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REVIEW ARTICLE

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Service-oriented manufacturing: A literature review and future research directions

Abstract This study presents a systematic review of the literature on service-oriented manufacturing (SOM). Specifically, we focus on the impact of SOM on firm operating decisions, which distinguishes this work from previous reviews. This study proposes a classification framework for SOM research based on product flow, from its design to its final disposal. Although SOM has been studied for many years, most related research remains conceptual. Our criterion for choosing papers is that they must be relevant to practical problems. This review aims to provide readers a guide that will facilitate their search for papers in their field of interest. More importantly, we hope that this review can provide insightful managerial implications for SOM.

Keywords service-oriented manufacturing, product–service systems, servitization, servicing, operations management

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1 Introduction

With the rapid advancements in information and communication technologies, economies have undergone a structural shift from manufacturing to service worldwide. As shown in Table 1, many countries have made great achievements in extending their manufacturing companies into servitization business models (Mastrogiacomo et al., 2019; Neely et al., 2011). As we can see, US and UK are the countries with the highest percentage of servitized-manufacturing companies in 2018 (more than 50%). An earlier report of the US Department of Commerce also shows that the service sector comprises 80.3% of US gross domestic product (US Department of Commerce, 2013). Many famous firms, including GM and Bundles (a Dutch company), have devoted themselves to this trend. In China, the servitization extent is relatively low but has made a brilliant increment in the past few years. With great government support and huge potential market, many well-known Chinese manufacturers, such as Haier and Sany, have turned their traditional business to service-oriented models.

Table 1 Percentage of servitized companies in the manufacturing sector in different countries (Mastrogiacomo et al., 2019; Neely et al., 2011)

Countries	2007	2011	2018
US	58%	55%	53%
UK	24%	39%	56%
China	1%	19%	38%
Japan	11%	31%	41%
Germany	29%	28%	39%
Switzerland	28%	31%	39%

Service-oriented manufacturing (SOM) is an innovative model that has been generated by the integration of services and manufacturing (Davies, 2004; Windahl et al., 2004). As consumer culture has changed from demand for products to demand for personalization and experiences, manufacturers are eager to satisfy customers' requirements by offering products and services. Furthermore, overpopulation and shortages of resources have led manufacturers to try to meet customer needs by providing services rather than goods. Many famous manufacturers, such as IBM, BMW, and Rolls-Royce, have tried this new mode of operations to improve their competitiveness (Table 2).

This innovative trend has led to a revolution in manufacturing, and many reviews of and introductions to SOM have been conducted involving the impact of new technologies (Grubic, 2014; Núñez-Merino et al., 2020), system designs (Khorasani et al., 2020), and conceptions (Haase et al., 2017; Lightfoot et al., 2013) of SOM. Specifically, Wang et al. (2021) present a review on the servitization in operations management focusing on the impact of new information and communication technologies. However, most of these reviews discuss SOM from a macroscopic perspective. Motivated by this and by the popularity of SOM, we conduct a systematic literature review to discuss changes in firm operating decisions due to SOM. Different from previous reviews, we focus on operating decisions, such as business model options, product development, and income returns.

This study aims to provide a review of the literature on SOM in terms of operational decisions, encompassing various databases and journals. This review is intended to enhance the scholarly understanding of SOM by providing a comprehensive picture of underexplored changes in internal decision making caused by SOM. Based on the analysis of the available literature, we highlight managerial implications and provide new avenues for future research.

The rest of the paper is organized as follows. Section 2 presents the definition and characteristics of SOM. Section 3 presents the method by which papers were selected for this review, and they are analyzed in Section 4. In Section 5, we provide managerial implications. Section 6 presents suggestions for future research on SOM. Finally, Section 7 summarizes this study.

2 Definition and characteristics

The concept of SOM originated in Japan, which strongly supports related research (e.g., intelligent manufacturing systems). In the US, SOM is called service-based manufacturing or servitization. The Natural Science Foundation of the US has funded the "Exploratory Research on Engineering the Service Sector". In Europe, SOM is referred to as product–service systems (PSS), and the European Union (Frame-6) supports research on how to collaboratively design and manufacture products in a network environment. In China, SOM has been studied since 2007 (Sun et al., 2007). By combining SOM with Chinese characteristics, great developments have been achieved in this field (Li et al., 2009).

2.1 Definition

Vandermerwe and Rada (1988) first propose servitization, which is the prototype of SOM. They argue that services that are the main source of revenue for a manufacturer are different from traditional services relying on labor or expertise. Under SOM, a physical good is essential for delivering services. Similarly, Sheehan and Tegart (1998) propose service enhancement and indicate that services are gradually spreading in developed countries and that manufacturers should integrate services. Hawken (1993) vividly depicts the idea of servitization: What we want from these products is not ownership but the service that the products provide — transportation from the car, cold beer from the refrigerator, news or entertainment from our television, etc.

Tukker (2004) proposes a framework for PSS to illustrate its development process. PSS has three stages, namely, product-, use-, and result-oriented services. Product-oriented services are geared toward product sales and include some basic services, such as maintenance. Use-oriented services are characterized by the provider keeping the ownership, such as when leasing. With result-oriented services, customers and providers agree in principle, and manufacturers and customers focus on the functional result rather than the product. We consider SOM to be in the third stage.

Many scholars have also tried to define SOM from different perspectives, such as value-added supply chain (He et al., 2008; Li et al., 2009), product and service integration (Zhou et al., 2020; Sun et al., 2007), and customer centricity (Wu et al., 2011). Offering a comprehensive definition of SOM is difficult because it involves too many fields, including information systems, business management, and engineering design. We provide

Table 2 Classical cases

Industry	Firm	Description
Household	Bundles	Purchase appliances and charge customers a pay-per-wash fee
	Desso Carpets	Offer an operating lease for carpets
Office software	Xerox	Offer "document management" by charging customers for each page they print
Airline	Rolls-Royce	Provide pay-by-hour contracts for engines with airlines
Automakers	BMW, Ford, and Daimler	Charge customers based on their mileage or driving time
Computer services	IBM	Offer computing and storage services and charge customers for the use of the servers

a simple definition of SOM from a management perspective according to its mainstream definitions and characteristics.

We define SOM as an integration of services and products that improves manufacturers' profitability by providing customized services and that promotes sustainable development by innovating the product output process.

2.2 Characteristics

We argue that SOM has brought about a revolution in manufacturing, which has changed the mode of operations in the traditional manufacturing industry. As technology evolves, the concept and characteristics of SOM update. Haase et al. (2017) summarize a certain convergence regarding the key characteristics of SOM. Through our analysis from the management perspective, we identify the following main characteristics:

(1) Different from traditional services, physical goods are necessary to deliver SOM services. Although products and services are bound together, manufacturers and customers intend to focus on the service derived from the product. For example, Bundles is a Dutch company that offers services derived from households.

(2) SOM can reduce the environmental impact of the delivery of customer needs compared with traditional solutions. Under SOM, customers will curtail their usage due to the special payment.

