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RESEARCH ARTICLE

REVISED Overcoming Challenges in Implementing Condition Monitoring Services: Recommendations from an Expert Elicitation Exploratory Study

[version 2; peer review: 1 approved, 2 approved with reservations]

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v2 **First published:** 29 May 2025, **5**:151
https://doi.org/10.12688/openreseurope.20044.1
Latest published: 04 Aug 2026, **5**:151
https://doi.org/10.12688/openreseurope.20044.2

Abstract

Background

Condition Monitoring Services (CMS) have emerged as an important digitally enabled service offering within manufacturing servitization, allowing Original Equipment Manufacturers (OEMs) to remotely monitor equipment, improve maintenance performance, and create new service-based revenue streams. Despite the technological maturity of condition monitoring technologies, many OEMs continue to struggle with the successful implementation of CMS. This study aims to identify the challenges limiting CMS implementation, the solutions used to overcome these challenges, and the recommendations that can support successful CMS implementation.

Methods

An exploratory expert elicitation approach was adopted. Semi-structured interviews were conducted with 13 experts from OEMs, universities, research centres, and business consultancy organizations who possessed substantial experience in CMS implementation, digital servitization, and Industry 4.0. The interview data were analysed using inductive thematic analysis.

Results

The findings reveal that the principal barriers to CMS implementation are socio-technical rather than technological. Three interrelated groups of challenges were identified: challenges related to CMS value

Open Peer Review

Approval Status ? ? ✓

	1	2	3
version 2 (revision) 04 Aug 2026		? view	✓ view
version 1 29 May 2025	? view	✗ view	? view

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propositions, challenges associated with CMS design processes, and challenges concerning organizational and customer readiness. To address these challenges, experts proposed solutions centred on value quantification, co-creative and iterative service design, and service-oriented organizational capability development. The study further identified recommendations emphasizing customer-value-driven CMS design, dedicated and legitimate service units, and proactive management of organizational change.

Conclusions

Successful CMS implementation depends less on the sophistication of condition monitoring technologies and more on the ability of OEMs to align technological resources, organizational capabilities, customer requirements, and value creation mechanisms. By providing empirically grounded insights into the challenges, solutions, and recommendations associated with CMS implementation, this study extends both CMS and digital servitization literature and offers actionable CMS-specific guidance for OEMs seeking to transform condition monitoring technologies into sustainable service businesses.

Keywords
Internet of Things, digital servitization, product-service systems, condition monitoring services, digital manufacturing.



This article is included in the Horizon 2020 gateway.



This article is included in the Marie-Sklodowska-Curie Actions (MSCA) gateway.

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Author roles: Iriarte I: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Nguyen Ngoc H**: Data Curation, Formal Analysis, Investigation, Writing – Original Draft Preparation; **Lasa G**: Formal Analysis, Investigation, Methodology, Project Administration, Supervision, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant No. 814078 and the Provincial Council of Gipuzkoa, Grant No. Lehiakortasuna Indartzea-30.
The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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How to cite this article: Iriarte I, Nguyen Ngoc H and Lasa G. **Overcoming Challenges in Implementing Condition Monitoring Services: Recommendations from an Expert Elicitation Exploratory Study [version 2; peer review: 1 approved, 2 approved with reservations]** Open Research Europe 2026, **5**:151 https://doi.org/10.12688/openreseurope.20044.2

First published: 29 May 2025, **5**:151 https://doi.org/10.12688/openreseurope.20044.1

REVISED **Amendments from Version 1**

The revised manuscript differs substantially from the original version in terms of its theoretical framing, methodological rigor, analytical depth, and overall contribution. The original manuscript focused primarily on the technical aspects of Condition Monitoring Services (CMS) and discussed implementation challenges largely as practical barriers. In contrast, the revised version repositions CMS implementation within the broader context of digital servitization and adopts a socio-technical perspective as its main theoretical lens. This shift enables a deeper interpretation of CMS implementation as an organizational transformation process involving technological, organizational, human, and relational capabilities rather than a purely technological undertaking.

The theoretical background was completely restructured. The revised version now includes dedicated sections on CMS implementation challenges, approaches to successful implementation, and a clearly articulated research gap. Recent literature on digital servitization was incorporated to strengthen the theoretical foundation and better justify the research questions.

The methodology section was also significantly expanded. The revised manuscript provides a clearer justification for the expert elicitation approach, more detailed expert selection criteria, enhanced participant descriptions, a transparent explanation of the thematic analysis procedure, and a dedicated thematic saturation assessment. The coding process and theme development are now explicitly documented, improving methodological transparency and rigor. The findings, discussion, and conclusions were extensively rewritten. The findings are now structured around the three research questions and distinguish clearly between implementation challenges, solutions, and managerial recommendations. The discussion provides a deeper theoretical interpretation of the results and explicitly answers each research question. Finally, the conclusions now clearly articulate the theoretical and managerial contributions of the study, provide a more critical reflection on limitations, and offer more specific future research directions. Overall, the revised manuscript provides a more coherent, theoretically grounded, and practically relevant explanation of CMS implementation by OEMs.

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Introduction

Industry 4.0 has accelerated the digital transformation of manufacturing and created new opportunities for servitization, enabling Original Equipment Manufacturers (OEMs) to complement physical products with data-driven services (Kalsoom et al., 2020; Kowalkowski et al., 2017). Through servitization, OEMs seek to move beyond transactional product sales and develop long-term customer relationships based on value creation across the equipment lifecycle. Digital technologies such as the Internet of Things (IoT), cloud computing, and advanced analytics have further strengthened this transition by enabling new forms of service provision and value co-creation between manufacturers and customers (Rymaszewska et al., 2017; Kristoffersen et al., 2021). Consequently, digital servitization has become a central mechanism through which manufacturers pursue competitive advantage in Industry 4.0 (Agostini et al., 2026; Momenzadeh et al., 2026).

Within this context, Condition Monitoring Services (CMS) have emerged as an important digitally enabled service offering within manufacturers' servitization strategies. CMS enable OEMs to remotely monitor the condition and performance of equipment deployed at customer facilities through connected sensors, data acquisition systems, and analytical tools (Slatter et al., 2021). By providing continuous insight into equipment health and operational behaviour, CMS can support predictive maintenance, reduce unplanned downtime, optimize resource utilization, and improve lifecycle performance (Lanzilotti et al., 2022; Wu & Pi, 2023). Consequently, OEMs are increasingly offering CMS as a means of generating service-based revenue streams (Baines & Lightfoot, 2013; Hien et al., 2022).

The growing adoption of CMS reflects a broader shift toward Product-Service Systems (PSS), where value is created through a combination of physical products and lifecycle services. OEMs are no longer expected solely to deliver reliable equipment but also to support customer outcomes through advanced services. CMS implementation therefore requires more than technological expertise. It also involves the development of organizational capabilities that enable OEMs to transform data into customer value (Valtakoski, 2017; Keh et al., 2012). Recent studies further suggest that the success of digital servitization initiatives depends on how organizations align these capabilities to support value creation and capture (Agostini et al., 2026; Karatzas et al., 2026).

Despite the recognized potential of CMS, many implementation initiatives struggle to achieve their intended outcomes (Bousdekis et al., 2020; Hien et al., 2022; March & Scudder, 2019). Specific research in CMS has largely focused on technical challenges, including sensor selection, data availability, data quality, and predictive model accuracy (Goyal & Pabla, 2015; Selcuk, 2017). More broadly, maintenance-related research has long been criticized for emphasizing technical and analytical solutions while devoting comparatively less attention to broader implementation challenges in industrial practice (Fraser et al., 2015).

Emerging research in the wider field of digital servitization suggests that implementation barriers associated with digitally enabled services frequently extend beyond technical considerations (Münch et al., 2022). Research in digital servitization has highlighted the importance of value proposition design, service-oriented organizational capability development, organizational readiness, resource allocation, customer collaboration, and service delivery mechanisms in determining the success of digitally enabled services (Antikainen et al., 2018; Ingemarsdotter et al., 2021; Lee, 2020a, 2020b). Moreover, recent evidence suggests that digital servitization initiatives are frequently hindered by organizational, strategic, and managerial barriers that interact in complex ways and may even generate unintended negative consequences (Rietdijk, 2026).

In particular, Münch et al. (2022) argue from a socio-technical systems perspective that successful digital servitization depends on the development of complementary technological, organizational, and human capabilities. Similarly, Kohtamäki et al. (2020) show that servitization initiatives are characterized by inherent organizational tensions, requiring firms to balance competing demands related to resources, value creation, customer relationships, and service delivery. More recent studies suggest that such tensions intensify in digital servitization environments (Paiola & Grandinetti, 2026; Smania et al., 2026). Collectively, these findings suggest that CMS implementation should be understood as a socio-technical and organizational transformation process rather than merely a condition monitoring technology deployment challenge.

Digital servitization literature has examined challenges related to organizational transformation, capability development, customer engagement, and business model innovation (Kristiansen & Aas, 2026; Paiola & Grandinetti, 2026; Smania et al., 2026). However, these studies typically address digitally enabled services at a general level and provide limited insights into the specific implementation challenges and potential solutions associated with CMS. CMS possess distinctive characteristics, including continuous access to operational equipment data, integration with customer maintenance processes, dependence on predictive analytics capabilities, concerns regarding data ownership and cybersecurity, and the need to demonstrate measurable operational and financial value through maintenance-related outcomes.

Consequently, there remains limited empirical understanding of how technological, organizational, managerial, and relational factors interact during CMS implementation and how OEMs can transform condition monitoring technologies into commercially viable service offerings. While existing CMS research has largely concentrated on technical aspects, providing valuable insights into how condition monitoring technologies function, the broader digital servitization literature often examines digitally enabled services at a relatively high level of abstraction and frequently treats them as a homogeneous class of service offerings. As a result, considerably less attention has been devoted to understanding how manufacturers implement CMS as service offerings within their digital servitization strategies, including the challenges associated with creating, delivering, and capturing value from these services.

To address this gap, this study investigates: (i) the challenges perceived by the experts in CMS implementation, (ii) the solutions to overcome them, and (iii) the recommendations proposed for OEMs seeking to implement CMS offerings. The study contributes to the CMS and digital servitization literature in three ways. First, it extends the understanding of CMS implementation by conceptualizing it as a socio-technical challenge rather than a predominantly technological one. Second, it provides empirical evidence of how digital servitization tensions and paradoxes emerge in CMS implementation and identifies mechanisms through which OEMs can address them. Third, it translates broad digital servitization socio-technical principles into CMS-specific implementation guidance for OEMs.

Theoretical background

A socio-technical perspective on CMS implementation within digital servitization

CMS are digitally enabled service offerings through which OEMs collect, analyse, and interpret operational data from equipment deployed at customer facilities in order to support maintenance, operational optimization, and decision-making activities (Jardine et al., 2006; Ingemarsdotter et al., 2021). Enabled by Industry 4.0 technologies CMS allow OEMs to move beyond traditional equipment sales and provide lifecycle-oriented services based on continuous monitoring of equipment conditions (Paschou et al., 2020; Rymaszewska et al., 2017). Rather than being a technological solution alone, CMS allow OEMs to offer advanced maintenance, support customer outcomes, and generate new revenues through digital technologies (Wang et al., 2024). From a digital servitization perspective, CMS can be understood as a specific type of PSS in which value is co-created through the integration of physical products, IoT technologies, and service activities.

The implementation of CMS therefore involves more than the deployment of sensors and analytical tools. It requires OEMs to integrate digital technologies with service development processes, organizational structures, customer

engagement mechanisms, and new value propositions and business model innovation activities. Consequently, CMS implementation can be conceptualized as the process through which OEMs develop, deliver, and scale digitally enabled service offerings capable of generating value for both providers and customers (Agostini et al., 2026; Momenzadeh et al., 2026).

Although digital technologies enable new service opportunities for OEMs, successful implementation depends on the development of complementary organizational and managerial capabilities (Momenzadeh et al., 2026). OEMs must redesign internal processes and structures, develop service-oriented cultures, acquire new organizational capabilities, establish data governance mechanisms, and collaborate closely with customers throughout service delivery (Marcon et al., 2022). Consequently, CMS implementation should not be understood as a purely technological challenge but rather as an organizational transformation process within digital servitization affecting multiple dimensions (Münch et al., 2022).

To better understand CMS implementation challenges, this study adopts a socio-technical perspective on digital servitization. According to socio-technical systems theory, organizational outcomes emerge from the interaction between technological systems and social systems, rather than from technology alone (Münch et al., 2022). This perspective is particularly useful for CMS implementation because the value generated by condition monitoring technologies ultimately depends on how OEMs integrate technical solutions with customer operations, business processes, and service delivery mechanisms. Accordingly, implementation success may be constrained not only by technological limitations but also by organizational resistance, organizational capability gaps, weak value propositions, or difficulties in coordinating stakeholders. In addition, manufacturers frequently experience negative synergistic effects when multiple digital servitization barriers interact simultaneously, creating implementation difficulties that extend beyond isolated technological or organizational problems (Rietdijk, 2026).

Challenges in CMS implementation

Although condition monitoring technologies have matured considerably in recent years, the successful implementation of CMS remains a challenging undertaking for many OEMs. Increasingly, researchers argue that the principal barriers to digital servitization are not technological in nature but rather stem from organizational, managerial, and relational factors that hinder the transformation of technological capabilities into customer value (Marcon et al., 2022). The CMS literature starts to reflect similar observations. While technical challenges such as data quality, component selection, and predictive modelling remain important (Goyal & Pabla, 2015; Selcuk, 2017), a growing body of research points towards broader implementation difficulties related to customer collaboration, organizational readiness, organizational capabilities, change management, and business model development (Lee, 2020a, 2020b; Valtakoski, 2017; Werbińska-Wojciechowska & Winiarska, 2023).

One recurring challenge concerns the development of strong value propositions and business models for digitally enabled services. While CMS can generate significant operational benefits, OEMs often struggle to translate these benefits into compelling customer value propositions and sustainable revenue mechanisms. Research on digital servitization consistently reports tensions between traditional product-oriented logics and service-oriented value creation approaches, particularly when firms attempt to monetize digital services and justify investments to customers (Valtakoski, 2017; Visnjic et al., 2017; Kamp et al., 2023). These difficulties frequently contribute to the "service paradox", in which manufacturers invest heavily in service development without obtaining the expected financial returns (Gebauer et al., 2005; Kowalkowski et al., 2017). More recent research suggests that these tensions become particularly pronounced in digitally enabled services, where manufacturers must simultaneously balance digital technology investments, customer value creation, service monetization, and organizational transformation efforts (Paiola & Grandinetti, 2026).

A second challenge concerns organizational transformation and organizational capability development. The implementation of CMS frequently requires the creation of new roles, skills, routines, and service-oriented organizational structures that differ substantially from those of product-centric manufacturing organizations. Employees must develop service-oriented competences, data interpretation capabilities, and collaborative working practices that enable the effective delivery of digital services (Münch et al., 2022). In addition, manufacturers often face difficulties reallocating resources, coordinating cross-functional teams, and aligning service activities with existing operational structures (Marcon et al., 2022). These organizational challenges help explain why technologically mature condition monitoring solutions frequently fail to achieve widespread adoption.

A third challenge relates to customer collaboration and stakeholder alignment. Digital servitization requires deeper interactions between OEMs and customers because value is co-created through the continuous use of data, operational knowledge, and service expertise (Kohtamäki et al., 2019). However, manufacturers frequently encounter resistance

regarding data sharing, concerns about data ownership, lack of trust, and uncertainty surrounding responsibilities and risks associated with digital services (Ingemarsdotter et al., 2021; van de Kerkhof et al., 2016). These challenges are particularly significant in CMS because access to operational data is a prerequisite for CMS delivery. As a result, successful implementation depends on establishing collaborative relationships and governance mechanisms that facilitate information exchange and mutual trust. Such collaborative arrangements are increasingly important in digital servitization environments, where value is co-created across organizational boundaries and depends on the active participation of multiple stakeholders throughout the service lifecycle (Paiola & Grandinetti, 2026; Smania et al., 2026).

Approaches to successful CMS implementation

Beyond identifying challenges, recent literature in digital servitization has suggested some possible approaches that support successful CMS implementation. A recurring argument is that implementation success depends on the simultaneous development of technological, organizational, and human capabilities (Münch et al., 2022). Consequently, investments in IoT infrastructures and analytics should be accompanied by investments in workforce development, service management competences, customer engagement, and organizational structures capable of supporting service delivery.

Several studies have shown that many digital service initiatives in manufacturing fail because firms are unable to capture an appropriate share of the value they create (Kamp et al., 2023). These difficulties are increasingly recognized as critical barriers to realizing the performance benefits of digital servitization, particularly when firms struggle to align value creation mechanisms with business model innovation and service monetization strategies (Agostini et al., 2026; Karatzas et al., 2026). Linde et al. (2023) argue that successful digital servitization requires the development of suitable revenue models that align value creation with value capture throughout the service lifecycle. Examples include subscription models, outcome-based contracts, pay-per-use arrangements, and performance-based agreements. Consequently, the successful implementation of CMS requires not only technical feasibility but also mechanisms that enable sustainable monetization of the generated value.

Several authors highlight the importance of organizational transformation during digital servitization. Münch et al. (2022) argue that successful digital servitization requires the development and alignment of technological, organizational, and human capabilities, while Marcon et al. (2022) emphasize that manufacturers must redesign structures, processes, and organizational practices to support digitally enabled service offerings. Similarly, Zhang et al. (2025) demonstrate that successful digital servitization implementation is closely associated with organizational change processes involving culture, learning, organizational capability development, and strategic alignment. These studies suggest that OEMs must actively manage change rather than treating CMS implementation as a standalone technological project. Similarly, Minaya et al. (2026) show that managers' strategic perceptions of Industry 4.0 significantly influence the extent to which firms embrace digital servitization initiatives and redesign their organizations around service-oriented objectives.

