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Analysis of a supply chain in the ceramic sector: a look at business processes

Análise de uma cadeia de abastecimento do setor cerâmico: um olhar sobre os processos de negócios

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Abstract: Given the importance of structuring organizations in supply chains as a mechanism for competitiveness, as well as process management for the good operational performance of these chains, this article aims to map and analyze the business processes of a supply chain of the ceramic sector located in northeastern Brazil. To achieve the proposed objective, Lambert, Cooper, and Pagh's (LCP) model of supply chain management is adopted, which comprises, within its analysis dimensions, the mapping of the dimensional structure of the chain, its processes, and management components. As a result, it was possible to characterize the configuration of the chain under analysis, highlighting the company's proximity focused on the upstream direction of the chain and, consequently, the complexity of the supply operations. Furthermore, based on the problems and inefficiencies identified during the mapping of the supply processes, this study proposes suggestions for changes and improvements to the ceramic sector's supply chain analyzed. By providing a detailed analysis of the dimensional structure of the chain, its processes, and managerial components, this article contributes to the continuous improvement of organizations by providing a practical discussion on the structuring of supply processes and emphasizing the importance of overcoming the identified inefficiencies.

Keywords: LCP Model; Business processes; Supply Chain and Ceramic Sector.

Resumo: Tendo em vista a importância da estruturação das organizações em cadeias de suprimentos como mecanismo de competitividade, bem como do gerenciamento de processos para o bom desempenho operacional dessas cadeias, este artigo tem por objetivo mapear e analisar os processos de negócios de uma cadeia de abastecimento do setor cerâmico situada no nordeste brasileiro. Para atingir o objetivo proposto, é adotado o modelo de Lambert, Cooper e Pagh (LCP) de gerenciamento de cadeias de suprimentos, que compreende dentro de suas dimensões de análise, o mapeamento da estrutura dimensional da cadeia, seus processos e componentes gerenciais. Como resultados foi possível caracterizar a configuração da cadeia em análise, destacando-se a proximidade da empresa foco no sentido *upstream* da cadeia e, consequentemente, a complexidade das operações de abastecimento. Além disso, a partir dos problemas e ineficiências identificados durante o mapeamento dos processos, este estudo propõe sugestões de mudanças e melhorias para a cadeia de abastecimento analisada. Ao oferecer uma análise detalhada da estrutura dimensional da cadeia, seus processos e componentes gerenciais, este artigo contribui para o aprimoramento contínuo das organizações,

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fornecendo uma discussão prática sobre a estruturação dos processos de abastecimento e destacando a importância de superar as ineficiências identificadas.

Palavras-chaves: Modelo LCP; Processos de negócios; Cadeia de abastecimento e Setor cerâmico.

1 Introduction

The ceramic industry is an important sector of the Brazilian economy. According to data from the National Association of Ceramic Manufacturers for Coverings, Sanitary Ware and Similar Products (ANFACER), Brazil stands out worldwide in the production of ceramic coverings, being the third largest producer and the third largest consumer of these products in the world. Furthermore, it also stands out for its performance in exports, occupying sixth place in the list of countries that export the most ceramic products (ANFACER, 2023). In addition to this perspective, the National Association of the Ceramic Industry (ANICER) highlights the sector's annual revenue at R$18 billion, generating 293 thousand direct jobs and another 900 thousand indirect jobs, contributing to the country's economic development (ANICER, 2021).

According to Dondi et al. (2021), Supply Chains Management (SCM) play a strategic role in the development and performance of the global ceramics sector, due to their efficiency in providing the necessary resources for the production and distribution of finished products among the different agents in the chain. This is a need highlighted by the new dynamics of the organizational environment, characterized by competitiveness, unpredictability, dissolution of boundaries between companies and inter-organizational relationships (Dhaifallah et al., 2019; Gomes & Kliemann, 2015; Mao & Chen, 2021).

For authors like Chaib et al. (2020), these business clusters can be understood as a network of independent agents that interact with each other to add value to the end consumer throughout the distribution of their products. According to the authors, the parties involved in the composition of these chains range from raw material suppliers, industries, distributors, retailers, and other economic agents to the final consumer, highlighting the synergy that involves these different entities.

