology to increase productivity in manufacturing industries (Nayeri; Sazvar; Heydari, 2023).

The techno-economic orientation of *I4.0* originated a problem by focusing on the technology and digitalisation and ignoring crucial principles such as sustainability and human aspects (Breque; Nul; Petridis, 2021; Nayeri; Sazvar; Heydari, 2023; Nixdorf; Zhang; Ansari; Grosse, 2022). These issues provoked the Fifth Industrial Revolution (Industry 5.0 or *I5.0*) changing the concepts and focus of the *I4.0* to embrace the social, resilient, and sustainable dimensions (Javaid; Haleem; Singh; Suman; Gonzales, 2022; Nayeri; Sazvar; Heydari, 2023). *I5.0* focus on human-machine connectivity and cooperation, describing how they work together and defining the laws for the contact between people and machines (Javaid; Haleem; Singh; Suman; Gonzales, 2022).

The extrapolation of I5.0 to other sectors and environments emerged as the X5.0 movement (Wang; Zheng; Yin; Shih; Wang, 2022), such as Society 5.0 (Ciasullo; Orciuoli; Douglas; Palumbo, 2022; Huang; Wang; Li; Zheng; Mourtzis; Wang, 2022) and Operator 5.0 (Romero; Stahre, 2021). The need to integrate I5.0 technologies to provide outstanding services is also recognised in the literature, being one of the main trends for transforming companies (Aheleroff; Mostashiri; Xu; Zhang, 2021). One of the benefits of I5.0 applied to services is the increase in resilience with a quick recovery system (Nayeri; Sazvar; Heydari, 2023). Service 5.0 emerge as the integration of I5.0 principles and technologies in service organisations.

Nevertheless, migrating to service 5.0 means facing a lack of knowledge background requiring further investigation (Nixdorf; Zhang; Ansari; Grosse, 2022; Wang; Zheng; Yin; Shih; Wang, 2022). Researchers tend to focus on technological advances but consider few social and human aspects (Li; Rich; Found; Kumar; Brown, 2020; Loureiro; Guerreiro; Tussyadiah, 2021; Wilkens, 2020). Furthermore, organisations find it complex to integrate I5.0 technologies with workers, processes, and business strategies (Chowdhury; Budhwar; Dey; Joel-Edgar; Abadie, 2022). Furthermore, a hindering factor is the limited understanding among human workers about the technological

impact on their jobs (Chowdhury; Budhwar; Dey; Joel-Edgar; Abadie, 2022; Poba-Nzaou; Galani; Uwizeyemungu; Ceric, 2021).

Advancing in the subject means upgrading skills to adopt technologies and creating effective collaboration and partnership between AI and human intelligence (Makarius; Mukherjee; Fox; Fox, 2020). *I5.0* places human needs in the spotlight, focusing on their knowledge about their tasks and the organisation culture, which comprises the essence of lean (Davies; Coole; Smith, 2017; Nayeri; Sazvar; Heydari, 2022; Wang; Zheng; Yin; Shih; Wang, 2022). Furthermore, the technology forming the background of *I5.0* fits lean management approaches by introducing extra customisation, better productivity, waste elimination, quality improvement, and segmentation (Aheleroff; Mostashiri; Xu; Zhang, 2021).

Lean helps to achieve I5.0 by enhancing the ability of humans of being creative, flexible, and capable of solving problems, which provides a supportive organisational culture and knowledge background enabling technological advancements and innovations (Alves, 2022; Davies; Coole; Smith, 2017; Moencks; Roth; Bohné; Romero; Stahre, 2022; Wang; Zheng; Yin; Shih; Wang, 2022). The culture of continuous improvement leads not only to accept the I5.0 change but actively drive it (Davies; Coole; Smith, 2017). Conversely, I5.0 provides the infrastructure to potentially enhance the lean capability of an organisation both at the operational and enterprise level (Davies; Coole; Smith, 2017).

The development of lean in service organisations is known as lean service (Vadivel; Sequeira; Sakkariyas; Boobalan, 2022). Combining lean and I5.0 in service organisations leads to LS5.0, defined as the integration and symbiosis of I5.0 technologies and principles with the lean services aiming to create, enhance, and deliver customer value through a socio-technical system based on technology. It creates a learning environment to promote a lean mindset, share and advance knowledge, and orchestrate I5.0 technology.

The perspective of lean puts workers and organisational culture as protagonists instead of focusing on technologies. Integrating lean service and Services 5.0 creates a symbiotic environment aligning culture, people, and technology toward value delivery. This paper aims to review the literature to identify opportunities and future research avenues toward the construction of LS5.0. We undertook an in-depth review of the literature following the Systematic Search Flow (SSF) (Ferenhof; Fernandes, 2016). As a result, we analysed 42 documents to identify the state-of-the-art X5.0. We

organised the content following the People-Process-Technology (PPT) framework of lean (Morgan; Liker, 2020) to compose the PPT framework of LS5.0 and its 12 principles. Expanding lean to service digitalisation opens many possibilities and benefits. Technology fosters continuous improvement methods by providing data and enabling Reciprocal Learning (RL) while lean enables technology adoption by establishing an adaptative mindset focused on integrating human-machine toward value delivery.