(3) As an innovative business pattern, SOM includes a change in payment methods and a shift in product ownership. For example, Xerox not only sells printers but also offers customers printing services and charges them based on the number of pages printed; and Rolls-Royce and its contractual partners share power-by-hour contracts.

Other features are derived from these primitive characteristics. For example, SOM changes the relationships among supply chain members (Zhou and Wang, 2009). Manufacturers should consider the entire life cycle of a product due to a shift in ownership. Moreover, manufacturers have begun to introduce customers into the product design phase to satisfy customer requirements.

3 Research methodology

We use a systematic literature review approach (Tranfield et al., 2003) to ensure that the scope of our study of SOM is appropriate, which facilitates the provision of a classification scheme in terms of product flow. As shown in Fig. 1, a firm initially determines its business model (e.g., a sales strategy or servitization). Under a sales strategy, the business revenue mainly comes from product sales, whereas under servitization, manufacturers obtain compensation from customers through their usage of products. After determining the business model, manufacturers optimize their product design and manufacturing to deliver their products or services. When a fault occurs during product use, an optimal policy should be implemented to resume operations. Under SOM, manufacturers bear all the costs that are incurred to keep products operational. Finally, different disposal policies are made under different business models because the product ownership is different.

Our literature search is broad given that this study focuses on the operating decisions of a manufacturer in different phases. The Web of Science (WoS) database has a broad coverage of peer-reviewed journals; thus, we use this database and ensure that the scope of the literature is appropriate by searching for keywords (across all WoS journals) that include "Servitization", "Service-oriented manufacturer", "Servicing", and "Product–service systems". These keywords are based on the different terms of SOM in different countries, which frequently appear in the literature on SOM. Selviaridis and Wynstra (2015) and Baines et al. (2009) consider the performance-based contract (PBC) to be highly related to the context of SOM, and they propose that PBC can be an important facilitator of servitization. Benjaafar and Hu (2020) argue

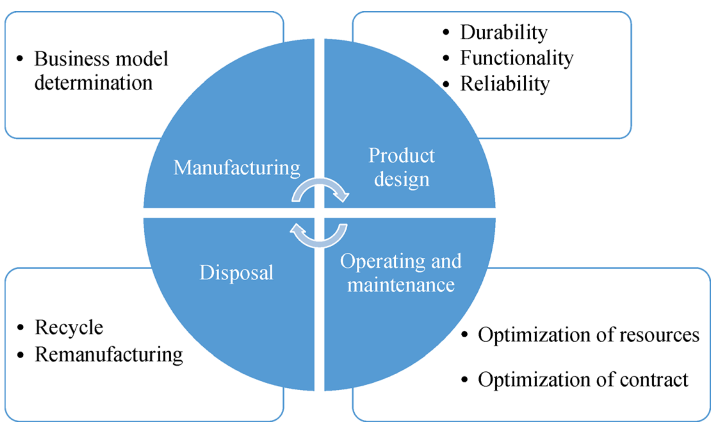

Fig. 1 Process for making firm operating decisions.

that the sharing economy is often referred to as servitization. In the sharing economy, a manufacturer also offers its products with a pay-per-use strategy. Therefore, in our review, we initially covered literatures on PBC and sharing economy, which are highly related to SOM.

The review period covers literature from 2000 to the present, and Fig. 2 shows how we select papers. After excluding conference proceedings, book chapters, editorial materials, and other non-peer-reviewed sources, we evaluated the identified papers written in English by reading their abstracts. Many review papers on SOM involving different fields have been published, which we enumerate in Table 3. After evaluating these reviews, many papers were eliminated from our study because they have already been reviewed in those published reviews. As we focus on the literature on SOM in terms of operational decisions, we also use "Service transformation", "Business model", "Product design", and "Operating and maintenance" as keywords for searching, but the final selected papers are highly related to the keywords of "Servitization", "Service-oriented manufacturer", "Servicing", and "Product–service systems".

We performed a cursory reading of these papers and then selected papers that focus on how SOM affects firm decisions, ranging from business model options to the final disposal of used products. In our review, we highlighted the papers that provide insights into decision making through mathematical models, which have not received sufficient attention in the previous reviews.

4 Analysis of SOM literature

In this section, we analyze four aspects of the available literature to show the impact of SOM on firm decisions, namely, choice of a business model, product design, optimization of measures to stay operational, and final disposal (recycling and remanufacturing).

4.1 SOM business model

Normally, a business model is defined based on the mode of operations or the system for product/service delivery; examples include a production-to-order system, the fast fashion industry, and the Toyota production system. These business models are based on the buyer–seller relationship.

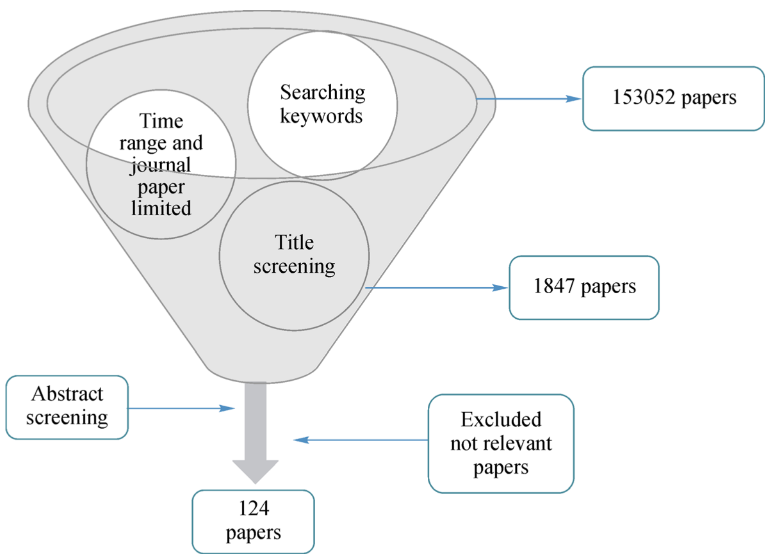

Fig. 2 Flow diagram of selecting papers.

Table 3 Review papers on SOM

Topic	Reviews
Technology	Wang et al. (2021); Bertoni and Larsson (2017); Boehmer et al. (2020); Grubic (2014); Larsen et al. (2018); Núñez-Merino et al. (2020); Da Silveira et al. (2001)
System design	Khorasani et al. (2020)
Supply chain management	Gosling and Naim (2009); Gunasekaran and Ngai (2005); Khorasani et al. (2020); Srivastava (2007)
Concept	Haase et al. (2017); Lightfoot et al. (2013); Lu (2017); Sun et al. (2007)
Industry analysis	Mahut et al. (2017); Shui and Szeto (2020); Bardhi and Eckhardt (2012); Li et al. (2009)
Customer impact	Demyttenaere et al. (2016)
Others	Zhang and Banerji (2017); Xin et al. (2017); Calabrese et al. (2019); Nudurupati et al. (2016); Zheng et al. (2019)

However, as a nontraditional business model, SOM delivers to customer services derived from products rather than ownership of those products.

