Scientia Iranica E (2020) 27(3), 1572–1592

Sharif University of Technology
Scientia Iranica
Transactions E: Industrial Engineering
http://scientiairanica.sharif.edu

Inventory model optimization revisited: Understanding service inventories to improve performance

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Received 23 January 2018; received in revised form 7 August 2018; accepted 3 November 2018

KEYWORDS
Service;
Inventory model;
Optimization;
Performance.

Abstract. Services are becoming increasingly important in the modern economy for both service and manufacturing firms; however, the inventory literature is focused mainly on physical goods and, thus, only few studies have considered services in optimization. Further to that, the traditional service management literature relies on an extremely narrow definition of inventory that excludes services because they are perishable. Thus, there is a lack of research on possible links between inventory optimization and service management. However, according to a new service inventory approach, business components such as tasks or information, as different from physical goods, can be performed and stored in anticipation of service demand as a form of service inventory, that is, inventorying by anticipation rather than delaying the service. This paper aims to contribute to this lack of research by proposing a service inventory optimization model that integrates a service orientation to optimize tasks and information to be performed in advance. In contrast with the traditional inventory models where the objective is to optimize physical items, in this approach, physical products (whenever included) constitute only mechanisms for service provision. This service inventory model contributes to the optimization of the quantity of tasks or information to be anticipated and, thus, provides customers with a number of benefits.

1. Introduction

Inventory is widely researched in production and operations literature [1] and deeply relevant to the performance of any organization. More than a century ago, Harris [2] proposed the first inventory model, Economic Order Quantity (EOQ), which became a classical reference due to its appealing simplicity, flexibility, and focus on optimization. Yet, this classical paradigm refers solely to physical products: unitary items that manufacturing companies can order in lots, store in a warehouse, and ultimately use to maximize their productivity, from groceries in retailing to spare parts in transportation to food in restaurants to medical items in hospitals. With this view, inventory management literature largely ignores the storage and optimization of non-physical components or service activities. Several inventory optimization models adopt an internal,

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doi: 10.24200/sci.2018.50333.1639

goods-oriented logic with a focus on optimizing benefits for the vendor, without addressing customers' needs.

For traditional manufacturing firms, this perspective makes sense. They frequently regard services as added value or simply a sales tactic to remain competitive. However, modern manufacturing companies are increasingly adopting service provision positions, transitioning from supplying goods to providing services that actually create value for customers [3–5]. According to this logic, the reason for any company to exist is creating value for its customers and shareholders; thus, it must integrate goods and services together to satisfy customers and stay competitive. Hence, to foster profit maximization and improve service quality on a long-term basis, companies need to strategically identify and manage the optimal levels of service productivity [6].

Even as services have become more important throughout modern economies, this topic continues to be excluded from the inventory optimization literature. As a result of a systematic search performed to identify papers featuring inventory models dealing with services, no inventory models addressing service activities were identified, leading to a knowledge gap. By expanding the understanding of inventory optimization issues in service businesses though, we could address this knowledge gap and maximize several service attributes including speed, quality, customization, and price.

Specifically, it is noted that traditional service management literature asserts that services cannot be inventoried because they are perishable [7,8]. For example, an empty seat in a plane cannot be kept for the next flight or a hotel room not sold tonight is lost forever. This focus on the impossibility of storing a delivered service for later use reflects an extremely narrow definition of inventory, in which services are finished products instead of bundles of attributes that are produced through sets of processes [9]. Yet, business components might also be performed and stored in anticipation of Service Demand (SD) as a form of service inventory [9,10]. In this form of inventorying, the central goal is anticipating, not delaying, the service. Such a service inventory approach might serve to expand a traditional optimization focus to include the non-physical components of the service organization. From this perspective, the service inventory is a set of intangible components (e.g., tasks, information) that can be performed before customer demand takes place. The goal is to identify which tasks or information can be conducted in advance to render the core service and create value. This selection depends on the characteristics of each market, the costs associated with creating the service inventory, and the desired competitive position. By developing a Service Inventory Optimization Model (SIOM) based on the EOQ model, this study aims to expand a traditional inventory and optimization focus to include services.

It is well known that traditional goods can always be stored physically in designated places such as warehouses, distribution centers, or other areas to have them ready for use. An important question thus is whether it might be possible to use a traditional EOQ inventory model to optimize services. From a rigorous perspective, the answer is no; the traditional EOQ inventory model has been developed to optimize inventories of physical goods, and this study argues that it cannot be applied to optimize a number of intangible tasks and information required during a service delivery process. Additionally, traditional inventory models work on the assumption that physical goods are standardized given their material attributes (e.g., size, weight, volume, etc.). In contrast, service processes, although following standardized protocols in many cases, experience a number of expected and unexpected changes and variations during their execution, and we argue that they require a different optimization approach from the products' perspective. Furthermore, a traditional EOQ inventory model calculates the cost of inventory as the product of the per-unit inventory cost and the inventory average, reflecting the notion that the inventory levels of physical units are constantly changing over time. However, in the service inventory model proposed here, service tasks and information that can be prepared in anticipation are always ready on a particular time horizon, with the corresponding costs. In turn, there is not necessarily an average use of tasks or information in calculating the inventory cost. This status justifies the construction of a new service inventory model; this paper proposes a service inventory model with a service orientation that seeks to optimize the tasks and information to be performed in advance, in which physical products function as mechanisms for service provision. Although different in focus and orientation, this approach still aims to reduce costs by optimizing the costs related to anticipating the execution of some portion of work that can improve customers' benefits in terms of service quality, speed, service variety (customization), or price. The challenge is to select and perform tasks or information that will be truly valuable for customers and that competitors cannot imitate, such that the business operations become unique. In this view, companies must rethink how and when they should use their resources, as well as how suppliers and customers can participate in advancing some tasks or information, to involve these partners in collaborative value co-creation roles.

