The Global Performance of a Service Supply Chain: A Simulation-Optimization Under Arena

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Abstract. The service supply chain is a set of partners linked to service activities. It aims to achieve operational efficiency and organizational excellence through the fluid management of different resources and skills. This chain requires different costs and involves several processes. Knowing and evaluating the different costs of a service supply chain will allow to better manage the performance of the supply chain and subsequently improve the overall performance of the service company. We have established a conceptual basis for the different costs of a pharmaceutical distribution company. The proposed model allowed us to synthesize the different costs of a supply chain service.

Furthermore, through a simulation-optimization, with Arena simulation, we improved the operating scheme of this service chain. The optimization was carried out according to several scenarios and allowed us to improve three main performance indicators: the average response time per hour, the average response rate and the cycle time per hour.

Keywords: Supply chain service · Service logistics · Arena · Optimization · Simulation · Logistics costs · Global performance

1 Introduction

Initially designed for industry, logistics management methods are no longer being opened up to services, given the growing weight of the sector in the world economy, both in industrialized and low-income countries. Indeed, the sector mobilizes around 70% of the working population and nearly 75% of the world's market activities [1].

Service management has several intrinsic specificities and therefore requires in-depth reflection on the sector and on the best practices to adopt in supply chain management, within the framework of service supply chain management (SSCM). There is a dearth of research on SSCM in contrast to the abundance of studies on Manufacturing Supply Chain [2]. SSCM appears to be a dual concept combining traditional supply operations and activities to coordinate various resources in order to achieve customer satisfaction, while integrating constraints of time, capacity, shared resources and co-production.

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Faced with the investment and operating costs involved, companies are more than ever concerned to constantly assess the impact of logistics processes on performance, particularly at the commercial level. Indeed, logistics costs remain a major component of product and service costs, and thus indirectly influence sales prices. This field of research is increasingly coveted by many authors [3–6], as an object and a performance lever. Performance is no longer measured simply in terms of quality, time and cost, but also in terms of responsiveness, agility, efficiency and positive externalities in the territories. Meeting the challenge of reducing costs and simultaneously increasing customer value on a global scale therefore requires a radically different approach from responding exclusively to the market. Service logistics management has to deal with the integration of activities, the complexity of flows and the constraints of optimization. It is therefore a necessary factor in controlling the density of supply and demand through cost and price parameters. These optimizations seem to be more complex in service supply chains.

Hence the following problematic of this research: How can the overall cost of the Supply chain management (SCM) process in the service enterprise be optimized? The purpose of this article is to estimate the overall cost of the SSCM process and to measure its impact on the final price of the service. To address this issue, we will proceed to an empirical modeling based on a case study of a service company located in Morocco.

It is therefore necessary to assess through this modelling the impact of SSCM on the performance of the company under study. After a conceptual approach of SCM and SSCM, we consider a theoretical framework for modelling the costs of an SSCM. Finally, we will present a real example of a simulation of an SSCM through a case study.

2 Conceptual Framework

2.1 From Supply Chain to Supply Chain Management

The logistics chain includes all the operations carried out to manufacture a product or service, from the extraction of the raw material to the delivery to the end customer, including the processing, storage and distribution stages. In addition to the flow of materials, the supply chain involves the flow of information and financial flows. [7] give an operational view of supply chains: “a network of facilities that perform the functions of sourcing raw materials, processing these raw materials into components and then into finished products, and distributing the finished product to the customer”. [8] state that “the supply chain is a global network of organizations that cooperate to improve the flow of materials and information between suppliers and customers at the lowest cost and at the highest speed. The goal of the supply chain is customer satisfaction”. This definition inspires that the supply chain encompasses independent partners with a single global strategy. The vertical structure refers to the number of suppliers and customers in each link. Thus, a distinction can be made [9]:

- Product-related supply chains.
- Local supply chains: These are the small company supply chains through which product flows. They are local (corresponding to a focal company) and are, for example, made up of the different workshops of the same factory. These can be considered as customers and suppliers of each other.

