Advancing Sustainable Manufacturing through Pay-per-Use Servitization Model

Anand R. Moorthy[1,2,*] and *Mario* Rapaccini[3]

[1]Electrolux Professional S.p.A., Research Hub, 33170 Pordenone, Italy
[2]University of Pisa, Department of Information Engineering, 56122 Pisa, Italy
[3]University of Florence, Department of Industrial Engineering, 50139 Florence, Italy

Abstract. In the face of global environmental challenges and their significant impact, manufacturing firms have been recognized as major contributors to environmental degradation and emissions. Additionally, these firms encounter various challenges arising from evolving economies, emerging competitors, shifting consumer preferences, and rapidly advancing digital technologies. To address these challenges and foster innovation, manufacturers are turning to servitization as a strategic approach. Within servitization, the pay-per-use service model emerges as a promising solution. Furthermore, integrating circular economy principles into this model presents an opportunity for sustainable business practices. This paper examines successful examples of companies that have adopted servitization and effectively implemented pay-per-use models while incorporating circular economy principles. Drawing upon these lessons, we propose the "Wheel of Servitization" framework, which enables manufacturers to approach servitization holistically, ensuring that all critical dimensions are addressed to maximize the likelihood of success. By embracing servitization and pay-per-use models within a circular economy context, manufacturing companies can embark on a pathway towards sustainability, addressing environmental concerns and simultaneously meeting the demands of a rapidly changing business landscape.

Keywords: Sustainable manufacturing, Servitization, Pay-per-use model, Circular economy, Wheel of Servitization framework

1 Introduction

1.1 Background and Context

Manufacturing firms are not only significant contributors to global environmental issues [1] but also face various challenges [2] in today's dynamic business landscape. These wide range of challenges include the imperative to mitigate environmental impact [3,4], necessity to adapt to an evolving economy, competition from new market entrants [5], shifting consumer

* Corresponding author: anandrm.in@gmail.com

preferences [6] and rapid advancements in digital technologies [7]. These factors necessitate innovation and strategic approaches for manufacturers to ensure their long-term success and sustainability.

1.2 Environmental impact of manufacturing companies

Manufacturing companies play a substantial role in global environmental impact and emissions [8]. Their operations involve the extraction of raw materials, energy consumption, production processes and transportation and these activities contribute to greenhouse gas emissions, air and water pollution and resource depletion [9]. The scale of manufacturing activities, particularly in sectors such as automotive, electronics and heavy industry, results in a substantial environmental footprint [10].

Manufacturing companies must acknowledge their environmental responsibility and adopt sustainable practices to mitigate their impact. Servitization offers a promising pathway for achieving sustainability [11] by shifting from product-centric models to service-oriented approaches.

1.3 Challenges Faced by Manufacturing Firms

The manufacturing sector operates in a dynamic business environment influenced by market conditions [12] and evolving customer preferences [13]. To maintain competitiveness, manufacturers must navigate market volatility and uncertainty while adapting their strategies, production systems, and supply chains [14, 15].

The industry faces new challenges from innovative market entrants, disruptive technologies, and changing consumer demands, necessitating a culture of innovation and strategic partnerships [16, 17]. The rise of sustainability concerns [18], personalized experiences, and digitalization requires manufacturers to adapt their product offerings and customer engagement approaches [19].

Digital technologies like AI, IoT, big data analytics, and automation present opportunities for process optimization and improved customer experiences, but their adoption requires investment, upskilling, and cybersecurity measures [20].

Servitization [21] offers a strategic solution, transforming traditional models into service-oriented offerings [22] that align with evolving consumer preferences and enhance resource efficiency. Addressing these challenges is paramount for manufacturing firms to remain competitive, resilient, and sustainable.

1.4 Significance of the study

This study delves into the strategic implications of integrating servitization and sustainability for manufacturing companies. Embracing servitization allows manufacturers to offer integrated solutions that address customer needs while minimizing environmental impact.