In sum, service is the result of the interactions taking place between customers and suppliers through personnel, physical resources, and processes, aiming to satisfy customer needs [11]. Such processes require the execution of tasks and information. Traditionally, due to their intangible and perishable nature, services, arguably, cannot be "inventoried"; thus, they happen during the service delivery process. In this paper, a way to conceptualize service inventory is proposed by anticipating the execution of service tasks and information as a means to virtually "store" some part of the service to be performed, aiming to improve quality, customization, speed, and price. Based on this proposition, the service inventory model determines the optimal quantity of service tasks and information to be anticipated; therefore, they can be virtually "stored" to be ready for use before service is required by the customer. No existing service inventory model focuses on the optimization of anticipated intangible components (tasks and information) while integrating internal (provider) and external (customer) perspectives. Therefore, a multi-disciplinary approach is adopted that integrates EOQ inventory contributions with service management research to propose a new SIOM that contributes to the optimization of some part of the service (tasks or information) prior to customer demand and, thereby, provides benefits for customers including higher service quality, greater speed, enhanced service customization, or lower prices. The proposed service inventory model contributes to not only inventory research, but also service research, as this model is rooted in the notion that service components can be inventoried by incorporating the customer perspective; in addition, the model contributes to a better understanding of how anticipation and optimization might affect customer benefits.

The rest of the article is structured as follows. Section 2 begins with the proposed theoretical framework and a review of the existing EOQ inventory models. Section 3 presents a detailed derivation of the proposed service inventory model. Section 4 contextualizes the service inventory model with some service business examples. Finally, Section 5 details the conclusions and Section 6 offers some suggestions for further research.

2. Theoretical framework

2.1. Existing work on EOQ inventory models

Sellers of goods must determine the quantity of products to purchase from suppliers to satisfy customer demand and still achieve profitability. Lot sizing and optimization thus are critical issues for manufacturing companies, with direct impacts on the economic efficiency of their activities; therefore, various approaches in prior literature address these challenges (e.g., [12]. The EOQ inventory model can determine optimal inventory levels while minimizing the total cost associated with the purchase, delivery, and storage of products [1,2,13]. A century after its initial publication, the EOQ has extended in various ways, as researchers have added incremental conditions in an attempt to model real-world situations. Thus, the EOQ provides a foundation for a large number of papers that relax different restrictions to build new inventory models with emphasis on cost and profit, which reflect specific, actual situations.

An early extension of the EOQ sought to resolve scheduling difficulties associated with lot sizes [2,14]. Later research included quantity discounts [15], the production (or replenishment) rate, backorders with stockout penalties, and inflation [16,17]. A dynamic version of the lot-sizing problem also appeared [18]. The extensions of the EOQ grew exponentially, leading to EOQ with multiple setups costs [19], a present value formulation [20], a stochastic version [21], temporary one-time discounts [22], an EOQ with learning [23], EOQ models with nonlinear holding costs [24], deteriorating items [25–28], supplier credits [29], imperfect quality [30,31], recycling [32–34], EOQ for reverse logistics environments [35,36], and partial and full backordering [37,38] to mention just a few.

In several good reviews of EOQ inventory modeling approaches, Pentico and Drake [37] summarized EOQ inventory models related with partial backordering, while Khan et al. [39] offered an overview of all extensions with imperfect quality, and Bouchery et al. [40] reviewed the integration of the EOQ inventory model into sustainability research. Andriolo et al. [41] explored the evolution of these extensions over a century and, also, provided a research agenda that suggests, among other things, developing integrated inventory models to include environmental aspects for sustainable supply chains and studying the social impact of inventory and purchasing decisions. Glock et al. [42] provided an excellent survey of literature reviews on EOQ models to help primary researchers position their own research, reveal the different types of EOQ inventory models, and identify new starting points for research. Janssen et al. [43] presented an up-to-date review of perishable inventory models, which is a complement to the review of Bakker et al. [44]. Shekarian et al. [45] presented an ample review in the arena of fuzzy inventory management with the aim to identify and classify the main achievements obtained. Recently, Kok et al. [46] proposed a typology for the multi-echelon inventory field. This typology is applied to categorize and review the widespread research of multi-echelon inventory models under uncertain demand.

2.2. Inventory models with service components

Despite the extensive literature on inventory models and optimization, few studies have considered service as a core factor or component. Recognizing the evident need to develop a theoretically solid and managerially relevant conceptualization of inventory models, we reviewed existing research to build on those pieces that have discussed service issues. Specifically, to identify papers that feature inventory models dealing with services, we searched for "service inventory model" in the Scopus database, restricting our search to paper titles so that we could find publications whose primary consideration was service in inventory models. No publications used "service inventory model" as a compound term; thus, we modified this search to identify publications including any of these three words in their titles. As a result, 72 papers, from 1981 to 2018, were found, and both their topics and the components included in their proposed models were reviewed. After excluding the articles that did not feature any service notions, 42 papers were obtained that could help us determine how the term "service" was conceptualized. According to this analysis, in existing inventory literature, service refers to the service level and plays a role as an indicator of system performance, either as a conceptual notion or a component within inventory models.

For example, five articles that linked the service level, as a conceptual notion, to other performance measures such as the accomplishment of pre-established target goals, quality, or responsiveness were found. Thiel et al. [47] showed that service-level quality was a non-monotone function of the inventory record's inaccuracy rate; Samadi et al. [48] asserted that the quality of the services offered to customers was a significant factor that directly affected demand and, therefore, must be considered for developing inventory models. With a Monte Carlo simulation model for a legal firm, Swenseth and Olson [49] built a professional service inventory chain, taking into account the need to satisfy demand, minimize costs, and maintain a good quality level, such that professional services personnel were managed as inventories. Gzara et al. [50] proposed two integrated network design and inventory control models for a service-part logistics system to fulfill warehouses' service-level requirements and, finally, Byun et al. [51] derived a probabilistic inventory model for wireless service providers.

In the remaining 37 publications, the service level as a component of the inventory model constitutes the predominant approach. In these existing models, the service level denotes the rate at which performance goals are achieved (e.g., the percentage of calls answered by a call center); therefore, it mainly functions as a constraint.