- Intra-organizational supply chains: large companies with sites located in different countries. However, this term can be extended to companies with several locations in one country.
- Inter-organizational supply chains: These include at least two independent companies.
- International supply chains: These are supply chains where one or more organizational units operate in different countries.

In modern business management, sole proprietorships cannot compete as independent entities, but rather as active members of the broader supply chain involving a network of enterprises and multiple relationships [10]. As such, supply chains operate in an ever-changing environment and are vulnerable to a myriad of risks at all levels [11].

SCM emerged in the 1980s and became widely promoted in the 1990s. It is difficult to identify and advocate for a single, standardized definition of SCM. Indeed, as a unifying concept, its approach is close to a management philosophy or vision of the networked enterprise that aims to reduce costs and improve the quality of service to the consumer. [12] define it as "the systemic, strategic coordination of traditional operational functions and their respective tactics within a single company and between partners in the supply chain, with the aim of improving the long-term performance of each member company and the entire chain". The management of a supply chain must be analyzed at two distinct levels: on the one hand, strategic management consisting of forecasting demand (final or intermediate), and planning medium- and long-term resource requirements. On the other hand, operational management, which consists of constantly adapting the scheduling of activities according to unforeseen events and hazards [13]. Despite its relative newness, the concept of SCM has been the subject of a rich literature. Numerous literature reviews have been conducted to examine trends in the publication, methods and theories of SCM [14]. According to [15], it could be said that there is at least a consensus that SCM is an evolving discipline or branch of knowledge, and it is natural that, in the process, researchers would disagree on the meaning of the term SCM and its applications.

While the concept of SCM has emerged and flourished in the context of industry, at both the academic and practitioner levels, there is a wealth of research addressing the issue in the services field.

2.2 From Supply Chain Management to Service Supply Chain Management

[16] define the Service Supply Chain (SSC) as a network of suppliers, service providers, consumers and other support units that perform the functions of transacting the resources required to produce services, transforming these resources into core or support services, and delivering these services to customers. Thus, a service supply chain represents an institutionalized configuration of one or more service providers engaging with one or more service customers for a common purpose [17]. SSCM is the management of information, processes and resources throughout the service supply chain to the delivery services or products effectively served to customers [18].

The structure of SSC has some similarities to that of the product supply chain, as services are created, purchased and transferred from one element to another in a chain form [19]. The structure of the SSC is a network complex, combining direct or indirect service around the service integrator [20]. The structural difference in a service supply chain is essentially due to the unique characteristics of services, which distinguish them from goods. These differences also change the nature of service operations in practice. The main distinguishing feature of services is intangibility. Services cannot be seen, touched, smelled or tasted. This intangibility of services is the main reason why a number of logistics activities cannot be applied to service supply chains. In a service supply chain, it is not inherently possible to ensure the physical delivery of the service from the supplier to the producer and then to the consumer. Simultaneity reflects the fact that customers must be present for the service to be provided. In a service environment, the customer generally contributes to the production process, and once production is achieved, it is followed by instantaneous consumption in a simultaneous manner. Heterogeneity takes into account the fact that it is not easy to standardize services. Each client experiences a different service each time he or she receives it, depending on his or her perceptions, mood and service atmosphere. This is one of the main reasons for the complexity of planning and analyzing service production and measurement. Services are perishable and if a service is not consumed when it is available, there is no chance of storing it for future use. Unused capacity is lost forever. This characteristic makes it impossible to store services in a warehouse, which means that the storage function is completely inapplicable in service supply chains. Finally, service industries are labor-intensive. Thus, the impact of the human aspect in service operations is remarkable, accompanying the complexity it creates.

In the service sector, supply chain management focuses on dyadic customer-supplier relationships rather than the unidirectional movement of physical goods. The services supply chain indicates that service providers have relationships with other service companies that contribute to customer satisfaction. It is important to note that the performance of each firm depends on the activities and performance of other firms and therefore research studies should move from dyadic business relationships to triads and commercial networks.

In services, the customer-supplier duality implies that production flows not only from suppliers to customers, but also from customers to suppliers. As a result, production flow is bi-directional, which is a key factor in linking traditional supply chain concepts to the realities of the service process. The simplest form of a bi-directional supply chain is for customers to provide their inputs to the service provider, who converts the input into an output that is delivered to customers [21].

