Application of a Methodology for the Management of Risk in a Pharmaceutical Supply Chain

N. Anich and M. Mateo

Abstract The supply chains of a business are designed to respond to a variety of clients' and customers' requests. Given the increasing complexity of the chain management, nowadays it is also important to design them in order to face different kinds of customers and also different kinds of risk to satisfy their requests. We have developed a methodology to redesign a supply chain including decisions to balance the performance indicators and the possible risks. The paper describes the application of the first steps in this methodology for the distribution of pharmaceutical products to customers, from hospitals to pharmacies. The result is a diagnostic of points with higher risks in the supply chain, to focus the changes in the redesign.

Keywords Supply chain management · Design · Risk · Methodology

1 Introduction

In recent years, the increasing expectative of customers has led to changes in the supply of goods. According to Chopra and Meindl [9], the organizations involved in the direct or indirect way in the satisfaction of clients' requests are integrated into the supply chain (SC). Usual entities in a chain may be external suppliers; distribution centers (DC), or demand areas [14]. The supply chain management (SCM) deals with the planning and management of all activities involved in the acquisition, conversion, and distribution to move products or their components up to the customers. Moreover, besides the flow with destination the customers, each day the reverse logistics are achieving more importance.

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Several events (which can be set in different classifications, for instance: meteorological or geological events, like earthquakes; geopolitical, as a consequence of government decisions…) may affect the global supply chains. This can be transformed into risks that break the regular flows. Their management is studied in the SCRM, Supply Chain Risk Management [17].

Simultaneously, the changes in society and business have brought uncertainty in the markets, a global competition with competence firms, longer times and distances in supply chains, customization of products or shorter lifecycles. Kaplan and Garrick [13] already formulated some questions that a firm responsible had to face: What can go wrong? What are the risks? What are the consequences?

Progressively, companies are adapting their business models to face a higher number of supply chain interruptions, changes in the capacity constraints, some quality problems, etc. Therefore, they should study risks, understood as a combination of events and consequences [1, 11]. The methodology here proposed and applied on a specific supply chain pretends to help managers in this way, to redesign a supply chain in order to manage different ways of risks. Some works have faced the design [6, 12], but any for redesign, whose starting point is the current chain. This is the main difference with previous papers as, in our case, data can be obtained from reality and planned changes can be defined. Moreover, for the redesign we introduce some usual tools in management, like the strengths, weakness, opportunities, and threats (SWOT) analysis.

The application of the methodology is framed in the pharmaceutical sector. Clients may be divided between private, such as pharmacies and private health institutions, and public health institutions, whose demand comes from public auctions and long-term contracts. This research summarizes the first steps in the so-called methodology for redesign the chain taking into account the risk and its associated elements. The result is a diagnostic of the points in the chain to pay attention in order to reduce risks.

The paper is organized as follows. In Sect. 2, a brief introduction to Supply Chain Risk Management is given. Section 3 introduces the methodology with the corresponding 7 steps; the application to the pharmaceutical distribution is done through Sect. 4. Finally, Sect. 5 provides the conclusions and the future work to be developed.

2 Supply Chain Risk Management

A supply chain configures a network of organizations through different links, in the different processes and activities that produce value in the form of products and services for the consumer [10]. This complex adaptive system depends on the number of nodes in the chain, their location, and the set of interrelationships, and will lead to chains of different degree of complexity [8]. The risk may be the probability of occurrence of an event or threat, which is independent of the consequences [3, 5]. The threat in an event is an external factor of risk that affects the chain.

This event has uncertainty, since there is no exact information on the appearance instant or the magnitude, scope, and duration. The consequences of the disruption will be directly related to the chain attributes of vulnerability and resilience. The consequences may have multiple dimensions, to be expressed in economic, material, system states (active/passive), and others [2].

Many researchers have sought answers, through models, to the challenges caused by the changes and the necessary redesign of the chain. They have proposed mainly the maximization of efficiency, effectiveness, or responsiveness. Effectiveness is defined as the ability to deliver the right product, in the right place, at the right time, in the right conditions and packaging, in the right amount, with the correct documentation, for the right user, while in front of a demand the ability to quickly assess and take into account needs is necessary [7]. Nevertheless, in general, the models developed for the design of the chain try to solve particular situations [6].