The service level constraint refers to the availability of the stock needed to deliver the expected service level at a minimum cost, which may reflect three common service-level measures: the stockout or ready rate α, the fill rate β, or the cumulative fill rate γ service level. According to Schneider [52] and Chen and Krass [53], the α service level reflects the probability that the inventory on hand does not fall below a critical level at the end of any period; the β service level expresses the expected fraction of demand covered from inventory on hand in any period; in addition, the γ service level expresses the expected ratio of cumulative demand that can be covered from inventory to the total cumulative demand during the lead time, plus a review period. This measure is thus equivalent to β, except that the ratio spans multiple periods rather than just one unique period.

As is shown in Table 1, most inventory models include service level as a constraint using the fill rate level. In all cases, the service level constraint is imposed while minimizing the total cost of an inventory system.

Inventory models are also traditionally focused on systems optimization to accomplish performance goals; however, more recent research increasingly expands the model restrictions to include new components, as service levels, and thus better simulate real-world situations. Over time, inventory models have become more sophisticated, especially as supply chains grow to involve more actors and operations facing more complex circumstances. All these contributions allow for cost reductions and better performance, but they also have neglected intangible components and customer needs. This knowledge gap strongly indicates the need for a wider, multidisciplinary approach to integrate service components in inventory models.

2.3. Service research with an inventory component

Service research initially emphasized goods versus services dichotomy. Services were defined in relation to goods and how they could be produced and marketed. The distinctive characteristics of services such as their Inseparability, Heterogeneity, Intangibility, and Perishability (IHIP) were considered unique to them and, in a traditional goods-oriented logic, value was attached to the product or service from the provider's perspective only [54]. However, IHIP characteristics might be neither exclusive nor generic to services, since they vary across different situations and conditions. Therefore, IHIP characteristics require further exploration from a customer perspective, particularly in relation to how to manage them to create memorable customer experiences [55].

The resulting paradigm change challenges the idea that inventories are limited to material goods [10,56]. Services might be "stored" in systems, machines, knowledge, people, and networks in line with a metaphor in which "the ATM is a store of standardized cash withdrawals. The hotel is a store of rooms" ([56], pp. 123–24). In other cases, services might be routinely inventoried before "production," purchase, or consumption, as the case of airlines or theaters, rather than solely after production. "When a university hires

Table 1. Existing inventory models integrating service level components.

Authors	**Service component**	**Main contribution**
Schneider [52]	Service level as constraint (stockout level, fill rate level, and cumulative fill rate level)	Evaluation of three common service-level measures
Mehrez & Ben-Arieh [71]	Service level as constraint (stockout level)	Extensive multi-item inventory model with probabilistic demand and service level constraints
Lagodimos [72]	Service level as constraint (stockout level, fill rate level, and cumulative fill rate level)	Multi-echelon models for evaluating the service performance of two-echelon divergent networks operating under periodic review statistical inventory control echelon-based policies and using either a push or a pull rationing policy
Ouyang & Wu [73]	Service level as constraint (fill rate level)	Mixture inventory model with lead time and order quantity as decision variables.
Hillier [74]	Service level as constraint (stockout level)	Multiple-period model with service level constraints to compare the effect of commonality in single- and multiple-period cases
Ouyang & Chuang [75]	Service level as constraint (fill rate level)	Mixture inventory model with backorders and lost sales, where the stockout cost term in the objective function is replaced by a service level constraint
Ouyang & Chuang [76]	Service level as constraint (fill rate level)	Mixture of back-orders and lost sales periodic review inventory model subject to a service level constraint, where both the lead time and the review period are decision variables
Chen & Krass [53]	Service level as constraint (stockout level, fill rate level, and cumulative fill rate level)	Inventory models in which the stockout cost is replaced by a minimal service level constraint that requires a certain level of service to be met in every period
Xu et al. [77]	Service level as constraint (fill rate level)	Approximate analytical two-location inventory transshipment model combining the order-quantity, reorder-point (Q, R) continuous review ordering policy with the hold-back amount, which limits the level of outgoing transshipments.

Table 1. Existing inventory models integrating service level components (continued).

Authors	**Service component**	**Main contribution**
Lee et al. [78]	Service level as constraint (fill rate level)	Continuous review inventory model considering the mixtures of distribution of the lead time demand including a service level constraint in which the lead time, order quantity, and reorder point are decision variables
Chu et al. [79]	Service level as constraint (fill rate level)	Revised algorithms for mixed inventory backorder and lost sales problem in which both the lead time and order quantity are treated as decision variables, as developed by Ouyang and Wu [73]
Lee et al. [80]	Service level as constraint (fill rate level)	Continuous review inventory model considering the mixtures of distribution of the lead time demand and controllable exponential backorder rate. Service level constraint is also included, considering lead time and the order quantity as decision variables
Liang et al. [81]	Service level as constraint (fill rate level)	A simplified and theoretically rigorous algorithm to improve the weaknesses and shortcomings of Ouyang and Chuang [76]
Hung et al. [82]	Service level as constraint (fill rate level)	Refining Ouyang and Chuang's [76] algorithms to provide an optimal replenishment solution for decision-makers
Jha & Shanker [83]	Service level as constraint (fill rate level)	A model for an integrated vendor-buyer problem to jointly determine the optimal order quantity, lead time, and number of shipments from the vendor to the buyer during a production cycle while minimizing total expected costs of the vendor-buyer integrated system including service level constraints
Jha & Shanker [84]	Service level as constraint (fill rate level)	Single-vendor, single-buyer integrated production inventory problem for decaying items
Tajbakhsh [85]	Service level as constraint (fill rate level)	Continuous-review (Q, R) inventory model with a fill rate service constraint, relaxing the assumption that the distribution of lead time demand is known
Xu & Sun [86]	Service level as constraint (fill rate level)	A multi-item, multi-echelon inventory system that allows lateral transshipments, direct delivery, and emergency ordering following stockouts

Table 1. Existing inventory models integrating service level components (continued).