Thus, several operations are concomitant in an SSC. In the SSC model [16] there are seven main activities (Fig. 1):

– Demand management;
– Capacity and resource management;
– Customer relationship management;
– Supplier relationship management;
– Order process management;
– Service performance management;
– And information and technology management.

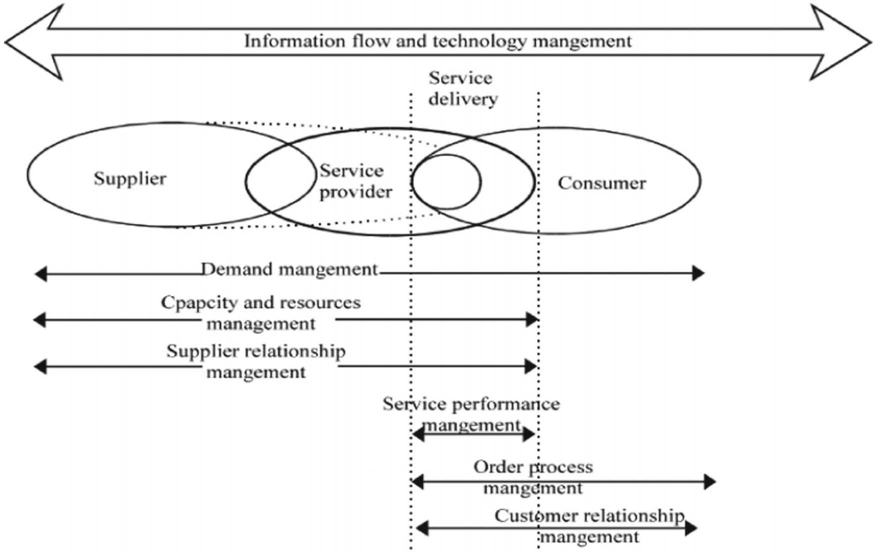

Fig. 1. The IUE-SSC model [16]

In a service supply chain, it is important that each member of the supply chain cares for and works with the other members of the system [22]. In fact, the key spirit of modern supply chain management, which differentiates it from more traditional logistics management, is the emphasis on coordination and collaboration among supply chain members [23]. Coordination is therefore essential in the supply chain management of services [24].

Adapting the supply chain approach to different service sectors is therefore essential. To help supply chain actors meet customer demand at the best conditions, the SSC must offer several tools and levers for action in the service of operational excellence through cost control.

3 SSCM Cost Estimation Model

3.1 General Principles of Supply Chain Management Service Modelling

The problem at issue here is the modelling-simulation of the overall cost of an SCM, to inform the relevance of operational or tactical logistics management decisions in the context of a service activity.

[25] the founder of modelling, defines this methodology as an approach to presenting company policies and as a tool to help solve top management problems. It schematizes the management of the mutation of systems in which flows circulate and their modifications are represented by differential equations. The design of a dynamic Foresterian-type system model consists in defining the boundary between the system and its environment.

In this sense, several SCM modeling works are already published. First, [26] analyzed a survey of supply chain management in two small manufacturing firms in Campo Limpo. The objective of the authors was to create the conditions for strategic decision making to prioritize the implementation of SCM in small firms and to achieve agility, flexibility and cost reduction for the operating system through supply chain cost modeling. [27] has also chosen SCM modeling specifically for pharmaceutical distribution. He presented extensions of the inventory optimization model of [28] by complementing the vertical cooperation between the supplier and its customers with a horizontal alliance and an exchange of information between customers. [29] developed a simulation model using a combination of ARENA and OptQuest. The multi-scale system studied is subject to several assumptions, such as: stochastic demand and capacity, deterministic supply time. [30] estimated supply chain expenditures in the cost of the final product. The authors evaluated the main supply chain processes and their components through the relationship between supply chain expenditures and the price of the final product, classifying supply chain costs and minimizing them as an assumption for final price competitiveness. For [31] future research directions include developing models for forecasting service demand, combining time series and causal methods, developing models for service resource planning, examining the relationships between service provision, service capacity and service resources, and strengthening quantitative assessment of supply chain performance of products and services from a systems perspective.