Even though studies acknowledge the necessity of placing culture at the centre, orchestrating human-technology duality to enhance value delivery, the integration of lean and X5.0 is still insipient in the literature. The lean orientation of stimulating organisational learning, creativity, and problem-solving culture, when aligned with technologies capable of enhancing value delivery, provides a better customer experience. Based on this, we outline the contributions of our study as follows:

- Present state-of-the-art X5.0 to provide an overview of the literature and research avenues. We also analyse the advances in Industry 4.0 to grasp technological trends;
- Present the technologies in X5.0 through the service perspective;
- Connect lean, service digitalisation, and X5.0;
- Undertake the pioneer effort to build the LS5.0 concept;
- Identify opportunities to advance in LS 5.0;
- Discuss the integration of LS 5.0 for a Lean Society 5.0 and circular economy chains;
- Identify valuable research opportunities to expand knowledge in LS5.0 and implications for service management and innovation.

The remainder of the paper is outlined as follows. Section 2 provides a theoretical background regarding I5.0, service digitalisation, and lean service. Section 3 presents the methodology with a statistical analysis of publications. Section 4 discusses LS5.0 from the PPT framework perspective. Section 5 presents the future trends and research opportunities toward LS5.0. Finally, Section 6 concludes the work, providing managerial implications for service management and innovation.

2 THEORETICAL BACKGROUND

Organisations compelled to be competitive and provide differentiated products cause waves of new technologies applied to processes. They characterise

different ages of industrialization portrayed as industrial revolutions (Industry X.0). The first industrial revolution occurred by the age of steam, the second by the application of electricity, and finally, the third by information technology (Fantini; Pinzone; Taisch, 2020; Ghobakhloo, 2018; Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang, 2022). Subsequently, the application of Cyber-Physical Systems (CPS) within industrial production systems led to the fourth industrial revolution (*I4.0*) (Ghobakhloo, 2018).

It meant a shift from machine-dominant manufacturing to digital manufacturing (Oztemel; Gursev, 2020), adopting technology to interconnect artifacts enabling real-time analysis of large amounts of information (Davies; Coole; Smith, 2017). I4.0 promoted efficiency to a higher level with the emergence of several technologies (Rübmann; Lorenz; Gerbert; Waldner; Engel; Harnisch; Justus, 2015; Vaidya; Ambad; Bhosle, 2018; Wang; Zheng; Yin; Shih; Wang, 2022; Torre; Bonamigo, 2024). The technological advancements in *I4.0* focused on the profitability of organisations while neglecting environmental and social metrics (Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang, 2022; Maddikunta; Pham; Prabadevi; Deepa; Dev; Gadekallu; Ruby; Liyanage, 2022).

This scenario led to the necessity of aligning technologies with human capability. The new paradigm is to improve a sustainable, human-centric and resilient industry called I5.0 (Alves, 2022). *I5.0* complements the existing *I4.0* (Alves, 2022), combining human subjectivity and intelligence with the efficiency and precision of machines, reflecting the value of humanistic care, thus realising the evolution toward symbiotic ecosystems (Huang; Wang; Li; Zheng; Mourtzis; Wang, 2022; Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang, 2022; Maddikunta; Pham; Prabadevi; Deepa; Dev; Gadekallu; Ruby; Liyanage, 2022). The fundaments of *I5.0* are the human-centricity and resilience. People are the path to achieve flexibility, agility, and robustness against disruptions in process.

The human-centricity implies more fault tolerance capabilities and improves working conditions (Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang, 2022; Nayeri; Sazvar; Heydari, 2023). Resilience is the capability of the system to recover quickly to a stable state after a disruption (Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang, 2022). It is characterised by the capacity of anticipation, robustness, and time to recover after a disruption (Nayeri; Sazvar; Heydari, 2023).

I5.0 preconises not only the use of technologies but sustainability as well.

Bioeconomy is the smart use of biological resources to balance ecology and industry (Demir; Döven; Sezen, 2019). It is applied to add value to the service by using resources appropriately conserving the environment. Digital transformation is a big challenge to organisations. The priority lies in developing people and preparing the workforce by offering purposive education and training that promotes lifelong learning (Dombrowski; Wullbrandt; Fochler, 2019).

2.1 THE DIGITAL TRANSFORMATION OF SERVICES

Service organisations manage data, information, and knowledge via technological applications. It enables orchestrating players for value creation, providing enhanced customer experience through digital transformation (Soto Setzke; Riasanow; Böhm; Krcmar, 2021; Wirtz; Kunz; Hartley; Tarbit, 2022). Henriette, Feki and Boughzala (2016) define it as a disruptive or incremental change process, starting by the application of digital technologies, then evolving into a holistic transformation to pursue value creation.

The role of technology depends on the organisation and its individuals (Mergel; Edelmann; Haug, 2019). Structural changes toward digital transformation imply in processes based on new methods, attempting to keep a pace with digitisation (Ulas, 2019). In a service context, digital transformation stimulates innovation since it represents a change in value creation strategies by applying flexible data-based management models capable of quick meeting dynamic customer demands (Schallmo; Williams; Boardman, 2017).