Authors	Service component	Main contribution
Jaggi & Arneja [87]	Service level as constraint (fill rate level)	Exploration of the benefits of just-in-time philosophy relative to reduced lead times and setup costs in a periodic inventory model with service level constraint, when the protection interval demand is normally distributed.
Joshi & Soni [88]	Service level as constraint (fill rate level)	A model with service level constraint and controllable lead time in a fuzzy stochastic environment in which expected shortages are calculated using the credibility distribution, treating lead time demand as fuzzy stochastic.
Cheng et al. [89]	Service level as constraint (stockout level)	Proposition of two variants of a production planning problem in the hybrid push-pull systems.
Lin [90]	Service level as constraint (fill rate level)	A mixed inventory policy for a controlled setup cost in the stochastic continuous review model, involving controllable backorder rate and variable lead time in which the stockout cost is replaced with a service level constraint
Ma & Qiu [91]	Service level as constraint (fill rate level)	A distribution-free continuous review inventory model in the presence of a service level constraint
Shahpouri et al. [92]	Service level as constraint (fill rate level)	An integrated vendor-buyer inventory model considering the lead time and ordering cost as decision variables. To avoid imprecision in estimating shortage costs, the service level constraint is considered
Jha & Shanker [93]	Service level as constraint (fill rate level)	An integrated production-inventory model in a batch production environment for supplying a set of buyers, with a service level constraint for each buyer
Hidayat et al. [94]	Service level as constraint (fill rate level)	A two-echelon supply chain inventory model for a single supplier and single buyer of one product, facing a stochastic demand condition with the reorder point as a decision variable, solved simultaneously with the buyer's order quantity, length of lead time for the buyer, and number of shipments using the service level constraint in place of the shortage cost.

Table 1. Existing inventory models integrating service level components (continued).

Authors	Service component	Main contribution
Bieniek [95]	Service level as constraint (stockout level)	A model considering inventory location, where the decision is made to minimize the holding costs and supply costs of safety stock from the central warehouse to the customer.
Jiang et al. [96]	Service level as constraint (fill rate level)	A two-echelon inventory model with one supplier and several retailers to satisfy certain service levels and minimize total inventory cost
Cheng et al. [97]	Service level as constraint (fill rate level)	Two bi-objective inventory models to minimize inventory costs while maximizing customer service using cycle service level and fill rate.
Sarkar et al. [98]	Service level as constraint (fill rate level)	Extension of the model of Moon and Choi [99] with the consideration of setup cost reductions and quality improvement. Initial investments and the service level constraint are used to obtain the optimal result.
Yilmaz et al. [100]	Service level as constraint (fill rate level)	Service level equation with a different approach in the forward-reserve models
Annadurai [101]	Service level as constraint (fill rate level)	A distribution-free continuous review model in the presence of a service level constraint for optimizing lead time by considering an extra crashing cost and ordering cost
Jaggi et al. [102]	Service level as constraint (fill rate level)	Revision of Ouyang and Chuang [76] and Liang et al. [81] for a wide range of the levels of service when demand during the protection interval (T + L) is normally distributed
Kurdhi et al. [103]	Service level as constraint (fill rate level)	An integrated production-inventory model for a single-vendor, two-buyer problem with partial backorder and controllable lead time under independent, normally distributed demand among buyers. Service level constraint corresponding to each buyer is included to limit shortages.
Kurdhi et al. [104]	Service level as constraint (fill rate level)	Two fuzzy continuous review inventory models under service level constraint in the case of partial backorder and when the quantity received is uncertain, where order quantity, reorder point, lead time, and ordering cost are decision variables

Table 1. Existing inventory models integrating service level components (continued).

Authors	Service component	Main contribution
Hemapriya and Uthayakumar [105]	Service level as constraint (fill rate level)	Addressing the feasibility of decreasing the ordering cost and the lost sales due to stockout in a continuous review inventory model with shortages considering the situation when the quantity received is uncertain. This inventory model considers service level constraint. Here, the lead time crashing cost is a function of negative exponential lead time.
Jauhari and Saga [106]	Service level as constraint (fill rate level)	A joint economic lot-sizing problem under stochastic demand for a vendor-buyer system is proposed. Here, the demand and the buyer's ordering cost are considered to be fuzzy. The vendor's manufacturing process is imperfect and the buyer's screening process is imperfect too. Additionally, the vendor has the opportunity to make an investment to reduce the setup cost.

a new professor, tapes a lecture, or assigns resources for a course in a future semester, in effect, it is inventorying part of an educational service, and when students internalize the values of university education, they have inventoried the knowledge and skill base for lifelong learning. In short, they have created human capital that they can draw on for their benefit over many years or decades" ([54], p. 331).

Accordingly, service inventory alters the way service is conceptualized and operationalized. Following the definition offered by Vargo and Lusch ([54], p. 334), services are the "application of specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself." Therefore, they might be considered sets of interactions that take place before, during, and after service delivery, through which service providers and customers co-create value. The interactions involve task performance, information, and other resource exchanges and affect how customers perceive the services as benefits [57].

Due to the dynamic nature of services, many researchers have attempted to find new ways to manage service capacity, increase productivity, and enhance service quality while still maximizing profits. Diverse tools and techniques have been developed to address the main issues of service operations management [58]. For example, queue and bottleneck management tools function to manage demand, especially in settings where capacity is a constraint, based on the premise that queues are inevitable. Because perceived waiting time tends to be greater than actual waiting time, these techniques attempt to reduce perceived waiting time at defined levels of resource utilization [59]. Thus, they emphasized the relevance of identifying key tasks that represent bottlenecks. Even when queuing and bottleneck management do not address service inventory, the identification of key tasks can highlight areas where a service component can be inventoried.