Our analytical model (Fig. 2) is based on that of [32]. This choice is justified by the authors' interest in the integration and transversely of logistics activities in order to better account for the requirements of overall performance.

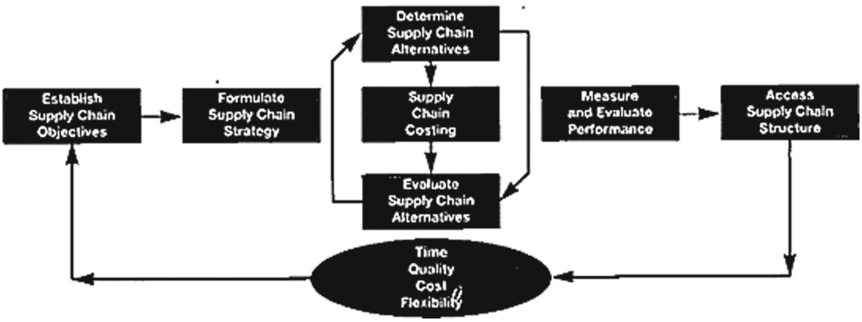

Fig. 2. Estimate logistics costs [32]

3.2 Proposal for Modelling the Cost of Supply Chain Management Services

Our objective is therefore to determine the cost impact of supply chain processes on the entire operations of the service company. For example, we used a case study example of a Moroccan drug distribution company to model the cost determination process of the SSCM. The pharmaceutical supply chain must make it possible to make the products administered to patients as efficiently as possible, in conditions that guarantee safety and traceability while complying with the many regulations surrounding pharmaceutical products and their dispensing [33]. We conducted interviews with those responsible for this drug supply chain and modelled the chain according to the service chain flow diagram (Fig. 3).

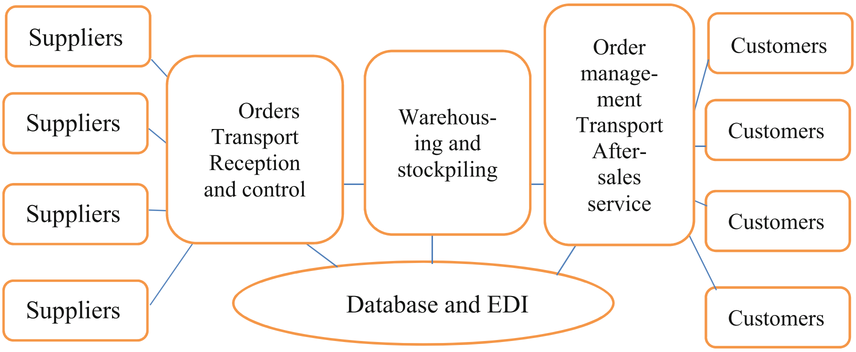

Fig. 3. Scheme of operation of an SSCM (Authors)

While being inspired by the above model and taking into account the specificities of the logistic process of the selected company (urgency, perishability, availability, etc.), we propose the following simulation model:

$$\mathrm{TCSSCM} = \mathrm{CS} + \mathrm{CRC} + \mathrm{CSW} + \mathrm{COP} + \mathrm{CIM} + \mathrm{TC}$$

With:

TCSSCM = Total Cost of Service Supply Chain Management
CS = Cost of supply
CRC = Cost of reception and control
CSW = Cost of storage and warehousing
COP = Cost of Order Processing
CIM = Cost of Information Management
TC = Transportation Cost

The components of this equation make the task of achieving effective supply chain cost management difficult. Indeed, the total cost must be optimized, taking into account the service level defined for the company, based on the approach chosen by the company.

We have broken down the various cost parameters of SSCM in Table 1:

It therefore appears that the overall cost of SSCM remains multi-dimensional, including different parameters corresponding to the different phases of the reference company's logistics process. An integrated approach to these costs is therefore necessary to develop the competitiveness and therefore the performance of the company. However, the relevance of such a model requires a significant weighting of the different cost parameters.

