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Supply chain mapping: Analysis of processes, flows and actors in Latin-American case studies

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Article Info

Abstract

The holistic study of a supply chain is one of the challenges that this philosophy presents today. This is due to the increasing diversity of stakeholders, relationships and flows that develop, with the consequent complexity in its management and performance. The article is motivated by the need to develop a reliable tool for academic and research based analysis of Latin American supply chains characteristics, relationships, processes, products and services. This is done from a literature review, along with the expertise of supply chain specialists and empirical testing in case studies through the application and validation of a practical guide. There were organized different techniques for mapping and preliminary analysis of processes, actors and flows from a tool box perspective, which implied flexible study of varied supply chains. It was proven the feasibility of the tool to study either complex or simple chains, to promote knowledge generation, skills transfer and strong links among academic, research and business practice. This work has important practical and managerial implications for supply chain design, performance and improvement.

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Introduction

The term supply chain has its splendor in the 90's and continues to this day. In the rise of the internet, supply chains expand their borders, and change philosophies from a physical space to a virtual one. This brought with it, the need to develop new forms in supply chains, such as the security ISO 28000 Standard (Supply Chain Security Management System). In this context, agile and flexible chains are needed in the face of changes in the environment. Added to this, has emerged the development of additive manufacturing where advanced technologies and customer customization reappear, with the emergence of 3D printers (Santander et al., 2020), and reinforced by industry 4.0 (Yadav et al., 2020).

On the other hand, reverse approach within the chain has arisen, being included in the circular economy from the birth of materials upstream to the reuse current downstream (Shahsavar et al., 2022). Hence, holistic study of a supply chain is one of the challenges that this philosophy presents today, due to unknown and uncertain scenarios (Moosavi et al., 2022), and diversity of actors that are related from the reverse and non-reverse flows of materials and services.

For Lambert et al. (2005) the challenge in supply chain management was based on its own configuration: a network of organizations or business units ranging from primary suppliers to final customers; and the need to implement processes across the organization's functions, while integrating them with other key links in the network.

From these elements, the need arises to identify and relate the actors in a supply chain from a holistic perspective. This encourages decision-making due to knowledge from our partners or possible clients. Therefore, the objective of this article is to develop a reliable tool for academic and research based analysis of Latin American supply chains characteristics, relationships, processes, products and services.

Literature Review

Connections between Mapping of Processes and Supply Chains

Gardner and Cooper (2003), pioneers in mapping processes in the chain, suggest the need to visualize processes and actors. At the same time, they affirm that the identification of the processes to prepare the map already contributes to making knowledge transferable and exchangeable between the actors in the chain. In addition, these focus on the mapping, planning, structure and strategy of the chain. This demonstrates the interdisciplinarity of this approach with the rest of the mapping techniques in different processes.

From these elements, Gardner and Cooper (2003) analyze the different maps used in various disciplines and possible to apply in the mapping of SC. Among them, they mention cartography. This mapping shows its usefulness at this time. The study by Gardner and Cooper (2003) focuses on chain mapping and strategy where three main distinctions are made between SC strategic mapping and process mapping: orientation, level of detail and purpose. At the same time, they define attributes of the CS map: in geometric, perspective and implementation issues. These elements form the basis of the SC topology used in this study.

In this sense, Farris (2010), develops an analysis of strategic mapping techniques applied to SCs. The author applied the university training process to refine mapping techniques. This practice was used in this research, in undergraduate and graduate logistics and SC classes. In the study, geovisualization is used as a basis for mapping, the levels of relationships and magnitude of the flows. At the same time, it was stated that strategic mapping was in its beginnings and shows the need to mix this approach with other management techniques (Pareto), and the links of the chain are not included in the study, and the symbols used are based in this research.

Certainly, within the assumptions of supply chain management, operational performance has played a relevant role for decades, as reported by Jayaratne et al. (2012) in their review of the literature, and it is manifested in the reasons adduced by these authors to map a supply chain: improve the strategic planning process, distribution of supporting information, support the design and configuration of the supply chain, clearly show channel dynamics, provide a common foundation or perspective for SC design, improve communications, monitoring of implemented strategies and support supply chain analysis.