This business structure model allows not only to optimization of work and its processes but mainly acts in the management of supply and demand, based on the synchronization and control of product and information flows. However, these are robust structures that require commitment from the parties involved to maintain a level of integration and coordination that ensures the fulfillment of the strategic objectives defined by these agents (Wieland, 2021).

This need is evidenced in the work of Lambert et al. (1998) when discussing supply chain management, highlighting the importance of analyzing and managing business processes for their proper functioning. According to the authors, the ability to manage and integrate the multiple members of the chain will define the final success of the group's companies, given the competitiveness of the external market. However, Lambert & Cooper (2000) point to the lack of work in the specialized literature that presents mechanisms and methodologies through which companies can analyze and manage the supply chains of which they are part.

In addition to the above, Chanpuypetch & Kritchanchai (2020) emphasize the challenge and complexity of managing and controlling processes in organizations. For the authors, a high level of coordination and collaboration is necessary between the individuals involved and the company's business functions. The complexity of supply chain processes and relationships maximizes these challenges.

Therefore, this article aims to analyze a supply chain in the ceramics sector with an emphasis on its business processes. To this end, the LCP model is adopted, an acronym with the initials of its proponents Lambert, Cooper, and Pagh. This model allows understanding and managing supply chains from three perspectives, namely: their dimensional structure, their business, and its management components.

Hence, this article contributes to specialized literature by presenting a discussion regarding supply chain management through an applied case, as well as practical contributions to the ceramic sector, especially the company object of this study, through understanding and analysis of your chain.

2 Supply Chain Management and its organizational processes

The fierce competition between companies has contributed to the change in how they face market challenges and organize their strategies, so that the efficiency of their production system is no longer the result of isolated actions alluding to a single company, but rather, of the effort set of multiple entities, whose main objective is the delivery of a good or distribution of service, as advocated by Fagundes et al. (2010). Jüttner et al. (2007) define supply chains as a cluster of companies that cooperate, intending to control, manage, and improve the flows inherent to an organization's business processes.

Regarding the characteristics of supply chains, it is possible to highlight the non-linearity of the relationships in the chain links, as it is a complex network formed by members who act directly in generating value and by agents who are indirectly involved in supporting the processes (Porto et al., 2014). Furthermore, the long-term relationship and communication between its members is highlighted, favoring the achievement of competitive advantage, process reliability, and a better ability to face market uncertainties (Huemer, 2012).

In a complementary way, Wieland (2021) warns of the need to manage and improve processes, strategies, and collaborations in supply chains to ensure the balance of the demand-supply binomial, thus avoiding disruptions that put the operability of the production system at risk.

However, SCM is not something trivial, but requires understanding and managing not only the flow of materials involved between the agents that make it up but also an understanding of the financial flow and the value generated to the final consumer, as well as policies external to the chain, social responsibility and concern about the risks that threaten its operations (Corrêa, 2012; Yalcin et al., 2020). Regarding SCM, there are different approaches and models for this purpose, about which the authors Lélis & Simon (2013) highlight four main methodologies as presented in Table 1.

Table 1. Main SCM methodologies

Models	Characteristics
Cooper, Lambert, and Pagh model (LCP)	This model seeks to manage the interrelationships of supply chains based on their dimensional understanding, business processes, and management components.
SCOR Model (*Supply Chain Operations Reference*)	Proposed by the Supply Chain Council (SCC), this model promotes SCM through basic business processes: plan, supply, produce, deliver, and return with an emphasis on its performance metrics.
MSU Model (*Michigan State University*)	This model is based on the multifunctional characteristic of supply chains and is supported by eight pillars, which are: Product design and redesign; Process design and redesign; Performance measurement; Capacity management; Planning; Purchase/supply; Make/produce and Deliver.
IMD Model (*International Institute for Management Development*)	This methodology works on chain management from the perspective of four dimensions, namely: Execution of processes without failure; Focus on managing demand throughout the chain; Partnerships, Outsourcing, and Supply.

Source: Lélis & Simon (2013).