Recent research further suggests that manufacturers are often required to simultaneously pursue competing goals such as standardization and customization, efficiency and flexibility, technological innovation and customer intimacy, as well as exploration of new service opportunities and exploitation of existing product businesses (Paiola & Grandinetti, 2026; Smania et al., 2026). Rather than eliminating these tensions, literature suggests that successful organizations develop organizational mechanisms and coping practices that enable them to coexist with these tensions over time. This implies that increasing service complexity requires organizational structures, governance mechanisms, and managerial practices capable of balancing competing demands related to customer value creation, operational efficiency, standardization, and customization (Kohtamäki et al., 2020; Paiola & Grandinetti, 2026).

Leadership also plays an important role in the implementation process. Tagscherer and Carbon (2023) highlights that digital servitization requires leaders capable of articulating a service-oriented vision, coordinating multidisciplinary teams, fostering organizational learning, and managing resistance to change. Leadership therefore becomes a key mechanism for aligning technological initiatives with strategic objectives and facilitating the transition from product-centric to service-oriented business models.

Finally, successful implementation of CMS often relies on iterative and collaborative approaches that actively involve customers throughout service development and deployment. Pilot projects, co-creation activities, gradual service extensions, and continuous feedback mechanisms have been identified as effective practices for reducing uncertainty, validating value propositions, and building trust among stakeholders (Sjödin et al., 2020; Iriarte et al., 2023). These approaches enable firms to refine service offerings while simultaneously increasing customer readiness, stakeholder commitment, and organizational learning. Such practices are particularly relevant in CMS, where service success depends on continuous interaction between OEMs and customers and on the shared use of operational data.

Research gap

Despite the growing body of research on digital servitization, current knowledge regarding how to overcome the specific CMS implementation challenges remains fragmented. Existing studies typically address isolated challenges of implementation, such as technical solutions for data acquisition and predictive analytics (Lee et al., 2014), organizational capabilities for digital servitization (Münch et al., 2022), digital servitization business models and value capture mechanisms (Agostini et al., 2026), service revenue mechanisms (Linde et al., 2023), or customer co-creation practices in servitization (Sjödin et al., 2020; Iriarte et al., 2023).

While these contributions provide valuable insights, they are often examined independently and therefore offer a partial view of the implementation process. As a result, knowledge about how these different dimensions interact in practice remains limited. This limitation is particularly important because recent research increasingly portrays digital servitization as a multidimensional socio-technical transformation process involving organizational capabilities, organizational legitimacy, stakeholder relationships, value proposition and business models, and organizational tensions and paradox management (Kristiansen & Aas, 2026; Paiola & Grandinetti, 2026; Momenzadeh et al., 2026).

In addition, much of the existing literature in digital servitization discusses implementation challenges and solutions at a relatively high level of abstraction and treats digital services in a comparatively homogeneous manner. Recommendations frequently focus on broad organizational capabilities, digital transformation strategies, or business model adaptation (Kohtamäki et al., 2020; Tagscherer & Carbon, 2023; Zhang et al., 2025). Although these recommendations are managerially valuable, they are often developed for digital servitization in general and are not specifically linked to the particular implementation conditions of CMS. CMS present unique characteristics that distinguish them from many other digital services, including continuous access to operational equipment data, integration with customer maintenance processes, management of data ownership and cybersecurity concerns, dependence on predictive analytics capabilities, and the need to demonstrate measurable operational and financial value from maintenance-related outcomes. Consequently, generic digital servitization recommendations may not fully address the practical realities encountered by OEMs in implementing CMS.

Therefore, there remains a need for more empirical research capable of providing a grounded understanding of CMS implementation. By focusing on expert perspectives, this study seeks to generate actionable and context-sensitive insights that complement existing theoretical knowledge and provide a more specific understanding of CMS implementation in OEM environments.

Ketokivi and Choi (2014) indicate that exploratory qualitative studies are particularly valuable when existing knowledge remains fragmented and when theory development benefits from understanding complex real-world phenomena through expert perspectives. Accordingly, this study adopts an exploratory expert elicitation approach to investigate CMS implementation by OEMs. In particular, the study addresses the following research questions:

- RQ1: What are the implementation challenges that limit market success of CMS?
- RQ2: What are the potential solutions to overcome these challenges?
- RQ3: What recommendation should an OEM take to offer CMS successfully?

Methodology

Research approach

This study adopts an exploratory qualitative research design based on expert elicitation. The approach is appropriate because CMS implementation by OEMs represents a complex socio-technical phenomenon involving technological, organizational, managerial, and customer-related dimensions whose interactions remain insufficiently understood in the existing literature.. Although prior research in CMS implementation and digital servitization literature has identified a variety of technical and organizational barriers, current knowledge remains fragmented and provides limited understanding of how these challenges interact during real-world CMS implementation. Furthermore, existing solutions within digital servitization literature for successful CMS implementation tend to be formulated at a relatively generic level and are often insufficiently connected to the specific characteristics of CMS. Consequently, there is a need for context-sensitive and practice-oriented insights capable of complementing existing theoretical knowledge and improving understanding of CMS implementation by OEMs.

Expert elicitation is particularly suitable when investigating highly specialized domains where relevant knowledge is dispersed among experienced practitioners and researchers and when the objective is to obtain context-rich insights rather

than statistical generalization (Bogner & Menz, 2009; Gläser & Laudel, 2009; Meuser & Nagel, 2009). In our context, CMS implementation requires expertise spanning CMS implementation, advanced services, digital servitization, and Industry 4.0. Consequently, expert interviews provide access to practical knowledge and implementation experiences that cannot be easily captured through surveys or quantitative approaches.

The study follows an exploratory logic consistent with Ketokivi and Choi (2014), who argue that qualitative inquiry is particularly valuable when existing theory does not sufficiently explain a complex managerial phenomenon and when deeper contextual understanding is required. The objective is therefore not statistical generalization but the generation of analytically generalizable insights regarding the challenges, solutions, and recommendations associated with CMS implementation by OEMs.

Expert selection and sampling

Following Gläser and Laudel (2009), expertise was defined as possessing specialized knowledge and practical experience directly relevant to CMS implementation. Experts were selected using purposive sampling because the objective was to access information-rich participants capable of providing informed perspectives on the phenomenon under investigation.

To be included in the study, participants had to meet the following criteria: (i) direct involvement in CMS design, development, deployment, or management; and (ii) demonstrated expertise in one or more relevant domains, including digital servitization, advanced services, industrial service design, industrial service management, or Industry 4.0.

Given the multidisciplinary nature of CMS implementation, particular attention was devoted to incorporating complementary perspectives spanning technological, organizational, and business domains. CMS implementation requires not only expertise in monitoring technologies and data analytics, but also knowledge of servitization, service development, customer value creation, and business model innovation. Therefore, experts were intentionally selected from different but complementary backgrounds, including OEMs, business consultancy, universities, and industrial research centres. This strategy was adopted to capture the multidimensional nature of CMS implementation and reduce the risk of relying on a single organizational perspective.

A list of 20 potential experts meeting the selection criteria described above was compiled. Experts were identified through professional networks, previous research collaborations, industrial projects, and conference participation. Thirteen experts accepted the invitation to participate and were included in the study (Table 1).

Table 1. Expert profile.

Expert	Major fields	Business	Role	Working years	Background and relevance
Expert #1	Software and Systems Engineering	University	Researcher	18	Contributing knowledge on digital infrastructures, system integration, and data management capabilities required for CMS implementation.
Expert #2	Service Design, New Service Development	University	Researcher	11	Providing expertise on service-oriented value proposition design, customer involvement, and service innovation processes relevant to CMS implementation
Expert #3	Servitization, PSS, Advanced Services	Business Consultancy	Senior Consultant	22	Senior consultant supporting manufacturers in servitization transition, contributing practical experience on business model transformation and organizational change.
Expert #4	Servitization, Business Model Innovation	University	Researcher	19	Providing expertise on value capture, service strategy, and organizational transformation associated with advanced services.
Expert #5	Digital Manufacturing, IoT, Automation	University	Researcher	11	Researcher specialized in Industry 4.0 technologies, IoT, and automation, contributing knowledge on technological enablers required for CMS implementation.

Table 1. *Continued*

Expert	Major fields	Business	Role	Working years	Background and relevance
Expert #6	Servitization, PSS, Advanced Services	Research Centre	Researcher	23	Applied researcher in a machine-tool, involved in industrial servitization and advanced maintenance projects with OEMs, providing extensive experience in CMS implementation across multiple firms.
Expert #7	Service Management, Service Operations	OEM	Service Manager	9	Service manager directly responsible for industrial service delivery, contributing first-hand experience regarding customer adoption, service operations, and CMS commercialization.
Expert #8	New Service Development, IoT, Automation	OEM	Head of IoT and Automation	21	Industrial manager leading IoT-enabled service initiatives and digital transformation projects, providing practical insights into CMS deployment, data integration, and organizational change.
Expert #9	New Service Development, IoT, Automation	OEM	Researcher in IoT and Automation	26	Senior industrial expert involved in the development of IoT-based solutions and advanced maintenance services, contributing extensive experience in the technological and operational aspects of CMS implementation.
Expert #10	Servitization, PSS, Advanced Services	Research Centre	Head of R&D	23	Head of R&D in a machine-tool technology research centre, leading collaborative projects with OEMs on servitization, advanced services, and digital manufacturing solutions.
Expert #11	Software R&D, Servitization, PSS	Research Centre	Head of RDI Software Development	14	R&D manager responsible for software development and digital service innovation projects, contributing expertise on software-enabled servitization and industrial digital platforms.
Expert #12	Service Management, Service Operations	OEM	Service Manager	11	Service manager with direct responsibility for industrial service operations and customer support activities. Contributes practical insights into the delivery of advanced services, customer readiness, and the organizational challenges associated with implementing CMS.
Expert #13	Service Design, New Service Development	Research Centre	Development Manager	20	Development manager in a machine-tool technology research centre, responsible for new service development initiatives conducted in collaboration with OEMs. Contributes expertise on translating technological capabilities into customer-oriented service offerings, and designing advanced service concepts.

The final sample consisted of 13 experts from Spain, Portugal, the United Kingdom, Sweden, Finland, and Germany. Four experts were employed by OEMs in roles directly related to CMS operations. One expert was a senior consultant specialized in manufacturing servitization. Four experts were researchers from universities with recognized expertise in servitization, industrial service design, Industry 4.0, and digital manufacturing. The remaining four experts belonged to several research centres specialized in machine-tool equipment and advanced manufacturing systems. These last four

experts held senior research positions and possessed extensive experience participating in industrial projects focused on machine monitoring, IoT-enabled services, advanced maintenance solutions involving OEMs.

The sampling strategy intentionally combined experts from industrial practice and applied research environments to ensure a multidimensional understanding of CMS implementation and to avoid relying on a single organizational perspective. As CMS implementation involves technological, organizational, and business challenges that frequently transcend the boundaries of individual firms, research centres experts were considered particularly valuable because of their broad exposure to multiple OEMs. Their contributions complemented the direct operational insights provided by OEMs participants and enabled a richer understanding of CMS implementation challenges and solutions.

In total, the experts possessed between 9 and 26 years of professional experience, with an average of approximately 18 years. This combination of practical industrial knowledge, applied research expertise, and servitization consultancy experience provided a robust basis for exploring implementation challenges, potential solutions, and recommendations associated with CMS implementation by OEMs.

Data collection

Data were collected through semi-structured expert interviews, a method that provides the flexibility required to explore complex and emerging phenomena (Miles et al., 2013). Given the exploratory nature of the study and the objective of obtaining practical insights into CMS implementation, semi-structured interviews were considered particularly appropriate because they allow experts to draw upon their own experiences while enabling the researchers to probe relevant implementation issues in greater depth (Bogner & Menz, 2009; Meuser & Nagel, 2009).

Prior to each interview, participants received an information package containing the research objectives, a brief summary of the study background, confidentiality assurances, and an informed consent statement. Following the recommendations of Saunders et al. (2016), this preliminary information helped participants understand the purpose and scope of the study while enhancing the credibility and transparency of the interview process. Participants were informed that their identities would remain confidential and that the collected material would be used exclusively for research purposes. Consent was obtained through signed consent forms and/or verbal confirmation before the interviews were recorded.

An interview guide was developed to ensure consistency across interviews while maintaining sufficient flexibility to explore emerging themes. The complete interview protocol including the interview guide is available in the Extended Data repository (Iriarte et al., 2026). The interview guide was structured around the three research questions of the study and focused on: (i) Challenges associated with CMS implementation, (ii) Solutions for overcoming these challenges, and (iii) Recommendations for achieving successful CMS implementation.

To minimize response bias (Myers & Newman, 2007), interviews began with broad, open-ended questions inviting experts to freely discuss their experiences and perspectives regarding CMS implementation. Once experts had provided their initial reflections, follow-up questions were used to explore specific issues in greater depth, including technological, organizational, managerial, customer-related, and business model aspects of implementation. This approach allowed experts to introduce themes that they considered relevant while ensuring adequate coverage of the research questions.

The semi-structured format also provided interviewers with the flexibility to adapt the sequence and wording of questions according to each participant's expertise and professional background. Following the recommendations of Cenamor et al. (2017) and Raddats et al. (2022), emerging topics were explored whenever they contributed to a richer understanding of the phenomenon under investigation. This iterative and conversational format was particularly valuable given the multidisciplinary nature of CMS implementation and the varied backgrounds of the participating experts.

To further reduce potential social influence and reciprocal bias, each expert was interviewed individually rather than in group settings, following the recommendations of Calabrese et al. (2019). All interviews were conducted by two authors to maintain consistency in the interview process and interpretation of responses (Benedettini, 2022).

The interviews were conducted in English between October and November 2024 and lasted between 40 and 60 minutes, with an average duration of approximately 50 minutes. All interviews were audio-recorded and transcribed for subsequent analysis. The resulting dataset comprised approximately 90 pages of interview transcripts, representing a rich source of expert knowledge regarding the challenges, solutions, and implementation recommendations associated with CMS deployment by OEMs.

Data analysis

The interview data were analysed using an inductive thematic analysis approach (Braun & Clarke, 2006; Thomas, 2006). This approach was selected because the objective of the study was to explore how experts perceive the challenges, solutions, and recommendations associated with CMS implementation without imposing predefined theoretical categories. Consistent with the exploratory nature of the research, the analysis sought to allow relevant patterns and themes to emerge from the empirical material while remaining guided by the study's research questions.

The analysis was conducted manually by two researchers following an iterative five-stage process of independent coding, analytical discussion, thematic refinement, and consensus building. First, all interview transcripts were reviewed multiple times to achieve familiarity with the data and obtain a holistic understanding of the experts' experiences and viewpoints. During this phase, researchers recorded preliminary observations, recurring challenges, proposed solutions, and implementation practices identified across the interviews.

Second, meaningful statements related to the three research questions were extracted from the transcripts and assigned initial descriptive codes. A meaningful statement was defined as any segment of text containing relevant information regarding implementation challenges, solutions, or recommendations for successful CMS implementation. This initial coding generated a large set of data-driven codes grounded directly in the experts' narratives.

Third, the initial codes were compared, grouped, and organized into preliminary categories according to their conceptual similarity. This process involved continuously comparing codes across interviews to identify recurring patterns as well as divergences in expert perspectives. During this stage, categories were iteratively refined through discussions between the researchers to ensure a consistent interpretation of the data.

Fourth, preliminary categories were further reviewed, merged, refined, and consolidated into first-order themes. This process required the elimination of overlapping categories and the clarification of boundaries between themes. The purpose was to ensure that each first-order theme represented a coherent and distinct implementation issue discussed by the experts.

Finally, related first-order themes were aggregated into broader second-order themes representing higher-level patterns across the dataset. These second-order themes constituted the analytical structure used to present the findings and provided an integrative view of the challenges, solutions, and recommendations associated with CMS implementation. The final thematic structure subsequently informed the organization of the findings around challenges, solutions, and recommendations corresponding to the three research questions.

Following this procedure, the analysis progressed from raw interview data to increasingly abstract levels of interpretation. Across the 13 interviews, a total of 177 meaningful statements were identified and coded. These statements were subsequently grouped into 30 preliminary categories, which were refined into 25 first-order themes and ultimately consolidated into eight second-order themes. Table 2 summarizes the progression of the analysis process.

To enhance analytical rigor, both researchers independently reviewed the transcripts and participated in regular analytical discussions throughout the coding process. Rather than measuring statistical inter-coder reliability, the study followed a reflexive thematic analysis approach in which differences in interpretation were actively discussed and used to refine

Table 2. Summary of the data analysis process.

Analytical process	Description	Output
Familiarization	Repeated reading of 13 interview transcripts and recording of initial observations	Understanding of dataset
Initial coding	Identification of meaningful statements related to the research questions	177 meaningful statements
Category development	Grouping of similar codes into preliminary categories	30 categories
Theme refinement	Merging and refining categories to eliminate redundancy	25 first-order themes
Theme aggregation	Grouping first-order themes into higher-level conceptual themes	8 second-order themes

theme development until a shared understanding of the data was achieved (Braun & Clarke, 2006). This collaborative process strengthened the credibility, consistency, and transparency of the analysis.

Data saturation

Given the exploratory nature of the study and the use of expert elicitation, the adequacy of the sample was assessed through thematic saturation rather than statistical representativeness (Guest et al., 2006; Mason, 2010). Thematic saturation refers to the point at which additional interviews cease to generate substantially new concepts, themes, or insights relevant to the research questions. Consequently, the objective was not to reach a predetermined sample size but to continue data collection until the identified themes became sufficiently stable and recurring across participants.