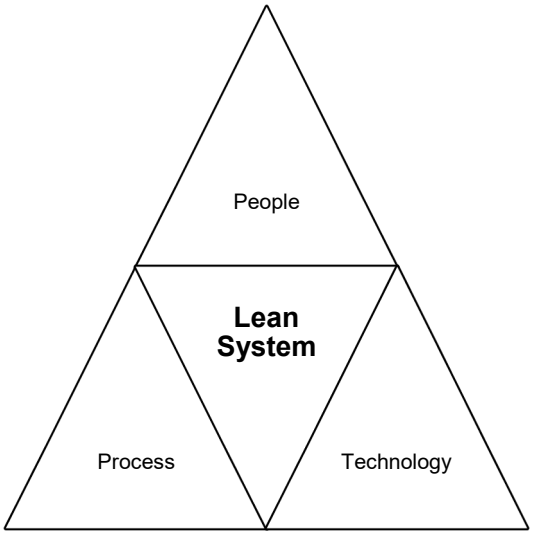
The digital transformation in services require a focus on team learning for the digital environment. It includes the development of skills for social learning, redesign process for delivering contenting, knowledge sharing, and informal problem solving (Sousa; Rocha, 2019). Thus, digital transformation provides services aided by technologies such as AI and robots powered by data for offering new solutions (Basole; Patel, 2018).

2.2 LEAN SERVICES

Lean principles support digital transformation (Alves, 2022). Lean is based on value creation while eliminating waste. Since it focuses on perfection, it seeks cost reduction, zero defects, and zero inventories. Its principles are to identify value, identify the value chain, make value flow seamlessly, make the customer pull value, and seek

perfection (Womack; Jones, 2003). Lean can be considered a sociotechnical approach (see Fig. 1) for developing and improving processes and people (Morgan; Liker, 2020).

Figure 1 - Socio-Technical Systematic



Source: adapted from Morgan and Liker (2020).

Lean service is lean applied to services (Gupta; Sharma; Sunder, 2016), improving key performance indicators in economic aspects, behaviours of people and service outputs benefits (Dombrowski; Malorny, 2018; Gupta; Sharma; Sunder, 2016). In services, the lean approach considers customer value as a set of service deliveries, including output benefits, value creation, and customer experience (Petrusch; Vaccaro, 2019). In manufacturing environments, seven wastes guide lean waste elimination activities: overproduction, motion, inventory, defects, over-processing, waiting, and transport (Ohno, 1988; Shingo, 1989).

Lean applied to services also focuses on waste elimination (Qu; Ma; Zhang, 2011). Wastes in services are present in-service design (delivering what customers do not want, including extra functions and adding cost or time), provision (delivery with excessive lead times and morosity), ability (ability not fully explored), process (adding extra complexity), and delays (wait times of costumers and providers).

3 METHODOLOGICAL PROCEDURES

We undertook a review to evaluate research opportunities and future perspectives for developing the Lean Service 5.0 knowledge background. We applied

the Systematic Search Flow (SSF), as proposed by (Ferenhof; Fernandes, 2016), which is a method with four phases (Figure 2). The search strategy adopted in our review comprises the identification of suitable sources and the definition of inclusion and exclusion criteria.

Figure 2 - Systematic Search Flow

Source: adapted from Ferenhof and Fernandes (2016).

The data sources were research and review articles, and conference papers indexed in Scopus, EBSCO, Compendex, Emerald, Science Direct, and Web of Science. We excluded grey literature such as reports and non-academic research. We selected only publications in English with available full-text access. Following the SSF procedure, we defined the search query through an initial exploratory search to identify keywords in the field of *I4.0* and *I5.0*. Subsequently, we tested our results and improved the query to extract a quality pool of publications from databases.

Our research query was (("digital transformation" OR digitalisation OR digitalization OR "smart service*") AND ("industry 5.0" OR "Socio-technical systems") AND (lean OR "Toyota production system")). We proceeded by extracting and forming the pool of publications and filtering it to generate the literature background of this research (Table 1).

Table 1 - Systematic bibliographic review results and portfolio

	Extraction and filtering	**Publications**
Extraction (29th nov. 2022)	Science Direct	271
	Scopus	4
	Emerald	334
	EBSCO	50
	Web of Science	2
	Village	4
	Total	665
Filtering	Duplicated elimination	654
	Title, abstract and keywords	241
	Full-text	62
	Portfolio	42

Source: The authors (2024).

We analysed the literature by generating a datasheet with relevant criteria for establishing LS5.0 state-of-the-art and identifying research opportunities. We created thematic groups to organise the publications and findings. Based on this, we synthesised the most relevant research topics and literature gaps toward LS 5.0 knowledge consolidation. We analysed the content according to Bardin (2011), considering as inclusion and exclusion criteria: (i) documents presenting a relationship between people and technologies in the context of services; (ii) documents exposing the relationship between lean or digital/technological services; and (iii) documents presenting the characterisation of I5.0 applied to services or lean.

We organised content based on three analysis units (Bardin, 2011) to consider knowledge advances according to the PPT framework (see Fig. 1). The PPT is a consolidated model for transforming and managing an organisation toward lean (Kayikci; Subramanian, Dora; Bhatia, 2022). We concluded our review by writing the findings in a document. Table 2 presents the portfolio comprising this research.