This business model has permeated various industries. Why companies have accepted this business model is a topic of interest. In practice, managers are concerned about when and how to adopt this trend. In addition, how to design an effective organizational or supply chain mechanism to coordinate this paradigm is an important research direction. We propose a framework for research on these management concerns, as shown in Table 4.

4.1.1 Business model options

In our paper, we discuss three factors that affect the implementation of SOM, namely, profitability, environment, and customer acceptance.

Profitability: Definitely, the primary reason that manufacturers adopt SOM is that this business model offers them high potential to improve their profitability. In most papers, profitability is evaluated by comparing SOM to the traditional business model (i.e., sales strategy) (Bellos et al., 2017; Örsdemir et al., 2019). These papers focus on the special way compensation is obtained under SOM, in which customers are charged based on their use of the product. This method may allow manufacturers to reach customers who cannot afford their products under the sales strategy. However, given that customers do not bear the operating costs, they may use the product carelessly and improperly, which brings manufacturers the risk of high operating costs. Therefore, whether servitization is better than other business paradigms for the manufacturer's profitability is unclear. Agrawal et al. (2016) find that servitization is more profitable only when customer needs are pooled. Tian et al. (2021) explore when and how automakers enter the car-sharing market by optimizing the price in the sales market and the number of cars that entered into the car-sharing market. Many papers show that the relationship between these business modes is complicated, and they may be complementary (Bellos et al., 2017) or mutually exclusive (Örsdemir et al., 2019). The market environment, enterprise status, and product characteristics considerably affect the choice of business model.

Environment: A growing body of literature on business models also emphasizes their environmental value (Schaltegger et al., 2016). Serious environmental problems affect human health and can become a limiting factor for further development, which leads to the rethinking of traditional manufacturing and environmental protection (Qian, 2014). Under SOM, customers prefer to curtail their use because servitization transforms the fixed cost associated with possessing a product to a variable cost associated with its use, which benefits the environment. Many studies on SOM have highlighted its environmental advantages (Brandstotter et al., 2003; Li et al., 2010).

However, if we fully understand how the structural characteristics of SOM affect the enterprise and customer decisions, we may find that servitization is not always advantageous in terms of the environment. Some papers have shown that in certain cases, this new business model may harm the environment (Agrawal and Bellos, 2017). Under SOM, more customers can use a product that they cannot afford under the sales strategy. The manufacturing of more durable and higher-efficiency products increases those products' usage due to the reduction in operating costs, and this increase in usage damages the environment.

Customer Acceptance: Choosing a business model also relies on the degree of customer acceptance. Sometimes, customers prefer the traditional business model because the prices of servitized offerings are considerably higher than the sum of the production costs (Barquet et al., 2013; Nudurupati et al., 2016). To reach more customers, servicing manufacturers have to launch pay-by-use contracts in which customers pay for the amount of use rather than for ownership of the product. A further consideration is that people are accustomed to the original consumption concept that if they want to use a product, they must buy it first; this familiarity may impede customer acceptance of the SOM business model.

Many studies have begun to consider human behavior when studying the SOM business model. Bellos et al. (2017) consider impacts of consumer preference heterogeneity on driving performance. They find that when people prefer better driving performance, the sales strategy has more benefits. However, Avci et al. (2015) analyze the implementation of business models intended to eliminate range anxiety related to electric vehicles by charging customers according to their battery usage.

4.1.2 Organizational design

A firm's organization determines the manner it operates and supports the implementation of its business strategy. Current research finds that firms should enhance the transition from a product-centric to a customer- or

Table 4 Classic papers

Management concern	Influencing factor	Studies
Choice of business model	Profitability	Agrawal and Bellos (2017); Bellos et al. (2017); Örsdemir et al. (2019)
	Environment	Agrawal and Bellos (2017); Örsdemir et al. (2019)
	Customer acceptance	Bardhi and Eckhardt (2012); Ghosh and Shah (2015); Hamari et al. (2016)
Organizational design	Structural design	Pierce (2012); Ghosh and Shah (2012)

service-centric organization (Fang et al., 2008; Kowalkowski et al., 2017; Martínez et al., 2010). To coordinate the SOM business model, organizational changes are required not only internally (Gebauer et al., 2005) but also externally. These include downstream modifications directed toward customers and upstream modifications directed toward suppliers.

Zhang and Banerji (2017) argue that communication methods should change because the value creation process changes under SOM, and value is delivered through service offerings instead of products. People should fully understand the firm's integrated offerings rather than only focusing on the product.

We argue that when changing the organizational structure to develop SOM, manufacturers should fully investigate the internal and external conditions of the company. Within a company, specialization and professionalism directly affect customer satisfaction with service delivery. Brax (2005) finds that in the past, management of the product and service teams was separate, which considerably hinders the reconfiguration of the organization because these teams lack knowledge of one another.

Externally, differences between supply chain members also hinder the development of SOM. These differences include the level of technology, the enterprise culture, and financial conditions. Certainly, a manufacturer seeking to develop SOM needs to reequip with advanced technologies and invest a large number of resources in the early stages. In a parallel supply chain, if a strong firm (e.g., a manufacturer) wants to change its organization to adopt this business model, then the manager must consider whether the firm's partners have the same willingness and ability to accept this change. Changing the firm's original organization without considering its partners' conditions may lead to worse results. Therefore, the organizational transition to SOM is a gradual process that must fit the firm's internal and external environment.

4.2 Product design

Under traditional strategies, product design aims to satisfy customer expectations. Firms persuade more customers to buy their products by enriching their product functions, applying new materials, and advertising extensively. This approach tends to create many problems, such as resource waste, excessive consumption, and mismatch between supply and demand. For a servitized manufacturer, rather than selling goods, the goal is to solve the customers' problems. Given that physical goods are needed to deliver services, product designs must be sufficiently accurate to satisfy customer needs with the fewest resources possible.

From the current SOM literature, we summarize three aspects of product design that relate to servitization. As shown in Table 5, product design aims to improve profitability for firms, ensure product reliability for customers, and protect the environment for society.

As shown in Table 5, almost all the papers are related to profitability. Undoubtedly, the primary reason that a manufacturer adopts this new strategy is to improve profitability. Some papers have shown that an increase in service intensity may benefit companies in terms of the growth in their sales and profitability (Gebauer et al., 2005; Kohtamaki et al., 2015; Benyoussef Zghidi and Zaiem, 2017). Therefore, with SOM, product design needs to satisfy the manufacturer's goal of generating more benefits. In contrast with the sales strategy, SOM requires manufacturers to consider future operating costs, including maintenance and all other costs incurred to keep the products operational, when optimizing product design. As manufacturers try to precisely satisfy customer needs, unnecessary functions that increase operating costs are eliminated, which effectively avoids resource waste and benefits the environment. This attempt reflects the social responsibility of the company. Therefore, introducing the operating costs into SOM research can blend the three objectives. Örsdemir et al. (2019) find that product design relies on the operating efficiency of manufacturers. Higher operating efficiency implies that fewer resources are consumed during operation, which generates more revenue for manufacturers. Bellos et al. (2017) also claim that when an automaker intends to enter the car-sharing market, the car models that it intends to introduce into the market should have high fuel efficiency.