To assess saturation, data collection and analysis were conducted concurrently. Following the recommendations of Guest et al. (2006), interviews were analysed sequentially in successive rounds, allowing the researchers to monitor the emergence of new insights throughout the research process. As coding progressed, attention was paid to the number of new meaningful statements and first-order themes generated in each analytical round.

As shown in Table 3, the first six interviews generated the majority of the implementation challenges, solutions, and recommendations identified in the study. The subsequent four interviews expanded the thematic coverage of the dataset and provided additional contextual variation. During the final analytical round, the last three interviews contributed further examples and supporting evidence but did not result in the identification of new first-order themes. Instead, these interviews reinforced and enriched the existing thematic structure. This pattern indicated that additional data collection was unlikely to substantially modify the analytical framework and therefore thematic saturation was considered achieved.

This iterative process enhanced the credibility and dependability of the findings while ensuring that the resulting themes remained firmly grounded in the empirical material. Together, the expert selection procedure, the systematic coding process, the achievement of thematic saturation, and the transparent reporting of the analytical steps strengthen the credibility, dependability, and analytical robustness of the study's findings.

Findings: Challenges, solutions, and recommendations for CMS implementation

The analysis identified findings corresponding to the three research questions of the study. First, experts described the challenges that limit the successful implementation of CMS. Second, they proposed practical solutions for overcoming these challenges. Finally, they offered recommendations for OEMs seeking to implement CMS successfully.

The detailed coding structure, including first-order themes, second-order themes, and illustrative quotations, is available in the Extended Data (Tables E1 to E4). The findings presented below focus on the higher-level themes that emerged from the analysis.

Table 3. Assessment of thematic saturation.

Analytical round	Interviews analysed	New statements	Emerging first-order themes	Emerging second-order themes	Saturation notes
Round 1	Experts 1–6	102	17	6	Majority of implementation challenges, solutions, and recommendations identified
Round 2	Experts 7–10	48	8	2	Additional variation and contextual insights identified
Round 3	Experts 11–13	27	0	0	No substantially new themes emerged; interviews provided confirmation and additional examples
Final output	13 experts	177	25	8	Thematic saturation achieved

Challenges in CMS implementation

The analysis identified three main categories of implementation challenges that hinder the successful implementation of CMS: (i) challenges related to the CMS value proposition, (ii) challenges related to the CMS design process, and (iii) challenges related to organizational and customer readiness. Together, these themes answer RQ1.

Challenges related to the CMS value proposition

One of the most prominent challenges identified by the experts concerned the development and communication of the CMS value proposition. According to the interviewees, many CMS initiatives fail because customers do not perceive sufficient value to justify the investments, organizational changes, and risks associated with CMS adoption.

The interviews consistently indicated that OEMs struggle to demonstrate to their customers how CMS create value beyond existing maintenance practices. Although technical benefits may be evident, customers frequently fail to recognize how these benefits translate into meaningful operational or financial outcomes. As a result, the perceived benefits of CMS are often insufficient to motivate customers to modify existing practices and trust in CMS offerings.

A further challenge identified by the experts is the lack of value quantification in the value proposition. Many OEMs struggle to express CMS benefits through measurable indicators such as financial savings, productivity improvements, asset availability, or downtime reduction. Without tangible evidence of economic value, customers frequently find it difficult to justify investments in CMS and compare them against alternative priorities competing for organizational resources.

Another challenge concerns the difficulty of developing value propositions that address multiple customer stakeholder groups simultaneously. Experts observed that CMS offerings are often designed from a technical perspective without adequately considering the different expectations of managers, maintenance personnel, operators and other actors involved in the customer's organization. Consequently, a value proposition that appeals to one stakeholder group may not necessarily be perceived as valuable by others.

Challenges related to the CMS design process

The second group of challenges relates to how CMS offerings are designed conceptually and developed for deployment.

First, experts highlighted difficulties of OEMs in understanding customer service-requirements. Several participants noted that OEMs frequently rely on assumptions regarding customer needs rather than systematically validating them through customer engagement activities. This often results in CMS offerings that fail to reflect the operational realities of different customer contexts.

Second, customer heterogeneity was considered a particularly important issue. According to the experts, potential customers differ significantly in terms of technological maturity, maintenance capabilities, organizational culture, resources, and willingness to adopt new CMS. However, CMS are frequently developed using generic product-centric design approaches that assume similar conditions across customers. Such assumptions can result in misalignments between CMS characteristics and customer capabilities.

Another challenge concerns access to customer resources. Successful CMS implementation often requires access to operational data, equipment, facilities, processes, and personnel. Experts reported that customers are frequently reluctant to provide such access due to concerns related to confidentiality, trust, cybersecurity, data ownership, and operational risk. Consequently, obtaining access to the resources required for CMS delivery represents a significant obstacle during implementation.

Challenges related to CMS requirements and customer readiness

The third challenge category concerns the organizational and operational requirements necessary to support CMS implementation, both by OEMs and their customers.

Experts observed that CMS implementation frequently requires changes in infrastructures, systems, processes, competences, and organizational routines, both in OEMs and customers. Difficulties arise when CMS must be integrated into existing operational environments that were not originally designed to support digital services. Legacy equipment, incompatible systems, and fragmented organizational processes were repeatedly cited as major barriers.

Lack of organizational readiness was another recurring concern. Interviewees noted that many OEMs attempt to develop and implement CMS without developing the skills, service capabilities, and structures necessary to support advanced service delivery. Existing personnel often possess strong technical competences but limited experience in service development, customer engagement, financial analysis, and value-based selling.

Finally, experts emphasized customer readiness challenges. In many cases, customers are hesitant to modify established routines, working practices, and decision-making processes. According to the interviewees, implementation difficulties frequently arise not because of customers' technological limitations but because customers perceive the required organizational and behavioural changes as too demanding. Consequently, customer willingness to change becomes a critical factor influencing CMS adoption.

In response to RQ1, the study demonstrates that CMS implementation challenges extend well beyond technological considerations. The findings reveal three interconnected groups of barriers: challenges related to CMS value proposition, challenges associated with CMS design process, and challenges concerning organizational and customer readiness. Collectively, these challenges suggest that the market success of CMS is largely determined by how effectively OEMs create and communicate value, align service offerings with customer requirements, and manage the organizational changes required on both OEM and customer sides. Therefore, the major barriers to CMS implementation are rooted less in the maturity of condition monitoring technologies and more in the socio-technical challenges associated with value creation, service development, organizational transformation, and customer alignment.

Solutions to CMS implementation challenges

The experts proposed a range of solutions to overcome the implementation challenges identified above. Consistent with the challenge structure, the proposed solutions can be grouped into three categories: solutions related to the CMS value proposition, solutions related to the CMS design process, and solutions related to organizational and customer readiness.

Solutions related to the CMS value proposition

To address value proposition challenges, experts consistently emphasized the importance of developing robust and clearly articulated CMS value propositions.

A first solution involves demonstrating value through tangible benefits and measurable outcomes. According to the interviewees, CMS offerings should clearly communicate operational improvements and economic benefits rather than focusing primarily on technical features and functionalities. Customers need to understand how the CMS contributes to their business performance and operational objectives.

Therefore, experts repeatedly argued that CMS value propositions should be supported by clear metrics, financial indicators, and business cases. Quantifiable evidence related to productivity improvements, downtime reduction, maintenance savings, and return on investment was considered essential for reducing uncertainty and facilitating adoption.

Experts also stressed the importance of adopting a broader perspective on value creation by considering multiple stakeholder groups within customer organizations. Rather than designing CMS exclusively for maintenance departments, OEMs should consider the needs of managers, operators, IT technicians, and other stakeholders within customer organizations involved in decision-making and service use.

Finally, several interviewees advocated modular service offerings. Rather than introducing comprehensive CMS packages from the outset, OEMs should provide smaller and lower-risk service modules that allow customers to progressively experience and validate the benefits of CMS before expanding adoption towards more advanced service levels. In this sense, another commonly proposed solution was to target innovative customers and early adopters during the initial stages of implementation. According to the experts, pilot customers provide valuable learning opportunities while simultaneously generating evidence of service value that can later support wider adoption among more conservative customer groups.

Solutions related to the CMS design process

Regarding CMS design processes, experts highlighted the importance of adopting more co-creative and iterative development approaches.

A recurring recommendation was the use of co-creative and iterative service design processes that continuously incorporate customer feedback and learning during CMS development and beyond. According to the interviewees, CMS should evolve through repeated cycles of testing, feedback, refinement, and validation rather than through linear design approaches.

In addition, experts emphasized the need for more rigorous customer segmentation activities. OEMs should systematically investigate customer requirements, operational realities, and levels of technological and organizational readiness before developing their CMS offerings. In this sense, several participants highlighted the importance of on-site observation in customers' facilities and collaborating with industry associations, customer networks, and other ecosystem actors to improve understanding of customer needs and market dynamics.

Finally, participants highlighted the need to address concerns regarding access to customer resources and data. Building trust through co-creation practices, transparency, clear communication, and appropriate governance mechanisms was considered essential for facilitating customer adoption of CMS offerings.

Solutions related to organizational and customer readiness

The third group of solutions focused on increasing readiness for CMS implementation within both OEM and customer organizations.

To improve integrability, experts proposed gradual implementation strategies based on modular services, pilot projects, and phased deployments. Such approaches allow organizations to experiment with CMS on a smaller scale before committing to broader organizational changes. This is related to solutions for CMS design processes.

Service-oriented organizational capability development emerged as another important solution. Experts emphasized the need to strengthen competences related to service management, customer collaboration, business development, financial analysis, and value communication within dedicated service units. According to the experts, many OEMs possess strong technical and engineering capabilities but lack the service-oriented skills required to effectively commercialize and scale CMS offerings. In particular, organizations need capabilities to identify customer needs, translate technical functionalities into customer value propositions, quantify business benefits, develop sustainable revenue models, and manage long-term customer relationships.

Experts also highlighted the importance of multidisciplinary teams capable of integrating expertise from engineering, digitalization, maintenance, sales, marketing, and service management. Such capabilities enable organizations to bridge the gap between technological development and market adoption, improve internal coordination, and support more effective value creation, delivery, and capture. Consequently, service-oriented organizational capability development was viewed not only as a means of improving CMS implementation but also as a critical prerequisite for transforming condition monitoring technologies into viable and sustainable service businesses.

According to the participants, CMS implementation is frequently constrained when service activities remain dispersed across engineering, production, and sales departments without a clear organizational owner. Experts repeatedly highlighted the need for organizational structures capable of leading service development activities, coordinating interactions with customers, building new organizational capabilities, developing business cases, and managing CMS implementation projects over time. Several interviewees also recommended the creation of dedicated service units responsible for CMS development and delivery. These units should possess sufficient autonomy to develop service offerings, coordinate implementation activities, and facilitate collaboration across organizational functions. This means that dedicated service units should be legitimized by OEM management. Legitimized service units provide the authority, resources, and continuity required to develop CMS offerings systematically and align technological capabilities with customer needs and business objectives.

Regarding customer readiness, experts highlighted the importance of demonstrating value through pilot projects and successful implementation examples. Customers become more willing to adopt CMS when they can observe tangible benefits in operational contexts similar to their own. This is connected with solutions proposed regarding CMS value propositions. In this sense, several participants also proposed flexible commercialization mechanisms, including staged investments, subscription models, and financial support arrangements. Such approaches were viewed as effective ways of reducing adoption barriers and lowering the perceived risks associated with CMS investments.

Regarding RQ2, the findings indicate that overcoming CMS implementation challenges requires the simultaneous alignment of value creation mechanisms, service design practices, and service-oriented organizational capabilities. At the value proposition level, experts emphasized the importance of quantifying CMS benefits, developing robust business cases, and tailoring value propositions to multiple stakeholder groups. At the design level, the findings highlight the role of co-creative, iterative, and customer-centred design processes supported by customer segmentation, field observations, and pilot implementations. Finally, at the organizational level, successful implementation requires legitimate service units with multidisciplinary service capabilities, and gradual implementation pathways that reduce customer uncertainty and resistance to change. Taken together, these findings suggest that successful CMS implementation depends on the simultaneous alignment of value creation mechanisms, customer-centred service development processes, and service-oriented organizational capabilities.

Recommendations for successful CMS implementation

While RQ2 focused on specific solutions for overcoming implementation challenges, the interviews also revealed broader managerial recommendations regarding how OEMs should approach CMS implementation strategically. These recommendations go beyond individual practices and instead reflect guiding principles capable of shaping decision-making, organizational priorities, and resource allocation throughout the development, commercialization, and scaling of CMS offerings.

Recommendations related to CMS design

The first recommendation emerging from the interviews is that CMS should be conceptualized and designed as customer-value-driven service offerings rather than technology-driven maintenance solutions. Throughout the interviews, experts consistently emphasized that customers rarely make adoption decisions based on technological sophistication alone. Instead, they evaluate CMS according to their contribution to operational performance, risk reduction, cost efficiency, and broader business objectives. Consequently, OEMs should prioritize understanding how CMS contribute to customer outcomes before determining technological features and functionalities. From this perspective, technological capabilities become enablers of value creation rather than the primary source of value themselves.

A second recommendation concerns the adoption of a co-creative mindset throughout CMS development. The experts repeatedly stressed that successful CMS are not developed internally and subsequently transferred to customers. Rather, they emerge through continuous interactions with customers and other stakeholders. This implies that OEMs should view customers as partners in service development rather than passive recipients of technology. Such partnerships facilitate shared learning, improve the relevance of service offerings, and reduce the risk of developing technologically feasible but commercially unattractive solutions.

A third recommendation is that CMS implementation should be approached as an iterative learning process rather than a predefined linear project. The experts consistently advocated gradual experimentation through pilot projects, prototypes, modular offerings, and phased deployments. Such approaches allow OEMs and customers to learn jointly, validate assumptions, demonstrate value, reduce uncertainty, and progressively adapt service offerings to evolving requirements. Consequently, implementation success depends less on detailed upfront planning than on the organization's ability to learn and adapt throughout the implementation journey.

Recommendations related to change management

The second group of recommendations concerns organizational transformation and change management.

A particularly important recommendation concerns the need to establish organizational legitimacy for service activities within product-centric OEMs. The experts repeatedly described situations where CMS initiatives struggled not because of technical limitations but because service-related activities lacked strategic visibility, authority, and organizational support. Consequently, successful implementation requires OEMs to explicitly recognize CMS as strategic business activities capable of generating customer value and future revenue streams. CMS must therefore be legitimized at the highest organizational levels rather than treated as secondary extensions of product businesses.

Building on this principle, the findings suggest that OEMs should create organizational structures capable of supporting the long-term development and growth of CMS. Dedicated service units emerged as one mechanism for achieving this objective. However, the experts emphasized that the effectiveness of such units depends less on their existence and more on their organizational legitimacy, decision-making authority, and ability to influence activities extending across multiple functions. From this perspective, dedicated service organizations should act as strategic integrators connecting customers, engineering, sales, digitalization, production, and after-sales services.

The findings further indicate that service-oriented capabilities should be viewed as strategic organizational assets rather than operational support functions. Successful CMS implementation requires the integration of technical expertise with competences related to service management, customer engagement, business development, financial analysis, and value communication. Therefore, capability development should be approached as a long-term investment supporting both organizational transformation and sustainable service growth.

Finally, the interviews suggest that CMS implementation should be understood as a dual change-management process involving both providers and customers. Implementation success depends not only on the capabilities of OEMs but also on the readiness of customers to modify existing routines, decision-making processes, and organizational practices. Consequently, OEMs should actively manage organizational change across both organizations by reducing uncertainty, demonstrating value incrementally, and supporting gradual adoption pathways. From this perspective, customer adoption becomes a process of organizational transformation rather than merely a technology purchasing decision.

Overall, the findings related to RQ3 suggest that successful CMS implementation requires a fundamental shift in managerial thinking. Rather than treating CMS as maintenance technologies or digital tools, OEMs should approach them as strategic digital servitization initiatives centred on customer value creation. This requires customer-value-driven service design, legitimate service-oriented organizational structures, multidisciplinary capabilities, and the active management of organizational change across both provider and customer organizations. Consequently, the successful implementation of CMS depends not only on technological capabilities but also on the ability of OEMs to transform how they create, deliver, and capture value through CMS.

Discussion

RQ1. What are the main challenges hindering successful CMS implementation?

The findings demonstrate that the principal barriers to successful CMS implementation are not primarily technological but socio-technical in nature. While the CMS literature has traditionally focused on advancing sensing technologies, diagnostics, prognostics, predictive analytics, and maintenance optimization (Ahmad & Kamaruddin, 2012; Jardine et al., 2006; Selcuk, 2017), the experts consistently identified challenges related to CMS value proposition, service design capabilities, and organizational readiness. These findings suggest that the critical bottleneck in CMS implementation has shifted from technology development towards the organizational capabilities required to successfully implement CMS offerings.

This finding complements and extends previous CMS studies that have acknowledged non-technical barriers, such as organizational resistance, integration challenges, and knowledge-management difficulties (Ingemarsdotter et al., 2021; van de Kerkhof et al., 2016). Whereas previous studies typically treat these barriers as isolated implementation problems, our findings indicate that they are interconnected and emerge from broader socio-technical misalignments affecting value creation, service development, and organizational transformation. In this sense, the findings move beyond the dominant technical perspective in CMS research and provide a more holistic explanation for implementation failures.

This interpretation aligns with the socio-technical perspective proposed by Münch et al. (2022), who argue that digital servitization success depends on the coordinated development of technological, organizational, and human capabilities. Similar arguments have recently been advanced within Industry 4.0 and digital servitization research, where implementation outcomes have been shown to depend on the balance between technological and organizational factors rather than on technology adoption alone (Marcon et al., 2022, 2024, 2025). The challenges identified in this study reflect deficiencies across all three capability domains. Consequently, the findings support the view that CMS implementation should be understood as the development of a socio-technical organizational capability system that integrates technological resources, service capabilities, organizational structures, and customer relationships rather than as a technology deployment project.