Table 2 - Portfolio of documents

Authors	Title	Source
A1. Nayeri; Sazvar; Heydari (2023)	Towards a responsive supply chain based on the industry 5.0 dimensions: A novel decision-making method	Expert Systems with Applications
A2. Chowdhury; Budhwar; Dey; Joel-Edgar; Abadie (2022)	AI-employee collaboration and business performance: Integrating knowledge-based view, socio-technical systems and organisational socialisation framework	Journal of Business Research
A3. Brauner; Ziefle (2022)	Beyond playful learning Serious games for the human-centric digital transformation of production and a design process model	Technology in Society
A4. Gupta; Singh; Gupta (2022)	Developing human resource for the digitization of logistics operations: readiness index framework	International Journal of Manpower
A5. Moencks; Roth; Bohné; Romero; Stahre (2022)	Augmented Workforce Canvas: a management tool for guiding human-centric, value-driven human-technology integration in industry	Computers & Industrial Engineering
A6. Kristensen; Saabye; Edmondson (2022)	Becoming a learning organisation while enhancing performance: the case of LEGO	International Journal of Operations & Production Management
A7. Sindhwani; Afridi; Kunar; Banaitis; Luthra; Singh (2022)	Can industry 5.0 revolutionize the wave of resilience and social value creation? A multi-criteria framework to analyse enablers	Technology in Society

A8. Yu; Xu; Ashton (2023)	Antecedents and outcomes of artificial intelligence adoption and application in the workplace: the socio-technical system theory perspective.	Information Technology & People
A9. Fenner; Arellano; Dzengelevski; Netland (2023)	Effect of lean implementation on team psychological safety and learning	International Journal of Operations & Production Management
A10. Wang; Zheng; Yin; Shih; Wang (2022)	Toward human-centric smart manufacturing: A human-cyber-physical systems (HCPS) perspective	Journal of Manufacturing Systems
A11. Träskman (2022)	Smartness and thinking infrastructure: an exploration of a city becoming smart	Journal of Public Budgeting, Accounting & Financial Management
A12. Nixdorf; Zhang; Ansari; Grosse (2022)	RL in Production and Logistics	IFAC-PapersOnLine
A13. Javaid; Haleem; Singh; Suman; Gonzales (2022)	Understanding the adoption of Industry 4.0 technologies in improving environmental sustainability	Sustainable Operations and Computers
A14. Hamzaoui; Julien (2022)	Social Cyber-Physical Systems and Digital Twins Networks: A perspective about the future digital twin ecosystems	IFAC-PapersOnLine
A15. Furstenau; Zani; Terra; Sott; Choo; Saurin (2022)	Resilience capabilities of healthcare supply chain and supportive digital technologies	Technology in Society
A16. Alves (2022)	Lean Thinking: an essential mindset	IEEE Engineering Management Review
A17. Huang; Wang; Li; Zheng; Mourtzis; Wang (2022)	Industry 5.0 and Society 5.0: Comparison, complementation and co-evolution	Journal of Manufacturing Systems
A18. Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang (2022)	Industry 5.0: Prospect and retrospect	Journal of Manufacturing Systems
A19. Li; Claes; Kumar; Found (2022)	Exploring the governance mechanisms for value co-creation in PSS business ecosystems	Industrial Marketing Management
A20. Maddikunta; Pham; Prabadevi; Deepa; Dev; Gadekallu; Ruby; Liyanage (2022)	Industry 5.0: A survey on enabling technologies and potential applications	Journal of Industrial Information Integration
A21. Sarkar; Routroy; Sultan (2022)	The impact of co-creation and co-invention in supply chains: a bibliometric review	Arab Gulf Journal of Scientific Research
A22. Li; Kassem (2021)	Applications of distributed ledger technology (DLT) and Blockchain-enabled smart contracts in construction	Automation in Construction
A23. Romero; Stahre (2021)	Towards The Resilient Operator 5.0: The Future of Work in Smart Resilient	Procedia CIRP

	Manufacturing Systems	
A24. Wellsandt; Klein; Hribernik; Lewandowski; Bousdekis; Mentzas; Thoben (2021)	Towards Using Digital Intelligent Assistants to Put Humans in the Loop of Predictive Maintenance Systems	IFAC-PapersOnLine
A25. Bharosa (2022)	The rise of GovTech: Trojan horse or blessing in disguise? A research agenda	Government Information Quarterly
A26. Ciasullo; Orciuoli; Douglas; Palumbo (2022)	Putting Health 4.0 at the service of Society 5.0: Exploratory insights from a pilot study	Socio-Economic Planning Sciences
A27. Aheleroff; Mostashiri; Xu; Zhang (2021)	Mass Personalisation as a Service in Industry 4.0: A Resilient Response Case Study	Advanced Engineering Informatics
A28. Fantini; Pinzone; Taisch (2020)	Placing the operator at the centre of Industry 4.0 design: Modelling and assessing human activities within cyber-physical systems	Computers & Industrial Engineering
A29. Li; Rich; Found; Kumar; Brown (2020)	Exploring product service systems in the digital era: a socio-technical systems perspective	TQM Journal
A30. Peruzzini; Grandi; Pellicciari (2020)	Exploring the potential of Operator 4.0 interface and monitoring	Computers & Industrial Engineering
A31. Sahoo (2020)	Lean manufacturing practices and performance: the role of social and technical factors	International Journal of Quality & Reliability Management
A32. Keller; Bayer; Bausch; Metternich (2019)	Benefit evaluation of digital assistance systems for assembly workstations	Procedia CIRP
A33. Dombrowski; Wullbrandt; Fochler (2019)	Center of Excellence for Lean Enterprise 4.0	Procedia Manufacturing
A34. Breidbach; Choi; Ellway; Keating; Kormusheva; Kowalkowski; Lim; Maglio (2018)	Operating without operations: how is technology changing the role of the firm?	Journal of Service Management
A35. Dezi; Pisano; Pironti; Papa (2018)	Unpacking open innovation neighborhoods: of the lean smart city	Management Decision
A36. Janowski; Estevez; Baguma (2018)	Platform governance for sustainable development: Reshaping citizen-administration relationships in the digital age	Government Information Quarterly
A37. Ghobakhloo (2018)	The future of manufacturing industry: a strategic roadmap toward Industry 4.0	Journal of Manufacturing Technology Management
A38. Davies; Coole; Smith (2017)	Review of Socio-technical Considerations to Ensure Successful Implementation of Industry 4.0	Procedia Manufacturing
A39. Lamnabhi-Lagarrigue;	Systems & Control for the future of humanity, research agenda: Current and	Annual Reviews in Control

