Inventory model optimization revisited:
Understanding service inventories to improve performance

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Abstract

Services are increasingly important in the modern economy, for both service and manufacturing firms, yet inventory literature has been focused mainly on physical goods and, only a few studies have included services in optimization. On the other side, 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 in the link between inventory optimization and service management. However, according to a new service inventory approach, businesses 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 article aims to

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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 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 optimize the quantity of tasks or information to be anticipated and thus provides benefits for customers.

Keywords: Service, inventory model, optimization, performance

1. Introduction

Inventory is widely researched in production and operations literature (Choi [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, 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. But modern manufacturing companies increasingly are adopting service provision positions, transitioning from supplying goods to providing services that actually create value for customers (Gebauer et al [3]; Mathieu [4]; Young [5]). According to this logic, any company's reason to exist is to create value for its customers and shareholders, so 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 (Rust & Huang [6]).

Even as services become more important throughout modern economies, this topic continues to be excluded from 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, such that it constitutes a knowledge gap. By expanding the understanding of inventory optimization issues in services businesses though, we could address this knowledge gap, as well as maximize several service attributes, including speed, quality, customization, and price.

Specifically, we note that traditional service management literature asserts that services cannot be inventoried, because they are perishable (Fisk et al. [7]; Zeithaml et al. [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 get produced through sets of processes (Chopra & Lariviere [9]). Yet businesses components also might be performed and stored in anticipation of service demand, as a form of service inventory (Chopra & Lariviere [9]; Davis et al. [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 non-physical components of the service organization. From this perspective, the service inventory is the 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) that is based on the EOQ model, we aim to expand a traditional inventory and optimization focus to include services.

It is well-known that traditional goods can be always 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 we argue it cannot be applied to optimize the 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 in many cases standardized protocols, experience a number of expected and unexpected changes and variations during their execution, and we argue they require a different optimization approach from 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 during a particular time horizon, with corresponding costs. In turn, there is not necessarily an average usage of tasks or information in calculating the inventory cost. This status justifies the construction of a new service inventory model; we propose 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 are 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 task 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 (Grönroos [11]). Such processes require the execution of tasks and information. Traditionally, due to their intangible and perishable nature, it has been argued that services cannot be "inventoried", and 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 the mean to virtually "storing" 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, so 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, we adopt a multidisciplinary approach, integrating EOQ inventory contributions and service management research to propose a new service inventory optimization model (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 not only to inventory research but also to service research, as this model is rooted into the notion that service components can be inventoried by integrating the customer perspective, and it contributes to a better understanding of how anticipation and optimization might affect customer benefits.

The rest of the article is structured as follows. We begin with our theoretical framework in Section 2 with a review of the existing EOQ inventory models. After, we present a detailed derivation of our proposed service inventory model in Section 3. Section 4 contextualizes the service inventory model with some service business examples. Finally, we detail the conclusions in Section 5 and offer some suggestions for further research in Section 6.

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, so various approaches in prior literature address these challenges (e.g. Battini et al.

[12]). The EOQ inventory model can determine optimal inventory levels while minimizing the total cost associated with the purchase, delivery, and storage of products (Harris [2]; see also Choi [1] and Cárdenas-Barrón et al. [13]). A century after its initial publication, the EOQ has been extended in various ways, as researchers have added incremental conditions in an attempt to model real-world situations. Thus the EOQ had provided the foundation for a vast number of papers relaxing different restrictions to build new inventory models with a main focus on cost and profit, which reflect specific, actual situations.

An early extension of the EOQ sought to resolve scheduling difficulties associated with lot sizes (Harris [2]; Taft [14]). Later research included quantity discounts (Crowther [15]), the production (or replenishment) rate, backorders with stockout penalties, and inflation (Diegel [16]; Herron [17]). A dynamic version of the lot size problem also appeared (Wagner & Whitin [18]). The extensions of the EOQ grew exponentially, leading to EOQ with multiple setups costs (Aucamp [19]), a present value formulation (Chiu & Chen [20]), a stochastic version (Porteus [21]), temporary one-time discounts (Tersine & Price [22]), an EOQ with learning (Khan et al. [23]), EOQ models with nonlinear holding costs (Weiss [24]), deteriorating items (Elsayed & Teresi [25]; Mahmoodi et al. [26]; Singh & Rathore [27]; Wu & Zhao [28]), supplier credits (Chung [29]), imperfect quality (Salameh & Jaber [30]; Cheng et al. [31]), recycling (Dobos & Richter [32-34]). EOQ for reverse logistics environments (Alinovi et al. [35]; Zhou & Chen [36]), and partial and full backordering (Pentico & Drake [37]; Mokhtari et al. [38])—to mention just a few.