Importantly, the findings reveal that implementation success is shaped not by technological capabilities alone, but by the alignment of technological, organizational, and relational factors. This contribution advances the CMS literature by demonstrating how value creation, service development, organizational structures, and customer relationships collectively influence implementation outcomes. The findings also provide empirical evidence of how the service paradox materializes in the specific context of CMS implementation. Similar to the machine tool manufacturers studied by Kamp et al. (2023), many experts reported situations in which OEMs invested significantly in monitoring technologies, digital infrastructures, and data-processing capabilities but struggled to achieve customer adoption and profitable revenue streams. These findings reinforce the growing body of literature suggesting that investments in digital technologies do not automatically translate into business value (Karatzas et al., 2026; Agostini et al., 2026). They also support Rietdijk's (2026) argument that digital servitization barriers frequently reinforce one another, creating negative synergistic effects

that undermine value creation and value capture. In the CMS context, weaknesses in value communication, organizational alignment, customer engagement, and service design appear to interact and amplify implementation difficulties. These findings are particularly relevant in CMS contexts because the value generated by condition monitoring technologies depends on continuous access to operational data, integration with customer maintenance processes, and the ability to demonstrate measurable operational and financial outcomes. Such characteristics make CMS especially sensitive to failures in customer collaboration, value communication, and organizational alignment.

Furthermore, the findings illustrate several of the paradoxical tensions that characterize digital servitization. Consistent with Kohtamäki et al. (2020), experts repeatedly described tensions between product and service orientations, technological sophistication and customer value, and standardization and customization. Similar tensions have recently been identified by Paiola and Grandinetti (2026) and Smania et al. (2026), who argue that paradoxical demands emerge across multiple organizational levels during digital servitization journeys. Our findings suggest that these tensions are not peripheral challenges but structural characteristics of CMS implementation. Rather than disappearing as organizations gain experience, they require continuous balancing and managerial attention.

Therefore, the answer to RQ1 is that the main challenges hindering successful CMS implementation are not technological limitations but multidimensional socio-technical barriers involving value creation, service development, organizational transformation, and customer alignment. Successful implementation depends less on the sophistication of condition monitoring technologies and more on the ability of OEMs to align these interdependent dimensions.

RQ2. How can OEMs overcome the challenges associated with CMS implementation?

The findings indicate that overcoming CMS implementation challenges requires interventions primarily targeting organizational, relational, and managerial capabilities rather than additional technological investments. This observation reinforces the argument that the successful implementation of CMS depends less on the sophistication of condition monitoring technologies and more on the ability of OEMs to align technologies with value creation mechanisms, service development processes, and organizational capabilities. In this respect, the identified solutions represent practical mechanisms through which firms can address the socio-technical challenges discussed in RQ1.

A first set of solutions concerns value articulation and value quantification. Experts repeatedly emphasized the importance of demonstrating financial and operational benefits through business cases, ROI calculations, performance indicators, and outcome-based narratives. This observation is consistent with prior digital servitization research showing that value demonstration, value appropriation, and value capture remain among the most significant challenges associated with smart service offerings (Visnjic et al., 2017; Kamp et al., 2023). However, our findings extend this literature by suggesting that value communication should not be viewed as a downstream sales activity but as a core implementation capability. In CMS contexts, customer adoption depends not only on technological performance but also on the ability of OEMs to quantify, communicate, and continuously demonstrate service value. This finding is particularly relevant because CMS generate benefits that are often indirect, future-oriented, and difficult for customers to evaluate prior to adoption.

A second group of solutions focuses on CMS design and development. Experts advocated pilot projects, iterative implementation approaches, customer co-creation activities, and continuous customer involvement throughout the service lifecycle. These findings are consistent with research emphasizing experimentation, service innovation, and agile development practices in digital servitization contexts (Sjödin et al., 2020; Iriarte et al., 2023). At the same time, they challenge the implicit technology-centred logic found in much of the CMS literature, which frequently conceptualizes implementation as a sequence progressing from data acquisition to diagnostics, prognostics, and maintenance optimization (Jardine et al., 2006; Ahmad & Kamaruddin, 2012; Selcuk, 2017). Instead, our findings suggest that CMS implementation is better understood as a process of mutual learning in which both OEMs and customers continuously adapt technologies, processes, and expectations. This observation is particularly important in CMS contexts, where value creation depends on continuous access to operational data, integration with customer maintenance processes, and the joint interpretation of equipment performance information. Consequently, customer involvement becomes a prerequisite for implementation rather than simply a desirable design practice.

A third set of solutions concerns service-oriented organizational capability development. Experts stressed the importance of service units with multidisciplinary teams, customer engagement capabilities, financial competencies, and service management expertise. These findings strongly reinforce the capability-based view of digital servitization proposed by Münch et al. (2022) and are consistent with recent evidence indicating that organizational capabilities represent a critical determinant of digital servitization success (Karatzas et al., 2026; Minaya et al., 2026; Momenzadeh et al., 2026). Importantly, the experts frequently identified capability development as a higher priority than further technological

investments. This suggests that many OEMs may currently suffer from organizational capability deficits rather than technology deficits. While condition monitoring technologies have reached relatively high levels of maturity, organizations often lack the structures, competences, and governance mechanisms required to transform technological capabilities into scalable service businesses. Consequently, capability development emerges not only as an implementation solution but also as a foundational condition for CMS implementation.

Interestingly, many of the identified solutions can also be interpreted as coping mechanisms for managing the paradoxical tensions associated with CMS implementation. Pilot implementations, modular service architectures, dedicated service structures, and phased deployment approaches help firms balance competing demands for standardization and customization, flexibility and efficiency, and product and service orientation. As CMS combine technological innovation, service provision, and customer collaboration, these tensions are particularly visible in CMS contexts. This finding directly supports the paradox perspective developed by Kohtamäki et al. (2020) and subsequently extended by Paiola and Grandinetti (2026) and Smania et al. (2026). Rather than eliminating tensions, successful CMS implementation appears to depend on developing organizational practices capable of navigating and balancing them over time.

Therefore, the answer to RQ2 is that successful CMS implementation requires the development of a socio-technical capability system through which technological resources, organizational structures, human competencies, and customer relationships are continuously aligned to support value creation, delivery, and capture. More specifically, OEMs can overcome implementation challenges by strengthening value articulation mechanisms, adopting co-creative and iterative service development practices, and developing service-oriented organizational capabilities. Rather than representing isolated solutions, these practices operate as complementary mechanisms that collectively enable the successful implementation and commercialization of CMS. This finding extends the digital servitization literature by translating broad servitization principles into concrete implementation approaches tailored to the specific realities of CMS.

RQ3. What recommendations support successful CMS implementation?

The findings suggest that successful CMS implementation should be approached as a digital servitization transformation rather than as the deployment of a condition monitoring technology. While the solutions discussed in RQ2 address specific implementation barriers, the recommendations identified by the experts reveal broader managerial principles capable of guiding the development, commercialization, and scaling of CMS offerings. Collectively, these recommendations indicate that implementation success depends on how OEMs think about CMS, organize around CMS, and manage organizational change rather than on the technological sophistication of the monitoring system itself.

A first managerial recommendation concerns designing CMS around customer value rather than technological functionality. Consistent with digital servitization research (Baines et al., 2017; Kowalkowski et al., 2017), the findings indicate that sustainable competitive advantage through CMS increasingly derives from delivering customer outcomes rather than selling technological features. Our findings extend this argument by showing that many OEMs continue to approach CMS through engineering-dominated logics, limiting customer acceptance and reducing opportunities for value capture. Successful implementation therefore requires shifting managerial attention from technological performance towards operational improvements, risk reduction, financial outcomes, and customer business objectives. In this sense, technologies should be viewed as enablers of customer value rather than as the primary source of value themselves.

The findings further highlight the importance of adopting a co-creative and iterative service-development logic. Echoing research on agile digital servitization and service innovation (Sjödin et al., 2020; Iriarte et al., 2023), the experts consistently argued that successful CMS offerings emerge through continuous interactions between providers and customers. However, our findings suggest that co-creation should not be viewed merely as a design tool. Rather, it represents a broader managerial mindset in which customers become active partners in value creation, learning, and service evolution. Similarly, iterative implementation approaches based on pilot projects, modular services, and progressive deployment allow uncertainties to be managed through experimentation and learning. Together, these findings suggest that OEMs should approach CMS implementation as a continuous learning process rather than as a predefined technology project.

A third recommendation concerns the establishment of organizational legitimacy for service activities. Experts consistently argued that CMS implementation requires organizational structures with sufficient authority, visibility, and resources to coordinate activities across engineering, sales, customer support, digitalization, and service functions. This finding extends existing digital servitization research by highlighting legitimacy as a critical but underexplored condition for service growth. Recent work by Kristiansen and Aas (2026) similarly identifies legitimacy as a key enabling mechanism facilitating resource allocation, managerial commitment, and cross-functional collaboration during digital servitization initiatives. Importantly, our findings suggest that legitimacy should not be viewed solely as an outcome of

servitization efforts. Rather, it appears to be a prerequisite for successful CMS implementation because organizations must first recognize CMS as strategic service businesses before they can effectively invest in the organizational structures required to support them. Therefore, the findings suggest that legitimized service units help secure resources, managerial support, and cross-functional collaboration, creating the conditions necessary for service development and growth.

Building on this principle, the findings suggest that dedicated service units can play an important role in institutionalizing service-oriented thinking within OEMs. In line with Biesinger et al. (2026), these units should not simply manage service delivery but should function as mechanisms for organizational learning, capability development, and service-business growth. Their role extends beyond coordinating implementation projects and includes connecting customers with internal organizational functions, ensuring the integration of customer knowledge into service development, and supporting the long-term evolution of CMS offerings.

The findings also emphasize the importance of viewing service-oriented capabilities as strategic assets. Echoing Münch et al. (2022), experts highlighted the need to complement engineering expertise with competencies in service design, value-based selling, financial analysis, customer relationship management, and business development. This observation aligns with recent literature showing that digital servitization outcomes depend on the integration of technological and managerial capabilities rather than on technological assets alone (Agostini et al., 2026; Joshi et al., 2026). Consequently, CMS implementation should be understood as a continuous capability-development process through which firms progressively build the competences required to create, deliver, and capture value from digital services.

Finally, the findings indicate that CMS implementation should be understood as a joint provider-customer transformation process. Consistent with studies emphasizing co-creation, ecosystem collaboration, and relational value creation (Sjödin et al., 2020; Nguyen et al., 2022a, 2022b; Iriarte et al., 2023), successful implementation requires organizational adaptation on both sides of the relationship. However, our findings extend this literature by demonstrating that customer transformation is not simply a consequence of adoption. The realization of CMS value depends on customers' willingness and ability to modify routines, maintenance practices, infrastructures, and decision-making processes. As a result, customer adoption should be viewed as an organizational change process rather than a purchasing decision.

Therefore, the answer to RQ3 is that successful CMS implementation requires OEMs to adopt a customer-value-driven service logic, embrace co-creative and iterative service development, establish legitimate service-oriented organizational structures, invest in multidisciplinary service capabilities, and actively manage organizational transformation across both provider and customer organizations. Collectively, these recommendations suggest that CMS implementation should be understood as a digital servitization journey rather than a condition monitoring technology deployment project.

Conclusions, limitations and future research

Contributions to theory and practice

This study explored the implementation of CMS by OEMs through an exploratory expert elicitation approach. Specifically, it investigated the challenges limiting CMS implementation, the solutions to overcome these challenges, and the recommendations that can support successful implementation.

Regarding RQ1, the findings demonstrate that the principal barriers to successful CMS implementation are socio-technical. The study identified three interconnected groups of challenges: challenges related to CMS value propositions, challenges associated with CMS design processes, and challenges concerning organizational and customer readiness. Therefore, the findings suggest that the success of CMS is largely determined by an OEM's ability to create, communicate, and capture value rather than by the maturity of the underlying CM technologies.

Regarding RQ2, the study identified a range of complementary solutions for overcoming these challenges. The findings suggest that successful implementation depends on the simultaneous alignment of value creation mechanisms, co-creative service design processes, and new organizational capabilities. In particular, experts emphasized the importance of quantifying value through business cases and performance indicators, involving customers throughout service development, adopting iterative implementation approaches, developing multidisciplinary service capabilities, and establishing dedicated organizational service-oriented structures responsible for CMS development and delivery. While the digital servitization literature frequently advocates broad approaches such as customer co-creation, organizational capability development, and business model innovation, the present study translates these generic principles into more concrete solutions tailored to the specific implementation realities of CMS by OEMs.

Regarding RQ3, the findings resulted in a set of managerial recommendations that elevate CMS from a maintenance technology initiative to a digital servitization transformation. The experts emphasized the need for OEMs to design CMS

around customer value rather than technological functionality, establish dedicated and legitimate service units with sufficient authority and autonomy, develop multidisciplinary capabilities, and actively manage organizational change on both provider and customer sides. Importantly, these recommendations go beyond generic guidance available in the digital servitization literature by addressing issues that are particularly salient in CMS contexts. Consequently, the study provides actionable recommendations specifically targeted at OEMs seeking to develop, commercialize, and scale CMS.

This study contributes to the CMS literature by extending the understanding of CMS implementation beyond technological considerations and highlighting its fundamentally socio-technical nature. The findings support recent digital servitization research arguing that value realization depends on the alignment of technological, organizational, and human capabilities. Furthermore, the study provides empirical evidence of how digital servitization tensions and paradoxes materialize in the specific context of CMS implementation and how OEMs can actively manage them. Importantly, the study complements the broader digital servitization literature, which often examines digitally enabled services at a relatively high level of abstraction, by translating these broader concepts into CMS-specific implementation challenges, solutions, and managerial recommendations. In doing so, the study provides a more contextualized understanding of how digital servitization unfolds in advanced maintenance service environments.

From a managerial perspective, the study offers actionable insights for OEM executives, service managers, innovation managers, and other practitioners involved in the implementation of CMS offerings. The findings suggest that many common implementation pitfalls originate from treating CMS primarily as technological solutions. Such an approach often results in poorly articulated value propositions, insufficient customer involvement, fragmented organizational ownership, weak service capabilities, and difficulties in demonstrating and capturing value. By identifying these pitfalls and proposing corresponding solutions, the study provides practical guidance that can support more effective service development and implementation efforts.

More specifically, the findings encourage OEM practitioners to move beyond a technology-centred implementation logic and adopt a service-oriented perspective focused on customer outcomes and value creation. This represents an important shift from current practices observed by the experts, where CMS initiatives are frequently led by engineering or digitalization functions with limited involvement of service management and customer-facing activities. The proposed recommendations emphasize the creation of legitimate and dedicated service units, the development of multidisciplinary service capabilities, the use of co-creative service design processes, and the active management of organizational change. Such practices can help organizations improve customer adoption, strengthen internal coordination, increase value capture, and reduce the risk of falling into the service paradox frequently reported in servitization research.

Ultimately, the study contributes practical guidance for OEMs seeking to transform condition monitoring technologies into sustainable service businesses. By treating CMS as digital servitization initiatives rather than standalone technology projects, OEMs can improve the effectiveness of implementation efforts, generate greater value for customers, and increase the likelihood of achieving long-term commercial success. More broadly, the findings suggest that the future success of CMS will depend less on further advances in monitoring technologies and more on the ability of OEMs to orchestrate technological, organizational, and relational capabilities into sustainable service-oriented business models.

Limitations and future research

The findings should be interpreted considering several limitations.

First, the study relies on the perspectives of thirteen experts and therefore reflects their informed perceptions and experiences regarding CMS implementation. Although expert elicitation is particularly suitable for exploring emerging and complex phenomena where knowledge is dispersed among experienced practitioners and researchers, the findings do not allow statistical generalization. Rather than seeking representativeness, the study aims to generate analytically generalizable insights that help explain how experts understand and address CMS implementation challenges. Consequently, the findings should be interpreted as informed expert knowledge rather than as evidence of the prevalence of specific challenges or practices across the broader population of OEMs.

Second, the study focuses specifically on CMS implementation by OEMs. While several findings may be relevant to other digitally enabled services, caution should be exercised when extending the conclusions to different forms of digital servitization. CMS possess distinctive characteristics. These characteristics may generate implementation challenges and organizational requirements that differ from those associated with other digital services. Therefore, the transferability of the findings to other digital servitization contexts should be assessed carefully and validated through additional research.

Third, regarding triangulation and participant validation, we acknowledge that the study did not employ multiple data sources or formal participant validation procedures. The findings are based exclusively on expert interviews and therefore

capture how experts interpret, explain, and make sense of CMS implementation challenges. Consequently, some findings may reflect retrospective interpretations, individual experiences, or context-dependent viewpoints that could differ from observations obtained through direct organizational studies.

A further limitation is the cross-sectional nature of the study. The interviews provide a snapshot of expert experiences and reflections at a particular point in time but do not capture how implementation processes develop over extended periods. Given that CMS implementation often involve long-term organizational transformation, future longitudinal studies could provide valuable insights into how capabilities, organizational structures, customer relationships, and implementation outcomes evolve throughout different stages of the servitization journey.

Taken together, these limitations suggest that future research should complement expert-based insights with longitudinal, multi-stakeholder, and case-based investigations capable of examining CMS implementation processes as they unfold in practice.

Several opportunities for future research emerge from this study.

First, future studies could examine CMS implementation longitudinally to better understand how implementation challenges, organizational capabilities, and customer relationships evolve over time and across different stages of digital servitization. Such studies would help explain not only what challenges occur, but also how organizations successfully overcome them and how socio-technical capabilities develop throughout the implementation journey.