3 Methodology for Supply Chain Risk Management

Many methodologies for supply chain design cannot address all types of chains with their particular issues. Moreover, they do not differ between a design, starting from an idea and put in practice, and a redesign, whose starting point is the current chain, and this brings differences from a methodological focus, which have not been addressed [6, 12, 14]. As a result, we propose a methodology for supply chains which are running and have as objective the continuous improvement in adaptive terms to scenarios of uncertainty. According to Mateo and Anich [15], several characteristics of this methodology are as follows:

(a) As the objective is the redesign, it starts from a priori solution and changes must be proposed on it.
(b) A hierarchical top-down approach is used, where in the first stages the objective is to obtain the information of the actors and processes. In the redesign, the processes and activities take on more relevance than the actors involved.
(c) Reverse logistics will be also considered.
(d) The mathematical models are one of the possible elements related to the design of the chain and must be placed in an appropriate frame.
(e) This methodology considers recursive stages, i.e. the periodic evaluation of the participant units, objectives of the supply chain, and links between these units that define the underlying structure of the network.

This methodology is composed of the following seven steps [15]:

1. Definition of the object of the SC (according to the dominant actor), an environment analysis (competence, clients, or laws, among others), and the formulation of objectives. It is important to segment the markets, and consider simultaneously the initial and the potential markets.

2. Definition of the existing SC, as a priori design. According to Corominas et al. [12], this will be done at several levels (the macro, the meso, and the micro) through the M-graph, the m-graph, and the μ-graph.
3. Definition and/or evaluation of the model of SCM and the strategic coherence of the SC (reality versus objectives). Two kinds of tools may be used: some economic indicators as, for instance, orders delivered on time over total orders; other analysis usual in business, like strengths, weaknesses, opportunities, and threats (SWOT).
4. Study of the customers and the possible scenarios of demand. The objective is to determine the demand (based on historical data) by types of customers and channels of distribution. An analysis on demand risks will permit to evaluate possible scenarios.
5. Identification and evaluation of risks in the supply chain, by determining current and latent threats. They will be sequenced according to impacts: ABC classification of the threats. Finally, it is necessary for the determination of risk prevention policies to prevent emerging threats; risk mitigation policies to reduce the impact of these threats; and risk recovery policies to limit the time when the system is not in the usual state.
6. Analysis of the redesigned chain, final state, using optimization if possible (multicriteria context and looking for an improvement in the degrees of vulnerability and resilience against possible disruptive events).
7. Evaluation of the accomplishment of objectives. If the requirements and objectives fixed in step 1 are not satisfied, go back to step 5 (change policies for risk detection and mitigation) or step 1 (change objectives).

4 Application to a Pharmaceutical Supply Chain

4.1 Definition of the Object

The supply chain to be evaluated corresponds to the distribution of pharmaceutical products in Chile. The distributor has a high pressure from customers, since they require short delivery times and a lot of flexibility in orders. At this moment, more than 750 active ingredients (i.e. medicines) are sold, provided by more than 80 domestic and foreign suppliers. The products must reach the different points of sale, classified into three different channels or types of clients: retail or pharmacy, private health, and public health (Table 1). The delivery points are more than 1100, divided into 396 pharmacies for retail sale, 61 for private health institutions, and 650 for public health institutions.

The distributor manages different lists of products according to each channel, which implies that a list may have common products with the rest or not. In addition, the distributor develops its own brand. Nowadays, it has registered more than twenty products which are manufactured in different countries over the world (Brazil, India, or Germany, for instance).

Table 1 Definition of the three different business channels in the pharmaceutical supply chain

Business channel	1. Retail sale	2. Private health sector	3. Public health sector
Type of client	Private pharmacies of the health system	Private institutions of health	Institutions of the public health system
Type of product	Medicines for individual consume	Mix of medicines for individual and massive consume	Medicines for massive consume
Objectives	Availability and response times	Right delivery quantities in a short time	Efficiency (low prices and low costs)

4.2 Definition of the Existing Supply Chain

The following step describes the architecture of the SC for the three different business channels of the company, through a set of graphs (the macro, meso, and microstructures for each business). In this paper, we only provide the respective graphs Figs. 1 and 2 for the two first structures and the first kind of clients. Instead, the third structure has too big dimensions to be included here.

From a macropoint of view, the M-graph (Fig. 1) is formed by procurement and distribution activities (P), the users or consumers (U), the collection of products in poor conditions (C), the recycling (R), and return to supplier or send to a special depot for active ingredients (D).