In the surveyed literature, we find that when studying the product design of SOM manufacturers, product attributes are divided into three dimensions, namely, durability, functionality, and reliability. We list some influential papers and their basic theories in Table 6.

Durability: In the durable goods literature, customer marginal utility decreases after each unit of use. Higher-durability goods deteriorate more slowly, which implies that higher durability results in an improvement in total customer utility (Desai and Purohit, 1998; 1999). As a product is used more frequently, it may require more frequent repairs and may be less energy-efficient (Deshpande et al., 2006); moreover, the operating costs increase

Table 5 Objectives of product design

Objective	Studies
Improving profitability	Kim et al. (2007; 2010); Subramanian et al. (2009); Agrawal et al. (2012; 2019); Atasu and Souza (2013); Jain et al. (2013); Bhattacharya et al. (2015); Lim et al. (2015); Agrawal and Bellos (2017); Alev et al. (2020); Tian et al. (2021); Bellos et al. (2017)
Satisfying customers	Bhattacharya et al. (2014); Lim et al. (2015); Alev et al. (2020); Bellos et al. (2017); Örsdemir et al. (2019)
Protecting the environment	Subramanian et al. (2009); Atasu and Souza (2013); Agrawal et al. (2012); Agrawal and Bellos (2017); Örsdemir et al. (2019)

Table 6 Implications of product design

Implication	Research theory (trade-offs)	Studies
Durability	Durability can prolong the duration of customer use; in addition, durability slows the deterioration of the marginal utility derived from using the product; however, durability requires higher production costs	Agrawal et al. (2012); Agrawal and Bellos (2017); Örsdemir et al. (2019)
Functionality	Higher functionality indicates a higher valuation of the service, but more functions may increase production and operation costs	Agrawal and Bellos (2017); Bellos et al. (2017); Huang et al. (2019)
Reliability	Higher reliability implies fewer interruptions and longer uptime, but upfront investments are also larger	Shafer et al. (2005); Kim et al. (2007; 2010); Öner et al. (2010); Dong and Tomlin (2012); Jin and Tian (2012); Zhang and Banerji (2017)

with use. Agrawal and Bellos (2017) focus on customer utility enhancement through high durability. Örsdemir et al. (2019) not only consider improvements in customer utility but also examine the effect of durability on operating costs.

Functionality: SOM aims to meet the individual needs of customers, which is reflected in product functions. Normally, high-performance products require more resources to maintain their operations. In addition, more specialized maintenance can reduce repair time. High functionality may increase operating costs, but it also increases customer utility. When studying product lines in the car-sharing market, Bellos et al. (2017) explore two measures of car performance, namely, driving performance and fuel efficiency. Good driving performance not only increases customer utility but also incurs high operating costs. Higher fuel efficiency indicates lower costs, but it reduces driving performance. The authors find that under SOM, manufacturers are more concerned about fuel efficiency. Huang et al. (2019) consider product durability and recyclability when studying durable goods.

Reliability: A servicing manufacturer charges customers based on their usage uptime. High-reliability goods help manufacturers improve their profitability by decreasing outage durations. In addition, higher reliability implies fewer repairs, which reduces operating costs. In the area of PBCs, product reliability can be an unavoidable problem (Kim et al., 2007; Öner et al., 2010), and we discuss it in the next section.

When studying the services derived from a product that involves more than one attribute of that product, the interactions among these attributes should be considered. For example, durability and reliability are highly positively correlated. However, the relationship between functionality and durability (or reliability) depends on product attributes (Bellos et al., 2017; Huang et al., 2019).

4.3 Operations and maintenance

In the use stage, a qualified servicing manufacturer should try to reduce interruptions to earn higher profits. The operational performance of a product is determined by the frequency of its failures and the time to restore it to service. Therefore, servicing manufacturers mobilize all their resources to meet customer expectations. The key question is how to support customers' usage of products at the lowest cost. We review the relevant literature and find that most studies focus on PBCs, which propels SOM development (Kim et al., 2007).

Traditionally, whenever a product fails and requires restoration, a service support firm charges customers according to the amount of resources consumed. However, under a PBC, customers are buying performance outcomes, which is similar to SOM. Kim et al. (2017) report that the full benefits of a PBC strategy are achieved when the manufacturers are transformed into total service providers who own the products, a situation which is almost the same as servitization. Therefore, exploring PBCs is one of the most important parts of research on servitization.

Selviaridis and Wynstra (2015) conduct a comprehensive literature review of PBCs across different disciplines, including transportation, medical services, and engineering. Here, we focus on the literature on PBCs in the field of manufacturing. We summarize the research on PBCs according to two topics: How to utilize resources to keep products operational and how to prevent moral hazard. Under SOM, the source of the manufacturer's compensation is the uptime of the product. To achieve customer satisfaction, a servicing manufacturer keeps its products available by optimizing its resources. In addition, the performance of a product is related to the customer's effort in using the product. Servicing manufacturers bear the operating costs and have ownership, which weakens the consumers' incentives to use the products properly. Customers may take free ride on the efforts of service providers. Scholars have attempted to optimize or design mechanisms to eliminate the influence of this moral hazard.

4.3.1 Optimization of resources

Under SOM, servicing manufacturers try to reduce the frequency of interruptions by allocating their resources most effectively. To achieve the desired service level, one or more measures are usually implemented, including maintenance policies, inventory management of repairable spare parts, and investment in product design. When reviewing papers, we find problems regarding how use uptime involving one or more of these measures can be improved (Table 7).

Maintenance: Under SOM, high repair efficiency indicates increased investment in professionals and tools, which can reduce interruption times by shortening the repair times. Success in this increases customer utility and manufacturer revenue. Therefore, the choice of maintenance policies is highly important.

Wang (2002) reviews the literature on maintenance, including two traditional types: Preventive and corrective. Most of this research focuses on in-house functional processes and assumes product users are also product maintainers. However, under SOM, customers who use products are not responsible for maintenance. The manufacturers offer maintenance services to enable product availability. The two main maintenance policies are preventive maintenance, which is performed periodically to improve reliability, and corrective maintenance, which is used to restore service when a product fails. In view of the two maintenance policies, Tarakci et al. (2006a) investigate how to induce a contractor to select the maintenance policy that optimizes the total profit of the manufacturer and contractor under a PBC. Tarakci et al. (2006b) show the influence of variation in individual process maintenance times and costs on channel coordination and profit. Alexander et al. (2017) extend Tarakci et al. (2006a; 2006b)'s work by considering the sensitivity of system coordination to the contractor's expected cost for minimal corrective repair. In addition, Qin et al. (2018) conduct a more comprehensive study by considering the equipment's fatal and nonfatal failures. They include age replacement models in a game-theoretic setting.