In their research, Beckman and Bernander (2015) use supply chain mapping as a tool to analyze the relationships between actors, the flow of information, components that the author uses as a means to identify gaps in supply chain traceability pharmaceuticals. They illustrated three appropriate mapping techniques as follows: Value Chain Analysis (VSM) serves to reduce waste based on principles of agility (lean), focuses on physical and information flows, is used to

represent processes and activities at different levels of planning (Masood, 2017) and even may help define Strategy Map aiming to strengthen links between the corporate and supply chain strategy; IDEF0 methodology aids the design and implementation of integrated systems and flows across different functions of an organization; and process mapping helps to increase visibility in search of efficiency and effectiveness, customer service and profitability, while focusing on physical flows, resources and support information flows.

In this sense, Petrović and Arsovski (2016) propose the SCOR model, combined with the Global Supply Chain Forum model, for the representation of the processes of an automotive chain from the point of view of operations and global strategy of the chain. The first focuses on the analysis of demand, supply, planning, distribution and reverse logistics operations; while the second visualizes inter organizational relationships through the cascading deployment of processes, sub-processes, and relationship activities with customers and suppliers (Lambert et al., 2005, Kusrini et al., 2019). In these cases, the difference with traditional process maps is that they use a logistics classification.

On the other hand, Wichmann et al. (2018) propose the use of ontology and text extraction method to configure the chain. The authors acknowledge that a basic supply chain map must answer the questions: who supplies whom (nodes and relationships), with what materials, parts, or services (physical flow), for what type of end product (product), from where (geographical context), and when supplier-client relationships are generated (time).

MacCarthy et al. (2022), review the academic literature and state that there is diversity in the mapping carried out by researchers and a lack of clarity about the different types of maps developed. They claim that SC mapping has been used as a general term for studies at very different levels of aggregation. At the same time, they define the basic elements to create a SC map and elaborate a formal hierarchy of supply systems to map at different levels of analysis. The research was based on examples from the textile and clothing industry.

Mubarik et al. (2023), propose a comprehensive measure of cartographic SC that takes into account its various dimensions. The authors classified the dimensions of the mapping as: ascending, intermediate and downstream. They develop a tool for the evaluation of mapping in the chain, a significant element of this research. Despite the depth and scope of the study, the authors conclude that a gap exists in the literature on SC mapping instrumentation.

Beyond the particularities of each proposal, the representation of flows, processes, actors and links is key to designing or evaluating supply chains. In some cases, the studies focus on the mapping and strategic relationship of the chain, and in other cases they infer a methodology for the identification of dimensions and elements to take into account when preparing the map although, the authors conclude that there is a gap in the literature on this topic. At the same time, there is the need to identify a chain mapping methodology for unknown and complex environments, where the actors and links in the chain are not fully formalized; but it is necessary for the evaluation and identification of stakeholders, links, flows and processes.

Methodology

This research focused on illustrating a reliable tool for academic and research implications of mapping supply chains from the Latin American region, particularly from Ecuador, Mexico and Cuba.

Data Collection

BestLog case study approach (Guerola Pérez, 2009) was used to get a comprehensive understanding of the subject under analysis. Data were collected with the use of brainstorming sessions for stakeholders´ identification; structured interviews and questionnaires to managers and employees for describing actors, flows and relationships from companies of the studied chains and direct observation and checklists for process based variables analysis. These instruments were administered and profoundly illustrated in previous researches (Cañadas Salazar & Sablón Cossío, 2019). The fieldwork lasted from September 2018 to January 2022.

Data Analysis

The data analysis was performed under a qualitative descriptive approach. The research design is non-experimental since no variables were manipulated´ (Hernández-Sampieri et al., 2006).

The research consisted of three stages: (1) preliminary empirical application, (2) analysis and generalization on selected cases, and (3) experts´ validation of tested practical guide.

Preliminary application

This stage aims to prove a first version of a set of techniques and methods for supply chain mapping. To perform preliminary application, the authors selected two supply chains previously studied by Acevedo-Urquiaga et al. (2020) from two different sectors, locations and topology and afterward documented general and particular analysis that helps configuring and refining a practical guide for academic and research based study of supply chains. Seven steps were established , based on key elements outlined in theoretical foundations addressed in literature: representation of flows, processes and actors as key aspects to designing or analyzing the design of supply chains, process approach implications (Gardner & Cooper, 2003; Lambert et al., 2005; Petrović & Arsovski, 2016); integration of knowledge into the chain strategy, inter and intra-organizational relationships (Gardner & Cooper, 2003); combined use of techniques depending on type, objective and aspect to emphasize (Beckman & Bernander, 2015).