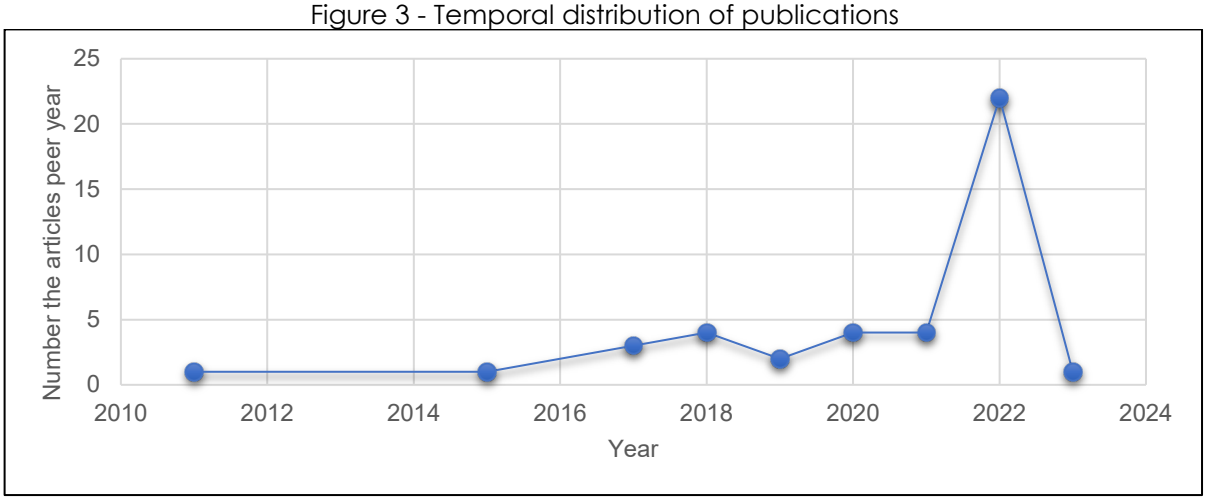
Annaswamy; Engell; Isaksson; Khargonekar; Murray; Tilbury; Samad; Nijimeijer; Hof (2017)	future roles, impact and grand challenges	
A40. Smith; Anderson; Fox (2017)	A quality system's impact on the service experience	International Journal of Operations & Production Management
A41. Lee; Harindranath; Oh; Kim (2015)	Provision of mobile banking services from an actor–network perspective: Implications for convergence and standardization	Technological Forecasting and Social Change
A42. Baxter; Sommerville (2011)	Socio-technical systems: From design methods to systems engineering	Interacting with Computers

Source: The authors (2024).

3.1 Statistical description

We analysed our portfolio after content analysis based on the temporal distribution of publications, main keywords characterising the field of study, application environments, and leading publishers. These factors provide an overview of the path literature follows and the future tendencies for LS5.0. Figure 3 shows the temporal distribution of works, indicating the growing interest of the research community.

Figure 3 - Temporal distribution of publications



Source: The authors (2024).

Organisations are embracing the digital revolution. The growth of publications reflects the tendency to consider digitalisation as the path to enhance value delivery and deal with the volume of data. We analysed 223 keywords to identify the most

preferred ones in X5.0. The leading terms are "Industry 4.0", "Industry 5.0", "Digitalisation", and "Internet of Things". Of the 42 Journals, the leading publisher is the International Journal of Operations & Production Management. X5.0 has most works in journals related to business management, marketing, service management, industrial management, and technologies. Governmental and city administration represent most applications, followed by logistics, healthcare, energy, design, mobile banking, and maintenance.

4 LEAN SERVICE 5.0 THROUGH THE PPT FRAMEWORK

In this section, we discuss the findings, opportunities, and research avenues toward LS5.0. We organised this section according to the PPT framework. We analysed 42 articles and identified topics and insights related to our research.

4.1 EVALUATION OF LEAN SERVICE 5.0 IN THE PEOPLE PERSPECTIVE

Combining lean service and I5.0 means human-machine working together to learn and improve processes to enhance value delivery in services. Technologies create an environment favouring collaborative work and the development of new skills through knowledge sharing (Chowdhury; Budhwar; Dey; Joel-Edgar; Abadie, 2022). It enables customers to be actively involved in service delivery and value co-creation. Lean service considers people as the key to integrating machines, processes, and technologies (Ferenhof; Cunha; Bonamigo; Forcellini, 2018).