Operations planning and scheduling techniques focus on finding a balance between demand and supply plans at all levels by forecasting demand and organizing operations to match it, integrating overbooking, or stabilizing revenues to counteract customer no-shows [60]. By planning operations, the firm can maximize its resource utilization and minimize its costs. Optimization is a key component, though even if some tasks or complete services could be scheduled and performed in advance, no formal model details a process for inventorying tasks to increase customers' benefits.

Another common concept in service operations management centers on service capacity and demand using Service Level Agreements (SLA) to lay out the terms, conditions, and penalties for the delivery of services between a service provider and customers. An SLA specifies the services to be delivered in a business relationship and exclusions; it describes how the service provider's performance will be measured and provides a legal structure for relationship management including contract monitoring and dispute resolution. It also specifies the remuneration for core services and expenses incurred and offers a means to calculate the cost of additional (non-core) services [61,62]. A key advantage of SLA is that it prepares both provider and customer to co-create the service, with the potential for identifying tasks and information that need to be performed or obtained before the service can be delivered. However, their application has been limited to specific industries.

In contrast, the yield management approach, originally used by airlines, is widely adopted to help service firms in various industries manage their service capacity more profitably. This technique applies information systems and price strategies to maximize company revenues and profit. Prices are set according to predicted demand levels, allowing price-sensitive customers who are willing to purchase at off-peak times to obtain favorable prices, while price-insensitive customers who want to purchase at peak times also can do so [63,64]. Yield management uses reservation systems to distribute demand [65]. These practices represent a type of service inventory, from the provider's perspective, because they help minimize costs and maximize profits. However, yield management does not address customers' needs. With focus on profits, it is frequently perceived by customers as unfair, especially in industries where the practices are not common [66–68]; therefore, it affects perceived service quality.

The increasing use of information systems also has made data analysis more relevant across all the previously mentioned techniques. Data mining, as an interdisciplinary approach, supports the discovery of patterns in large datasets by leveraging artificial intelligence, machine learning, statistics, and database systems. The main goal is to extract information and turn it into valuable knowledge about business activities (markets, employees, customer habits and preferences, patterns, and trends); therefore, it represents a very useful tool to manage capacity and demand [69].

The contributions discussed in this section have been made mainly by service academics and practitioners, looking for innovative ways to maximize service efficiency, quality, and profits. However, in this goods-dominant logic, strategies focused on internal criteria and customers play passive roles, mainly as recipients and not as participants, such that their needs are rarely even considered. Optimization has a role, but not necessarily focused on customer benefits. Despite some of these approaches that are based on the notion of planning or forecasting service operations, we found no evidence that they conceptualized anticipation as a service component to be optimized. Thus, we argue for the need of developing a service inventory model that addresses service from a wider perspective as a collection of processes including intangible components (tasks and information) that can be anticipated and optimized to maximize both organizational and customer benefits.

2.4. Service inventories

As discussed previously, the dominant view in inventory research implies that only physical products can be inventoried. The lack of research on non-physical components in inventory models may be due to the difficulty associated with modeling inventory service tasks or information. Service inventory based on tasks or information differs completely from product inventory; therefore, the considerations in managing service inventory must be distinct from those in managing physical products. Many service textbooks promote the notion that intangibles such as services cannot be stored [70]. However, the previously noted change in the way that service characteristics (Inseparability, Heterogeneity, Intangibility, and Perishability - IHIP) have been conceptualized emphasizes the need for an extended service inventory definition. From this perspective, some service operations management concepts might be considered precedents of service inventories; however, no integral approach exists that translates these efforts into customer benefits.

According to Chopra and Lariviere [9], a service inventory includes the processes performed before the clients' arrival, to request a service. Thus, a kind of buffer of service tasks or information arises to help deal with variability in demand and establish a quicker response time to clients' requests. In other words, service tasks or information might be completed by the anticipation of demands so that organizations can create customer value through better response times, quality, customization, and prices. In this process, customers engage in different levels of participation either as part of the anticipation, by providing information or performing a task, or as a beneficiary of the service anticipation [9,10]. These arguments suggest the potential for a new SIOM, as detailed next.

3. Towards developing a Service Inventory Optimization Model (SIOM)

The proposed service inventory model is based on the analysis of the traditional EOQ inventory model components and key concepts from service research. In building this model, we consider anticipation, of tasks or information, as a cost; this anticipation cost is the main unit of analysis and the variable to be optimized. Thus, the selection of key tasks and information to be anticipated represents a significant decision, determined by the provider, depending on its industry, performance goals, and expected impact in terms of customer benefits (quality, speed, customization, and price). In line with the traditional EOQ model, different cost categories are also considered to build this service inventory model, namely Service Inventory Organization Costs (SIOC), Service Inventory Execution Costs (SIEO), and Service Inventory Costs (SIC). However, as different from inventorying manufactured goods, these sets of costs are developed to reflect the need for organizing, executing, and preparing the use of those anticipated tasks and information as a way of service inventory.

In contrast with the traditional EOQ model where the inventory level is changing over time requiring an average inventory level to be calculated, in the Service Inventory Optimization Model (SIOM), there is no need for "storing" tasks and information limited to physical space; they could be virtually "stored" almost infinitely. Therefore, there is no need to establish a parameter to determine the moment at which service tasks and information should be anticipated again in the service process. This always allows keeping the optimal level of tasks and information virtually "stored", guaranteeing the appropriate service provision to customers and improving quality, customization, speed, or price.

In this section, the arguments for identifying each of the cost components of the SIOM are detailed next; in general, service dynamics across pre- and production stages is captured and the operationalization of service inventories is enabled [9].

3.1. Service Inventory Organization Cost (SIOC)

The anticipation of tasks or information to ensure that the service is ready to be provided when the client needs it is crucial in competitive markets, especially because perceived waiting time has such a notable influence. Long waits might even cause customers to decline to buy the service, leading to lost sales. Identifying which relevant tasks and information to anticipate and getting organized to anticipate them can create costs, or *service inventory organization costs (SIOC)*, which can be expressed in dollars per anticipation. That is, SIOC represents the cost of getting organized to perform each anticipation of tasks or information to be ready to serve customers such as gathering resources required to ensure the tasks or information are ready before they are required as part of the service.