Step 1 Product/service and actor's selection. First, the product or service to be studied is selected and, from this, the main actors in the unknown and uncertain chain are identified, and the corresponding clients are delimited. It is valid to consider that actors may group for other strategic alliances reasons other than a product or service delivery. The actors are listed and, by means of some group work technique, they are classified according to their fundamental activity.

Step 2 Description of relationships, suppliers, clients and flows. Each actor is described from a holistic perspective, and in addition, who his clients, suppliers and collaborators are (Cañadas Salazar & Sablón Cossío, 2019).

Material, informative and financial flows, are described. Suppliers are identified, not only for raw materials but also for machinery, spare parts, containers and packaging. Further, it is used to analyze products and services as well as results generated.

Step 3 Activities and links characterization. Actors are classified according to their main activity in relation to the chain (distribution, production, supply, wholesale, storage, marketing, services) and hence they are grouped by process. The predominance of one or other classification conditions the chain type.

Step 4 Focal company analysis. The existence of a node (Focal company), that can either use centralized or decentralized management mechanisms is verified. The fist implies that a single entity (virtual company) collects and transmits the information to the other nodes so that they can develop the corresponding processes; and the second point to decentralized collaboration, where each node relates to the one it deems appropriate and, depending on the needs, each one can be both collaborative and non-collaborative type, given its relationship with others (Hernández Hormazabal, 2011; Pibernik & Sucky, 2007).

Step 5 Chain topology. The chain classification depends on: product flow, structure of the supply chain, type of information exchange, type of supply chain, object of the chain, number of actors involved, actors who determine its governance, degree of transformation of the product, geographical scope and chain level (Gardner & Cooper, 2003; Hernández Hormazabal, 2011).

Step 6 Chain mapping. The number of actors and links are quantified according to expression $m_i \times n_i$. As actors interrelate through the material, informational, financial and knowledge flow upstream and downstream, arrows identify the direction of flows, differentiated by colors: red, blue, black, gray and yellow, as shown in Figure 1.
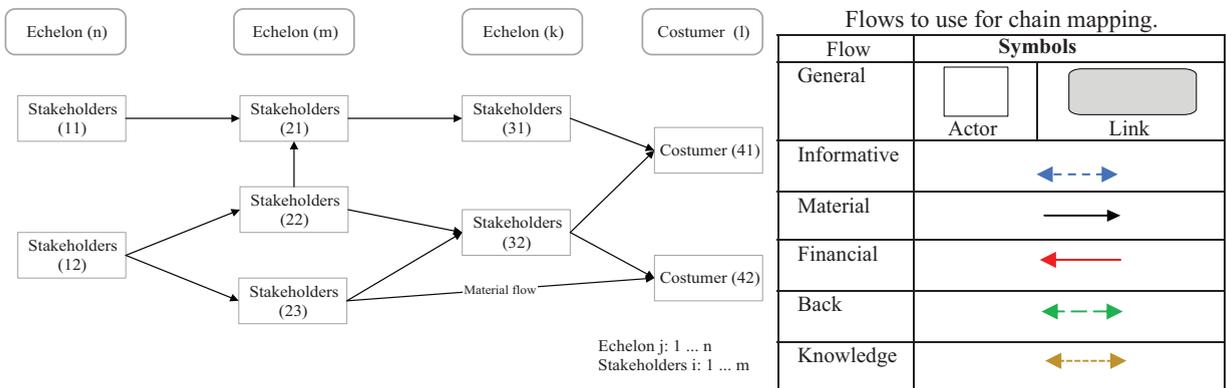

Figure 1 Map of the supply chain

Knowledge flow representation is based on: suppliers' information needs about products or services; product / customer feedback on information and knowledge involved in production or service delivery, distribution, decision-making, value addition activities, application and monitoring of knowledge acquired in the creation of value; and production and service impact assessment on efficiency, effectiveness, quality, and competitiveness.

Step 7 Process analysis. Process analysis and description either at the network level, or within the organizations, comprehends a representation of the links and actors, the scope definition of the supply chain flows and process variables evaluation. Depending on the depth and objective of the study, different flow diagrams should be used (Biazzo, 2002; White & Miers, 2008; Hernández Nariño et al., 2009; Lugo, 2012; Mayer et al., 1992; Ripoll Feliu & Dickinson González, 2015; Viñas del Hoyo, 2015).