However, Lambert et al. (2005) highlight the LCP and SCOR models as the main methodologies for SCM. For the authors, these models are the only ones that are based on a detailed understanding of the chain's business processes, allowing a more holistic assessment of supply chains. So, this article used the LCP model to analyze its object of study. This choice was based on these criteria: (i) the scope of the model in capturing not only business processes but also the dimensional understanding of the chain; (ii) due to the model's conceptual structure and ease of implementation and (iii) because it is a widely disseminated methodology without commercial bias, as discussed by Simon & Pires (2006).

In this way, the LCP model comprises the analysis of the supply chain under three distinct dimensions, as shown in Figure 1.

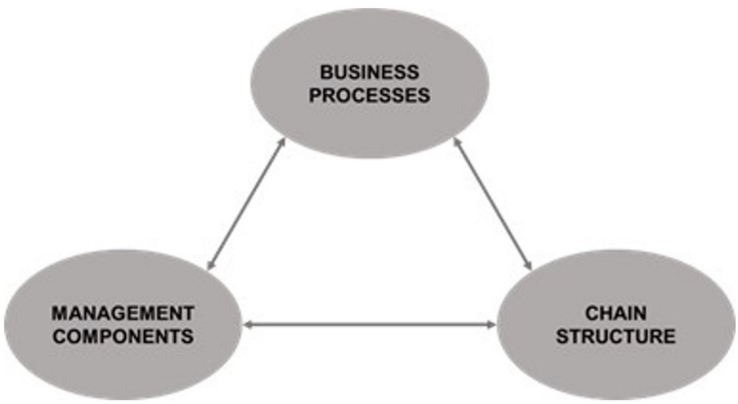

Figure 1. Dimensions of the LCP model.
Source: Adapted from Lambert & Cooper (2000).

The first of its dimensions, i.e., the structure of the chain, concerns which agents are considered key members in SCM operations. Next, in the dimension of business processes, it is analyzed which of them are important and which should relate to the key members, defined a priori. Finally, the management components measure the level of integration and management of defined business processes. Table 2 presents the subcategories present in each of these dimensions.

Table 2. LCP model subcategories

1. Chain Structure	1.1 Types of Members	1.1.1 Primary Members
		1.1.2 Support Members
	1.2 Structural Dimensions	1.2.1 Horizontal Structure
		1.2.2 Vertical Structure
		1.2.3 Focus Company Position
2. Business Processes	2.1 Customer Relationship Management	
	2.2 Customer Service Management	
	2.3 Demand Management	
	3.4 Order Fulfillment	
	2.5 Production Flow Management	
	2.6 Supplier Relationship Management	
	2.7 Product Development and Commercialization	
	2.8 Returns Management	

Table 2. Continued…

1. Chain Structure	1.1 Types of Members	1.1.1 Primary Members
		1.1.2 Support Members
	1.2 Structural Dimensions	1.2.1 Horizontal Structure
		1.2.2 Vertical Structure
		1.2.3 Focus Company Position
3. Management Components	3.1 Physical and Technical	3.1.1 Operation Planning and Control
		3.1.2 Workflow Structure and Activities
		3.1.3 Organizational structure
		3.1.4 Product Flow Structure
		3.1.5 Information Flow Structure
	3.2 Management and Behavioral	3.2.1 Management Methods
		3.2.2 Leadership and Power Structure
		3.2.3 Risk and Reward Structure
		3.2.4 Culture and Attitude

Source: Adapted from Lambert & Cooper (2000).

The types of chain members categorize its agents into those that are strategic and therefore play an important role in the value generation process (primary members); and those who support, as the name suggests (support members), supply chain operations (Lambert & Cooper, 2000). Also, according to the authors, concerning structural dimensions, the horizontal structure is understood as the number of layers that make up the supply chain. In contrast, the vertical structure presents the number of members in each of these layers. Regarding the positioning of the focus company, this reflects how close the main company is configured to one of the directions: upstream (proximity to suppliers) or downstream (proximity to customers).

Furthermore, processes represent a set of activities and tasks that generate and add value to the product, and consequently, to its consumer. Therefore, mapping, analysis, and standardization of processes are necessary to facilitate the exchange of information and product flow between different chain members (Carmo & Silva, 2020).

Within this context, logistics supply operations are important processes that integrate supply chain activities. The correct management of these operations is crucial for the success and good operational performance of the global chain, so supply chain management aims to promote the supply of inputs necessary for producing agents and those internal to the chain, in quantity, quality, and correct time for its transformation (Pimenta & Ball, 2015; Prata et al., 2013; Santis et al., 2017; Saragih et al., 2020).