The study highlights the potential of pay-per-use service models to enhance competitiveness, adapt to market dynamics, and mitigate environmental issues. Drawing on insightful case studies, this study provides valuable guidance and learnings for manufacturing firms striving to develop and implement sustainable business models.

1.5 Objectives of the Paper

The main objectives of this paper are to:
1. Investigate the suitability of the pay-per-use service model within the servitization framework and its potential benefits for manufacturers.
2. Showcase successful examples of companies that have entered servitization and successfully offered pay-per-use models incorporating circular economy principles.
3. Present a framework that allows manufacturers to address key dimensions of servitization and maximize the success of their outcomes.

2 Servitization as a Solution for Manufacturers' Challenges

2.1 Definition and Benefits of Servitization

Servitization, a strategic shift in manufacturing business models, involves transitioning from product-centric approaches to providing integrated services alongside products [23]. This transformation encompasses the shift from one-time product transactions to long-term value creation through a combination of products, maintenance, repairs, upgrades, and related services [24]. By embracing servitization, manufacturers can establish enduring customer relationships, capture additional revenue streams, and differentiate themselves in the market. This strategic approach also addresses the challenges faced by manufacturing firms, offering solutions such as revenue diversification, enhanced customer engagement and satisfaction, differentiation from competitors [25], promotion of resource efficiency and circular economy principles [26], as well as adaptation to digitalization and technological advancements for optimized service delivery and value-added solutions.

2.2 The Suitability of the Pay-per-Use Service Model within Servitization

Within the servitization framework, the pay-per-use service model emerges as a suitable strategy for manufacturers [27]. It allows customers to pay for actual usage or outcomes, aligning with changing preferences and providing ongoing revenue streams. This model promotes resource efficiency, product longevity, and incentivizes sustainable design [28]. By adopting servitization and pay-per-use, manufacturing companies can navigate challenges, including competition, changing preferences, and digital technologies while pursuing sustainability.

3 Theoretical Background

To strengthen our analysis, we draw upon several relevant theoretical frameworks. The Resource-Based View [29] sheds light on how companies leverage their unique resources and capabilities to implement successful pay-per-use models. The Service-Dominant Logic perspective [30] emphasizes the co-creation of value through customer interactions and highlights the importance of customer experience in driving success. Another relevant framework is the "Product-Service System" (PSS) [31, 32] approach which conceptualizes the integration of products and services as a system. Here companies offer bundles of tangible products, intangible services, and supporting infrastructure to address customer needs. The circular economy theory [33] provides a foundation for integrating sustainability principles, promoting waste reduction, resource efficiency, and product lifecycle extension. Additionally, technology adoption and innovation theories [34] help explain the factors

influencing technology integration, while risk management theories assist in identifying and mitigating potential risks associated with new business models.

4 The Cases of Companies Embracing Servitization

Building upon the literature review and theoretical framework, this section presents a series of case studies highlighting the successful implementation of pay-per-use models with the incorporation of circular economy principles. These examples shed light on real-world applications of servitization and provide valuable insights into how companies have effectively embraced this transformative business model. By examining these case studies, we can understand how organizations align their offerings with customer needs, optimize resource use, reduce waste, and contribute to a more sustainable manufacturing ecosystem.

4.1 Rolls-Royce:

Rolls-Royce, a leading aerospace manufacturer, has embraced servitization through their "TotalCare" program. This pay-per-use model provides airlines with comprehensive engine maintenance, repair, and overhaul services [35]. Rolls-Royce's value proposition lies in guaranteeing engine availability and performance, reducing downtime, and optimizing operational costs for airlines. Their business model incorporates flexible pricing structures based on engine utilization, ensuring cost-effectiveness and scalability. Technologically, they utilize IoT connectivity, data analytics and remote monitoring to proactively identify maintenance needs and optimize engine performance. Rolls-Royce prioritizes customer experience through seamless onboarding, responsive support, and customization options. Risk management is addressed through contractual agreements, financial risk mitigation and robust contingency plans. They collaborate closely with airlines and maintenance partners, forming strong partnerships to ensure reliable service delivery. In terms of sustainability and circular economy, Rolls-Royce promotes resource efficiency by refurbishing and reusing engine components, extending product life and reducing waste.