Each supply chain was analyzed according to type of object (output), number of links and actors identified. Process based variables were observed during description and information collection from actors (responsiveness to demand planning; collaboration in customer relations, order fulfillment / service delivery, customization of manufacturing, start product / service development, life cycle support, reverse logistics, collaboration in supplier relationships).

Analysis of lessons learned and generalization on selected cases

Analysis of commonalities and differences from preliminary test, served to extend the application to other case studies. Preliminary application should yield lessons learned and possible adjustments to the route to follow and techniques to use.

In academic meetings with Industrial Engineering students from universities of Mexico, Ecuador and Cuba, there were selected manufacturing and services based supply chains. This selection was based on topology, non-formalized chains and products that are significant for the region's economy.

Each supply chain was analyzed according to type of object (output), number of links and actors identified. Process based variables were observed during description and information collection from actors (responsiveness to demand planning; collaboration in customer relations, order fulfillment / service delivery, customization of manufacturing, start product / service development, life cycle support, reverse logistics, collaboration in supplier relationships).

Experts' validation of proposal

A two rounds Delphi method was used to validate the proposal. Selected experts were asked the following questions: (1) will it be useful to structure a practical guide for supply chain mapping?; (2) are the steps and tools selected a proper structure for the aforementioned instrument?; and (3) would the practical guide be effective for academic and research purpose?

Results

The application in two case studies, allowed checking empirically the feasibility of the proposal and making adjustments, as well as delineating new courses in the research.

Case study: Supply Chain in a Cuban Health Environment

The chain offers health service to women of childbearing age, pregnant women, postpartum women and newborns. The services provided depend specifically on the pathology of the patient and the characteristics of the hospital. There were fifty-six actors identified and six links produced by them; they belong predominantly to the Ministry of Public Health, one of them to the Ministry of Industry, another to the Ministry of Foreign Trade and Foreign Investment and the Ministry of the Food Industry.

The key actors' description involved relevant characteristics: (1) pharmacies are in charge of supplying industrial and non-industrial medicines; (2) importing company´s function is choosing and contacting suppliers of raw materials and products according to demand for medicines; (3) packaging material, bulbs and chemical components, reagents, spare parts, technological equipment and some finished products are imported from four international suppliers; (4) national suppliers guarantee non-medical resources; (5) pharmaceutical laboratories ensure a major part of basic medicines for health centers and they produce according to serial production lines; (6) Medical and Industrial gases of Cuba´ company belonging to the Ministry of Industries, satisfies the demand for medicinal oxide, carbon dioxide and nitrous oxide; (7) drugs, medical and non-medical logistics operators specialize in products distribution throughout the country, the second one provides more than 3,000 mostly imported consumable materials, instruments, clinical laboratory glassware, and dental material, and the third operator is a wholesaler and retailer of non-medical resources for maintenance and

transportation processes; and (8) electromedicine office guarantees technical services for medical equipment, spare parts and technologies (Figure 2).

The chain is classified as flexible (the product flow), general (the structure), sequential (the type of information exchange), network (supply chain), service (object), complex (number of actors involved), government-based structure (by the actors that determine governance), national (geographic scope), and value network (by the chain level).

Chain and processes analysis, aided by characterization seized up by mapping, made it possible to identify gaps in collaboration practices and service delivery. The main problem was the low correspondence between the service offered and the logistic operations performance that are guaranteed to influence the quality of the service in the long term.

Case study: Coconut Supply Chain

The study chain belongs to the coconut sector. Mapping was carried out in the 22 cantons of the province of Manabí, through an interview guide that allowed describing six links (Figure 3): suppliers, producers, wholesalers and distributors, manufacturers, sellers and customers, and these are made up of 160 actors,

77 vendors, 34 producers, 39 wholesalers and distributors, and 10 manufacturers (Romero Delgado et.al 2021). The industries associated with the actors are part of the Ministry of Industry and Productivity.