Still regarding the LCP model, it seeks to evaluate eight generic business processes found in any supply chain, such as plant processes, that is, the focus company's processes responsible for the development and production of the product, to processes directly related to the consumer responsible for planning and controlling demand and supporting customers, maintaining the expected level of service. Furthermore, the LCP is concerned with return activities, which are those relating to reverse logistics and product returns, helping to minimize the impact and inconvenience caused by these activities.

Given the multiple business processes, structural dimensions and complexities of supply chains, Lambert & Cooper (2000) argue that it is neither appropriate nor viable (in some cases) to integrate and manage all these processes. Therefore, they are categorized as follows:

a) **Managed business processes**: these are critical processes within the chain and must be managed in an integrated and collaborative way between the different members of the chain.
b) **Monitored business processes**: these are not critical processes, but they are important for the operational performance of the chain and should therefore be monitored by the focus company.
c) **Unmanaged business processes**: these are processes that do not directly involve the focus company, so their management must be the responsibility of other members. Processes in this category are associated with more external layers in the dimensional structure of the supply chain.
d) **Non-member business processes**: these are processes external to the supply chain under analysis, although they may directly or indirectly affect its performance.

Finally, the management components attest to the level of integration of the chain and ensure its success. Such components allow evaluating the chain from different perspectives, from the tangible and measurable perceptions promoted by the physical and technical components to aspects that are not so tangible such as the managerial and behavioral components. However, despite the intangibility and difficulty of evaluating some of these, all management components presented in Table 2 are of paramount importance for integration between members, ensuring a collaborative environment, and contributing to the implementation of the aforementioned business processes in supply chains (Lambert & Cooper, 2000).

3 Methodological procedures

Regarding methodological aspects, this article is characterized as a case study, as it is empirical research within a real context, as advocated by Gil (2002) and Miguel (2007). To this end, a specific case relating to the supply chain in the ceramic sector was analyzed.

This case was studied from a qualitative approach, while it was proposed to explore and describe the business processes for the focus company and its interrelationships with other entities in the chain. The study was conducted following the steps presented in Figure 2.

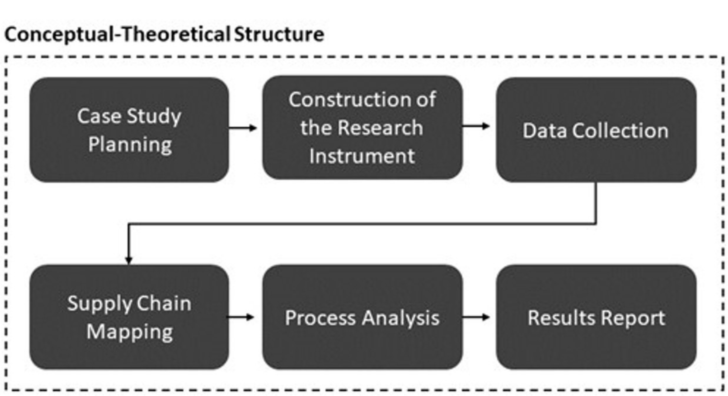

Figure 2. Methodological steps.
Source: Adapted from Miguel (2007).

Firstly, a bibliographical study was conducted to define a conceptual-theoretical framework to support the discussion encouraged in this case study. The definition of the theoretical framework was essential not only to justify the importance of this research and its contribution to the construction of knowledge related to the topic in question but also to define the approach to be used to achieve the proposed objectives in light of the literature. To this end, the Scopus and Web of Science databases were used, due to their scope in indexing national and international journals. Table 3 summarizes the results of the bibliographic survey.

Table 3. Bibliographic survey.

	Scopus	*Web of Science*
Search 1: (TITLE-ABS-KEY ("supply chain management") AND TITLE-ABS-KEY (model* OR tool*)) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j"))	5,442	2,950
Search 2: (AUTHOR-NAME (lambert) AND AUTHOR-NAME (cooper) AND AUTHOR-NAME (page) AND TITLE-ABS-KEY ("supply chain management"))	2	1
Total	5,444	2,951
Initial Sample (Removing duplicates)	3,015	
Excluded	2,954	
Final Sample	**61**	

Source: The authors (2024).