4.2 John Deere:

John Deere, a renowned manufacturer of agricultural machinery, has successfully implemented servitization through their "John Deere FarmSight" initiative [36]. They offer a pay-per-use model that integrates advanced machinery, agronomic expertise and precision farming technologies. The value proposition centers around enhancing farm productivity, optimizing input costs for farmers and reducing environmental impact. John Deere's business model includes revenue streams from equipment usage, agronomic services and data-driven insights. Technologically, they leverage IoT connectivity, data analytics and remote monitoring to enable real-time field monitoring, predictive maintenance and personalized recommendations. Customer experience is prioritized through tailored onboarding, proactive support and continuous engagement. Risk management measures include data security protocols, clear contractual agreements and contingency plans. John Deere collaborates extensively with agronomic partners, technology providers and local dealers to deliver integrated solutions. In terms of circular economy, they focus on resource efficiency by designing durable machinery, promoting sustainable farming practices and facilitating responsible product disposal.

4.3 Philips Lighting:

Philips Lighting (now Signify), a leading lighting solutions provider embraced servitization through their "Light as a Service" offering [37]. This program provides lighting solutions to customers based on a pay-per-use model, focusing on energy efficiency, cost savings and sustainability. Philips Lighting's value proposition centers around providing high-quality lighting, personalized experiences and reduced energy consumption. The business model includes revenue streams from lighting subscriptions, energy savings and maintenance services. Philips Lighting utilizes connected lighting systems, IoT technology and data analytics to optimize lighting performance, enable remote monitoring and deliver personalized lighting experiences. Collaboration with architects, facility managers and energy providers ensure the successful implementation of their lighting solutions. Circular economy principles are incorporated through responsible product disposal, recycling initiatives and energy-efficient lighting designs.

4.4 Schindler:

A manufacturer of elevators and escalators, Schindler implemented servitization through their "Schindler Ahead" platform [38]. This platform offers predictive maintenance, performance monitoring and personalized services for their vertical transportation systems. The pay-per-use model focuses on maximizing uptime, improving energy efficiency, and providing a seamless passenger experience. Schindler's business model includes revenue streams from service subscriptions, energy savings and equipment upgrades. They leverage IoT connectivity, data analytics and remote monitoring to optimize maintenance schedules, proactively address issues and improve energy consumption. Customer experience is prioritized through intuitive interfaces, personalized services and 24/7 support. Schindler collaborates with facility managers, building owners and technology partners to deliver comprehensive solutions. They promote circular economy principles by refurbishing and reusing components, reducing energy consumption, and optimizing the life cycle of their products.

4.5 Schneider Electric:

Schneider Electric, a global leader in energy management and automation solutions, has embraced servitization through their "EcoStruxure" platform [39]. This platform offers pay-per-use solutions for optimizing energy efficiency, building management and industrial automation. Their value proposition revolves around reducing energy consumption, improving operational efficiency, and achieving sustainability goals. Schneider Electric's business model includes revenue streams from energy savings, automation services and data-driven insights. They leverage IoT connectivity, data analytics and edge computing to enable real-time monitoring, predictive maintenance, and energy optimization. Customer experience is enhanced through personalized solutions, remote monitoring, and responsive support. Risk management measures include cybersecurity protocols, clear contractual agreements, and business continuity plans. Schneider Electric collaborates with energy providers, technology partners and system integrators to deliver integrated solutions. Circular economy principles are incorporated through responsible product design, recycling programs and resource-efficient manufacturing practices.