3.2. Service Inventory Execution Cost (SIEC)

The cost of actually performing tasks or information in advance can be expressed in dollars per anticipated task or information. It constitutes the *Service Inventory Execution Cost (SIEC)*.

3.3. Service Inventory Cost (SIC)

When a service is delivered, those service tasks and information anticipated before are used (in that service) and, thus, they are anticipated again to keep the optimal number (of tasks and information). Thus, following the anticipation, tasks or information are "waiting" for some time before being used; then, once used, they are immediately "replaced" by new ones so that they can always be ready for the next customer. In this case, there is a related *Service Inventory Cost (SIC)*, accounted for in dollars per task or information and per time unit. That is, SIC is the cost incurred for having the anticipated task or information ready and waiting to be used as part of the service. As explained earlier, virtually "storing" these anticipated tasks or information always allows keeping their optimal level needed to be ready for use without waiting for a "reorder" level, as there is no need to establish a parameter to determine the moment when service tasks and information should be anticipated again in the service process, guaranteeing the appropriate service provision for customers and improving quality, customization, speed, or price.

This conceptualization represents a key difference from the traditional EOQ model, where the inventory level is changing over time requiring an average inventory to be calculated due to physical space limitations related to tangible goods, thus requiring the definition of a reorder parameter.

3.4. Service Demand (SD)

Service Demand (SD) reflects the total number of services performed to satisfy customers' requirements. Every time a customer requests a service, some tasks must be performed, and information must be used to cover the SD. Based on the goal to be achieved in terms of customer benefits, SD might include a predetermined number of anticipated tasks or information. Thus, SD is expressed as the total tasks or information per time unit.

3.5. Quantity of Service Inventory (QSI)

The decision variable in the service inventory model is the quantity of service inventory (QSI) that is equal to the quantity of tasks or information required to be conducted in advance to be ready when the service is requested by the customer so that the service provider can co-create value with customers.

3.6. Total Service Inventory Cost (TSIC)

The *Total Service Inventory Cost (TSIC)* comprises three category costs. First, the *total SIOC* of all anticipations during a planning horizon (e.g., a year) is the product of the cost of getting organized to perform one anticipation (SIOC) and the number of anticipations required on that time horizon. The number of anticipations is equal to the total SD divided by the QSI ($\frac{\mathrm{SD}}{\mathrm{QSI}}$). Therefore, total *SIOC* can be expressed as follows:

$$\frac{[SIOC][SD]}{QSI}.$$

Second, this paper includes the *TSIC* of tasks or information performed in anticipation, which is the product of the SIC and the QSI. Each anticipation is conducted and "stored," waiting to be used as part of the service and, then, is immediately replaced;

therefore, this cost is always recurring. The *TSIC* of tasks or information is therefore determined as follows:

$$[SIC][QSI].$$

Third, the *total SIEC* of all anticipations is calculated by multiplying the SIEC associated with each anticipated task or information to satisfy customers' SDs. Formally,

$$[SIEC][SD].$$

Combining these three cost categories, we can derive the *TSIC* function to be optimized (TSIC) as follows:

$$TSIC(QSI) = \frac{[SIOC][SD]}{QSI} + [SIC][QSI] + [SIEC][SD].$$

3.7. Service Inventory Optimization Model (SIOM)

The preceding function contains a unique decision variable, namely the QSI. Simplifying the SIOM with differential calculus, we obtain:

$$QSI = \sqrt{\frac{[SIOC][SD]}{SIC}}.$$

Therefore, the SIOM indicates that the optimal quantity of service tasks or information to be performed in anticipation depends on the square root of the product of the cost of anticipating tasks or information and the tasks or information required to satisfy SD, divided by the SIC.

4. Contextualization of the SIOM

To highlight the relevance of the proposed new SIOM, contextualization is provided using general examples of different service tasks: preparing content for streaming, enabling mobile banking transactions, preparing practices and tools to provide business consultancy, and customizing high-end hotel room facilities according to customer needs, preferences, and habits. Services are becoming increasingly reliant on information and, due to technological advances, they include tasks that can be performed in advance to improve quality, reduce price, increase customization, and speed up service provision. Different inventory costs and model components for each of the examples are shown in Table 2 in detail. Each contextualization case begins by detailing the internal criteria used to select the tasks or information to be anticipated. Then, each model component is contextualized for a range of selected cases. The external criteria for optimization (quality, customization, speed, and price) then lead to the brief descriptions of the functions to be optimized. Finally, in Table 2, how customers participate in advancing tasks or information, as well as in the service itself, is explained.

4.1. Anticipating part of the service

The selection of tasks and information to be anticipated depends on the characteristics of the industry, the costs associated with anticipation, expected business performance, and the expected customer benefits (quality, price, customization, and speed). This process is relevant, in that the anticipation of selected tasks or information represents the service components to be optimized.

For example, for content streaming, the selected anticipation is a specific content (movie, song) that is ready to be delivered, 24/7. In this industry, having songs, movies, and other digital contents ready prior to customer demand is an absolute necessity, because customers expect a quick response and the flexibility to customize their content selection according to their preferences. For mobile banking, anticipation entails banking operations that are ready to be performed through mobile devices. Similar to content streaming, this anticipation reflects industry practices and customer expectations of availability, security, and customization.

In a business consultancy setting, the tools and practices must be ready to be used before the customer requires them, which offers a representative example of how work can be performed in advance and stored, even when customers have completely different profiles and needs. Finally, in the high-end hotel example, the costs are associated with creating customized rooms that match specific customer preferences, needs, and habits, even before customers' arrivals. All these practices are required, because they largely determine customer satisfaction, offering a representative example of customer participation relevance in service anticipation. In all of these cases, information technology plays a key role as an enabler of service anticipation.