In several good reviews of EOQ inventory modeling approaches, Pentico and Drake [37] summarize EOQ inventory models related with partial backordering, while Khan et al. [39] offer an overview of all extensions with imperfect quality, and Bouchery et al. [40] review the integration of the EOQ inventory model into sustainability research. Andriolo et al. [41] explore the evolution of these extensions over a century and also provide 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] provide 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] give 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] present 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] propose a typology for 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 extensive literature related to inventory models and optimization, little research considers 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 publications that discuss 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, so we modified this search to identify publications including any of these three words in their titles. We found 72 papers, from 1981 to 2018, and reviewed both their topics and the components included in their proposed models.

After excluding articles that did not feature any service notions, we obtained 42 papers that could help us determine how the term "service" has been conceptualized. This analysis revealed that in existing inventory literature, service refers to the service level and played a role as an indicator of system performance, either as a conceptual notion or a component within inventory models.

For example, we found 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. 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 needs 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-parts 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 37 remaining publications, service level as a component of the inventory model constituted the predominant approach. In these existing models, the service level denoted the rate at which performance goals are achieved (e.g., the percentage of calls answered by a call center), so it mainly functioned 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; and 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 thus is equivalent to β, except that the ratio spans multiple periods, rather than just one unique period.

INSERT TABLE 1 AROUND HERE

As we show 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 also traditionally focused on systems optimization to accomplish performance goals, but 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 face more complex contexts. All these contributions allow for cost reductions and better performance, but they also have neglected intangible components, as well as 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 (Vargo & Lusch [54]). However, IHIP characteristics might not be exclusive to services, nor are they generic, since they vary across different situations and conditions. Therefore, IHIP characteristics need further exploration from a customer perspective, particularly in relation to how to manage them to create memorable customer experiences (Edvardsson et al. [55]).

The resulting paradigm change challenges the idea that inventories are limited to material goods (Gummesson [56]; Davis et al. [10]). 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" (Gummesson [56]: 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 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 a 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" (Vargo & Lusch [54]: 331).

Accordingly, service inventory alters the way service is conceptualized and operationalized. Following the definition offered by Vargo and Lusch ([54]: 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 they affect how customers perceive the services as benefits (Vargo & Lusch [57]).

Due to the dynamic nature of services, many researchers have tried 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 (Victorino et al. [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 (Johnston & Clark [59]). They thus emphasize 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 the 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 (LaGanga [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, as well as 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 (Trienekens et al. [61]; Mubeen et al. [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, has been 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 (Fitzsimmons & Fitzsimmons [63]; Kimes [64]). Yield management also uses reservation systems to distribute demand (Altin et al. [65]). These practices represent a type of service inventory, from the provider's perspective, because they help minimize costs and maximize profits. But yield management does not address customers' needs. With its focus on profits, it is frequently perceived by customers as unfair, especially in industries where the practices are not common (Kimes [66]; McMahon-Beattie [67]; Taylor & Kimes [68]), so 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 data sets 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, trends), so it represents a very useful tool to manage capacity and demand (Han et al. [69]).

The contributions discussed in this section were developed mainly by service academics and practitioners, looking for innovative ways to maximize service efficiency, quality and profits. However, in this goods-dominant logic, strategies focus on internal criteria, and customers play passive roles, mainly as recipients and not as participants, such that their needs rarely are even considered. Optimization has a role, but the focus is not necessarily customer benefits. Despite some of these approaches are based on the notion of planning or forecasting service operations, we find no evidence that they conceptualize anticipation as a service component to be optimized. Thus, we argue for the need of 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, a 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, so 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 (Gummesson et al. [70]). However, the previously noted change in the way that service characteristics (IHIP) have been conceptualized emphasizes the need for an extended service inventory definition. In this perspective, some service operations management concepts might be considered precedents of service inventories, but no integral approach exists that translates these efforts into customer benefits.