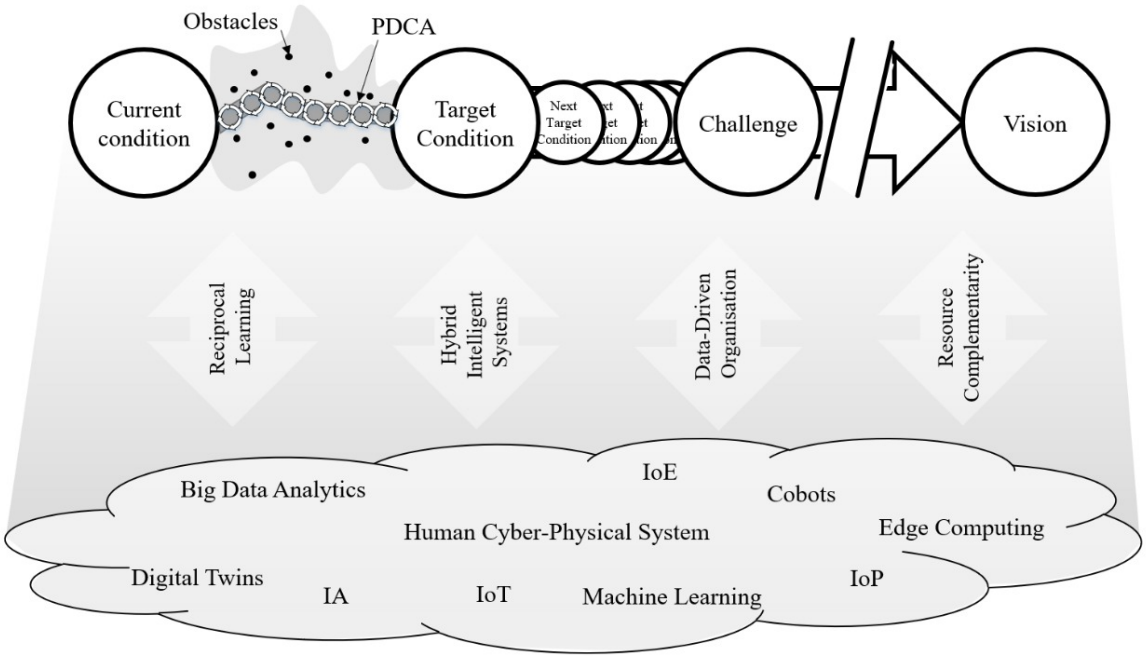
Technical systems alone cannot lead a company to continuous improvement and customer satisfaction. Similarly, lean cannot be sustained only by tools (Taherimashhadi; Ribas, 2018). Hence, the proactive participation of management, employees, customers, and suppliers, supports lean development (Sahoo, 2020). Culture and mindset are crucial to successful lean initiatives (Ingelsson; Bäckström; Snyder, 2018; Vlachos; Siachou, 2018). Lean combined with the human-centred focus of *I5.0* stimulates the development of technological skills in employees (Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang, 2022; Li; Rich; Found; Kumar; Brown, 2020). It improves the capitalisation potential of technologies and achieving new levels of productivity (Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang, 2022; Romero; Stahre, 2021).

Daily management focusing on establishing routines and mindsets in people enables orchestrating resources for learning and improving processes. Furthermore,

employees' ability and behaviour affect customer experience (Smith; Anderson; Fox, 2017). The Toyota Kata (TK) is an approach to develop lean and improve processes, stimulating the repetition of deliberated practices (Bonamigo; Bernardes; Conrado; Torres; Calado, 2022; Rother, 2009). The integration of TK to build LS5.0 consists of technologies and people learning together about processes, customers, value, and system behaviour (Figure 4).

The approach consists of a scientific method routine for solving problems, seeking to reach the ideal environment condition. In this context, the technologies that emerge in I5.0 support continuous improvement. As a result, it promotes RL, the human-machine symbiosis underpinned by exchanging knowledge symmetrically between both agents, enabling mutual understanding, learning, and coordination (Nixdorf; Zhang; Ansari; Grosse, 2022).

Figure 4 - Toyota Kata integrated with I5.0 technologies



Source: adapted from Rother (2009).

Technologies provide information to support scientifical learning during TK PDCA learning cycles. Integrating TK with the I5.0 technologies forms the basis for continuous improvement. They connect appliances for monitoring the process of gathering data through wireless networking technologies and IoT capabilities (Javaid; Haleem; Singh; Suman; Gonzales, 2022). According to Dombrowski, Wullbrandt and Fochler (2019), the Lean approach is the base for preparing the workforce for digital

transformation. They affirmed that lean stimulates new abilities since it promotes life-long learning. Thus, Lean is the path for the *I5.0* digitalisation and upgrading technical skills in the workers (Gupta; Singh; Gupta, 2022).

The required competencies for a successful technological transition are more regarding lean than new technologies (Ghobakhloo, 2018). The key to enhancing performance lies in methods and practices dictating how knowledge is shared to build a learning organisation (Kristensen; Saabye; Edmondson, 2022). Digital transformation combines technology with the creativity of people to solve problems and create value, leading to sustainable development (Alves, 2022).

Humans collect and interpret information in ways that sensors cannot easily recognise (Wang; Zheng; Yin; Shih; Wang, 2022). Lean service improves the efficiency of service production by improving people, resulting in customer satisfaction (Suárez-Barraza; Smith; Dahlgaard-Park, 2012). Sindhwani, Afridi, Kunar, Banaitis, Luthra and Singh (2022) consider human-technology integration crucial for achieving *I5.0* sustainability, placing people at the centre, and forming the bases for process improvement.

This integration pushes the adoption of technologies to assist people (Breidbach; Choi; Ellway; Keating; Kormusheva; Kowalkowski; Lim; Maglio, 2018; Leng; Sha; Wang; Zheng; Zhuang; Liu; Wueste; Mourtzis; Wang, 2022; Peruzzini; Grandi; Pellicciari, 2020). Learning techniques create an AI-oriented management culture, stimulating communication to provide better solutions (Yu; Xu; Ashton, 2023). The Lean service raises the morale of workers, which implies psychological safety, team autonomy, and establishment of routines (Fenner; Arellano; Dzengelevski; Netland, 2023). Mutual understanding of humans and machines is the foundation for symbiotic relationships, enabling shared responsibilities (Nixdorf; Zhang; Ansari; Grosse, 2022). According to Baxter and Sommerville (2011), digitalisation projects fail because engineers ignore the social complexity of the environment, focus on deadlines and costs, and underestimate the requirements of the social-technical system.