After removing duplicate articles from the initial sample, a screening phase was carried out by reading the titles, abstracts, and keywords of the resulting articles, to evaluate the adherence of the papers to the scope of the research. To this end, the following exclusion criteria were considered:

- Elimination of all papers that did not present a clear discussion regarding supply chain management, nor did they present any tool/methodology for SCM.

The planning stage is a phase characterized by defining the scope of the study and determining the object of analysis (Miguel, 2010). For this specific study, the industrial unit of a ceramic products factory was defined as a unique case to be analyzed, with this company being an agent of a supply chain in that sector.

The company in question has more than 35 years of experience in the ceramic tiles market. Being considered a large company, it is one of the main producers in Brazil and one of the leaders in the production of porcelain tiles. Its production capacity is approximately 4.3 million m^2/month, between its production units located in the states of Paraíba and Rio Grande do Norte.

To enable process mapping, it was necessary to understand the operational functioning of the company and its relationship with other agents in the chain. To this end, a questionnaire was created (see Appendix 1) in electronic form and applied virtually to the manager responsible for manufacturing processes, in the position of production manager of the organization. It is worth noting that the questionnaire was administered virtually as a result of health protection measures due to the Covid-19 virus pandemic.

Additionally, secondary data were collected to complement the information needed to understand the supply chain of the company being studied, thereby reducing bias in the study. Therefore, we analyzed documents provided by the company, such as process maps and workflows.

For the subsequent stage, the analysis of the business processes stipulated by the model, an adaptation of the methodology proposed by Drohomeretski et al. (2012) which consists of evaluating the application and representativeness of each of the processes identified in the chain under study, based on the parameterization of factors on a scale as shown in Table 4.

Table 4. Business process assessment framework.

Business processes	Company Analyzed					
	Yes/No	1	2	3	4	5
Business Process 1						
Business Process 2						
...						
Business Process N						

Source: Adapted from Drohomeretski et al. (2012).

In Table 4, the first column evaluates the presence of said process or not in the analyzed chain, while the others quantify the intensity of the presence of such a process in the chain's production system. Finally, the results achieved in the previous steps are reported below, in section 4.

4 Results and discussions

The chain studied in this article was analyzed from the perspective of the LCP model, and the results are reported and discussed in the following subsections.

4.1 Chain structure and characterization of the focus company

From the data collection instrument developed and the information collected, it was possible to delimit the structural dimensions of the chain, which this work proposed to study, as shown in Figure 3.

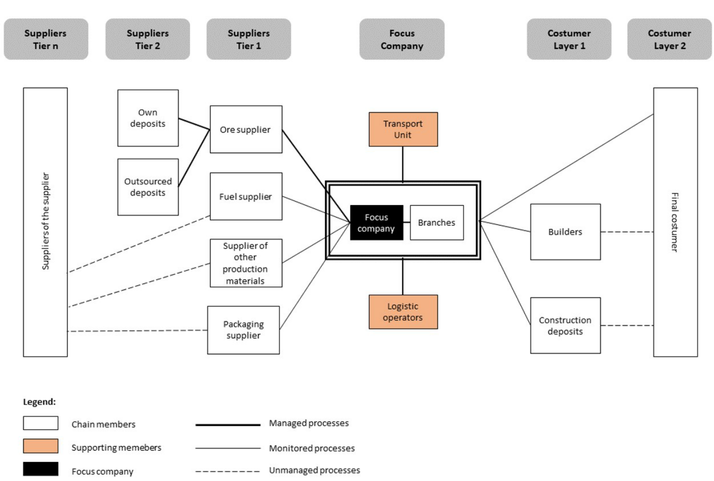

Figure 3. Structure of the supply chain under study.
Source: The authors (2024).

As recommended by the LCP model, the chain was dimensioned based on the mapping of the members that compose it. From Figure 3 it is possible to note that this supply chain has a horizontal structure of five layers, three of which are on the supply side and the others on the consumer side. Given this configuration, the proximity of the focus company to the upstream direction of the chain stands out, so supply operations are essential to the operational efficiency of the global chain, thus emphasizing the need to manage its operations.