Table 1. Decomposition of SSCM costs (Authors)

Elements	Criteria
CS	Cost of supplier selection Other procurement costs
CRC	Delivery handling costs Cost of control (internal/external)
CSW	Cost of stock ownership (insurance, security, rent, depreciation, labour,…)
COP	Cost of placing supplier orders Supplier order tracking cost Cost of preparing customer orders
CIM	Cost of managing a client file Supplier file management cost Amortization cost (Plant, equipment, material and software…) Operating costs (Insurance and IT security)
TC	Cost of transport on purchases Cost of transport on sales

4 Service Supply Chain Modeling and Optimization with Arena

4.1 Simulation and Optimization of the Drug Supply Chain with Arena

The growing importance of SCM is encouraging research to find techniques to better analyze it. Modelling and simulation are among these tools [34]. The choice of simulation is justified when we seek to reproduce the operation of a system, a logistics distribution network, and to test scenarios to propose possible improvements. The main advantages of simulation are flexibility, speed and low cost. In addition, simulation has become for years a very good decision support solution [35]. Simulation offers the possibility to study the behavior of complex phenomena. It takes into account stochastic variables and their evolution over time [36]. It also offers the possibility of studying scenarios by varying the simulation parameters. Simulation and optimization are two powerful tools that are widely used in a wide range of industrial and engineering applications. On the one hand, simulation refers to the reproduction of real-world processes or systems over time [37], while optimization seeks to find the best (solution) of a given solution space with respect to certain criteria [38].

Arena is a powerful discrete-event simulation software. Systems are described from the perspective of entities that are traversed by flows using available resources. ARENA models are structured hierarchically and modularly. Elementary modeling components, called modules, can be selected from model panels, such as Basic Process, Advanced Process, and Transfer Process, and placed on a canvas being built [39]. ARENA uses a hierarchical architecture for simulation modeling, i.e., modules are defined using other modules. ARENA makes it possible to build a model by proposing more or less detailed representation primitives (later called blocks or modules). It also allows the creation of graphic animations to visualize the behavior of the model during the simulation. The blocks are grouped in different libraries (templates). ARENA offers a great flexibility of use and combination of objects. It has more than 5000 complex animation objects included in the Arena animation library. It also allows for data compatibility and unlike other tools that use proprietary scripting languages, Arena uses a standard VBA editor and the Arena object model to build custom user interfaces and custom data interfaces to Arena models. As far as model building and execution is concerned, a collection of panels is provided.

We have performed two simulations. The first one is performed with initial data from the interviews conducted. The second simulation is done with the integration of the desired optimizations after several scenarios. We have presented only the optimized version of the model. This optimization concerned:

- Reduction of procurement lead times for suppliers and distribution center;
- Increasing the size of lots purchased;
- Introducing two sales lines in each distributor;
- Centralization of purchasing and delivery functions.

The model was simulated on a one-year horizon. Stock levels are monitored in real time by the logistics service provider and the supplier concerned. The logistics service provider still sends a replenishment order to the vendor if necessary, to confirm the requested quantity.

The set of flow charts made it possible to depict the important business processes of the multi-step distribution system from the placing of orders to their dispatch. The simulation tool will be used to analyze the different management strategies and network configurations. The stock is kept in a central distribution center (DC) from where it can be moved or stored. Assuming that there are only two stores in the DC and that there is only one product in the system. Each customer orders only one unit. Both the DC and the stores work 7 days a week and 12 h a day.

The first model relates to the sales operation in the retailer's store. The distribution process is triggered by an order from the customer at retailer level. At the beginning, the customer unit allows the generation of customer demand throughout the simulation. The number of customers that will arrive at store A per hour is based on a fish distribution of 10. The number of customers that will arrive at store B per hour is based on a fish distribution of 4. Then, for each customer demand, the value of the quantity ordered is assigned by the demand variable. When the demand for each product is defined, the retail stock check is done by the Stock Control variable. If the retailer has sufficient stock, the customer demand is met, otherwise a replenishment order is triggered in the block Launch Distributor Order (Fig. 4). Otherwise a purchase order is automatically initiated in DC. If the demand is satisfied, the delivered quantity must be deducted from the stock amount (inv_store [Type] - Demand). The replenishment lead time for a purchase order from the vendor to the DC is based on an even distribution of 3 days. The replenishment lead time for a purchase order from DC to either of the stores is based on an even distribution of (4 to 24) h.