4.2. Service Inventory Organization Cost (SIOC)

The SIOC, as defined previously, is the cost of having all the resources required to perform each anticipation of task or information and, thus, advance the service to be delivered to customers. In content streaming services, this cost may entail paying for the rights to the movies or songs to be streamed, including careful selections of the premiere and classical movies, songs, or videos. The cost of these rights likely varies according to factors such as novelty and demand. The cost of being prepared for customers' content selections also involves developing robust information technology infrastructure (e.g., servers, software, and information systems) that can store and manage vast amounts of digital content and enable customers to

Table 2. Service inventory model: components, criteria, contexts, and functions.

Model components/ case (optimization internal criterion)	SIOC	SIEC	SIC	SD	QSI	Optimization of external criterion (customer)	Function optimized with model (internal + external criteria)	Customer participation
Content streaming (adding/eliminating, accessing, streaming) Process to deliver specific content to watch or hear through streaming, 24/7 (e.g., Netflix, Spotify)	Cost of paying for movie/series/song rights to stream content Cost of developing a system to select and customize preferences Cost of developing an ICT infrastructure to store and deliver high-quality digital content 24/7	Cost of uploading content for streaming Cost of categorizing uploaded content	Cost of maintaining content to be available online	Type and amount of content available at any time for customer access	Optimal amount of content to buy and keep available	Lower price Greater customization	Anticipating content availability to allow customers to select it freely	Customer provides information about preferences and habits. Customer selects content, place, time, and frequency of use, according to suggestions.
Mobile banking (accessing, validating, operating, and securing) Process to deliver banking operations (consultations, transfers, and payments) through mobile devices 24/7	Cost of developing banking policies for mobile devices. Cost of developing a mobile operations portfolio Cost of developing ICT infrastructure to provide safe, fast, reliable mobile banking operations 24/7, including security elements (firewalls, tokens, and cards)	Cost of making banking information available through mobile devices	Cost of maintaining banking information available online	Amount of information available at any time to perform customers' mobile transactions	Optimal amount of information available at any time to perform mobile transactions	Faster speed	Anticipating information availability to allow customers to transact with mobile devices	Customer downloads and configures mobile banking apps Customer decides to access and exchange information to perform transactions at chosen place, time, and frequency

Notes: ICT = Information and Communication Technology.

create digital accounts and customize their preferences. These aspects must be ready in anticipation of the tasks and information associated with streaming services. Similarly, for mobile banking, the cost of preparation for customers' selection of operations includes the development of robust information technology infrastructure; however, it features the costs of adequate security policies for banking transactions.

In business consultancy services, the cost of organizing the service inventory may involve the identification and selection of relevant tools and practices such as simulators, surveys, or business analytics tools that might facilitate the consultancy process, which have costs to acquire. In this case, an important anticipation cost relates to the selection and hiring of specialized staff, who can make an adequate balance between business customer needs and selected tools and practices. The creation of a mechanism to enable data transfers and sharing is another important cost for these services.

Finally, for high-end hotel services, preparation for customizing room facilities involves the cost of developing a set of personalization options and policies for customers, reflecting the elements most valued by customers and, also, a careful evaluation of the limits of what a hotel can offer without affecting other

Table 2. Service inventory model: components, criteria, contexts, and functions (continued).

Model components/ case (optimization internal criterion)	SIOC	SIEC	SIC	SD	QSI	Optimization of external criterion (customer)	Function optimized with model (internal + external criteria)	Customer participation
Business consultancy (diagnosing, advising, and assessing) Process of preparing tools and practices to provide business consultancy services to corporate clients	To identify and select standard tools and practices for business consultancy Cost of creating a business information database (markets share, trends, etc.) Cost of creating data sharing infrastructure Cost of getting specialized staff	Cost of selection, purchase, and storage of business information Cost of developing a catalogue of standard tools and practices for diagnosing, advising, and assessing companies Cost of training consultants to use standardized tools and practices	Cost of specialized staff Cost of maintaining business information database Cost of maintaining a sharing information platform	Type and amount of tools and practices required to satisfy business customers' demands	Optimal number of tools and practices available to conduct consultancy	Higher quality Faster speed	Anticipating staff and resource (information, practices, and tools) availability to provide business consultancy services	Business customer does not participate in anticipation Business customer defines goals to be achieved during the consultancy process.
High-end hotels (booking, registering, hosting) Process of customizing rooms according to customer preferences, special needs, and habits (e.g., Ritz-Carlton, Marriot)	Cost of developing customization options and policies for customers. Cost of developing ICT infrastructure to support online information exchange, storage, and transactions Cost of developing a flexible operation policy that allows for special requests and empowers employees	Cost of preparing hotel rooms according to customer preferences, special needs, and habits	Cost of maintaining customized rooms ready but not being used	Number of customized rooms ready to be used	Optimal number of customized rooms ready to be used	Higher customization Higher quality	Anticipating room availability with specific requirements	Customer provides data about the stay (dates, number of guests), personal room preferences, special needs, and habits.

Note: ICT = Information and Communication Technology.

customers. It also might entail costs to acquire specific products and items (e.g., pillows, cradles, wheelchairs, and sheets). An information system is also required to support the registration and track customers' requests and preferences.

4.3. Service Inventory Execution Cost (SIEC)

The SIEC is the actual cost of performing the selected service anticipation. In the case of content streaming services, it may include tasks related to categorizing and uploading digital content. Even if this process can be automatized, it still involves some cost, which is likely the key to making customer selection more efficient. Even if mobile banking transactions can be automated, the cost of executing the defined policies and creating an operations portfolio for each customer similarly must be considered. For business consultancy services, the cost relates to the development of standardized processes to apply previously selected tools and practices to different business scenarios, including costs to train consultants in the use of standard tools and processes. Finally, high-end hotel services incur costs to adapt room facilities to special needs and customer requests, such as adding pillows, adapting the temperature, changing the sheets, or installing a cradle before a customer's arrival. It may also involve the cost of employees who are required to make these adaptations.