Inventory of Repairable Spare Parts: A high level of repairable spare parts in inventory facilitates reductions in the product's downtime for manufacturer because the faulty parts can be quickly replaced instead of repaired. Under SOM, servicing manufacturers charge customers based on the customers' realized outcome values. A higher inventory level leads to shorter disruption times, which increases the manufacturer's revenue, and customers can achieve higher utility. However, increased inventory also results in higher costs and the need for greater storage capacity. As a result, the optimal inventory level is usually constrained by the storage capacity or financial problems (Tang et al., 2018). As shown in Table 7, many studies involve how to optimize the inventory management of spare parts to achieve the target service level for customers.

In the study of the inventory management of repairable spare parts, the dominant model is METRIC, which is developed by Sherbrooke (1968); this method optimizes inventory levels by using a greedy heuristic method. Since then, METRIC has been developed in many ways, such as multi-indenture, transshipment, and multi-item inventory models (Muckstadt, 1973; Graves, 1985; Axsäter, 1990). However, these studies assume infinite repair capacities — an assumption that significantly underestimates spare part requirements. Sleptchenko et al. (2003) optimize spare part inventory levels assuming limited repair capacities. Nowicki et al. (2008) find significant effects of revenue functions on the optimal inventory levels.

Inventory of Repairable Spare Parts and Maintenance: The recent study on spare part inventory models has been driven by the emergence of SOM. Many scholars have focused on profit maximization rather than cost reduction, because SOM requires high-reliability outcomes, and they have investigated how to optimize the combination of the inventory levels and maintenance of spare parts. In view of repair time, part inventory, and inherent reliability levels, Jin and Wang (2012) maximize the supplier's profit margin based on exponential and linear revenue functions. They find that more information is needed on usage rates to mitigate contractual uncertainty under PBCs. Buyukkaramikli et al. (2015) develop quantitative models that integrate inventory-level decisions with capacity-related decisions for repair shops. They find that in comparison with the fixed capacity mode, the two-level capacity mode can generate substantial savings. Kim et al. (2017) investigate the influence of the ownership of different spare parts on the optimal inventory level and repair efficiency. They argue that under SOM, manufacturers have stronger incentives to invest in reliability improvements, which leads to savings in acquiring and holding spare product assets.

Inventory of Repairable Spare Parts and Reliability: Improving product reliability implies higher levels of investment in products, but that investment decreases the operating costs and downtime of the product. Optimizing the level of investment in a product usually involves considering maintenance efforts or spare part inventory.

The level of investment in a product and the spare part inventory are the two main factors that determine disruption times. Öner et al. (2010) provide an efficient optimization algorithm to gain managerial insights. Kim

Table 7 Operating measures

Measure	Studies
Maintenance	Tarakci et al. (2006a; 2006b); Alexander et al. (2017); Jiang et al. (2020)
Inventory management	Nowicki et al. (2008)
Inventory management and maintenance	Sleptchenko et al. (2003); Jain et al. (2013); Kim et al. (2007; 2010); Dong et al. (2018); Qin et al. (2018; 2020)
Inventory management and reliability	Jin and Wang (2012); Öner et al. (2010)

et al. (2017) investigate the decisions regarding investment in products and the spare part inventory level that the manufacturer makes during two phases. During the development phase, the manufacturer determines the level of investment in the product, and during the exploitation phase, decisions about the spare part inventory level determine the service level of after-sale repairs. The authors find that PBCs provide strong incentives for the manufacturers to invest in reliability improvements, which reduces the expense of the spare part inventory. Jin and Tian (2012) show that spare part provisioning and reliability analysis are two tightly coupled problems. They investigate the trade-off between reliability design and inventory levels with a dynamic stocking policy.

As shown in Table 7, we find limited papers on the interactions between maintenance and reliability. Moreover, no paper has fully explored the interactions among the three measures thus far; hence, further study is required.

4.3.2 Optimization of contracts

In the study of PBC, a critical problem is how to reduce the impact of moral hazard. Holmstrom (1982) indicates that each player might have incentives to take free-ride on the other player's effort, which results in suboptimal outcomes. Lafontaine (1992) applies empirical models to investigate moral hazard, as the equipment's operational performance is determined by the joint efforts of the user and the service provider. If one of them exerts more effort, then the other will exert less effort to reduce costs. Double-sided moral hazard is ubiquitous when studying contracts in a supply chain. Normally, optimizing the contract structure can effectively mitigate moral hazard in a supply chain. Recently, some scholars have introduced business interruption (BI) insurance to contract mechanism design to reduce the effect of moral hazard (Table 8).

Contract Design: Under SOM, servicing manufacturers and customers may bear extremely large moral hazard risk, depending on who is more sensitive to mechanical failures. For normal durable goods, such as home appliances and shared bikes, product failures may affect customers less than the servicing manufacturer because customers can find replacements quickly for broken appliances. For example, a computer provides an alternative to a broken television. As all the operating costs are incurred by the servicing manufacturer, the manufacturer bears the risk of the customers' improper use and hopes that customers display reasonable care when using products. However, product failures have a greater influence on customers in the case of, for example, key equipment, such as elevators and aero-engines. Customers hope that servicing manufacturers exert more effort to ensure that the product is available because when these products fail, customers face great, even life-threatening, losses. Therefore, preventing product failure in servitization involves the complementary efforts of servicing manufacturers and customers. Considerable work has been conducted to design novel contracts that incentivize customer effort. Guajardo et al. (2012) empirically investigate how product reliability is affected by two types of contracts, namely, the time and material contract (T&MC) and the PBC. Under a T&MC, manufacturers are compensated for the amount of resources consumed. Under a PBC, product reliability is considerably higher than that under T&MC.

Romano (1994) and Bhattacharyya and Lafontaine (1995) show that a simple linear contract results in the second-best outcome when the manufacturer is risk-neutral. Many studies have assumed that manufacturers are risk-neutral and apply linear contracts to examine contract design (Bhattacharya et al., 2015; Roels et al., 2010). Various contracts under SOM can be represented by linear contracts, such as pay-per-time, pay-per-call, and service-level agreements. Hasija et al. (2008) examine contract types when information asymmetries exist regarding worker productivity, showing how different combinations of these contract features enable core firms to better manage vendors.

Corbett et al. (2005) focus on the double-sided moral hazard problems to analyze the amount of effort to exert when trading off between costs and benefits. Tarakci et al. (2006a) consider an uptime-bonus contract to induce the contractor to select an optimal maintenance policy to incentivize more effort. They introduce an incentive contract based on a combination of a target uptime level and a bonus that always leads to the desired win–win coordination. They further study whether a bonus contract can guarantee coordination between one firm and multiple contractors (Tarakci et al., 2006b). Bhattacharya et al. (2014) explore the joint product improvement efforts of a customer and a support center under different contract types. In their study, a gain share contract is found to be optimal when efforts are unobservable.