Second, additional research could investigate the role of dedicated service units in greater depth. In particular, future studies could explore how organizational legitimacy for service activities is established, maintained, and strengthened within product-centric manufacturing organizations. Such work could provide a deeper understanding of the organizational mechanisms that support the implementation of CMS.

Third, future studies could compare different sectors, firm sizes, and digital service types to identify the contextual conditions under which particular implementation practices are more or less effective. Such comparative analyses would contribute to refining managerial recommendations and developing more context-sensitive implementation frameworks.

Fourth, future research could investigate the interaction between value creation, value communication, and value capture in CMS contexts. Given the importance of value quantification identified in this study, further research could explore how OEMs develop business cases, pricing models, and commercialization strategies that support customer adoption while ensuring sustainable value capture.

Finally, future studies could expand the perspective beyond OEMs by incorporating customers, technology providers, and ecosystem partners. Multi-stakeholder studies could provide a richer understanding of how collaboration, trust, data governance, and organizational change influence the implementation and scaling of CMS across organizational boundaries.

Ethics statement

This study was approved by the Research Ethics Committee of Mondragon Unibertsitatea under reference number IEB-20240909, on 9th September 2024. All research procedures adhered to the ethical standards set by the committee and complied with the Declaration of Helsinki and its subsequent amendments. Informed consent to participate was obtained in advance, primarily in written form via email. In some instances, verbal consent was obtained. This approach was reviewed and approved by the ethics committee, given the remote nature of the study. Verbal consent—recorded at the time of the interview—was considered both ethically appropriate and logistically practical, supporting participant accessibility and the protection of data privacy.

Data availability statement

All research data underlying the results of this article—including the call for participants, consent forms, interview guides, and fully manually anonymised interview transcripts—are available on Mendeley Data under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0). The interviews were transcribed using Tactiq; no other software was used for data processing or analysis.

Extended data

Mendeley: Overcoming Challenges in Implementing Condition Monitoring Services: Recommendations from an Expert Elicitation Exploratory Study, 10.17632/tf74rr4jsj.1 (Iriarte et al., 2026).

This project contains the following extended data:

- call for participants, consent forms, interview guides, interview transcripts, and data analysis.

Data is available under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0).

References

Agostini L, Filosa C, Nosella A: **Digital technologies, servitization and business models: An integrated literature review.** *J Eng Technol Manag.* 2026; **80**: 101971.

Ahmad R, Kamaruddin S: **An overview of time-based and condition-based maintenance in industrial application.** *Comput Ind Eng.* 2012; **63**(1): 135–149.
Publisher Full Text

Antikainen M, Uusitalo T, Kivikytö-Reponen P: **Digitalisation as an enabler of circular economy.** *Procedia CIRP.* 2018; **73**: 45–49.
Publisher Full Text

Baines TW, Lightfoot H: *Made to Serve: How manufacturers can compete through servitization and product service systems.* Baines T, Lightfoot H, editors. John Wiley & Sons; 2013.

Baines T, Lightfoot H: **Servitization of the manufacturing firm: exploring the operations practices and technologies that deliver advanced services.** *Int J Oper Prod Manag.* 2014; **34**(1): 2–35.
Publisher Full Text

Baines TS, Ziaee Bigdeli A, Bustinza OF, *et al.*: **Servitization: revisiting the state-of-the-art and research priorities.** *Int J Oper Prod Man.* 2017; **37**(2): 256–278.
Publisher Full Text

Benedettini O: **Green servitization in the single-use medical device industry: how device OEMs create supply chain circularity through reprocessing.** *Sustainability.* 2022; **14**(19): 12670.
Publisher Full Text

Biesinger B, Saleschus M, West S, *et al.*: **Transforming manufacturers into service-driven learning organizations: Practitioner-oriented review and change framework.** *J Serv Theory Pract.* 2026; **36**(4): 704–734.
Publisher Full Text

Bogner A, Menz W: **The theory-generating expert interview: epistemological interest, forms of knowledge, interaction**. In: *Interviewing Experts.* Palgrave Macmillan UK; 2009; pp. 43–80.
Publisher Full Text

Bousdekis A, Apostolou D, Mentzas G: **Predictive maintenance in the 4th industrial revolution: benefits, business opportunities, and managerial implications.** *IEEE Eng Manag Rev.* 2020; **48**(1): 57–62.
Publisher Full Text

Braun V, Clarke V: **Using thematic analysis in psychology.** *Qual Res Psychol.* 2006; **3**(2): 77–101.
Publisher Full Text

Calabrese A, Levialdi Ghiron N, Tiburzi L, *et al.*: **The measurement of degree of servitization: literature review and recommendations.** *Prod Plan Control.* 2019; **30**(13): 1118–1135.
Publisher Full Text

Castellano E, Zubizarreta PX, Pagalday G, *et al.*: **Service 4.0: The reasons and purposes of industry 4.0 within the ambit of after-sales maintenance.** *Optimum Decision Making in Asset Management.* 2017. pp. 139–162.
Publisher Full Text

Cenamor J, Rönnberg Sjödin D, Parida V: **Adopting a platform approach in servitization: leveraging the value of digitalization.** *Int J Prod Econ.* 2017; **192**: 54–65.
Publisher Full Text

Cheah SLY, Yang Y, Saritas O: **Reinventing product-service systems: the case of Singapore.** *Foresight.* 2019; **21**(3): 332–361.
Publisher Full Text

Çınar ZM, Abdussalam Nuhu A, Zeeshan Q, *et al.*: **Machine Learning in predictive maintenance towards sustainable smart manufacturing in industry 4.0.** *Sustainability.* 2020; **12**(19): 8211.
Publisher Full Text

Fraser K, Hvolby HH, Tseng TL: **Maintenance management models: a study of the published literature to identify empirical evidence: a greater practical focus is needed.** *Int J Qual Reliab Manag.* 2015; **32**(6): 635–664.
Publisher Full Text

Gebauer H, Fleisch E, Friedli T: **Overcoming the service paradox in manufacturing companies.** *Eur Manag J.* 2005; **23**(1): 14–26.
Publisher Full Text

Gläser J, Laudel G: **On interviewing "good" and "bad" experts**. In: *Interviewing Experts.* Palgrave Macmillan UK; 2009; pp. 117–137.
Publisher Full Text

Gómez J, Marquez AC, León PM, *et al.*: **Outsourcing maintenance in services providers**. In: Martorell S, Soares CG, Barnett J, editors. *Safety, Reliability and Risk Analysis: Theory, Methods and Applications.* London: Taylor & Francis Group; 2009; pp. 829–837.
Reference Source

Goyal D, Pabla BS: **Condition based maintenance of machine tools—a review.** *CIRP J Manuf Sci Technol.* 2015; **10**: 24–35.
Publisher Full Text

Guest G, Bunce A, Johnson L: **How many interviews are enough? An experiment with data saturation and variability.** *Field Methods.* 2006; **18**(1): 59–82.
Publisher Full Text

Hien NN, Lasa G, Iriarte I, *et al.*: **An overview of industry 4.0 applications for advanced maintenance services.** *Procedia Comput Sci.* 2022; **200**: 803–810.
Publisher Full Text

Holgado M: **A systems engineering approach to performance-based maintenance services design.** *Processes.* 2019; **7**(2): 59.
Publisher Full Text

Ingemarsdotter E, Kambanou ML, Jamsin E, *et al.*: **Challenges and solutions in condition-based maintenance implementation - a multiple case study.** *J Clean Prod.* 2021; **296**: 126420.
Publisher Full Text

Iriarte I, Hoveskog M, Nguyen Ngoc H, *et al.*: **Service design for digital servitization: facilitating manufacturers' advanced services value proposition design in the context of Industry 4.0.** *Ind Mark Manag.* 2023; **110**: 96–116.
Publisher Full Text

Iriarte I, Ngoc HN, Lasa G: **Extended data: Overcoming Challenges in Implementing Condition Monitoring Services: Recommendations from an Expert Elicitation Exploratory Study.** *Mendeley Data.* 2026; **V1**.
Publisher Full Text

Jardine AKS, Lin D, Banjevic D: **A review on machinery diagnostics and prognostics implementing condition-based maintenance.** *Mech Syst Signal Process.* 2006; **20**(7): 1483–1510.
Publisher Full Text

Joshi S, Sharma M, Gunasekaran A, *et al.*: **Sustainable smart manufacturing through digital servitization: A systematic literature review using use cases.** *Int J Comput Integr Manuf.* 2026.

Karatzas A, Dousios D, Bastl M: **When digital servitization pays off for manufacturing SMEs: A configurational approach.** *Technol Forecast Soc Change.* 2026; **231**: 124781.

Kalsoom T, Ramzan N, Ahmed S, *et al.*: **Advances in sensor technologies in the era of smart factory and industry 4.0.** *Sensors (Basel).* 2020; **20**(23): 6783.
PubMed Abstract | Publisher Full Text | Free Full Text

Kamp B, Zabala K, Zubiaurre A: **How can machine tool builders capture value from smart services? Avoiding the service and digitalization paradox.** *J Bus Ind Mark.* 2023; **38**(2): 303–316.
Publisher Full Text

Keh P, Rodhain F, Meissonier R, *et al.*: **Financial performance, environmental compliance, and social outcomes: the three challenges of reverse logistics. Case study of IBM montpellier.** *Supply Chain Forum: An International Journal.* 2012; **13**(3): 26–38.
Publisher Full Text

Ketokivi M, Choi T: **Renaissance of case research as a scientific method.** *J Oper Manag.* 2014; **32**(5): 232–240.
Publisher Full Text

Kohtamäki M, Einola S, Rabetino R: **Exploring servitization through the paradox lens: Coping practices in servitization.** *Int J Prod Econ.* 2020;

226: 107619.
Publisher Full Text

Kohtamäki M, Parida V, Oghazi P, *et al.*: **Digital servitization business models in ecosystems: a theory of the firm.** *J Bus Res.* 2019; **104**: 380–392.
Publisher Full Text

Kowalkowski C, Gebauer H, Oliva R: **Service growth in product firms: past, present, and future.** *Ind Mark Manag.* 2017; **60**: 82–88.
Publisher Full Text

Kristiansen M, Aas TH: **Building legitimacy in digital servitization: An exploratory case study in manufacturing.** *J Manuf Technol Manag.* 2026; **37**(1): 65–86.
Publisher Full Text

Kristoffersen E, Mikalef P, Blomsma F, *et al.*: **Towards a business analytics capability for the circular economy.** *Technol Forecast Soc Change.* 2021; **171**: 120957.
Publisher Full Text

Lanzilotti CO, Pinto LFR, Facchini F, *et al.*: **Embedding product-service system of cutting tools into the machining process: an eco-efficiency approach toward sustainable development.** *Sustainability.* 2022; **14**(3): 1100.
Publisher Full Text

Lee J: **How to establish industrial AI technology and capability**. In: *Industrial AI.* Springer Singapore; 2020a; pp. 119–159.
Publisher Full Text

Lee J: **Killer applications of industrial AI**. In: *Industrial AI.* Springer Singapore; 2020b; pp. 63–117.
Publisher Full Text

Lee J, Wu F, Zhao W, *et al.*: **Prognostics and Health Management design for rotary machinery systems—Reviews, methodology and applications.** *Mech Syst Signal Process.* 2014; **42**(1–2): 314–334.
Publisher Full Text

Lightfoot HW, Baines T, Smart P: **Examining the information and communication technologies enabling servitized manufacture.** *Proc Inst Mech Eng B J Eng Manuf.* 2011; **225**(10): 1964–1968.
Publisher Full Text

Linde L, Frishammar J, Parida V: **Revenue models for digital servitization: A value capture framework for designing, developing, and scaling digital services.** *IEEE Trans Eng Manag.* 2023; **70**(1): 82–97.
Publisher Full Text

Malmberg L: *Building design capability in the public sector: Expanding the horizons of development.* vol. 1831. Linköping University Electronic Press; 2017.

March ST, Scudder GD: **Predictive maintenance: strategic use of IT in manufacturing organizations.** *Inf Syst Front.* 2019; **21**(2): 327–341.
Publisher Full Text

Marcon É, Marcon A, Ayala NF, *et al.*: **Capabilities supporting digital servitization: a multi-actor perspective.** *Ind Market Manag.* 2022; **103**: 97–116.
Publisher Full Text

Marcon É, Marodin GA, Frank AG: **Combining organizational and social factors to support Industry 4.0 implementation: A sociotechnical and configurational analysis of technology adopters.** *IEEE Trans Eng Manag.* 2024; **72**: 146–160.

Marcon É, Soliman M, Ayala NF, *et al.*: **A system view of how balancing sociotechnical factors in Industry 4.0 implementation: Evidence from interviews and ethnographic research.** *Comput Ind Eng.* 2025; **203**: 111047.

Mason M: **Sample size and saturation in PhD studies using qualitative interviews.** *Forum Qual Sozialforsch.* 2010; **11**(3)
Publisher Full Text

Matthyssens P, Vandenbempt K: **Moving from basic offerings to value-added solutions: strategies, barriers and alignment.** *Ind Market Manag.* 2008; **37**(3): 316–328.
Publisher Full Text

Meuser M, Nagel U: **The expert interview and changes in knowledge production**. In: *Interviewing Experts.* Palgrave Macmillan UK; 2009; pp. 17–42.
Publisher Full Text

Minaya PE, Avella L, Trespalacios JA: **Strategic perception of Industry 4.0 and its impact on digital servitization in manufacturing firms.** *J Manuf Technol Manag.* 2026; **37**(1): 111–131.

Miles M, Huberman M, Saldaña J: *Qualitative data analysis: a methods sourcebook.* 3rd ed. Sage Publications; 2013.
Reference Source

Mishra A, Badhotiya GK, Patil A, *et al.*: **Servitization in the circular supply chain: delineating current research and setting future research plan.** *Manag Environ Qual.* 2023; **34**(4): 1035–1056.
Publisher Full Text

Momenzadeh K, Mohammadian A, Vares H: **Mapping the digital servitization journey: A meta-synthetic framework of antecedents, processes, and outcomes in Industry 4.0.** *Ind Manag J.* 2026; **18**(1): 117–135.

Mourtzis D, Angelopoulos J, Boli N: **Maintenance assistance application of engineering to order manufacturing equipment: a Product Service System (PSS) approach.** *IFAC-PapersOnLine.* 2018; **51**(11): 217–222.
Publisher Full Text

Mourtzis D, Siatras V, Angelopoulos J: **Real-time remote maintenance support based on Augmented Reality (AR).** *Appl Sci.* 2020; **10**(5): 1855.
Publisher Full Text

Mulders M, Haarman M: **PdM 4 Predict the unpredictable.** *Mainnovation.* 2017.
Reference Source

Münch C, Marx E, Benz L, *et al.*: **Capabilities of digital servitization: Evidence from the socio-technical systems theory.** *Technol Forecast Soc Change* 2022; **176**: 121361.
Publisher Full Text

Myers MD, Newman M: **The qualitative interview in IS research: examining the craft.** *Inf Organ.* 2007; **17**(1): 2–26.
Publisher Full Text

Nguyen NH, Lasa G, Iriarte I: **Human-centred design in industry 4.0: case study review and opportunities for future research.** *J Intell Manuf.* 2022a; **33**(1): 35–76.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Nguyen HN, Lasa G, Iriarte I, *et al.*: **Human-centered design for advanced services: a multidimensional design methodology.** *Adv Eng Inform.* 2022b; **53**: 101720.
Publisher Full Text

Paiola M, Grandinetti R: **Paradoxical tensions in digital servitization strategies: A processual and multi-level analysis.** *J Bus Ind Mark.* 2026; **41**(13): 149–165.
Publisher Full Text

Paschou T, Rapaccini M, Adrodegari F, *et al.*: **Digital servitization in manufacturing: a systematic literature review and research agenda.** *Ind Market Manag.* 2020; **89**: 278–292.
Publisher Full Text

Raddats C, Naik P, Ziaee Bigdeli A: **Creating value in servitization through digital service innovations.** *Ind Market Manag.* 2022; **104**: 1–13.
Publisher Full Text

Rietdijk B: **The negative synergistic effects and consequences of digital servitization barriers.** *Ind Mark Manag.* 2026; **136**: 34–52.
Publisher Full Text

Roda I, Macchi M, Fumagalli L: **The future of maintenance within industry 4.0: an empirical research in manufacturing**. In: Moon I, Lee GM, Park J, *et al.*, editors. *Advances in production management systems. Smart manufacturing for industry 4.0. APMS 2018. IFIP Advances in Information and Communication Technology.* Vol. 536. Cham: Springer; 2018; pp. 39–46.
Publisher Full Text

Rymaszewska A, Helo P, Gunasekaran A: **IoT powered servitization of manufacturing – an exploratory case study.** *Int J Prod Econ.* 2017; **192**: 92–105.
Publisher Full Text

Saunders A, Lewis M, Thornhill A: *Research methodsb for business students.* 7th ed. Harlow, United Kingdom: Pearson Education Limited; 2016.
Reference Source

Selcuk S: **Predictive maintenance, its implementation and latest trends.** *Proc Inst Mech Eng B J Eng Manuf.* 2017; **231**(9): 1670–1679.
Publisher Full Text

Silvestri L, Forcina A, Introna V, *et al.*: **Maintenance transformation through industry 4.0 technologies: a systematic literature review.** *Comput Ind.* 2020; **123**: 103335.
Publisher Full Text

Sjödin D, Parida V, Kohtamäki M, *et al.*: **An agile co-creation process for digital servitization: a micro-service innovation approach.** *J Bus Res.* 2020; **112**: 478–491.
Publisher Full Text

Smania GS, Ayala NF, Coreynen W, *et al.*: **Understanding paradoxical tensions and coping strategies in platform-based servitization.** *Ind Mark Manag.* 2026; **132**: 1–16.
Publisher Full Text

Slatter R, Sivasothy P, Seewig J: *Condition monitoring for agricultural vehicles using magnetoresistive sensors.* 2021: 377–388.
Publisher Full Text