4.6 General Electric (GE):

General Electric (GE), a multinational conglomerate implemented servitization through their "GE Digital" platform [40, 41]. They offer pay-per-use solutions for industrial equipment and asset performance management. The value proposition centers around equipment reliability, predictive maintenance and improved operational efficiency. GE's business model includes revenue streams from equipment uptime, performance improvements and service subscriptions. Technologically, they leverage IoT connectivity, data analytics and machine learning algorithms to optimize equipment performance, reduce downtime and enable remote monitoring. Customer experience is enhanced through customized solutions, real-time insights, and proactive support. Risk management measures include data security protocols, robust contractual agreements, and contingency plans. GE collaborates with industry partners, technology providers and maintenance experts to deliver comprehensive solutions. In terms of circular economy, they focus on extending the life cycle of equipment, optimizing energy consumption, and implementing sustainable manufacturing practices.

4.7 Philips Healthcare:

Philips Healthcare, a leading provider of medical devices and solutions, adopted servitization through their "Managed Equipment Services" offering [42]. They provide pay-per-use models for medical equipment, including imaging systems and patient monitoring solutions. The value proposition revolves around improving patient outcomes, reducing costs and ensuring healthcare providers have access to advanced technologies. Philips' business model includes revenue streams from equipment usage, maintenance services and upgrades. Technologically, they leverage IoT connectivity, data analytics and cloud-based platforms to monitor equipment performance, optimize workflows and enable remote diagnostics. Customer experience is enhanced through seamless equipment integration, user-friendly interfaces and comprehensive training and support. Risk management measures include adherence to strict regulatory standards, data privacy protection and service-level agreements. Philips Healthcare collaborates with hospitals, clinicians, and technology partners to deliver tailored solutions. Circular economy principles are incorporated through responsible product disposal, recycling programs and eco-design practices.

4.8 Caterpillar:

Caterpillar, a leading manufacturer of construction and mining equipment, has implemented servitization through their "Caterpillar Pay for Use™" program [43]. This program offers customers the option to pay based on machine usage and performance rather than outright purchase of equipment. Caterpillar's value proposition focuses on providing customers with reliable, high-quality equipment while reducing their upfront costs. The business model includes revenue streams from equipment usage fees, maintenance services and performance guarantees. Caterpillar leverages advanced telematics technology, remote monitoring, and data analytics to optimize equipment performance, anticipate maintenance needs and maximize resource efficiency. They collaborate with dealers, suppliers, and customers to ensure seamless implementation and support. In terms of sustainability, Caterpillar promotes the reuse and remanufacturing of components, reducing waste generation and conserving resources.

4.9 Michelin:

Michelin, a renowned tyre manufacturer, embraced servitization through their "MICHELIN® Fleet Solutions™ program" [44]. This program offers pay-per-use tyre management services to fleet operators, focusing on optimizing tyre performance, reducing fuel consumption, and extending tyre life. Michelin's value proposition lies in helping customers achieve cost savings, improve safety, and minimize their environmental impact. The business model includes revenue streams from tyre usage fees, rethreading services, and data-driven insights. Michelin utilizes tyre sensor technology, data analytics and predictive maintenance algorithms to monitor tire conditions, provide real-time recommendations and enhance fuel efficiency. Collaboration with fleet managers, maintenance providers and technology partners is crucial for delivering comprehensive solutions. Michelin's circular economy efforts involve tyre recycling and the development of sustainable tyre materials.

4.10 BMW:

BMW, a renowned automobile manufacturer, has embraced servitization through their "Access by BMW" program [45]. This program offers customers access to a fleet of vehicles through a subscription-based model, providing flexibility and a seamless driving experience. BMW's value proposition focuses on providing customers with access to a range of vehicle models, maintenance services and exclusive experiences. The business model includes revenue streams from subscription fees, maintenance packages and additional services. BMW leverages advanced vehicle connectivity, digital platforms and personalized customer interfaces to enhance the driving experience and offer convenience. Collaboration with technology partners, insurance providers and mobility service providers are essential for delivering a comprehensive mobility solution. BMW's sustainability efforts include electric vehicle options, energy-efficient manufacturing processes and responsible end-of-life vehicle disposal.