When studying moral hazard under SOM, linear

Table 8 Measures to reduce the effect of moral hazard

Directions	Measures	Studies
Contract design	Under a PBC, more efforts implies more costs: Clients can obtain more utility, and the contractor can obtain more revenue from a longer use time when either or both improve their effort	Bhattacharyya and Lafontaine (1995); Kim and Wang (1998); Corbett and DeCroix (2001); Guide Jr and van Wassenhove (2009); Jain et al. (2013); Bhattacharya et al. (2014)
BI insurance	Such insurance compensates for losses due to interruptions or the risk of free-riders, but insurance fees must be paid	Dong and Tomlin (2012); Serpa and Krishnan (2017); Dong et al. (2018); Qin et al. (2018; 2020)

contracts have many advantages. However, we argue that more novel contracts are required and should be studied, not only linear contracts. Jain et al. (2013) introduce a tiered contract structure that eliminates losses due to double-sided moral hazard. They use a double-sided moral hazard framework to study the decisions of manufacturers and customers when ensuring the availability of equipment. Our review of the literature reveals that research on mitigating moral hazard through contract design usually focuses on how to incentivize manufacturers to exert more effort.

Insurance Operations: BI insurance has recently been introduced in SOM. With BI insurance, either servicing manufacturers or customers can be compensated when a disruption occurs to one of the firm's facilities. In a supply chain, firms usually allocate the financial liability of an operational failure through a predesigned contract. However, third parties also provide a cover for losses when firms purchase BI insurance.

Dong and Tomlin (2012) explore the interactions among business insurance, emergency sourcing, and inventory management, finding that insurance can improve the marginal value of inventory and emergency sourcing. Dong et al. (2018) study the interplay among inventory, interruption insurance, and preparedness actions in production chains. Martínez et al. (2016) consider the tradeoff between the base stock level and BI insurance. In view of insurance-based risk mitigation policies, Qin et al. (2018) investigate the PBC strategy and find that BI insurance not only decreases PBC-induced risks but also provides a feasible way to improve usage life.

Originally, research suggests that the use of insurance leads to inefficiencies due to moral hazard because business insurance can decrease incentives to ensure operational reliability (Kleindorfer and Saad, 2005). However, Serpa and Krishnan (2017) find that in a multifirm setting instead of a single-firm setting, BI insurance can decrease the effect of moral hazard. Qin et al. (2020) use a principal–agent model to study the influence of BI insurance on resource-based contracts and PBCs. Their results show that BI insurance plays contrasting roles in motivating a service supplier's effort under the two contracting mechanisms.

BI insurance provides a new direction for studying SOM because purchasing a BI insurance may have a large influence on decisions regarding maintenance, spare part inventory, and investment in manufacturing. As a newly emerging business pattern, introducing BI insurance to servitization induces more manufacturers and customers to accept SOM by decreasing the effect of moral hazard.

4.4 Recycling and remanufacturing

Under SOM, the servicing manufacturer retains ownership of the product, which is highly different from the case under a sales strategy. SOM is a closed-loop supply chain in which there exist (reverse) flows of used products back to manufacturers. The effective disposal of used products can be a core competence in such markets. However, we find few papers that analyze this problem by introducing recycling and remanufacturing into the context of servitization.

4.4.1 Recycling

Many scholars have focused on optimizing collection methods for reused goods given different targets (Savaskan et al., 2004; Ferguson and Toktay, 2006). Under SOM, recycling can be more effective due to Internet of Things technologies and lifetime information management.

During collection under SOM, smart products and recycling shops obtain data about collection volumes and the capacity of collection sites and obtain streamlined estimations of future demand for materials (Jun et al., 2009). Certainly, sorting used goods is a costly process but it determines the recovery value. Smart SOM products make it possible to define appropriate recycling processes by providing the composition of their materials (Condea et al., 2010). Recycling bins with sensors and connectivity have upended traditional recycling strategies, which facilitates the implementation of recycling at the household level.

4.4.2 Remanufacturing

Remanufacturing recovers the value of used products and reduces resource and product waste. Hence, remanufacturing reduces environmental burdens, which is a target for SOM. This aspect is comprehensively reviewed by Guide Jr and van Wassenhove (2009). The research on remanufacturing is roughly divided into three strands, namely, technology, product design, and management.

Product design usually determines the value of remanufacturing. Normally, more durable goods are more remanufacturable, which indicates that recyclability and durability can be enhanced simultaneously. Atasu et al. (2008) and Gu et al. (2015) find that different forms of product recovery and different market characteristics greatly affect decisions regarding quality. As product design is an important decision for a servicing manufacturer, the SOM literature is closely related to papers that explore product design implications (Plambeck and Wang, 2009; Atasu and Subramanian, 2012).

5 Implications

This study takes stock of the SOM literature that focuses on practical firm decisions. We derive implications for managers from our analysis of the related papers.

Implication 1. Product development is the basis for all other decisions, and offering product lines to satisfy different types of customers may reduce firms' benefits.

Product design includes the optimization of the design throughout the product life cycle based on product flow (Kim et al., 2007; 2010; Öner et al., 2010). Firms do not pursue only product features that are needed to satisfy customers when they use SOM rather than the sales strategy. Under SOM, product design is jointly affected by customer needs and the requirements of the firm, including its constraints due to operating costs (Örsdemir et al., 2019), recycling policies, and remanufacturing targets (Atasu and Subramanian, 2012).

When traditional strategies are used, longer product lines help firms improve profitability by achieving higher total demand and larger market shares, although this may not be true under SOM. When offering a long product line, different types of goods require firms to invest more in multiple specialists and tools to keep those goods operational. This phenomenon greatly increases total costs, and offering a long product line may not improve profitability well. Agrawal and Bellos (2017) provide evidence that a firm should pool customer needs and offer services with fewer products (Bellos et al., 2017).

Implication 2. In view of heterogeneity in customers or in product characteristics, the relationship between SOM and the sales strategy is highly complicated. Under certain conditions, they complement and enhance each other.

Normally, the choice between the sales and servitization business models depends on the firm's operating efficiency (Örsdemir et al., 2019). However, a hybrid business model allows the firm to better price discriminate by more effectively segmenting the customers. For example, customers with a higher use frequency choose the sales option, while the ones with a lower use frequency choose SOM, which makes the hybrid business model more attractive than either pure business model. However, if the unit production cost is extremely high, then the sales strategy is more profitable because the total production cost under the SOM strategy outweighs the benefits.

Under SOM, firms prefer to produce goods that are more durable, which can increase the valuation of the products in the sales market. Thus, when considering high- or low-end segments in the market, SOM can allow a firm to increase its per-unit profit from selling products. In addition, high-end manufacturers benefit more from the combination of SOM and the sales strategy (Agrawal and Bellos, 2017). Under the sales strategy, only those in the high-end segment enjoy the product, whereas SOM allows more customers (particularly those in the low-end segment) to use the service. High-end manufacturers can reach both segments in the market by using both business models.

Normally, the objective of SOM is to improve firm profitability by offering more services with fewer product types (Bellos et al., 2017). Servicing manufacturers want to satisfy customers by offering customized services. According to the available literature, the advantages of the SOM business model are widespread across firms (Bhattacharyya and Lafontaine, 1995; Dong and Tomlin, 2012; Kim and Wang, 1998). Every firm faces its own demand, but each firm is rational and focuses on results; from this perspective, the heterogeneity across firms is extremely low. Common customers also focus on the process. For example, driving performance is tied to the car model, which cannot be replaced by a service. Therefore, SOM is not a good choice in industries in which obvious customer heterogeneity exists or customers have a strong attachment to products.