The literature presents cases of technology assisting in improving services and delivering value. Computers and sensors train people to reduce process and response times (Bannan; Torres; Purohit; Pandey; Cockroft, 2020; Giorgio; Roci; Maffei; Jocevski; Onori; Wang, 2021). Computational systems adapt and learn to enhance human interpretation and sensemaking (Nixdorf; Zhang; Ansari; Grosse, 2022). Furthermore, knowledge shared with patients allows their collaboration to plan and improve the

treatment (Ciasullo; Orciuoli; Douglas; Palumbo, 2022). Additionally, AI and machine learning assist people in identifying solutions for problems such as waste control, resource optimisation, and carbon neutrality (Javaid; Haleem; Singh; Suman; Gonzales, 2022).

4.2 EVALUATION OF LEAN SERVICE 5.0 IN THE PROCESS PERSPECTIVE

Lean orchestrates processes seeking to comprehend the contribution of different areas to deliver value (Rother; Shook, 2003). Based on this, processes are optimised according to lean principles for efficient use of resources, agile decision-making, collaborative intelligence, innovation, and digital technology (Breidbach; Choi; Ellway; Keating; Kormusheva; Kowalkowski; Lim; Maglio, 2018; Chowdhury; Budhwar; Dey; Joel-Edgar; Abadie, 2022). The fundaments for creating processes aligning digitalisation and lean is the involvement of workers (Lamnabhi-Lagarrigue; Annaswamy; Engell; Isaksson; Khargonekar; Murray; Tilbury; Samad; Nijimeijer; Hof, 2017).

Chowdhury, Budhwar, Dey, Joel-Edgar and Abadie (2022) affirmed that AI systems contribute to collaborative working and developing new competencies in people since it stimulates knowledge sharing. Thus, AI assist in developing abilities for continuous improvement and digital transformation (Fenner; Arellano; Dzengelevski; Netland, 2023; Simonyte; Adomaitiene; Ruzele, 2021). Digital transformation seeks to reduce human intervention, using real-time data, and pollution-free practices (Maddikunta; Pham; Prabadevi; Deepa; Dev; Gadekallu; Ruby; Liyanage, 2022). Furthermore, it aims to create resilient processes with capabilities related to anticipation, preparation, robustness, and recovery capacity (Nayeri; Sazvar; Heydari, 2023).

Consolidated data creates knowledge to support process configuration and adaptation (Peruzzini; Grandi; Pellicciari, 2020) to increase productivity, quality, performance, satisfaction, and safety (Romero; Stahre, 2021). Nevertheless, digitalising processes without preparation results in waste generation and automation (Alves, 2022). Among the benefits of digitalising processes are the real-time report on their status (Ciasullo; Orciuoli; Douglas; Palumbo, 2022), upgrading the technical skills of people based on knowledge (Davies; Coole; Smith, 2017; Gupta; Singh; Gupta, 2022), and process improvement (Romero; Stahre, 2021; Tortorella *et al*., 2022).

Continuous improvement uses the scientific method in cycles of

experimentation to achieve desired results. Thus, technology gathers information, controls processes, shares knowledge, trains people to develop skills, and models experimentation. The potential for adopting technologies in lean service implementation is the performance and operational data metrics that transmit real-time system performance through the CPS network (Davies; Coole; Smith, 2017). These technologies integrated with lean lead to resilient processes, i.e., a structured and controlled process enabling to: (1) anticipate (identify possible disruptions); (2) prepare (for executing the recovery plan); (3) gain robustness (capable of recovering); and (4) recover (after disruptions) (Nayeri; Sazvar; Heydari, 2023).

4.3 EVALUATION OF LEAN SERVICE 5.0 IN THE TECHNOLOGY PERSPECTIVE

Organisations face a significant transformation in providing on-demand services with high reliability, scalability, and availability in a distributed environment, including personalised services like MPaaS and PaaS (Aheleroff; Mostashiri; Xu; Zhang, 2021). Lean supports this transformation providing a path to evolve from the technological focus of *I4.0* to *I5.0* (Alves, 2022). Technologies adhere to lean since they enable data-oriented decisions and scientifical thinking (Aheleroff; Mostashiri; Xu; Zhang, 2021), control human actions (Breidbach; Choi; Ellway; Keating; Kormusheva; Kowalkowski; Lim; Maglio, 2018), more integrated, agile, and adaptable systems (Peruzzini; Grandi; Pellicciari, 2020), and increase efficiency (Nayeri; Sazvar; Heydari, 2023).

Digitised services enhance the chances to fit changes in the market (Sahoo, 2020). According to Ciasullo, Orciuoli, Douglas and Palumbo (2022) and Breidbach, Choi, Ellway, Keating, Kormusheva, Kowalkowski, Lim e Maglio (2018), the exploitation of advanced technologies fosters the creation of an ecosystem with services coproduction and value co-creation. The socio-technical system produces a 'win-win' situation where employees are more productive, technology is successfully adapted, and organisations achieve better performance (Yu; Xu; Ashton, 2023) with reduced risks (Janowski; Estevez; Baguma, 2018). The capability to rapidly process large volumes of data assist in decision-making and increasing value (Sarkar; Routroy; Sultan, 2022).