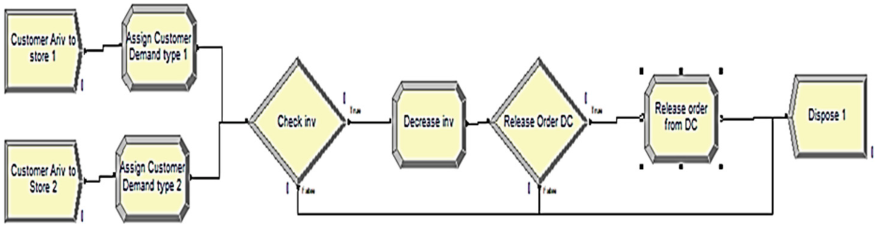

Fig. 4. Distributor model (Authors)

At the level of the central distributor, an entity is generated to trigger the arrival of retail orders in the module Arrival of Retail Orders. This entity allows the creation of supply orders for the products requested by retailers. Once the supply order is created, the stock check process (the StockDistributor variable) is activated. If the stock is sufficient, the retailer order is fulfilled after a delivery time ensured by the block Delayed Supply Distributor (follow normal law), otherwise the quantity not fulfilled is reserved to be fulfilled in the next replenishment (Reserve Unsatisfied Quantity Distributor). The process continues in case there is sufficient stock by updating the retailer stock, otherwise an order is launched at the supplier level (Launch Supplier Order) (Fig. 5).

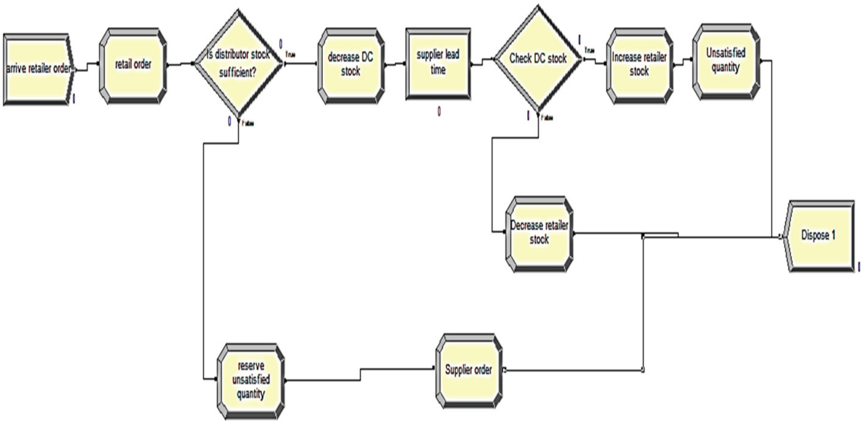

Fig. 5. Central distributor model (DC) (Authors)

In the vendor segment, the procurement process is triggered by the receipt of distributor orders, and since the vendor has no capacity restrictions, the purchase order goes through the Vendor lead time block representing the vendor's lead time. Then a check of the distributor stock is made through the variable StockDistributor, to update its inventory (Fig. 6).

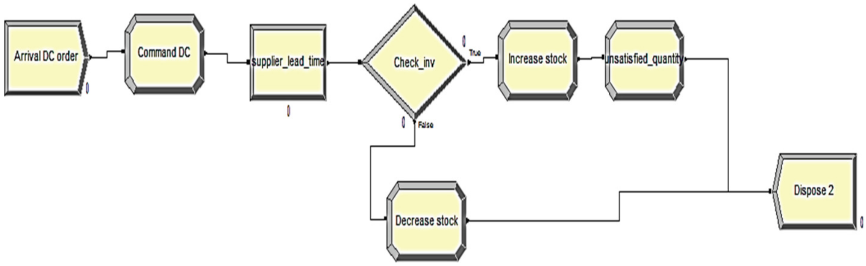

Fig. 6. Supplier model (Authors)