4.4. Service Inventory Cost (SIC)

Once the task or information has been anticipated, the "waiting" period begins before delivering the service. For digital content streaming and mobile banking services, it likely includes the cost of maintaining content or information online. Technology costs have steadily decreased; however, this cost might still entail the potential risk that customers do not select some contents for which the streaming service has paid or do not need extreme security policies that the bank has established. In the business consultancy setting, the cost instead refers to maintaining business tools and practices (e.g., licenses, memberships, and access) and keeping highly specialized staff "on call" to offer diagnosis and advice to customers. For high-end hotel services, these costs entail customizing room facilities according to the needs and preferences of specific customers, ready to be used. The cost of not having that room available for other customers is also featured in the SIC.

4.5. Service Demand (SD)

In this context, SD is the amount of tasks or information required to satisfy customer requests. Considering streaming content services, SD is not only the quantity but also the type of content that must be available for customers to select among, which in turn requires a deep analysis of customer demand patterns and external information such as new contents and formats that are likely to be released in the future. In mobile banking, it represents the mobile operations and data required to fulfill customers' requests. For the business consultancy, SD represents the number of consultants, tools, and practices needed (tools configured and employees trained) to provide service for customers. For example, if a business customer requires advice on talent management, the consulting company needs to have a human resources specialist available. Finally, SD relates to the number of rooms that needs to be available for customers' use in the hotel example.

4.6. Customer participation and impact of anticipation

Anticipation should have effects on quality, speed, customization, and price; in the contextualization presented here, customers can function as either participants or beneficiaries. In the content streaming setting, customers participate by providing information about their preferences and habits and, as a result, they benefit from paying lower prices for contents due to economies of scale and from receiving greater customization related to when, where, and how to access the selected contents. In mobile banking, customer participation is mainly a beneficiary and able to access and exchange information to perform quick mobile transactions anytime and anywhere. Customers of the business consultancy service do not participate in anticipation; however, as beneficiaries, they receive higher service quality and speed, because the consultants have been previously trained and prepared with the most relevant tools and practices to respond to these customers' demands. When the high-end hotels prepare room facilities according to customers' needs and preferences, they provide the customers with higher quality and customization, contributing to the creation of memorable experiences, especially if those customers have already provided information about their preferences in previous visits so that the hotel can anticipate some tasks without any explicit request from customers.

5. Limitations and further research

With its theoretical nature, this research offers the first step toward a service inventory model that can optimize specific tasks or information to be executed in advance to enable the provision of highly valuable services for customers. Further research can continue these efforts, and we suggest several avenues here. First, it would be interesting to empirically study whether any significant differences arise in the actual performance of companies that apply traditional inventory models versus those that shift and start using the proposed SIOM.

Second, further research could measure the impacts of the services SIOM for customers, as well as how they influence the value co-creation process.

Third, it would be interesting to develop SIOMs for different settings, with varying constraints in terms of time, service quality, and human and technical resources.

Fourth, research should apply the model in different contexts and conduct empirical studies in various areas (e.g., hospitality, healthcare, and transportation). These empirical results can form a basis for the refinement of the model.

Fifth, the proposed inventory model is developed based on the total cost function minimization. Minimizing these costs does not always produce higher profits though; therefore, further research might explore the optimization of service inventory models by considering the maximization of the profit function.

Sixth, in addressing the optimization of service operations, organizations are considered as isolated units here. However, companies are part of their surrounding business context, in which they interact with other entities. Therefore, an integrated approach might support the development of the service inventory model for an integrated supply chain, with several members in each stage of the chain.

Seventh, as a natural next step, it is suggested that the service-based inventory model be integrated with a traditional, goods-based inventory model. Most firms rely on both goods and services; thus, an integrated inventory optimization model is greatly required and can even transcend the goods versus services divide to focus instead on value and value creation for different stakeholders. In this case, researchers might include not only firms and their customers but also corporate social responsibility questions, which are becoming increasingly important for all businesses.

Eighth, research should zoom in on specific components in the model such as the SIC and quality of service inventory.

Ninth, another interesting topic for future research is making specific optimization efforts for different stakeholders such as customers, employees, owners, or shareholders, as well as service inventory optimization over different time horizons and across disparate demand situations.

Finally, future research might focus on the development of service design/redesign tools to integrate the notion of service inventory optimization into different stages of the whole customer experience journey.

Overall, we acknowledge that this manuscript aims to break new ground in the inventory theory. We intend to expand current knowledge so far limited to inventorying physical goods by setting a new framework for services. This is only the first step towards many other future contributions. It is expected that the proposed conceptual model be refined, enriched, and empirically tested for fueling additional publications.

6. Conclusions

This study developed a Service Inventory Optimization Model (SIOM) based on the Economic Order Quantity (EOQ) model with a focus on optimizing anticipated intangible components (tasks and information) while integrating internal (provider) and external (customer) perspectives. Therefore, this paper presented a multidisciplinary approach that integrated EOQ inventory contributions and service management research to propose a new service inventory model to optimize some part of the service (tasks or information) that can be anticipated prior to customer demand. The examples we offer on the contextualization of the model also reveal how the proposed service inventory model might contribute to the optimization of service performance, with impacts on the customer's benefits (i.e., service quality, speed, customization, and price). The application of the proposed model to identify those parts of the service to be anticipated and optimized provides companies with good insights to develop and deploy the optimal level of resources to respond to customers' demands, including technology, highly-specialized employees or redesigned processes enabling customer participation, to name a few. A key, distinctive characteristic of the proposed service inventory model is its focus on optimization as a process to provide benefits for both the firm and the customer based on a paradigm that goes beyond the traditional goods/services divide.

Finally, this service inventory optimization model can help practitioners and managers who seek to improve their business operations by reducing costs, increasing profits, and enhancing service levels. With this proposed service inventory optimization model, decision-makers can increase the customization of their organization offers and provide additional services, having an impact on customer satisfaction. Service inventory optimization might also be considered as a source of differentiation for companies as they cannot be easily imitated. In addition, by applying this model, firms can provide reliable services more rapidly, thereby enhancing the productivity of their skilled workers and the value of their services.

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