According to Chopra and Lariviere [9], a service inventory includes 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 quicker response times to clients' requests. In other words, service tasks or information might be completed by 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 (Chopra & Lariviere [9]; Davis et al. [10]). These arguments suggest the potential for a new service inventory optimization model, as we detail next.

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

Our proposed service inventory model is based on the analysis of traditional EOQ inventory model components and key concepts from service research. In building this model, we regard 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, price). In line with the traditional EOQ model, we also consider different cost categories to build this service inventory model, namely, service inventory organization costs, service inventory execution costs, and service inventory costs. However, as different from inventorying manufactured goods, these sets of costs are developed to reflect the need of organizing, executing and having ready for use 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" of 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 in which service tasks and information should be anticipated again in the service process. This allows to keep always the optimal level of tasks and information virtually "stored", guaranteeing the appropriate service provision to customers, improving quality, customization, speed or price.

We detail the arguments for identifying each of the costs components of the service inventory optimization model next; in general, they can capture service dynamics across pre- and production stages and enable the operationalization of service inventories (Chopra & Lariviere [9]).

3.1. Service Inventory Organization Cost (SIOC)

The anticipation of tasks or information to ensure 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 even might cause customers to decline to buy the service, leading to lost sales. Identifying which relevant tasks and information can be anticipated and getting organized to anticipate them creates costs though, or *service inventory organization costs*

(SIOC), which can be expressed in dollars per anticipation. That is, SIOC refers to 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 associated with 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 that had been anticipated 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 are always 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 allows to keep always 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 in which service tasks and information should be anticipated again in the service process, guaranteeing the appropriate service provision to customers, 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

Service demand (*SD*) reflects the total number of services performed to satisfy customers' requirements. Every time that a customer requests a service, some tasks must be performed, and information must be used to cover the service demand. Depending on the goal to be achieved in terms of customer benefits, it 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

The decision variable in the service inventory model is the quantity of the service inventory (*QSI*), 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

The *total service inventory cost* (TSIC) comprises three category costs. First, the *total service inventory organization cost* 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 in that time horizon. The number of anticipations is equal to the total service demand (SD) divided by the quantity of service inventory ($\frac{SD}{QSI}$). Therefore *total service inventory organization costs* can be expressed as:

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

Second, we include the *total service inventory cost* of tasks or information performed in anticipation, which is the product of the service inventory cost (SIC) and the quantity of service inventory (QSI). Each anticipation gets conducted and "stored," waiting to be used as part of the service, and then is immediately replaced, so this cost is always occurring. The total *service inventory cost* of tasks or information therefore is determined by:

$$[SIC][QSI] .$$

Third, the *total service inventory execution cost* of all anticipations is calculated by multiplying the service inventory execution cost (SIEC) associated with each anticipated task or information to satisfy customers' service demands (SD). Formally,

$$[SIEC][SD] .$$

Combining these three cost categories, we can derive the *total service inventory cost* 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 quantity of service inventory (QSI). Simplifying the service inventory optimization model (SIOM) with a differential calculus, we obtain:

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

Therefore, the service inventory optimization model (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 service demand, divided by service inventory cost.

4. Contextualization of the Service Inventory Optimization Model (SIOM)

To highlight the relevance of our proposed new service inventory optimization model, we provide some contextualization, 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 increasingly rely on information and, due to technology advances, include tasks that can be performed in advance to improve quality, reduce price, increase customization, and speed up service provision. The different inventory costs and model components for each of the examples we detail appear in Table 2. For each contextualization, we start by detailing the internal criteria used to select the tasks or information to be anticipated. Then we contextualize each model component for the range of selected cases. The external criteria for optimization (quality, customization, speediness, price) then lead into the brief descriptions of the functions to be optimized. Finally, in Table 2, we explain how customers participate in advancing tasks or information, as well as in the service itself.