Characterization of each actor in the chain under study points out important information: suppliers classify as local, provincial and even national agrochemical sales centers, providing farmers with inputs and soil fertilizing services; producers cultivate coconut for both local and national markets; wholesalers/distributors manage marketing and harvesting of coconuts, and they use warehouses for sale to merchants for subsequent distribution in the country; manufacturers produce coconut in an artisanal way; vendors sell coconut water to the final consumer, whether in pipes, glasses or bottles; clients consume coconut and fresh and dried fruit derived sweets, alcoholic preparations, ice cream parlor, pastry shop and bakeries; and demand forecast reaches a value of 4,231,870 units.

The chain classifies as flexible (the product flow), general (the structure), sequential (the type of information exchange), network (supply chain), productive (object), complex (number of actors involved), national (geographic scope), and productive chain (by the chain level).
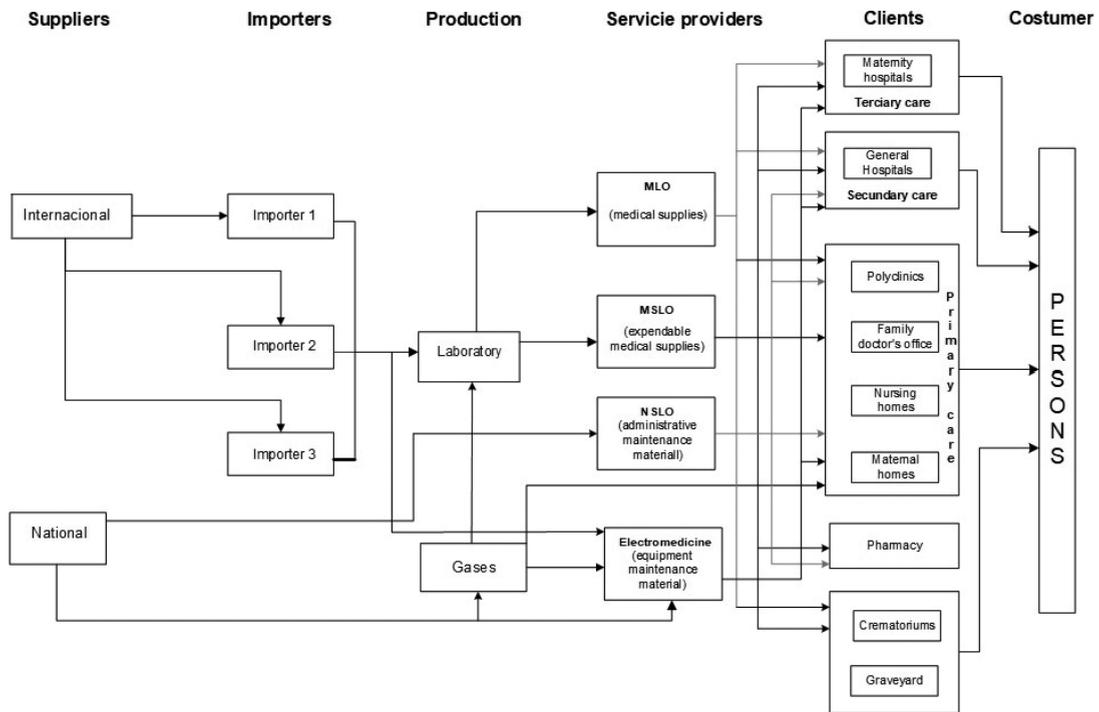

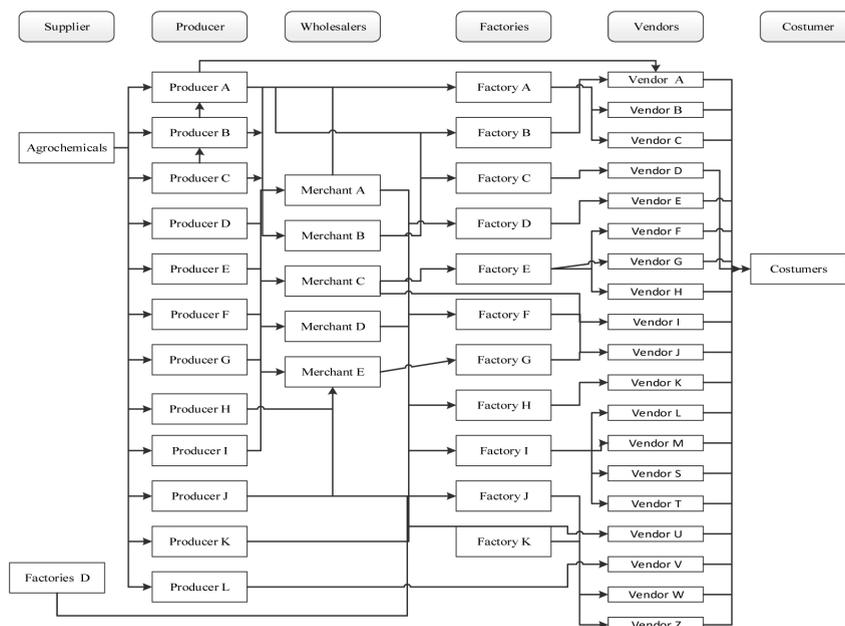**Figure 2** Supply chain of the health sector