Next, the meso structure corresponds to relations between the classes of elements contained in each vertex of the M-graph, where a class is the set of elements (that are not necessarily and probably identified in this stage) capable of executing a transformation of inputs into outputs. Therefore, the meso structure of the chain, built for each of the three different businesses, determines the type of relationship with suppliers, storage and delivery characteristics, types of collection and reprocessing.

From the vertex P (Fig. 1), there are five types of relationships with suppliers (Fig. 2): manufacturing own products (P1), strategic alliances with some national suppliers, with preferential conditions of cost in the long term (P2), with other suppliers without long-term contract and greater flexibility (P3), with manufacturers and/or distributors contacted only punctually to mitigate risks of shortages in the chain (P4), with manufacturers, as for the generic pharmacy products, that have a standard quality and price (P5).

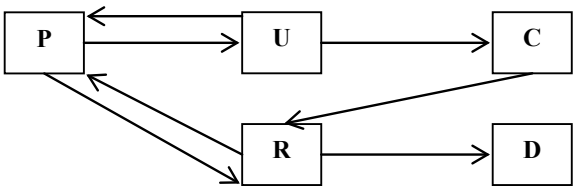

Fig. 1 M-graph for the retail sale in the pharmaceutical sector

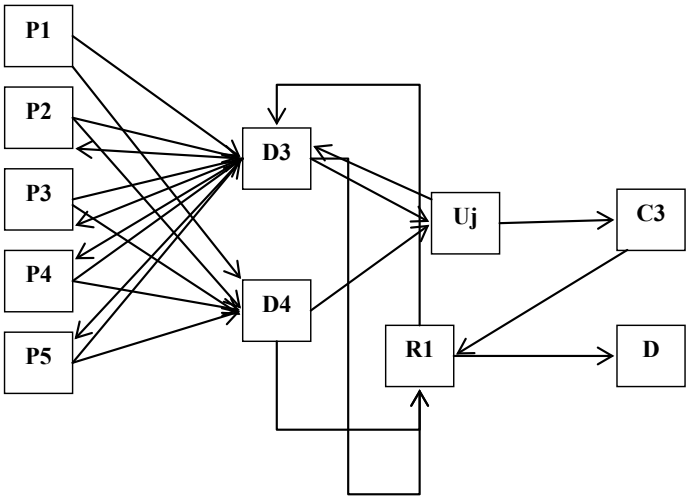

Fig. 2 Graph for the retail sale in the pharmaceutical sector

Imported products are stored and distributed by a logistic operator (D3) or with last-mile delivery (D4). All the output to any client Uj may be done from D3 or D4 (therefore, j can take values up to more than 1100). Finally, the collection of products in return (C3) and the preparation for the recycling R1 of them, before going to a depot for pharmaceutical products (D), complete the m-graph in Fig. 2. For instance, vertices P1–P5 are of type $T\alpha$ (beginning of the flow), while D3 and D4 are *Mm* (many inputs provide many outputs).

The SC microstructure reflects the facilities where operations are developed, the incoming flows between the facilities and the respective means of transport. In this supply chain, the distribution D3 and D4 is currently done through two centers, which are not in the same place (as they have 70 km between them). The number of delivery points Uj is more than 1100 throughout Chile, which has more than 4000 km from north to south. In fact, these delivery points are classified into 15 regions (most of them have the three kinds of order points and close to the local distributions centers). Currently, the distribution is outsourced to four different logistic operators, each one responsible for one or several regions. Considering this, the number of vertices in the μ-graph is very high. For this reason, the μ-graph is not provided.

4.3 Reality Versus Objectives: Strategic Coherence of the SC

Some economic indicators have been computed in the current supply chain. For any business, orders spend 2 days in preparation in the distribution centers and between 1 and 6 for transport, this depending on the delivery point location. Moreover, currently

the logistic costs are near 10% of the incomes from sales; finally, the fill rate, i.e. the inventory's availability to meet demand, is around 80%.

A strengths, weakness, opportunities, and threats (SWOT) analysis to know in which aspects the company is strong and in which ones it is weak may be.

- Strengths: good margin for some clients and products, own products, more variety of products than a single manufacturer and flexibility in the deliveries.
- Weakness: some logistic operations are inefficient, chain not designed for each specific type of client, no planning for purchases.
- Opportunities: increase the use of technology for traceability, treat each supplier and client according to its particular needs.
- Threats: high variability in the demand from public institutions, suppliers usually establish prices, competence with own suppliers.