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, 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 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 quick response rates 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 the content streaming, this anticipation reflects industry practices and customer expectations about 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 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 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 a robust information technology infrastructure (e.g., servers, software, information systems) that can store and manage vast amounts of digital content and enable customers to 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 being prepared for customers' selection of operations includes the development of a robust information technology infrastructure, but it also 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 adequate matches 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, being prepared to customize room facilities involves the cost of developing a set of personalization options and policies for customers, reflecting the elements most valued by customers but also a careful evaluation of the limits of what a hotel can offer without affecting other customers. It also might entail costs to acquire specific products and items (e.g., pillows, cradles, wheelchairs, sheets). An information system is also needed to support the registration and tracking of 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 likely is key to making customer selections 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 also may 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 the service is delivered. For the digital content streaming and mobile banking services, it likely includes the cost of maintaining content or information online. Technology costs have steadily decreased, but this cost still might 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, access) and keeping highly specialized staff "on call," to offer diagnoses 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 also features in the SIC.

4.5. Service Demand

In this context, service demand is the amount of tasks or information required to satisfy customer requests. Considering streaming content services, service demand is not just 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, service demand represents the number of consultants, tools, and practices needed (tools configured and employees trained) to provide the service to customers. For example, if a business customer requires advice on talent management, the consulting company needs to have a human resources specialist available. Finally, service demand relates to the number of rooms that need 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 contextualizations we present 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 as a beneficiary, 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, but as beneficiaries, they receive higher service quality and speed, because the consultants previously have been 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 already have provided information about their preferences in previous visits, so that the hotel can anticipate some tasks without any explicit request from customers.

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5. Limitations and Further Research

With its theoretical nature, this research offers a first step toward a service inventory model that can optimize specific tasks or information to be executed in advance, to enable the provision of higher value service to 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 service inventory optimization model. Second, further research could measure the impacts of the service inventory optimization model for customers, as well as how they influence the value co-creation process.

Third, it would be interesting to develop service inventory optimization models 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, transportation). These empirical results can form a basis for the refinement of the model.

Fifth, we developed the proposed inventory model according to a total cost function minimization perspective. Minimizing these costs does not always result in higher profits though, so further research might explore the optimization of service inventory models by considering the maximization of a profit function.

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

Seventh, as a natural next step, we suggest integrating the service-based inventory model with a traditional, goods-based inventory model. Most firms rely on both goods and services, so an integrated inventory optimization model is greatly needed and even could 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.

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

Ninth, another interesting topic for future research would be 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 the different stages of the whole customer experience journey.

Overall, we acknowledge 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. We expect our conceptual model to be refined, enriched, and empirically tested fueling additional publications.

6. Conclusions

We have developed a service inventory optimization model (SIOM) based on the EOQ model, with a focus on optimizing anticipated intangible components (tasks and information) and while integrating internal (provider) and external (customer) perspectives. Therefore, our article offers a multidisciplinary approach that integrates EOQ inventory contributions and service management research to propose a new service inventory model to optimize of 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). Using the proposed model to identify those parts of the service to be anticipated, and optimized, provide companies with the insights to develop and deploy the optimal level of resources to respond 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 a 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 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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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, 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, 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, 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.

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)	Refines 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

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 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.
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.

Authors	Service component	Main contribution
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 a 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
Hemapriya and Uthayakumar [105]	Service level as constraint (fill rate level)	Address 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.

Authors	Service component	Main contribution
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 opportunity to make an investment to reduce the setup cost.

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.

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**
Mobile banking (accessing, validating, operating, securing) Process to deliver banking operations (consultations, transfers, payments) through mobile devices 24/7	Cost of developing banking policies for mobile devices. Cost of developing a mobile operations portfolio Cost of developing an ICT infrastructure to provide safe, fast, reliable mobile banking operations 24/7, including security elements (firewalls, tokens, 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

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, 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 a 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 amount of tools and practices available to conduct consultancy	Higher quality Faster speed	Anticipating staff and resource (information, practices, 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.

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
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 an 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.

Notes: ICT = information and communication technology.

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