Figure 3 Coconut chain map of the province of Manabí, Ecuador

As reverse logistics and start product / service development reveal the main flaws, it was stated as the most relevant problem that low value-added products is affecting both the economic recycling for the actors of the chain, and the community development of the province.

Lessons learned and generalization on selected cases

This analysis produces either common or distinctive attributes to consider when managing supply chains. Both cases show complexities according to number of links and actors involved, its flows are flexible with a general structure, and sequential information exchange mechanisms. These attributes may signify there are similarities in process analysis like responsiveness to demand planning; collaboration in customer relations and suppliers; order fulfillment / service delivery.

The use of process mapping techniques was revised. Complexity of chain, non-formalized connections and data unavailability hinders effective utilization of methods like value stream mapping. That is why these criteria were considered in mapping technique selection.

According to revealed problems, improvement directions for both chains should point to quality and service level improvement, but for the healthcare chain, this improvement issue should focus on logistics operations performance. As for the coconut chain, product value addition and recycling turn out a priority.

The extended application of the practical guide to different chains promotes in depth study, based on characterization and description of actors, flows and links, selection of the most appropriate techniques and process based variables for analysis, according to the attributes previously revealed, together with knowledge sharing and research necessary to address particular issues of each chain. Table 1 summarizes the results obtained from all 15 case studies.

Table 1 Resumed analysis in all 15 case studies

Chain Case Studies	Object	Country	Number of links and actors	Industries	Process analysis							
					A	B	C	D	E	F	G	H
Orange	Product	Mexico	5 and 12	Juice industry	X	X	X		X	X	X	X
Tomato puree	Product	Cuba	8 and 91	Tomato puree industry, packaging	X	X	X	X	X	X	X	X
Milk	Product	Cuba	5 and 21	Dairy industry	X		X		X	X		X
Hospital	Service	Cuba	6 and 56	Medical gases industry, medicines and medical supplies industry	X	X	X					X
Service Marketer	Service	Cuba	8 and 142	Food industry suppliers	X	X	X		X	X		X
Panela	Product	Ecuador	4 and 18	Panela industry			X	X	X			X
Milk and cheese	Product	Ecuador	4 and 35	Dairy industry	X	X	X		X			X

Table 1 Continued

Chain Case Studies	Object	Country	Number of links and actors	Industries	Process analysis							
					A	B	C	D	E	F	G	H
Cacao	Product	Ecuador	5 and 1809	Cocoa and packaging industries		X	X		X	X	X	X
Organic coffee	Product	Ecuador	5 and 15	Coffee roaster		X	X		X	X		X
Coconut	Product	Ecuador	5 and 162	Food derivatives industry (ice cream, candy, milk, juice)	X	X	X	X	X	X	X	X
Banana	Product	Ecuador	7 and 46	Chifle and flour factory				X	X	X		X
Coffee	Product	Ecuador	6 and 74	Coffee roaster	X	X	X	X	X	X		X
Shrimp	Product	Ecuador	5 and 27	Shrimp packaging machine		X	X		X	X		X
Textile	Product	Ecuador	5 y 96	Textile shaping machines	X	X	X	X	X	X		X
Local cheese	Product	Ecuador	6 y 81	Dairy industry	X	X	X	X	X	X	X	X

Note: Legend:

A. Responsiveness to demand planning
B. Collaboration in customer relations
C. Order fulfillment / service delivery
D. Customization of manufacturing

E. Start product / service development
F. Life cycle support
G. Reverse logistics
H. Collaboration in supplier relationships

This table reveals the applications of the methodology in chains with differences on products and services, contexts and scope. This demonstrates the possibilities of using the tool and its generalization.