Our analysis of various case studies reveals the effectiveness of integrating pay-per-use models with circular economy principles in achieving sustainable servitization. These cases demonstrate how companies have successfully aligned their offerings with customer needs, optimized resource utilization, reduced waste, and contributed to a more sustainable manufacturing ecosystem. The practical examples shed light on the diverse aspects of servitization, encompassing value proposition, business model effectiveness, technology and infrastructure, customer experience, risk management, collaboration and partnerships, organizational capability, and sustainability. These examples underscore the significance of these dimensions in implementing pay-per-use servitization successfully.

5 The Wheel of Servitization Framework

Building on the insights derived from the aforementioned case studies and theoretical context, we present The Wheel of Servitization (Servit360°) framework. This framework elucidates the pivotal dimensions essential for successfully implementing the pay-per-use service model. It serves as an invaluable tool, empowering manufacturers to evaluate and enhance their pay-per-use servitization models while upholding sustainability principles. By examining these dimensions, manufacturers can gain a comprehensive understanding of their current status and identify specific areas that may warrant improvement. The framework encompasses the following dimensions:

1. Value Proposition: The value proposition dimension focuses on creating a compelling offering for customers. Manufacturers need to assess the uniqueness of their service,

customer benefits, competitive advantage, and alignment with customer needs. By understanding the value their service brings, manufacturers can differentiate themselves in the market and attract customers.

2. Sustainability and Circular Economy: this dimension represents the extent to which the pay-per-use service model aligns with sustainability and circular economy principles. Manufacturers should assess factors such as resource efficiency, waste reduction, product life extension and environmental impact reduction. By incorporating circular economy principles, manufacturers can minimize their environmental footprint and contribute to a more sustainable future.
3. Business Model: it evaluates the effectiveness and efficiency of the pay-per-use business model. The factors to be evaluated include pricing structure, revenue streams, cost management, scalability, and profitability. Manufacturers should ensure that their business model is financially viable and adaptable to changing market conditions.
4. Technology and Infrastructure: it assesses the technological capabilities and infrastructure required to support the pay-per-use service model. Manufacturers need to consider aspects such as IoT connectivity, data analytics, remote monitoring, and secure and reliable systems. By leveraging advanced technologies, manufacturers can optimize service delivery, improve operational efficiency, and enhance customer experiences.
5. Customer Experience: represents the overall journey and satisfaction of customers throughout the pay-per-use service. Manufacturers should assess elements such as ease of onboarding, customer support, responsiveness, customization options and overall satisfaction. Providing a seamless and delightful customer experience is crucial for customer retention and loyalty.
6. Organizational Capability: evaluates the readiness of the manufacturer to deliver pay-per-use services. Manufacturers need to consider aspects such as employee skills and training, organizational culture, change management and adaptability to new service-oriented practices. Building a service-oriented culture and empowering employees with the necessary skills are essential for successful implementation.
7. Collaboration and Partnerships: it refers to the extent of collaboration with stakeholders involved in the servitization efforts. Manufacturers should evaluate relationships with suppliers, technology providers, logistics partners and other stakeholders. Strong partnerships contribute to the success of the pay-per-use service model by ensuring reliable supply chains, access to necessary expertise and seamless integration of services.
8. Risk Management: it evaluates the measures in place to manage risks associated with the pay-per-use service model. Manufacturers need to consider financial risks, data security and privacy, contractual agreements, and contingency plans. By proactively identifying and addressing potential risks, manufacturers can ensure the smooth operation of their pay-per-use services.