At present, SOM is remarkably popular, and many firms have attempted to implement it. However, when adopting this business model, managers should fully consider the market characteristics and firm conditions.

Implication 3. A firm's advantages, such as high operating efficiency or low unit production costs, can damage the environment when it adopts SOM.

At present, a primary reason for promoting SOM is that it is environmentally beneficial (Atasu and van Wassenhove, 2012; Plambeck and Wang, 2009). Under SOM, manufacturers produce more durable goods, and customers reduce the frequency of product usage due to the unique payment method (Agrawal and Bellos, 2017). Under certain conditions, SOM is superior to the sales strategy when considering environmental benefits, but we find some counterintuitive implications in our analysis of the literature. Certainly, SOM is preferred when there exists high operating efficiency, which will lead to goods with better durability (Örsdemir et al., 2019). However, Jiang et al. (2021) find that if customers initially determine the duration of use, then the manufacturer prefers less durable goods because lowering the durability level can reduce production costs, and the increase in operating costs will be limited due to high operating efficiency.

Moreover, a low per-unit production cost leads firms to produce more goods to reach more customers under SOM (Bellos et al., 2017). For example, in China, the bike-sharing industry incentivizes more people to ride bikes, which have a low per-unit price. In addition, as the unit production cost of a bike is low, to reach more customers, the quantity of products is excessive. As a result, many idle bikes occupy road and sidewalk space, and resources are wasted due to the production of excessive goods. We hope these findings will help the government make better decisions.

6 Potential future research directions

Although SOM has been studied for a long time, many practical problems remain. This comprehensive review of related papers reveals that some topics have been under-explored. We summarize those research gaps in this section.

6.1 Integration of technology and management

We believe that the development of SOM is driven by advanced technologies that might facilitate the design of new business models and management structures (Bertoni and Larsson, 2017; Boehmer et al., 2020). However, we find that research on SOM usually separates technology from management.

Innovation in traditional management production systems usually depends on the existing technology. Such management innovations do not incentivize the development of new technology, whereas SOM is enabled by advances in technology (Wang et al., 2021). These new technologies determine the depth to which SOM can be developed, and, in return, expectations for SOM development can promote the emergence of new technologies. SOM and technology should complement each other. However, on the basis of the existing literature, the research on the interplay of technology and management in SOM is disjointed. Therefore, considering the influence of technology on management can be important when studying SOM. In the following, we identify some new technologies that affect management decisions (Núñez-Merino et al., 2020).

Crowdsourcing Design: The term "crowdsourcing" refers to "the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call" (Howe, 2006). Different from traditional product design, crowdsourcing design depends on the participation of customers and their feedback, which assists the firm in pooling customer needs. The characteristics of the crowd determine the success of crowdsourcing in new product development processes (Zhu et al., 2014; 2017). Therefore, designing a mechanism to choose crowd members that reflect real customer needs is crucial. Integrating crowdsourcing design into product development under SOM may greatly benefit firms.

Smart Operations: Under SOM, smart operations depend on remote monitoring, which facilitates the collection of information by the manufacturer regarding product location, availability, and status. Remote monitoring can be seen as a key enabler of SOM (Grubic, 2018).

With remote monitoring, the product status, including its current condition, operation, usage, and environment, can be monitored through advanced technologies (Ondemir et al., 2012; Ondemir and Gupta, 2014). Through the data collected, the performance and usage of a product can be evaluated accurately, and its current and predicted conditions can also be determined. Firms can utilize this information to determine the product's usage stage and understand the characteristics of the user and market segments, thereby providing strong support for product design and manufacturing. Therefore, firms need to develop dynamic management mechanisms to coordinate such data collection (Larsen et al., 2018).

In previous research (Kim et al., 2017; Dong et al., 2018; Jain et al., 2013), this technology is not considered, and scholars usually assume that maintenance occurs only when the product is broken or production is interrupted. After introducing technological advances, maintenance is performed adaptively with smart operations (i.e., preventative maintenance), which prevents major failures, expensive interruptions, and unnecessary part replacements. Introducing intelligent diagnostic technologies, such as data mining and statistical analysis, can allow the future condition of the product to be predicted, which generates many benefits, including cost reductions, with almost no interruptions to service. Therefore, by considering the influence of technology, firms' optimal decisions are expected to change considerably, and new studies are needed to fill this research gap.

Recycling and Remanufacturing: Studies focusing on recycling and remanufacturing in the context of SOM are limited; however, these concepts are critically important part of SOM. Different from traditional business models, SOM has advantages in remanufacturing due to technology advances in its products. Products with embedded sensors can eliminate the majority of remanufacturing uncertainties. Under SOM, a product is tracked during its use phase because of the built-in monitoring capabilities, which facilitates decision making about when to recycle and how to remanufacture (Ondemir and Gupta, 2014). Information from the product and component levels can be used for remanufacturing design, which not only improves the reliability of remanufactured products but also increases the value of remanufacturing.

6.2 Human behaviors

Manufacturers are facing the shift toward SOM; accordingly, they must engage with customer behaviors, which would considerably affect the profitability of servicing manufacturers.

Moral Hazard: Moral hazard has been widely studied, and considerable work has been conducted regarding how to optimize the design or introduce BI insurance to incentivize contractor effort. However, these novel mechanisms are designed to eliminate moral hazard between enterprises. They may not work between firms and final customers. Bardhi and Eckhardt (2012) claim that customers use products that they own more properly than products that they do not own. Moreover, as the servicing firms bear the operating costs and own the product, moral hazard in terms of overuse or other misuse is incurred. This phenomenon occurs because customers no longer worry about increases in maintenance costs or decreases in residual value. Overuse increases the revenue of firms, but operating costs also increase. In contrast of overuse, manufacturers may even worry about the risk that customers possess the product without using it or with an extremely low frequency of use. Such infrequent use damages the servicing manufacturer's profits considerably because a shorter duration of use implies less revenue, which can also be regarded as resource waste. Determining these behaviors helps servicing firms make optimal operating decisions and design effective mechanisms.

Ownership: Under SOM, servicing firms hope that customers focus on the service derived from the product instead of the actual product. Firms want to satisfy customer needs by offering multiple services and a lower variety of products. However, an overemphasis on services may lead to failures when customers have strong feelings of product attachment, which is defined as "the strength of the emotional bond a consumer experiences with a product" (Schifferstein and Zwartkruis-Pelgrim, 2008; Schifferstein et al., 2004). Bellos et al. (2017) report that when customers focus on the performance of cars, the sales strategy is preferred. At present, ownership is still the dominant mode of consumption. In practice, ownership can satisfy people's psychological needs, such as social acceptance and certainty, and the degree of product attachment affects the evaluation of the services. A lack of product ownership may lead customers to underestimate the value of the service (Demyttenaere et al., 2016). Car sharing helps people by reducing or eliminating costs, such as the expense of routine maintenance, insurance, and parking fees; however, many people still want to have their own car. The influence of product attachment on SOM may determine customers' acceptance of the SOM business model and also firm's profitability. Future research needs to focus on such attachment issues.