Considering the SWOT conclusions, the distributor has some incoherence between the objectives and the design decisions for the different channels, since its design is homogenized. Therefore, as its main focus is currently the reduction of costs as much as possible, the response times may be deficient. At the same time, the chain has sometimes inability to cope with the disruptions caused by the risks at different points of it.

4.4 Study of the Customers and Scenarios of Demand

The incomes from sales to the public health system represent the 77% of the total amount, followed by the 20% to retail sale (pharmacies) and only a 3% is sold to private health institutions. If the analysis is done geographically, most of the sales (60%) are concentrated in three regions.

An ABC classification for clients and products has been done in order to focus the study of risks in the more critical binomial client-products.

The 1107 clients are divided into 230 A clients, 306 B clients, and 571 C clients. A deeper analysis only on A clients indicates that 162 are delivery points of the public system and 68 are private businesses, 62 of which are pharmacies.

On the other hand, the 1499 products classified according to the sales are divided into 346 A references, 410 B references, and 743 C references. A deeper analysis on A products shows the relevance of the first eight ones compared to the rest; they are delivered to the public health system, thanks to long-term contracts.

If both analyses are done together, the 346 A references are demanded by the 230 A clients (i.e. 100% of the A clients), which supposes more than 4 million product units and a 67% of the incomes from sales. 407 B references, nearly all of them, are also requested by A clients (639,000 product units and a 11% of the incomes from sales). This gives an idea of quite homogeneity in the consumption of products considering the different clients.

Table 2 Risks in the M-graph of the SC in the case study

Risks	Vertex P	Vertex U
Strategic	SR1, SR2, SR3	SR4
Tactical	TR1, TR2	*
Operational	OR1, OR2	OR3

4.5 Identification and Evaluation of Risks in the Supply Chain

The supply chain of the three business channels is subject to similar risk events, which will be classified into strategic, tactic, and operative. These events are mainly determined by the reliability of the different actors in the chain, the quality of the product or global facts. The effects of disruption of these events are localized through the different vertices and arcs of the previous M-graph (Table 2). A selection of risks (initially, the most relevant ones) is as follows:

- Strategic: price fluctuations (SR1), reliability of national suppliers (SR2), reliability of logistic providers (SR3), variable demands (SR4).
- Tactic: inaccurate procurement planning (TR1), liquidity problems (TR2).
- Operative: strikes (OR1), product out of conditions (OR2), payments from public health institutions (OR3).

Some summarized results on the above risks are the following.

Although in the world the prices at this moment are stable, Chile is an emerging market in pharmaceutical products and it may suffer fluctuations (SR1). A price may vary up to 20% with respect to its main value. Besides, the probability that a price varies between two consecutive acquisitions of a product is 56%.

The mean delivery time of 12 suppliers (SR2) is 6 days or higher, followed by an important group which has values between 5 and 6 days. Only one of the suppliers P2 (Fig. 2) has a mean delivery time of 6 days, but 60% of them are in the second group. The suppliers do not accomplish delivery times or the requested quantity in 31% of the times, and in this subset only a 3% of the orders are partially delivered to the distribution center.

The reliability of logistic agents (SR3) is deficient, although the delays are not long times. To deliver an important number of orders, the times are 4 days or higher. These values can reach up to 15 days for the farthest regions.

Finally, the demand evolution in this market (SR4) is increasingly reflected in the average sales growth of 15% per year.

After considering the quantitative results given in Sects. 4.4 and 4.5, we can observe that the main decisions to prevent and mitigate risks must be taken on vertices P2, D3, and D4, and therefore in the arcs connecting these vertices in Fig. 2. This may be extended to the subset of Uj vertices associated with A clients.

5 Conclusions

Most of the papers devoted to SC design concentrates on a single kind of product or client [4]. Here, three kinds of customers are studied together, and although initially they are studied separately, this can lead to the improvement of the SC design by synergies. A methodology to deal with risks is presented and later applied to a case in the pharmaceutical sector. The first five steps of the methodology, basically the diagnostic of the current supply chain and the way to improve its initial functioning, are presented.

To achieve a good redesign, thanks to the figures obtained in step 5, a decision tree can be a good tool to visualize the possible alternatives for each business channel. This will allow to observe common decisions among businesses and evaluate a coordinated multi-business supply chain in search of good efficiency results and lower risks. Complementarily, a multi-objective model can be very useful to develop step 6 of the methodology, in the same way as, for instance, Nooraie et al. [16] propose.

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