Strauss A, Corbin J: *Basics of qualitative research.* 2nd ed. Newbury Park, CA: Sage; 1998.
Reference Source

Suri H: **Purposeful sampling in qualitative research synthesis.** *Qual Res J.* 2011; **11**(2): 63–75.
Publisher Full Text

Tagscherer F, Carbon CC: **Leadership for successful digitalization: A literature review on companies' internal and external aspects of digitalization.** *Sustain Technol Entrep.* 2023; **2**(2): 100039.
Publisher Full Text

Takata S: **Life cycle maintenance management**. In: Lee J, Wang B, editors. *Computer-aided maintenance.* USA: Springer; 1999; pp. 209–230.
Publisher Full Text

Takata S: **Maintenance-centered circular manufacturing.** *Procedia CIRP.* 2013; **11**: 23–31.
Publisher Full Text

Thomas DR: **A general inductive approach for analyzing qualitative evaluation data.** *Am J Eval.* 2006; **27**(2): 237–246.
Publisher Full Text

Turetken O, Grefen P, Gilsing R, *et al.*: **Service-dominant business model design for digital innovation in smart mobility.** *Bus Inf Syst Eng.* 2019; **61**(1): 9–29.
Publisher Full Text

Valtakoski A: **Explaining servitization failure and deservitization: a knowledge-based perspective.** *Ind Mark Manag.* 2017; **60**: 138–150.
Publisher Full Text

van de Kerkhof RM, Akkermans HA, Noorderhaven NG: *Knowledge lost in data: organizational impediments to condition-based maintenance in the process industry.* Zijm H, Klumpp M, Clausen U, *et al.*, editors. Springer International Publishing; 2016; pp. 223–237.
Publisher Full Text

Visnjic I, Jovanovic M, Neely A, *et al.*: **What brings the value to outcome-based contract providers? Value drivers in outcome business models.** *Int J Prod Econ.* 2017; **192**: 169–181.
Publisher Full Text

Wang K, Jing H, Wang D, *et al.*: **Joint quality and maintenance decisions under servitization business model.** *Int J Prod Res.* 2024; **62**(5): 1567–1585.
Publisher Full Text

Werbińska-Wojciechowska S, Winiarska K: **Maintenance performance in the age of industry 4.0: a bibliometric performance analysis and a systematic literature review.** *Sensors (Basel).* 2023; **23**(3): 1409.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Wu D, Pi Y: **Digital technologies and product-service systems: a synergistic approach for manufacturing firms under a circular economy.** *J Digit Econ.* 2023; **2**: 37–49.
Publisher Full Text

Zhang L, Chen J, Dong H: **The alignment between digital servitization strategies and digital servitization capabilities in Chinese manufacturing enterprises: A multi-case study.** *Systems.* 2025; **13**(8): 707.
Publisher Full Text

Open Peer Review

Current Peer Review Status: ? ? ✓

Version 2

Reviewer Report 12 August 2026

https://doi.org/10.21956/openreseurope.26701.r78566

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✓ **Muztoba Ahmad Khan**
Carroll University, Waukesha, Wisconsin, USA

The authors have addressed my main concerns. The theoretical background is now much better aligned with the findings. The methodology is also significantly clearer now that the authors have provided needed detail on expert selection, the coding process, and thematic saturation. I am satisfied with the revisions and have no further major comments.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: My area of expertise is servitization.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 12 August 2026

https://doi.org/10.21956/openreseurope.26701.r78567

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? **Shaun West**
Lucerne University of Applied Sciences and Arts, Horw, Switzerland

Overall assessment::

Version 2 represents an improvement over the original manuscript. The authors have responded to the earlier reviews and have revised the theoretical background, methodology, findings,

discussion and conclusions.

The manuscript now adopts a socio-technical perspective and positions CMS implementation within digital servitization.

It provides a clearer definition of CMS implementation, explains the relationship between CMS and PSS, identifies OEMs as the main target group, and presents a more coherent research gap. The methodology is also more transparent: the authors explain the expert selection criteria, expand the participant profiles, describe the coding process, and provide an explicit saturation assessment. The findings and discussion are now organised around the three research questions, while the conclusion presents clearer theoretical and managerial contributions.

These revisions address most of my original concerns. However, several reservations remain, principally concerning the empirical support presented in the Findings section, the depth with which the theoretical lenses are applied, the composition of the expert sample and the distinction between solutions and recommendations.

Major reservations

1. Empirical evidence in the Findings section

Although the Findings section is now considerably easier to follow, it contains almost no direct evidence from the interviews. The authors have moved the coding tables and illustrative quotations to the Extended Data. This improves readability, but it also removes participants' voices from the main manuscript. Statements such as “experts consistently emphasised” and “interviewees repeatedly noted” are difficult to assess without representative quotations or some indication of how perspectives varied across participants. For a qualitative study, the principal empirical claims should be demonstrably grounded in the data presented within the article.

The authors should include at least one, and preferably two, appropriately contextualised quotations for each higher-order theme, identified by participant number and background. In particular, quotations from OEM participants should be distinguished from those of university and research-centre participants. Contrasting or dissenting perspectives should also be reported where they occurred.

2. Application of the theoretical lenses

The introduction and theoretical background now establish socio-technical systems theory and the perspective of the servitization paradox. This is a considerable improvement. Nevertheless, the Discussion often uses these theories to label or confirm the findings rather than to generate a deeper explanation of them. For example, the manuscript claims to provide empirical evidence of servitization paradoxes. Still, the Findings section does not clearly identify the competing demands, organisational tensions or coping practices reported by participants. Likewise, the three principal categories—value proposition, design process, and organisational and customer readiness—are not systematically mapped onto the technological, organisational and human dimensions of the socio-technical lens.

The theoretical contribution would be stronger if the authors provided an integrative framework

or table showing:
* how the empirical themes relate to socio-technical capabilities;
* which paradoxical tensions arise during CMS implementation;
* how the proposed solutions respond to those tensions; and
* what is specifically distinctive about CMS compared with digital servitization generally.

Without this additional synthesis, the contribution remains valuable but primarily descriptive and confirmatory.

3. Sampling and transferability

The expert-selection process and participant profiles are much clearer. However, the study focuses on CMS implementation by OEMs, whereas only four of the 13 participants are directly employed by OEMs. The remaining participants offer relevant expertise, but their experience is primarily academic, consultative or based on collaborative research projects. The authors should therefore moderate claims that the findings establish the “principal barriers” experienced by OEMs. They should more precisely represent a synthesis of expert perceptions about those barriers. If confidentiality permits, the authors should also report the number of distinct OEMs represented and provide aggregate information about industrial sectors, company sizes and participants’ direct involvement in completed CMS implementations. The concept of analytical generalisation is now introduced, but the limits of transferring findings from this heterogeneous expert sample to OEM
practice should remain explicit throughout the discussion and conclusion.

4. Saturation and analytical transparency

Table 3 is a welcome improvement and more defensible than assuming saturation based on the number of interviews. Nevertheless, presenting interviews in three aggregated rounds obscures the evolution of the analysis. The authors should clarify whether the expert numbering reflects the chronological order of interviews, how the decision to stop data collection was made, and whether any additional potential participants remained available. An interview-by-interview cumulative grid would provide stronger evidence than the current three-round summary. The column labelled “new statements” also appears to count coded excerpts rather than genuinely novel concepts. It should be renamed or explained. The authors should distinguish between code saturation and meaning saturation, particularly because the final three interviews still generated 27 coded statements. Finally, the manuscript describes the method as reflexive thematic analysis while also emphasising independent coding and consensus. The authors should clarify their analytical position and briefly address researcher reflexivity and the ways in which the researchers’ backgrounds influenced coding and interpretation.

5. Distinction between RQ2 and RQ3

The distinction between “solutions” under RQ2 and “recommendations” under RQ3 remains less clear than the manuscript suggests. Pilot projects, customer co-creation, multidisciplinary capabilities, service units and change management appear in both sections. A challenge–solution–recommendation mapping would help demonstrate the analytical relationship between these categories and reduce repetition. The authors should explain whether recommendations represent a higher level of abstraction, a prioritised set of actions or a separate

class of empirical findings.

Minor revisions

The manuscript is much clearer than Version 1, but another careful language edit is required. Examples include:

* The title would read more naturally as Overcoming Challenges in Implementing Condition Monitoring Services: An Exploratory Expert-Elicitation Study and Recommendations for OEMs.
* On p. 7, “Tagscherer and Carbon (2023) highlights” should be “highlight”.
* On p. 8, remove the duplicated full stop after “existing literature”.
* On p. 8, RQ3 should be rewritten as: “What recommendations should OEMs follow to implement CMS successfully?”
* On p. 10, revise expressions such as “research centres experts” and “OEMs participants”.
* On p. 22, “CMS implementation often involve” should be “CMS implementation often involves”.
* The wording of the research questions should remain identical in the theoretical background, findings and discussion.

Summary

Version 2 is a stronger manuscript and now has a recognizable theoretical foundation, a clearer methodological account and a more coherent contribution. Most of my original concerns have been addressed. The remaining reservations concern how convincingly the empirical evidence supports the analysis and how fully the theoretical lenses are used to explain the findings.

I therefore recommend Approved with reservations, subject to strengthening the presentation of interview evidence, moderating claims based on the sample, clarifying the saturation assessment, and sharpening the theoretical synthesis.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Version 1

Reviewer Report 29 December 2025

https://doi.org/10.21956/openreseurope.21680.r64263

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Muztoba Ahmad Khan
Carroll University, Waukesha, Wisconsin, USA

This manuscript addresses the challenges of OEMs in provisioning condition monitoring services. This is an important topic in digital servitization and this study provides useful practitioner insights. However, the following issues limit the strength of the work and should be addressed.

The authors mention that CMS challenges “go beyond technical aspects,” yet the theoretical background section is dominated by technical descriptions (condition monitoring phases, failure modes, types of analytics). The organizational change and business model literature are included superficially. This creates a mismatch between the theory section (which is descriptive and technology heavy) and the findings (which emphasize business model issues, value propositions, and organizational readiness).

I feel that the sampling strategy is not described in enough detail. It is unclear how experts were identified and why the final group reflects the intended population. Table 1 shows a heavy dominance of researchers and research-center personnel, raising questions about whether the insights truly represent OEM challenges in a real-world sense. Only four OEM experts appear in the sample. This undermines the generalizability of the findings, especially given that CMS implementation difficulties are organizational and context-dependent, not merely conceptual.

The manuscript repeats Guest et al.’s (2006) finding that twelve interviews often reach saturation but does not demonstrate that saturation actually occurred in this study. The authors didn’t provide saturation grid or coding evolution. Instead, the authors assume saturation because they conducted 13 interviews. This is not methodologically defensible.

I also found the coding process difficult to evaluate because the paper does not show how codes were generated or refined. More transparency is needed to support the validity of the findings.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: My area of expertise is servitization.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 04 Aug 2026

Ion Iriarte

We thank the reviewer for these valuable observations. We agree that the previous version of the manuscript would benefit from a stronger alignment between the theoretical framing, the empirical findings, and the methodological description. In response, we have substantially revised the manuscript.

Theoretical background We comprehensively revised and restructured the theoretical background to better align with both the research objectives and the empirical findings. First, we significantly reduced the technical description of CMS and retained only the material necessary to define CMS and position it within the context of digital servitization and Product-Service Systems (PSS). This allowed us to devote considerably more attention to the organizational, managerial, and business dimensions of implementation. Second, we expanded the discussion of CMS from a digital servitization perspective. The revised manuscript now conceptualizes CMS as digitally enabled service offerings implemented by OEMs to support customer value creation and servitization strategies. This strengthens the link between CMS, PSS, digital servitization, and the business-oriented findings of the study. Third, we introduced a socio-technical systems perspective (Münch et al., 2022) as the primary theoretical lens. This perspective allows CMS implementation to be interpreted as a process requiring the alignment of technological, organizational, and human capabilities rather than as a purely technological challenge. This theoretical lens also enabled us to interpret the identified challenges, solutions, and recommendations as manifestations of broader socio-technical capability development processes rather than isolated implementation problems. Fourth, we developed two new subsections entitled “Challenges in CMS implementation” and “Approaches to successful CMS implementation.” These sections substantially strengthen the discussion of organizational transformation, capability development, customer collaboration, business model challenges, value capture, leadership, organizational legitimacy, and servitization tensions. In particular, the revised manuscript now analyses the service paradox as a manifestation of competing demands associated with customer value creation, service monetization, resource allocation, and organizational transformation. As a result, the revised theoretical background now more closely reflects the socio-technical and digital servitization challenges identified by the experts and provides a clearer foundation for discussing value propositions, organizational readiness, customer collaboration, service development, and business model innovation.

Methodology We substantially revised the methodological section to improve transparency regarding expert selection, coding procedures, and saturation assessment. Regarding the sampling strategy, we expanded the expert selection subsection to clearly explain: how

experts were identified; the inclusion criteria used; the rationale for purposive sampling; the expertise required for participation; the relevance of each participant to the research objectives. We further clarify that the objective of the study was not to collect perspectives exclusively from OEM employees but to capture expert knowledge regarding CMS implementation from multiple complementary viewpoints. CMS implementation is inherently multidisciplinary, involving technological, organizational, service, and business-model dimensions. We acknowledge that only four participants were employed directly by OEMs. However, the remaining experts were intentionally selected because of their extensive involvement in OEM-focused servitization, CMS, and Industry 4.0. In particular, the research-centre experts have accumulated experience across multiple OEM implementation contexts through long-term knowledge-transfer and industrial collaboration projects. Their perspectives therefore provide insights derived from numerous implementation experiences rather than from a single company. To make this clearer, we substantially expanded the expert descriptions in Table 1 and now explicitly acknowledge this characteristic of the sample in the limitations section. Regarding the coding process, we substantially improved transparency. The revised data analysis section now explains the progression from: raw interview data, meaningful statements, preliminary categories, first-order themes, and second-order themes. We also describe how two researchers independently examined the material and iteratively refined codes and themes through analytical discussions and consensus-building. In addition, the complete coding structure, including first-order themes, second-order themes, and illustrative quotations, is now provided in the Extended Data.

This improves traceability between the empirical material and the findings reported in the manuscript. Regarding thematic saturation, we agreed that the previous version did not provide sufficient evidence. The revised manuscript therefore no longer assumes saturation based solely on the number of interviews conducted. Instead, we introduced a dedicated subsection entitled “Data Saturation” and added Table 3, which documents the emergence of new meaningful statements, first-order themes, and second-order themes across successive analytical rounds. The analysis shows that no new first-order or second-order themes emerged during the final round of interviews, providing empirical evidence that thematic saturation had been achieved.

We believe these revisions have significantly strengthened the manuscript by improving the alignment between the theoretical framing, methodological approach, and empirical findings. Together, these changes enhance the rigor, coherence, credibility, and explanatory power of the study while providing a clearer contribution to both CMS and digital servitization research.

We are grateful for the reviewer’s comments, which have significantly contributed to improving the clarity, theoretical grounding, and methodological robustness of the manuscript.

Competing Interests: No competing interests were disclosed.

Reviewer Report 22 November 2025

https://doi.org/10.21956/openreseurope.21680.r64266

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Shaun West
Lucerne University of Applied Sciences and Arts, Horw, Switzerland

Paper Title: *Overcoming challenges in implementing condition monitoring services: expert elicitation*
Authors: Ion Iriarte, Hien Nguyen Ngoc, Ganix Lasa
Journal: Open Research Europe
Version: 1
Review Decision: Reject

1. Title
The title clearly states the topic and method, referencing condition monitoring services and expert elicitation. It is specific, relevant, and academically appropriate.
Areas to Improve:
- Add clarity about the industry or context (e.g., OEMs or industrial services).
- Consider explicitly labelling this as a qualitative or exploratory study.
- Reframe using more active voice to create a sharper impression.
- The phrasing is slightly abstract — stronger verbs would help.
- If the paper proposes solutions, signal this in the title.

2. Abstract
The abstract provides a general overview of the topic, stating that implementation challenges are primarily organisational. However, it lacks specificity and does not preview key findings or contributions.
Areas to Improve:
- Please include the number of participants and their profiles.
- Present at least one concrete finding or insight.
- Clearly state the research questions or objective.
- Replace vague phrases like “draws on insights” with specific outcomes.
- Use a stronger, more conclusive final sentence.

3. Introduction
The introduction references IoT and servitization, noting the struggle to implement CMS despite being technically ready. Three research questions are listed. However, the structure and clarity are weak.
Areas to Improve:
- The opening sentence is cluttered and poorly written, lacking clarity.
- Key terms, such as “condition monitoring services,” are not clearly defined.
- The narrative lacks cohesion between background, problem, and purpose.
- There is little effort to motivate the research with practical or theoretical urgency.

- Prior work is mentioned but not critically reviewed or contrasted.

4. Literature Review / Theoretical Background
The section outlines layers of CMS and technical/organisational barriers. It includes relevant literature but is overly descriptive and lacks analytical depth.
Areas to Improve:

- Fails to define a focused research gap until the end.
- Key theoretical foundations are not well-articulated.
- Lacks synthesis or critique of prior studies.
- Organising the literature thematically would help guide the reader effectively.
- The “service paradox” is mentioned but not analysed.

5. Methodology
Semi-structured interviews were conducted with 13 European experts. Sampling strategy and thematic analysis are mentioned, but without sufficient rigour or detail.
Areas to Improve:

- No explanation is provided for why this method is most suitable for addressing the research questions.
- Lacks a process flow or structure for how data was analysed.
- Interview questions or prompts are not included.
- No mention of coding software or reliability strategies.
- Thematic analysis is described vaguely and lacks transparency.