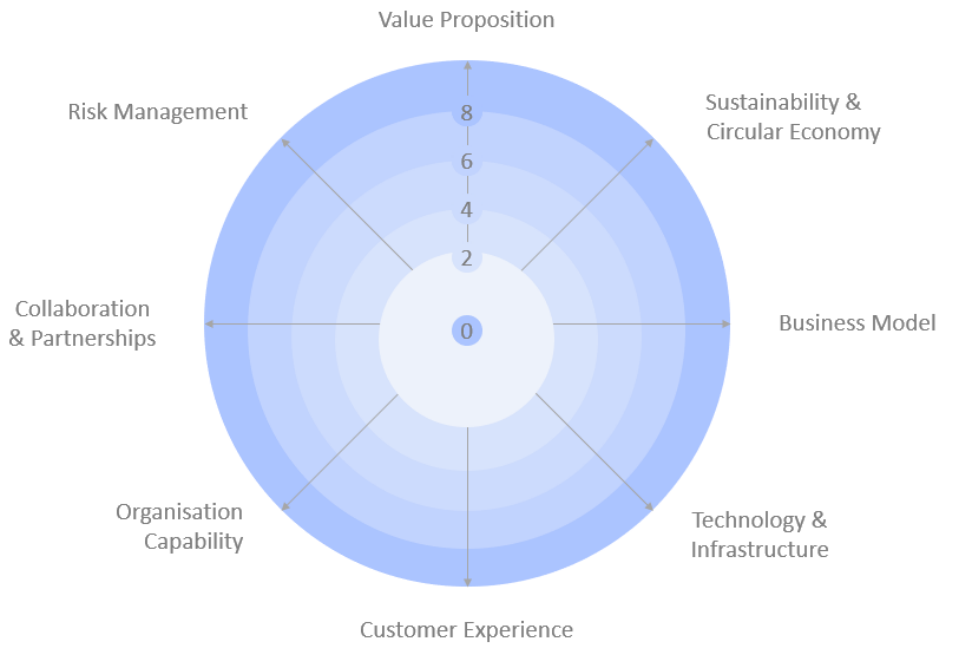

Fig. 1. Wheel of Servitization (Servit360°) with scale to measure achievement on each dimension

By utilising the Wheel of Servitization Framework, manufacturers can evaluate each dimension and identify areas for improvement in their pay-per-use servitization model. This holistic approach ensures that all critical aspects are addressed, maximising the likelihood of success and sustainability in the servitization journey.

5.1 Unlocking Synergies and Maximizing Benefits through Integrated Dimensions of the Servitization Wheel Framework.

By addressing all these dimensions and considering their interlinkages, manufacturers can achieve synergies and optimize the outcomes of their servitization efforts. For example, a strong value proposition aligned with customer needs enhances the customer experience, while effective risk management safeguards the financial stability of the business model. Collaboration and partnerships can facilitate access to sustainable resources and expertise, supporting the circular economy dimension. Overall, a holistic approach to servitization ensures that all dimensions are integrated and working together to maximize the benefits for both the manufacturer and the customers.

6 Conclusion

Servitization is a strategic pathway for manufacturing companies to achieve sustainability by addressing global environmental issues, evolving economies, changing consumer preferences, and digital technology advancements. Integrating pay-per-use service models with circular economy principles offers a promising approach for sustainable business practices. Successful examples highlight key dimensions essential for effective servitization implementation, encompassing value proposition, business model, technology and

infrastructure, customer experience, risk management, collaboration and partnerships, organizational capability, and sustainability. Our comprehensive framework "The Wheel of Servitization" (Servit360°) guides servitization strategy development, emphasizing the interconnectedness of these dimensions and the need for a balanced and integrated approach. Future research directions include long-term performance evaluation, industry-specific analysis, policy considerations, and technological advancements in servitization. The pay-per-use Servitization model empowers manufacturers to address environmental concerns, adapt to market dynamics, and thrive through sustainable practices, fostering growth, resilience, and customer satisfaction.

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