4.2 Results and Discussions

The performance indicators taken into account by this simulation model are:

– Satisfaction rate: Rate of orders fulfilled within the deadlines.
– The Average Response Time: Response time to a sales order
– Cycle time between retailer and DC

The four proposals led to a significant improvement in the three selected indicators Table 2. The results we have obtained coincide with [34] and [35]. Indeed, the response rate allows a reduction in inventory, which improves the performance of the supply chain. The indicators used are to be compared with the performance indicators taken into account by the simulation model of [9]. The difference in performance observed may be due to the difference between the two models or to the divergence of periods and study horizons. In this sense, the model we have proposed in this study places more emphasis on managerial variables and seems to be more explicit and comprehensive than other works. Also, the model obtained seems to be adaptable to different contexts and can be adapted to several future circumstances.

Table 2. Decomposition of SSCM costs (Authors)

Indicators	Average response time per hour	Average response rate	Cycle time per hour
Averages before optimization	0, 7	67, 52%	3, 2
Averages after optimization	0, 4	77, 41%	2, 8

We find that the logistics costs of the drug distribution company are strongly determined by the costs of the chain and the organization of the SSC. In this sense, there are several measures to reduce the costs of the SSCM: using Electronic Data Interchange (EDI) and new Big-Data technologies to reduce transaction costs and cycle time while improving predictive and instantaneous analysis of information. Use new forecasting and planning tools to centralize this information. It is essential to have a database that is both fast and comprehensive. Also, it is necessary to produce according to a production schedule that aims to optimize the balance between profit and customer service. As a result, there are several integrated productions, inventory planning, customer service, distribution and transportation functions to improve the feasibility of information, reduce inventory and improve service. In this sense, alliances and collaborative chains are an opportunity for service chain optimization. Centralizing SSCM support functions, such as central purchasing, to achieve economies of scale, reduce staff and increase productivity reduces transaction costs.

The application of the model has enabled the implementation of a path to visualize the operational and supply chain mapping related to the operation of services. In this research, the focus was on the detail of pharmaceutical service delivery in order to identify existing gaps in the system. This led us to optimize several improvements in relation to the results obtained. The main objective of implementing an effective logistics management system is to reduce the overall time spent in the system. In addition to providing a solution for time management and reduction, Research Plus encourages an improvement in the time spent by the customer and rapid inventory management. The difficulty of modeling is compensated by the great flexibility offered by this simulation tool, thanks to the block principle. This principle, close to programming languages, does not limit the modeler with a standard vision of the entities making up the supply chain, because the modeler has direct access to the smallest details on the model, and consequently the designed chain is highly customizable.

Whether in terms of products and services, or processes, it is essential to "de-complexify" everything that can be de-complexed in order to reduce or eliminate potential interruptions in the chain. The future belongs to increasingly differentiated and flexible supply chains.

5 Conclusion

The objective of this research paper was to discuss the nature of the service supply chain through SSC modeling. The work consists in identifying the different cost parameters of the SSCM and their impacts on the final price of the product. We chose to model SSCM in order to identify the main characteristics of performance management. Thus, we have modelled an SSC in order to propose ways to optimize costs by controlling the operations of the supply chain and the functional coordination of the different parameters of the chain.

In view of the differences in weight of the components of logistics costs of service companies, we intend to estimate their weighting coefficients, based on a quantitative study of companies in the sector. The relevance of such a simulation is likely to help company managers to rationalize their logistics projects and to improve the relevance of investment, outsourcing and collaboration decisions in this area.

In the literature, several works have dealt with supply chain simulation via the Arena tool, addressing the development of modeling strategies or ready-to-use packages, but none of these works proposes a complete model for full-scale cases. Our model comes from reality and seems to be consistent with the interviews conducted. The optimizations carried out have allowed a considerable progress of the different performance indicators selected. This methodological and empirical originality is predominant for this work. Nevertheless, a great difficulty of modelling is compensated by the flexibility offered by this simulation tool. This does not hide the intrinsic limitations of this model, such as the importance of a global vision of the company, the relativity of the data or the introduction of macro-economic data. These different perspectives offer new prospects for future research.

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