6. Results
Research questions organise results, and themes are presented in tables with supporting quotes. Findings indicate challenges in organisational integration and customer alignment.
Areas to Improve:

- Tables are overly complex and challenging to interpret.
- Quotes are short and lack context or analytical framing.
- The connection between themes and research questions is not always clear.
- No evidence of data triangulation or participant validation is provided.
- Over-reliance on first-order coding categories weakens clarity.

7. Discussion
The discussion reiterates existing findings and re-engages with the literature, but lacks analytical depth. There is minimal theoretical development or critique.
Areas to Improve:

- Does not explicitly answer all research questions.
- No critical engagement with contradictions, limitations, or failures.
- Lacks a comparative discussion with similar studies.
- Does not address how findings reduce or close the identified research gap.
- Claims of contribution are not adequately supported.

8. Conclusions and Limitations
Recommendations are offered, and the paper concludes that organisational issues are the main challenge. Limitations are acknowledged briefly.
Areas to Improve:

- The conclusion does not restate or clearly tie back to the research questions.

- The first paragraph is vague and poorly structured.
- Limitations are acknowledged without critical reflection.
- Future research directions are too general and lack actionable implications.
- The conclusion lacks a clear, final message of value.

English Language and Clarity
Clarity Issues:

- The text frequently employs passive voice and overly complicated phrasing.
- The writing violates clarity principles, including long sentences, imprecise words, and a lack of punch.
- The paragraph flow is uneven, particularly in the introduction and discussion sections.
- Several sentences are jargon-filled and would benefit from being rewritten in plain language.
- Overall readability is low and needs extensive editing to meet indexing standards.

Final Decision: Reject
This paper addresses a relevant problem area but falls short in execution across all core academic criteria: clarity, theoretical foundation, methodological rigour, and structured argumentation. The writing lacks precision, the literature review is insufficiently critical, and the results are poorly interpreted. The research questions are not convincingly answered, and the claimed contributions are vague.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
No

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: PSS innovation - I have in the past developed and supported the develment of condition based mainteance services.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for

reasons outlined above.

Author Response 04 Aug 2026

Ion Iriarte

Title: We thank the reviewer for this suggestion. In response, we have revised the title to better reflect the study's objectives, methodology, and contribution: *"Overcoming Challenges in Implementing Condition Monitoring Services: Recommendations from an Expert Elicitation Exploratory Study"* The revised title explicitly emphasizes: the focus on overcoming implementation challenges; the practical contribution in terms of recommendations; the use of an expert elicitation exploratory approach. We believe that the revised title provides a clearer and more informative description of the study while better reflecting its empirical and exploratory nature.

Abstract: We thank the reviewer for these constructive observations. To address these concerns, we completely revised the abstract. The revised abstract now:

- Clearly states the objective of the study, namely, to identify the challenges limiting CMS implementation, the solutions used to overcome them, and the recommendations supporting successful implementation by OEMs.
- Specifies the participant sample, indicating that the study is based on 13 experts from OEMs, universities, research centres, and consultancy organizations with expertise in CMS, digital servitization and Industry 4.0.
- Replaces general wording with a more explicit description of the research approach and findings.
- Presents concrete findings, including the identification of three major groups of implementation challenges well as the corresponding solutions and recommendations.
- Concludes with a stronger statement emphasizing both the theoretical contribution to CMS and digital servitization literature and the practical guidance provided to OEMs seeking to implement CMS.

We believe that the revised abstract now provides a more informative and representative overview of the study and addresses all the concerns raised by the reviewer.

Introduction: We have substantially revised the Introduction to improve clarity, coherence, theoretical positioning, and justification of the study. First, the opening section has been completely rewritten to provide a clearer and more logical progression from Industry 4.0 and digital servitization to the growing strategic importance of Condition Monitoring Services (CMS) for OEMs. This restructuring improves readability and establishes a stronger context for the study. Second, we strengthened the definition and explanation of CMS. The revised manuscript now explicitly presents CMS as digitally enabled service offerings through which OEMs create value by combining condition monitoring technologies, data analytics, and service activities to support customer outcomes throughout the equipment lifecycle. Third, we improved the narrative flow by explicitly connecting the emergence of CMS within digital servitization, the implementation difficulties experienced by OEMs, the limitations of the existing literature, and the resulting research gap addressed by this study. This creates a clearer link between the background, the problem statement, and the study objectives. Fourth, we strengthened the practical and theoretical relevance of the study.

The revised introduction now emphasizes that, despite significant technological advances, many CMS initiatives fail to achieve their intended outcomes because implementation challenges extend beyond technical factors and involve organizational, managerial, and relational issues. This provides a stronger justification for investigating implementation challenges from a digital servitization perspective. Finally, we expanded the review of prior research to move beyond a descriptive overview of technical CMS challenges. The revised introduction now contrasts the predominantly technology-oriented CMS literature with emerging socio-technical digital servitization perspectives. This comparison highlights the disconnect between the technical focus of existing CMS studies and the broader organizational and managerial challenges identified in digital servitization research. At the same time, the revised introduction acknowledges that the digital servitization literature typically examines digitally enabled services at a relatively general level of abstraction and therefore provides limited guidance regarding the specific implementation challenges associated with CMS. This distinction helps justify the need for a dedicated investigation of CMS implementation and provides a clearer rationale for the study and its research questions. We believe these revisions have substantially improved the clarity, coherence, theoretical grounding, and motivation of the Introduction while providing a clearer justification for the study's focus on CMS-specific implementation challenges, solutions, and recommendations

Theoretical Background We substantially revised and reorganized the entire theoretical background section. First, we restructured the literature review around thematic sections. The revised theoretical background is now organized around: (i) a socio-technical perspective on CMS implementation within digital servitization, (ii) challenges in CMS implementation, (iii) approaches to successful CMS implementation, and (iv) the research gap. This structure provides a clearer narrative flow and aligns the theoretical background more closely with the study objectives and research questions. Second, we clarified the concept of CMS implementation. The revised theoretical background now explicitly conceptualizes implementation as the organizational process through which OEMs develop, deliver, integrate, and scale CMS-based service offerings within a digital servitization strategy. Third, we strengthened the theoretical foundations of the study by incorporating socio-technical systems theory. In particular, we introduced the work of Münch et al. (2022) to frame CMS implementation as a socio-technical phenomenon requiring the alignment of technological, organizational, and human capabilities. We also incorporated the servitization paradox perspective proposed by Kohtamäki et al. (2020), which helps explain the competing demands that organizations face during servitization and digital transformation. Fourth, we substantially revised and expanded the subsection on CMS implementation challenges. Rather than simply mentioning the service paradox, the revised manuscript now analyses it as a manifestation of competing organizational demands associated with value creation, service provision, customer relationships, and resource allocation. This perspective helps explain why technologically mature CMS initiatives often fail to achieve their intended business outcomes. Fifth, we moved beyond a descriptive review of prior studies and introduced a more critical synthesis of the literature. The revised manuscript contrasts the dominant technology-oriented CMS literature with emerging research in digital servitization emphasizing organizational capabilities, service development, customer collaboration, organizational transformation, and business model innovation. This provides a stronger basis for identifying the limitations of current

knowledge and positioning the contribution of the study. Finally, the research gap is now introduced progressively throughout the literature review and culminates in a clearly articulated gap before the presentation of the research questions. Rather than arguing that knowledge is absent, the revised manuscript acknowledges existing contributions while highlighting that current CMS research remains predominantly technology-oriented and that digital servitization research discusses CMS implementation challenges and solutions at a relatively high level of abstraction treating digital services in a relatively homogeneous manner. This positioning provides a stronger justification for examining the specific implementation challenges, solutions, and recommendations associated with CMS. We believe that these revisions substantially strengthen the theoretical foundations, analytical depth, thematic coherence, and overall contribution of the theoretical background section.

Methodology We substantially revised the Methodology section to improve transparency, analytical rigor, and reproducibility. First, we expanded the justification for the research approach. In the revised manuscript, we explain that CMS implementation constitutes a complex socio-technical phenomenon involving multiple dimensions. While previous studies have identified individual technical or organizational barriers, knowledge about how these challenges are experienced, interpreted, and managed during real-world CMS implementation remains fragmented. Consequently, an exploratory qualitative design is particularly appropriate because it allows the investigation of a complex phenomenon where contextual factors are critical and where existing theory provides only a partial explanation of implementation practices. We further explain that expert elicitation is especially suitable in such situations because it enables access to experience-based knowledge, tacit understanding, and practical insights held by individuals directly involved in the phenomenon under study. Therefore, expert interviews were selected as the most appropriate method for generating context-rich insights into the challenges, solutions, and implementation practices associated with CMS by OEMs. Second, we completely revised the Data Analysis section and introduced a structured and transparent analytical procedure. The revised manuscript now describes the full progression from interview transcripts to meaningful statements, preliminary categories, first-order themes, and second-order themes. In addition, we provide a dedicated analytical flow table (Table 2) summarizing each stage of the analysis process. Third, we clarified that the interview protocol and guiding questions are available through the Extended Data repository (DOI provided in the manuscript). The revised text explicitly describes how the interview guide was structured around the three research questions and how follow-up questions were used to explore emerging themes. Fourth, we strengthened the discussion of analytical rigor and trustworthiness. The manuscript now explains that all coding was conducted manually by two researchers through an iterative process of independent review, discussion, refinement, and consensus-building. This procedure was adopted to enhance the credibility, consistency, and transparency of the findings. Finally, we substantially expanded the description of the thematic analysis. We introduced a dedicated Data Saturation subsection and Table 3 to demonstrate saturation rather than assuming it based solely on sample size. Table 3 documents the emergence of new meaningful statements, first-order themes, and second-order themes across successive analytical rounds. The results show that although the final interviews provided additional examples and contextual variation, no new first-order or second-order themes emerged during the final analytical round. This pattern indicates that the thematic structure had stabilized, providing empirical evidence that

thematic saturation had been achieved. We believe these revisions significantly improve the transparency, methodological rigor of the study and provide readers with a clearer understanding of how the findings were derived from the empirical data.

Results/Findings We substantially revised the entire Findings section. First, we simplified the presentation of the findings by moving the detailed coding tables (previously included in the main manuscript) to the Extended Data (Tables E1–E5). This allows interested readers to access the complete coding structure while improving the readability of the manuscript. The revised Findings section now focuses on higher-level themes and their interpretation rather than on detailed coding outputs. Second, we completely restructured the Findings section around the three research questions. The revised section is now organized into: Challenges in CMS implementation (RQ1), Solutions to CMS implementation challenges (RQ2), and Recommendations for successful CMS implementation (RQ3). This revision strengthens the connection between the empirical findings and the study objectives while improving the traceability of the results. Third, we reduced the emphasis on first-order coding categories and instead organized the findings around broader analytical themes. This thematic structure provides a clearer analytical narrative and makes the relationships between challenges and proposed solutions more explicit. Fourth, the recommendation section was substantially revised and elevated into a set of managerial propositions for successful CMS implementation. While the solutions section (RQ2) now focuses on specific implementation practices, while the recommendations section (RQ3) presents broader principles related to CMS design and organizational change management. This revision provides clearer analytical differentiation between solutions and recommendations and strengthens the managerial contribution of the study. Regarding triangulation and participant validation, we acknowledge that the study did not employ multiple data sources or formal participant validation procedures. This choice is consistent with the exploratory expert elicitation approach adopted in the study, whose primary objective was to capture and analyse expert knowledge and experience regarding CMS implementation. To enhance the trustworthiness and credibility of the findings, we instead relied on several established qualitative research practices, including purposive expert selection, a multidisciplinary expert sample, systematic thematic analysis, independent review and discussion of codes by two researchers, the provision of the complete coding structure in the Extended Data, and the assessment of thematic saturation as documented in the new Data Saturation subsection. Collectively, these measures were implemented to strengthen the dependability, transparency, and credibility of the findings. Overall, we believe that the revised Findings section is substantially clearer, more analytically focused, and more directly connected to the research questions, while the complete coding structure remains available through the Extended Data to ensure transparency and traceability. **Discussion** We substantially revised and restructured the Discussion around the three research questions (RQ1–RQ3) and strengthened its connection to both the CMS and digital servitization literatures. Specifically:

- Explicitly answering all research questions. The Discussion has been reorganized into three dedicated subsections corresponding to RQ1, RQ2, and RQ3. Each subsection now concludes with an explicit answer to the respective research question, synthesizing the findings and their implications. This structure improves clarity and ensures that all research questions are directly addressed.
- Stronger theoretical development and analytical depth. The revised Discussion moves

beyond describing findings and provides a deeper theoretical interpretation of the findings. This allowed us to explain why CMS implementation challenges occur, how they can be approached, and how this relates to broader theoretical debates within CMS and digital servitization literature.
- Stronger comparison with previous studies. We substantially expanded the comparison of our findings with both CMS and digital servitization research. The revised Discussion contrasts our findings and positions the results alongside recent studies.
- Clarification of how the findings address the research gap. The revised Discussion now explicitly argues that the study addresses a gap in CMS research concerning the organizational, managerial, and service-related dimensions of CMS implementation.
- Stronger and better-supported contributions. The contributions have been clarified and are now supported through the discussion of the findings and current literature.

Conclusion, Limitations and Future Research We substantially revised the entire section to strengthen its structure, analytical depth, and contribution. Specifically:
- We restructured the conclusion around the three research questions (RQ1–RQ3) and explicitly restated the main findings associated with each question. The revised conclusion now clearly summarizes the identified implementation challenges, proposed solutions, and managerial recommendations, thereby strengthening the connection between the research objectives, findings, and study outcomes.
- We completely rewrote the opening paragraph of the conclusion to provide a clearer overview of the study purpose, scope, and contribution. The revised opening now situates the study within the broader context of CMS implementation and digital servitization while clearly summarizing the focus of the research.
- We significantly expanded the discussion of theoretical and managerial contributions. Furthermore, the revised conclusion highlights how the study translates broad digital servitization concepts into more concrete implementation solutions and recommendations tailored to the specific characteristics of CMS.
- We strengthened the limitations section by providing a more critical reflection on the implications of the expert elicitation approach, the focus on CMS implementation by OEMs, the absence of multiple data sources and formal participant validation procedures, and the cross-sectional nature of the study. Rather than simply listing limitations, the revised manuscript discusses how these factors influence the interpretation and transferability of the findings.
- We revised the future research section to provide more specific and actionable research directions. The revised manuscript now proposes longitudinal studies examining how CMS implementation evolves over time, investigations into the development and legitimization of dedicated service units, and comparative studies across sectors, firm sizes, and digital service contexts.
- Finally, we strengthened the closing message of the paper. The revised conclusion emphasizes that successful CMS implementation depends less on the sophistication of condition monitoring technologies and more on the ability of OEMs to align customer value creation, service development practices, organizational capabilities, and change management processes. The concluding section now highlights how OEMs can transform condition monitoring technologies into sustainable service businesses through customer-centred value creation, legitimate service structures, multidisciplinary capabilities, and proactive management of organizational change.

We believe these revisions substantially improve the clarity, rigor, critical reflection, and practical relevance of the concluding section while providing a stronger synthesis of the study's contribution to CMS and digital servitization research.

English Language and Clarity We thank the reviewer for this observation and agree that the previous version of the manuscript would benefit from improvements in writing style, readability, and overall narrative flow. In response, we performed a comprehensive revision of the manuscript with a particular focus on language clarity and structure. The revisions included:

- Reducing the use of passive voice and rewriting numerous sentences using more direct and active constructions.
- Simplifying complex and lengthy sentences to improve readability and reduce ambiguity.
- Improving paragraph structure and logical flow, particularly in the Introduction, Theoretical Background, Findings, and Discussion sections.
- Replacing overly technical or jargon-heavy expressions with clearer terminology wherever possible while maintaining academic precision.
- Improving transitions between sections and paragraphs to strengthen the coherence of the overall argument.
- Reorganizing the Findings and Discussion sections to provide a clearer progression from challenges (RQ1), to solutions (RQ2), and finally to recommendations (RQ3).
- Strengthening the Discussion and Conclusions sections, ensuring that the narrative consistently links the empirical findings to the theoretical foundations and research questions.
- Revising the abstract, introduction, and conclusion to improve clarity, conciseness, and accessibility for a broader readership.

We believe that these revisions have substantially improved the clarity, consistency, and readability of the manuscript.

Final Decision

We thank the reviewer for this comprehensive assessment and for identifying areas requiring substantial improvement. We carefully considered each of these concerns and have thoroughly revised the manuscript. The revised version differs substantially from the original submission in terms of theoretical framing, methodological transparency, presentation of findings, and discussion. Regarding theoretical foundation, we substantially strengthened the conceptual grounding of the study by repositioning CMS implementation within the digital servitization literature. The revised manuscript now explicitly adopts a socio-technical perspective (Münch et al., 2022) to interpret the implementation challenges experienced by OEMs. In addition, the literature review was expanded and updated to incorporate recent contributions on digital servitization. These revisions provide a stronger theoretical basis for understanding CMS implementation. Regarding methodological rigour, we substantially expanded the Methodology section. The revised manuscript now includes: a detailed justification of the expert elicitation approach; transparent expert selection criteria and participant profiles; a comprehensive description of the interview protocol; a detailed explanation of the thematic analysis procedure; a new section describing the progression from codes to first-order and second-order themes; a dedicated discussion of

thematic saturation supported by a saturation table; an expanded discussion of analytical rigor, credibility, and trustworthiness. These additions significantly improve the transparency and reproducibility of the research process. Regarding the presentation and interpretation of results, the Findings section has been completely restructured. Rather than relying heavily on coding outputs, the revised manuscript organizes findings around the three research questions: implementation challenges (RQ1), solutions to overcome those challenges (RQ2), and recommendations for successful implementation (RQ3). The detailed coding structure was moved to the Extended Data (Data Analysis, Tables E1 to E4), while the manuscript now focuses on higher-level themes and analytical insights. In addition, the Discussion section was extensively rewritten to interpret the findings through the lenses of digital servitization literature. The Findings, Discussion, and Conclusions sections now explicitly address each research question individually and provide clear answers grounded in the empirical evidence. As a result, the revised manuscript now provides explicit and evidence-based answers to each research question, strengthening the coherence of the study and the support for its stated contributions. Regarding the claimed contributions, we clarified both the theoretical and managerial implications. The revised manuscript now explicitly explains that its contribution is not merely identifying implementation challenges, but providing empirically grounded, CMS-specific solutions and recommendations for OEMs. This distinction is important because much of the existing digital servitization literature offers generic recommendations, whereas our study translates these broader concepts into concrete implementation guidance for OEMs tailored to the particular characteristics of CMS. Finally, we conducted a comprehensive revision of the manuscript's language, structure, and readability.