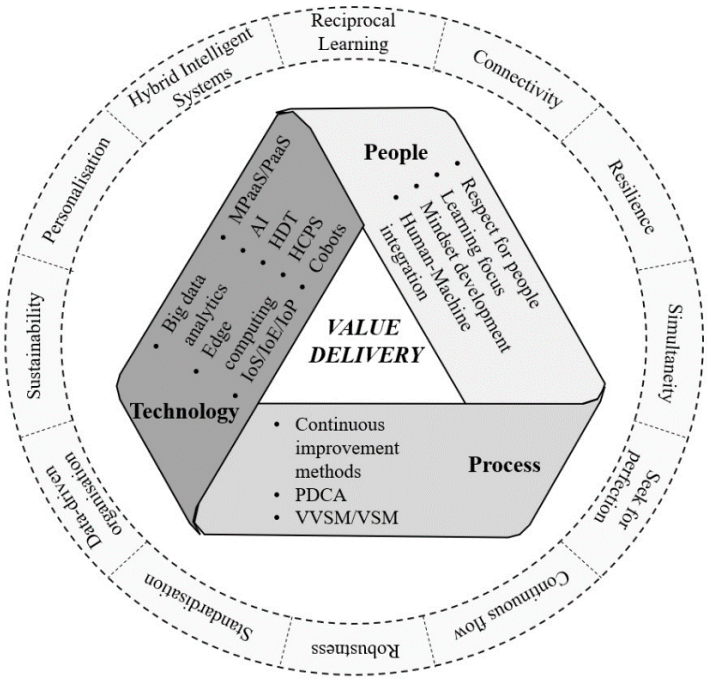
Hybrid Intelligence Systems accomplish complex goals by aligning human-machine intelligence (Nixdorf; Zhang; Ansari; Grosse, 2022). They collectively achieve superior results than each of them would have alone. Accordingly, it encompasses AI and human intelligence and encourages their complementary strengths (Nixdorf;

Zhang; Ansari; Grosse, 2022). Interconnectivity between organisations through IoT and cloud computing offers new ecosystems to share needs and capacities. Thus, physical resources are considered smart things that communicate with each other (Ghobakhloo, 2018; Wang; Zheng; Yin; Shih; Wang, 2022). In this context, the challenge is to orchestrate digital resources and capabilities, especially managing the incompatibility and isolation of different digital tools (Li; Claes; Kumar; Found, 2022).

Digital technologies facilitate interaction between organisations allowing businesses to create connectivity and interactivity to capture the latent needs of customers. The identification of needs assists in co-create value to deliver better results (Li; Rich; Found; Kumar; Brown, 2020). The complementarity of resources, such as HRC, aims to achieve the best combination of humans and robots, complementing competencies for flexible automation (Wang; Zheng; Yin; Shih; Wang, 2022).

We developed the PPT framework for LS5.0 (Figure 5). One of the main goals of lean is to align people, processes, and technologies to deliver value and achieve organisational goals. LS5.0 orchestrate people for a continuous improvement mindset assisted by I5.0 technologies. The improvement is based on the PCDA cycle to foster scientifical learning and VSM assisted by augmented reality or other technologies, providing real-time status according to the lean perspective.

Figure 5 - The Lean Service 5.0 PPT framework



Source: The authors (2024).

We defined 12 principles comprising LS5.0, where technology, continuous improvement, and organisational learning are integrated symbiotically to deliver value. They are based on a combination of the main principles of lean and I5.0. We highlight the data-driven service organisation, RL, and the seek for perfection as the main drivers for creating a transformational mindset in people for LS5.0.

5 CONCLUSIONS AND EVALUATION OF IMPLICATIONS FOR SERVICE MANAGEMENT AND INNOVATION

LS5.0 represents an evolution of Lean principles applied to the services sector. LS5.0 implies services capable of delivering value and excel customers' expectations through resilient, sustainable, robust, integrated processes. It enhances the chances of innovation, opening a new perspective and possibilities for service management (Chaves; Vieira; Bourguignon; Rodrigues; Zeferino; Santos, 2023; Zeferino; Ramos; Santos; Satolo; Braga Neto; Bourguignon, 2023).

From the LS5.0 perspective, where people learn from the technology, seeking to understand customers' behaviour not only when consuming the service but also the path that led them to decide to consume the service.

Lean preconises continuous efforts for restorative models by design (Fraga-Lamas; Lopes; Fernández-Caramés, 2021). It stimulates integrating technological solutions to co-innovate, co-design, and create sustainable service solutions.

Managers and practitioners benefit from LS5.0 regarding developing competencies in people. According to Huang, Wang, Li, Zheng, Mourtzis and Wang (2022), the goal of Society 5.0 is a human-centric super-smart society that provides value at the right moment, place, and format through cyber and physical space. LS5.0 can guide innovative solutions for just-in-time value delivery, integrating the physical and virtual worlds efficiently.

The findings of this study allow managers to consider digitalisation as the path to enhance value delivery and deal with the growing volume of data available. Based on the literature analysis, we identified some possibilities and benefits of expanding lean applications in services aiming the digitalisation and HCPS. On one hand, technology can foster continuous improvement methods by providing data and creating a RL environment. On the other hand, lean enables technology adoption by establishing an adaptative mindset focused on integrating human-machine toward value delivery.

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