Novel Payment Impact: Under the sales or leasing strategy, customers can predict their expenses during a certain period fairly accurately. However, under pay-by-use contracts, predicting expense may be difficult because it depends on future usage. For some customers, this uncertainty also affects the choice to use servicing manufacturers.

Few papers have focused on these behaviors when studying SOM. Determining the effects of these behaviors assists servicing firms in developing effective contractual mechanisms to eliminate or utilize such effects of behaviors.

6.3 Financing

In view of their form of compensation, servicing manufacturers are more likely to be capital constrained. Such firms charge fees based upon usage time; thus, the fees are not paid instantaneously. Moreover, the products serviced for customers are usually durable goods, and the production of such goods typically requires a large amount of investment. Hence, at present, SOM is emerging primarily among large manufacturers (Michalik et al., 2019). When a manufacturer does not have sufficient money on hand to engage in SOM, financing becomes a matter of cardinal significance.

Normally, when facing financial constraints, manufacturers turn to banks or other financial institutions for loans. Tang et al. (2018) and Deng et al. (2018) find that international financing has unique advantages. As Buzacott and Zhang (2004) report, BMW and PSA pay suppliers in advance for parts, and Ford provides loans to suppliers. In comparison with the traditional business model, SOM leads to a closer relationship between the servicing manufacturer and the customers. We argue that internal financing may provide great advantages under SOM. Jiang et al. (2021) show that with internal financing, the service receiver may offer a subsidy to the manufacturer to obtain higher utility.

6.4 Pricing mechanisms

Limited SOM papers have studied pricing mechanisms. Bundles is a Dutch company that purchases appliances from a German manufacturer and charges customers a pay-per-wash fee based on their usage. Bundles sets different prices to meet different customer needs. In addition, different pricing strategies change customer behaviors, which in turn affects firm performance. Chan et al. (2014) empirically analyze how different payment structures affect service performance; thus, in comparison with fixed fee payments, pay-per-service increases the reliability of the service system. In addition, their evidence indicates that pay-per-service can improve the performance of the system and reduce its costs when the operator bears the risk of product failure. However, if the operating costs are borne by the manufacturers, then this form of compensation can lead to poor performance.

Under SOM, servicing manufacturers and customers may have concerns, such as the customer's loss of product ownership and the servicing firm's additional operating costs. Hence, firms can offer various services by using different pricing strategies. Lim et al. (2015) study whether leasing batteries or offering different charging options can increase the adoption of electric vehicles when considering resale anxiety. They find that the degree of resale anxiety affects the choice of battery owning and leasing combinations.

The study of pricing strategies may help researchers and practitioners better understand the effect of customer behavior. A good pricing strategy encourages more people to accept SOM and enhances its potential advantages. Bicycle-sharing firms usually set different payment structures to appeal to more customers. For example, some customers prefer to be charged by the duration of use after the use is complete, whereas other customers prefer to pay in advance for a future period of unlimited use.

6.5 Competition

In practice, servicing firms may face many competitors that sell or lease similar products. For example, before the rise of the sharing economy, auto manufacturers only sold cars; but now, many companies have launched car-sharing schemes. Tian et al. (2021) and Jiang et al. (2021) assume that prices under SOM are fixed due to competition.

We find few papers that consider the influence of competition. If a manufacturer (e.g., automaker) intends to enter a servitization market (e.g., car-sharing market), it has to consider the size of the sales and leasing markets. When a servicing firm decides to price a service derived from its products, it considers not only similar services provided by other servicing firms but also the similar products sold by other firms.

Even if a monopolist adopts a mixed strategy of selling and servitization, internal competition still exists. For example, a monopolist must determine the service price and the sale price and the number of products to offer in the servitization and sales markets, respectively. Tian et al. (2021) study how a manufacturer that intends to enter the servitization market decides optimally regarding the sale price and the quantity of products it will place in the servitization market. Introducing competition when studying SOM is necessary because it greatly affects firm decisions.

6.6 Empirical research on servitization

Research on servitization is still dominated by theoretical work, and additional empirical research is required. Xin et al. (2017) show that only a small number of qualitative studies exist on servitization.

We find that most empirical research on SOM is related to how SOM systems are designed, and few papers have found that servitization is superior to other business models. Benedettini et al. (2015) even find that servitization may lead to a greater amount of bankruptcy risks for the supplying firm. The problem is that the firm may not be able to handle the new risks incurred by adding services. However, some studies have shown that in practice, servitization has environmental and economic advantages over sales-oriented businesses. More empirical research is needed to evaluate the SOM business model adequately.

6.7 Role of government

SOM is being promoted in most countries around the world, especially in China. Many documents and policies are relevant to the promotion of SOM. However, papers that have analyzed the role of the government in SOM are limited. In the fields of recycling and carbon emissions, many scholars have studied how firms optimize their decisions under the relevant legislation (Zhou et al., 2021; Atasu and Souza, 2013; Atasu and van Wassenhove, 2012; Atasu et al., 2009). The rise of SOM depends on technology, but advanced technology cannot sufficiently make SOM widespread. We argue that the government plays an important role in the promotion of SOM. Studying how governments can make policies that affect the development of SOM is necessary.

7 Conclusions

The number of studies on SOM problems has been growing steadily in recent years, and many recent reviews show its influence on manufacturing. However, we find that most reviews focus on SOM from a macroscopic point of view. Thus, in our work, we have selected papers that can guide managers or governments in making operating decisions. We highlight papers that use mathematical modeling methods to examine firm decisions regarding business model options, product development, maintenance policies, and the final disposal of used products. We argue that these papers can help us better understand how SOM affects decisions.

On the basis of our analysis of the selected papers, we derive managerial implications. When introducing SOM, a firm should be cautious and fully consider its conditions and product features. The sales strategy and SOM are not mutually exclusive; they can be complementary. For example, for a high-end manufacturer, servitization facilitates its ability to reach the low-end market segment, which helps explain why many luxury automakers, such as Daimler and BMW, have entered the car-sharing market. In addition, SOM may not be better for the environment because it incentivizes increases in customer usage by producing excessive goods. For the government, we suggest that the promotion of SOM be rooted in the features of industries when formulating policies.

SOM has been studied for many years, but in practice, this business model is still being explored and tested. Many problems remain for further study. The introduction of new technology will overturn the original decision-making mechanisms. Thus, under SOM, a firm should optimize its organizational structure and supply chain management to align with this business model that is new to them. SOM is changing the relationships between customers and servicing firms. Accepting this new consumption pattern may take some time for customers, and firms should consider the effects of human behaviors when making decisions. More novel price or contract mechanisms should be implemented to encourage more customers to accept the SOM business model.

We hope that this paper will help scholars develop a comprehensive understanding of SOM. Moreover, the managerial insights in our paper should facilitate managerial decision making.

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