We are grateful for the reviewer's critical assessment, which contributed significantly to improving the quality, rigor, and contribution of the manuscript. We believe that the revised version addresses these concerns comprehensively and presents a substantially stronger study than the originally submitted manuscript. Collectively, these revisions strengthen the theoretical foundation, methodological rigor, structured argumentation, interpretive depth, and overall contribution of the manuscript.

Competing Interests: No competing interests were disclosed.

Reviewer Report 30 August 2025

https://doi.org/10.21956/openreseurope.21680.r55266

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Brief summary of the manuscript

The manuscript presents a qualitative study focusing on the implementation of condition monitoring services (CMS) in the context of product service systems (PSS). It describes the challenges, potential solutions, and recommendations for successfully implementing CMS.

Positive aspects
The manuscript provides relevant empirical insights that help synthesize previously identified theoretical concepts in PSS. By focusing on implementation, the authors offer a perspective of an early / frontloading effort with the potential of impactful outcomes to CMS. The grammar and structure of the manuscript is commendable. It communicates ideas effectively and arguments are presented in a logical flow.

I thank the authors for their manuscript and the effort in conducting the study. The topic is highly relevant to smart manufacturing and the development of PSS. Below, I highlight my concerns for improving the quality of the study and point ways to overcome these concerns.

Major concerns

A major concern includes the absence of a theoretical lens supporting the contributions of the study. This shortcoming affects the entire manuscript including its justification, the theoretical background, findings and contribution chapters.

A theoretical lens is critical for contextualizing the research problem within existing knowledge and moving the field forward. Without a theoretical lens, interpreting findings may be surface-level, potentially missing deeper insights.

Currently, the manuscript argues for the use of an inductive logic, which assumes that theory does not exist. I am not convinced by this assumption. Consider the section of Findings. Currently, this section works more like a review of literature positioned around the insight of interviewees. Literature about challenges, potential solutions and strategies for success do not seem to be in short supply based on the current content of this chapter.

A way to overcome this short coming would be to modify the theoretical background. This section could provide deeper insight into the non-technical challenges of CMS / PSS. This aspect occupies only one paragraph but is the main focus of your study. Additionally, this section could also describe approach to potential solutions and successful implementation that may help interpret the findings of your interviews. Consider the following studies, their use of theory to interpret findings and position a theoretical contribution in qualitative studies:

Münch, C., Marx, E., Benz, L., Hartmann, E., & Matzner, M. (2022). Ref 1

Kohtamäki, M., Einola, S., & Rabetino, R. (2020). Ref 2

The manuscript would greatly benefit from presenting these theoretical underpinning already in the theoretical background chapter. The findings section could then provide deeper insights about the novel findings of your qualitative data collection in comparison to existing literature.

At the same time, the theoretical background could be better used to motivate / setup the

research questions of the study. There is nothing wrong with the research questions but there is a need to justify why these are currently relevant in light of recent findings.

The absence of a theoretical lens also has implications to the generalizability of your findings. The authors could benefit from describing the logic of their study that justifies generalizability of results and the use of theory to achieve it. Some ideas / examples of how to execute this in either an inductive or deductive logic in qualitative studies can be found in:

Ketokivi, M., & Choi, T. (2014). Ref 3

The concept of implementation is a cornerstone of the manuscript and one of the critical aspects for achieving a theoretical contribution. I do not think that the manuscript presents a sufficient conceptualization of implementation in the context of CMS or PSS. This problem could be addressed by offering an explicit definition grounded on the literature. The theoretical background should include a short synthesis of the constituent of implementation, its stakeholders, phases and implications to the end goals of PSS.

Closely related to the concern above is the absence of a clear definition of the target group of the manuscript. At the beginning of the article, it appears that the main target group, those responsible for implementing CMS, include manufacturing companies developing PSS. The chapter including the Findings and afterwards present a change of this perspective. After this chapter it appears that the target group is both the companies developing PSS and the end users of a CMS. The manuscript would greatly improve by establishing clearly the target group and presenting a consistent narrative throughout the text.

There is a need for improving the justification of an explorative study and its inductive reasoning.

The distinction between PSS and CMS is unclear in the current version of the manuscript. Do the authors mean that PSS is a special case of CMS? Is CMS an initial step in PSS?

The section of findings is very difficult to understand. One cannot distinguish between the voice of interviewees and literature. Additionally, this section presents a contradiction to the problem definition of the study. While problem definition states that there is limited literature on the topic, the findings section works more like a literature review of previous findings showing that there is in fact plenty of literature.

The section on potential solutions presents a structure including value proposition, design, and requirements. Why not use this same structure from the beginning of the article to classify challenges, potential solutions, and recommendations? Why is this exclusively applied to the potential solutions? Is it not possible to provide theoretical underpinnings justifying the classification of solutions in relation to value proposition, design and requirements?

The manuscript presents two contributions: a) an in-depth examination of implementation challenges and b) insights helping improve technological readiness and market success. A first problem with these is that they are presented for the first time very late in the text p. 16. Additionally, I am not convinced that manuscript achieves or intends to improve technological readiness. The argument followed throughout the manuscript is the focus on non-technological

challenges of CMS.

Minor concerns

Make sure to include the purpose of your study in the abstract. Additionally, the abstract would benefit from a clear description of its findings. This could include a clear description of the three major findings: challenges, potential solutions, and recommendations.

Describe the background of the interviewees and their relevance from a PSS perspective.

There is no in-text reference to the first and second order themes tables in the main section of the text for page 8 paragraph 2.

Perhaps I missed something, but what is the difference between “our three main research questions” and the “main questions” described in the first paragraph of the section Findings: challenges in p. 8.

The current version of the manuscript would improve by having separate paragraphs for each challenge described in findings section. Consider the current setup of the last paragraph of p. 8.

The text would benefit from an extended analysis / description of the managerial contributions of the study. What stakeholders will benefit? What pitfalls will be avoided and how will this contribute to improving current industrial / business practices? How do the results compare or improve the current way of working of practitioners?

The manuscript would benefit from a better description of its limitations leading to future steps.

References

1. Münch C, Marx E, Benz L, Hartmann E, et al.: Capabilities of digital servitization: Evidence from the socio-technical systems theory. *Technological Forecasting and Social Change*. 2022; **176**. Publisher Full Text
2. Kohtamäki M, Einola S, Rabetino R: Exploring servitization through the paradox lens: Coping practices in servitization. *International Journal of Production Economics*. 2020; **226**. Publisher Full Text
3. Ketokivi M, Choi T: Renaissance of case research as a scientific method. *Journal of Operations Management*. 2014; **32** (5): 232-240 Publisher Full Text

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: digital services in smart production logistics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 04 Aug 2026

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We sincerely thank the reviewer for this insightful and constructive feedback. Following your recommendations, we have substantially revised the paper.

Major concerns Introduction We substantially revised the Introduction to provide a clearer and more coherent narrative linking Industry 4.0, digital servitization, and Condition Monitoring Services (CMS). We strengthened the justification for the study by explicitly discussing the disconnect between the predominantly technology-oriented CMS literature and the broader organizational, managerial, and business-related challenges associated with CMS implementation. In addition, we incorporated the digital servitization literature recommended by the reviewer, particularly the socio-technical perspective of Münch et al. (2022) and the paradox perspective of Kohtamäki et al. (2020), to establish a stronger theoretical foundation for the study. The revised introduction now contrasts the technology-focused CMS literature with the broader digital servitization literature, while also acknowledging that digital servitization research often examines digitally enabled services at a relatively general level and therefore provides limited guidance regarding the specific implementation challenges associated with CMS. This revised positioning provides a clearer research gap, stronger theoretical motivation, and a more explicit rationale for the study's research questions and contributions.

Theoretical Background We substantially revised and reorganized the entire theoretical background section.
First, we restructured the literature review around thematic sections to improve readability and provide a clearer progression from the conceptualization of CMS to implementation challenges, implementation approaches, and the identification of the research gap. This new structure aligns the theoretical background more closely with the research questions and findings.
Second, we clarified the concept of CMS implementation. The revised theoretical background now explicitly conceptualizes implementation as the organizational process

through which OEMs develop, integrate, deliver, commercialize, and scale CMS-based service offerings within their digital servitization strategies.
Third, we strengthened the theoretical foundations of the study by introducing a socio-technical systems perspective based on Münch et al. (2022). This perspective serves as the primary theoretical lens of the study and frames CMS implementation as the outcome of interactions between technological, organizational, and human capabilities rather than as a purely technological challenge. We also incorporated the servitization paradox perspective of Kohtamäki et al. (2020), enabling us to analyse CMS implementation as a process characterized by competing demands related to value creation, customer relationships, business model development, and organizational transformation. These revisions also enabled us to articulate a clearer theoretical contribution. Specifically, the revised manuscript demonstrates how CMS implementation challenges, solutions, and recommendations can be interpreted through a socio-technical digital servitization perspective, thereby extending current understanding of CMS implementation beyond its traditional technological orientation. Fourth, we expanded the discussion of CMS implementation challenges and moved beyond a descriptive review of prior studies. The revised manuscript now provides a more critical synthesis of the literature by examining challenges related to value proposition development, organizational capability building, customer collaboration, organizational transformation, and business model innovation. In particular, the service paradox is no longer mentioned only briefly but is analysed as a manifestation of broader tensions associated with value creation, service monetization, resource allocation, and organizational change.
Fifth, we introduced a dedicated section reviewing approaches proposed in the literature for overcoming implementation challenges. This section synthesizes research on value creation, organizational capability development, paradox management, organizational transformation, business model innovation, leadership, and customer co-creation practices. This literature synthesis provides a stronger theoretical basis for interpreting the empirical findings and discussing potential implementation solutions.
Finally, the research gap is now developed progressively throughout the theoretical background rather than being introduced only at the end. The revised manuscript acknowledges the valuable contributions of digital servitization research while arguing that existing studies often address digitally enabled services at a relatively high level of abstraction and provide limited guidance regarding the specific implementation conditions associated with CMS. This stronger positioning provides a clearer justification for the exploratory nature of the study and for the three research questions.

Conceptualization of CMS implementation We agree that the concept of implementation was insufficiently defined in the original manuscript. Therefore, the revised manuscript explicitly conceptualizes CMS implementation as the organizational process through which OEMs develop, integrate, deliver, and scale CMS-based service offerings as part of their digital servitization strategy. This definition is positioned early in the theoretical background and used consistently throughout the manuscript.

Clarification of CMS and PSS The relationship between CMS and PSS has also been clarified. In the revised manuscript, CMS are conceptualized as a specific type of Product-Service System in which value is co-created through the integration of physical products, IoT technologies, operational data, and service activities.

Clarification of the target group We also addressed the reviewer's concern regarding the target group of the study. The revised manuscript consistently positions OEMs as providers of CMS offerings. While customer-related factors remain important because value co-creation is central to CMS implementation, the primary unit of analysis and intended audience of the study are now clearly defined as OEMs implementing CMS within their digital servitization strategies.

Exploratory approach and generalizability Finally, we strengthened the justification of the exploratory design by incorporating the arguments of Ketokivi and Choi (2014) regarding qualitative inquiry and theory development in complex organizational settings. The revised manuscript now explains that the objective of the study is not statistical generalization but the development of analytically generalizable insights concerning CMS implementation challenges, solutions, and recommendations.

Findings and Discussion We thank the reviewer for the valuable observations regarding the readability and analytical structure of the Findings section. We agree that the previous version did not sufficiently distinguish empirical findings from literature-based interpretation. To address this concern, we substantially revised the manuscript by clearly separating the Findings and Discussion sections. The Findings section now focuses exclusively on the empirical evidence derived from the expert interviews, whereas engagement with prior studies, theoretical interpretation, and the articulation of contributions have been moved to the Discussion section. This revision makes it easier for readers to distinguish between the perspectives of the interviewees and the authors' interpretation of the findings in relation to existing knowledge. Furthermore, the Discussion is now explicitly structured around RQ1–RQ3, providing clear answers to each research question and strengthening the link between the empirical results and the study objectives.
We also clarified the research gap throughout the Introduction and Discussion. Our intention was never to argue that literature on CMS challenges and solutions does not exist, but rather that existing CMS research has predominantly focused on technological aspects of condition monitoring systems (e.g., diagnostics, prognostics, sensing technologies, and predictive analytics), whereas considerably less attention has been devoted to the organizational, and managerial challenges associated with implementing CMS. In addition, the revised manuscript now acknowledges that while digital servitization research provides valuable insights into organizational transformation and capability development, it often addresses digitally enabled services at a relatively high level of abstraction. Consequently, the Discussion now positions our findings both against the CMS literature and within the broader digital servitization literature to explain how the study addresses this gap and provides more context-specific insights for CMS implementation. The revised Discussion explicitly links these themes to digital servitization research, particularly the socio-technical perspective (Münch et al., 2022), service innovation and co-creation literature (Sjödin et al., 2020), value capture research in advanced services (Kamp et al., 2023), and the servitization paradox perspective (Kohtamäki et al., 2020).
These theoretical connections help explain why the identified challenges emerge, how organizations can address them, and why they are particularly relevant within CMS implementation contexts. We thank the reviewer for highlighting the need to clarify the study's contribution.

We agree that the term technological readiness was not fully aligned with the actual focus and findings of the study.
Accordingly, we revised the contribution statements throughout the manuscript, including the Introduction, Discussion, and Conclusions sections. The contributions are now introduced earlier in the paper and are consistently aligned with the study's objectives and findings. More specifically, we removed references suggesting that the study contributes to improving technological readiness and instead emphasize that the study contributes to understanding the socio-technical dimensions of CMS implementation. The revised manuscript now explicitly argues that its contribution lies in identifying CMS-specific implementation challenges, proposing solutions to overcome them, and developing recommendations that translate broad digital servitization principles into more concrete implementation guidance for OEMs. We believe these revisions provide a more accurate representation of the study's objectives, findings, theoretical contribution, and practical relevance.

Minor concerns

Abstract We have substantially revised the abstract to provide a clearer and more comprehensive overview of the study. Specifically, the revised abstract now explicitly states the purpose of the study, namely to investigate the challenges limiting CMS implementation, the solutions used to overcome these challenges, and the recommendations that support successful CMS implementation by OEMs.

Background of the interviewees and their relevance from a PSS perspective We agree that the original manuscript did not sufficiently explain the relevance of the selected experts. To address this issue, we introduce a more detailed description of the expert selection criteria and the relevance of each participant to the phenomenon under investigation. In particular, we expanded Table 1 to include the professional background and specific relevance of each expert to CMS implementation.

In-text references We thank the reviewer for identifying this omission. In the revised manuscript, we have improved the consistency between the narrative findings and the coding structure. Specifically, explicit references to the first-order and second-order theme tables have been incorporated throughout the Findings section. *The "Three main research questions" vs the "main questions"* We thank the reviewer for highlighting this source of confusion. We agree that the terminology used in the previous version could suggest the existence of two different sets of questions. In reality, the "main questions" referred to in the Findings section corresponded directly to the three research questions presented earlier in the manuscript. To improve clarity, we have revised the wording throughout the manuscript and now consistently refer only to the three research questions (RQ1–RQ3).

Separate paragraphs for each challenge We thank the reviewer for this helpful suggestion. To address this issue, we substantially restructured the Findings section. The revised manuscript now presents the results through separate subsections and paragraphs corresponding to each major challenge category identified in the analysis. Specifically, challenges are now discussed separately under the themes of CMS value proposition, CMS design process, and organizational and customer readiness, with each challenge receiving

its own dedicated explanation.

Managerial contributions and limitations leading to future steps We thank the reviewer for these valuable suggestions. In response, we substantially revised the Conclusions, Limitations and Future Research section to strengthen both the managerial implications and the discussion of limitations. Regarding the managerial contributions, we further clarified how the findings can improve current industrial practice by helping OEMs avoid common implementation pitfalls such as: technology-centred value propositions, insufficient customer involvement, fragmented ownership of CMS initiatives, weak service-oriented capabilities, and limited value quantification and value capture mechanisms. We also expanded the managerial implications to explain how the proposed recommendations differ from and improve current practices observed by the experts. Regarding the limitations, we expanded the discussion beyond a brief acknowledgment of methodological constraints. The revised manuscript now critically reflects on the implications of relying on expert perceptions, the focus on OEMs and CMS contexts, the absence of multiple data sources and formal participant validation procedures, and the cross-sectional nature of the study. Furthermore, we explicitly connect these limitations to future research opportunities by proposing longitudinal studies, multi-stakeholder investigations, and research exploring the development of organizational legitimacy and dedicated service units in manufacturing organizations.
This revision now provides a clearer link between the study's limitations and future research directions.

We are grateful for the reviewer’s thoughtful and constructive comments, which have significantly strengthened the theoretical grounding, conceptual clarity, methodological justification, and overall contribution of the manuscript. We believe the revised version now provides a more coherent, theoretically informed, and practically relevant account of CMS implementation within the context of digital servitization.

Competing Interests: No competing interests were disclosed.