The validation of the practical guide empirically tested, resulted in a Kendall concordance coefficient, ranging from 0.7–0.8, with a significance level of .000–.004; and this supported that experts agree on the liability of mapping steps defined (actors listing, classification, description, grouping by function and links determination, focal company analysis, chain topology and mapping).

Discussion

Holistic analysis of Latin American chain environments continues to be an interesting subject. This is mainly reinforced by a variety of studies and mapping on supply chain purposes, for example sustainability (Fathollahi-Fard et al. 2022), the COVID-19 pandemic (Moosavi et al., 2022), planning and control (Kusrini et al., 2019), risks (Köksal et al., 2017), lean philosophy (El Kihel et al., 2019) value added processes (Megayanti et al., 2018). This last approach favors the definition of the weaknesses of the chain, and which variables to improve in it (capacity, contracting, demand, inventory).

Figures 2 and 3 show the map, its purpose is graphing the design and configuration of the chain. This mapping helped understanding chain characteristics, how actors relate, nature and dynamics of such relations, ways in which information, materials and knowledge are shared and how processes operate. This knowledge provides directions to organization for improvement strategy as stated by Mubarik et al. (2023), Then mapping together with process based variables, supported problem identification, made the chain and possible disruptions visible. For example, weaknesses in service delivery and product development may imply solutions associated to time cycles, inventory management, quality of information and knowledge flows and operational design to mention some relevant targets.

In this sense, the applications in case studies, mentioned earlier in the article, showed the flexibility and adjustability of this mapping proposal, and, at the same time, strengthen the direction of international trends. In fact, problem identification and improvement strategies based on supply chain analysis are nowadays challenged by more complex and changing environment. That is why system dynamics are acknowledged by authors as useful to model the dynamic interactions between elements within value chains, such as causal relationships and feedback loops between production and markets and their effects on the financial performance of value chain actors; robustness evaluation of the value chain or feedback analysis of implemented interventions. Muflikh et al. (2021) reported relevant results as of this issue in agricultural systems, which coincides with some chains under study.

In some cases, further training in adopting the case study techniques was required. This element is basic for the mapping application.

In relation to the value stream technique, mapping supply chains and identifying value-added activities can be difficult to apply in some contexts and situations, let alone in exploratory and multifactorial studies. This is in cases with absence of data and non-formalized string environments. This is a tool working with specific chain information and data. This element may not be considered at first in the study (especially in non-formalized chains). On the other

hand, it responds to the identification of value addition to processes (Megayanti et al., 2018; Tansuchat et al., 2017). Nonetheless, VSM is a praxis that can coexist with this proposal. In fact, the toolbox presented facilitates this goal.

Conclusion and Recommendation

This manuscript shows a field work based research that firstly confirms that chain mapping is relevant for supply chain visibility and understanding of links, actors, how it relates and collaborates, how process operates, and how this configuration favors or not the organizations involved. It is recognized as well that mapping could be the first step into finding gaps and disruptions for improvement strategy. There is abundant information available on different techniques used for mapping specific supply chains and its benefits; however, it is not common to find proposals that address various types of supply chains and provide a guide that facilitates the use of a toolbox, and that favors learning, research and academic linkage with business practice.

The case studies illustrated non-formalized chains from Latin America, where results denoted how feasible the tool could be to study either complex or simple chains, depending upon appropriate technique, to generate relevant knowledge; skills transfer mechanisms, and strong links of students and professor with business practice.

Hence these findings support theoretical contribution to supply chain mapping and analysis and even to improvement, collaboration and integration strategies for organizations; and additionally, reveal practical and managerial implications, and those are, on one hand, characterizing and analyzing processes, flows and actors may contribute to identify performance and design failures and, on the other hand, showing managers and communities key directions to study design and configuration of actors, their relations, processes operation and consequently improvement targets.

The authors considered as limitations that chain and process analysis is yet discreet, restricted to static and simple observation of configuration characteristics and indicators; it is not considered how behaviors, governance, support systems and environmental and multiple factors may change over time and subsequently affect chain performance.

Hence, future work will focus on researching and fertilizing the practical guide with methods for process and supply chain design, modeling and performance improvement from different perspectives like system dynamics.

Conflict of Interest

The authors declare that there is no conflict of interest.

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