The first supplier tier includes members who provide materials and inputs necessary for the productive operations of the focus company and its subsidiaries. These materials include clay ores (the main raw material), packaging, various production materials (chemical additives, steel, and alumina balls, diamond, felt, and resin discs, abrasives, diamond brushes, diamond rollers, and glue), and fuels (wood) for burning the product, as a production stage. In the case of upper layers, there are natural deposits from which mineral suppliers extract.

Regarding the supply of ores, these can be supplied from the company's deposits, as well as from third-party deposits depending on the need and availability of the clay mineral, see Figure 4. Therefore, the transport of these materials is carried out by the company's transport unit and by external logistics operators, both as support members of the chain as shown in Figure 3, these being responsible for moving cargo from the deposits to the production units, as well as the movement of intercompany materials, i.e., from one production unit to another (headquarters-branch). In this way, the vertical analysis highlights the existence of complexities in the operations and relationships between the links in the functioning of the chain.

On the other hand, in the downstream direction of the chain, operations take place without many complexities, with the main customers being construction materials warehouses and construction companies and can also serve the final consumer directly.

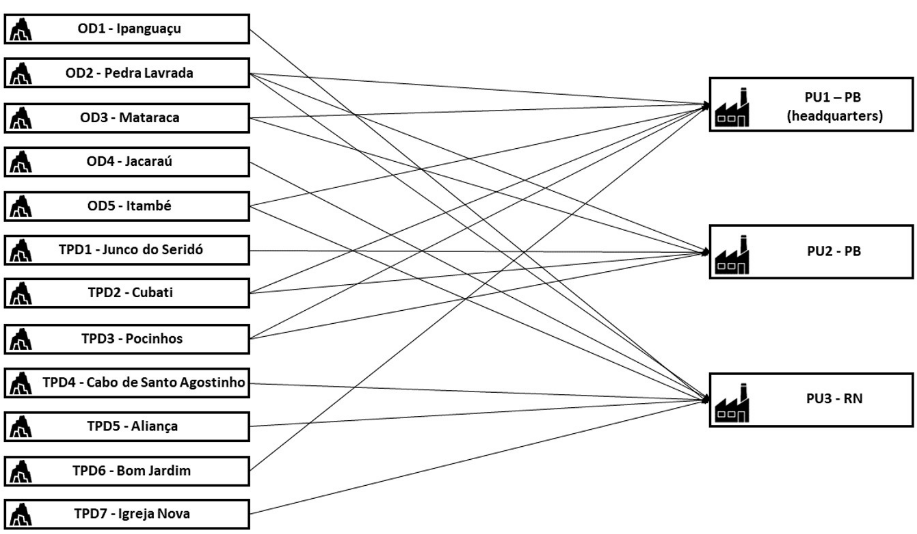

Figure 4. Ore supply.
Source: The authors (2024).

From Figure 4 it is possible to observe that the supply of clay ores to the production units (PU) comes from twelve deposits, five of which are owned by the company (OD) and the other seven are outsourced (TPD), which are geographically distributed between the Brazilian states of Paraíba (PB), Pernambuco (PE), Rio Grande do Norte (RN) and Alagoas (AL). Table 5 shows the inputs provided by each of them to the PUs.

Table 5. Supply details by deposit and PU.

Deposits	Productive Units (PU)	Ores Provided
OD1 - Ipanguaçu	PU3 – RN	Ipan clay
OD2 - Pedra Lavrada	PU1 – PB (Headquarters)	Ground Syenite, Feldspar, and Quartz
	PU2 – PB	Ground Syenite, deferrized Syenite, Feldspar, Quartz and Albite
	PU3 – RN	Feldspar and Quartz
OD3 - Mataraca	PU1 – PB (Headquarters)	Mataraca E Clay
	PU2 – PB	
OD4 - Jacaraú	PU3 – RN	Filito Jacaraú
OD5 - Itambé	PU1 – PB (Headquarters)	Itambé Clay, Front 5 and Front 1
	PU3 – RN	Itambé Clay
TPD1 - Junco do Seridó	PU2 – PB	Albite CP
TPD2 - Cubati	PU1 – PB (Headquarters)	Cubati White Clay
	PU2 – PB	
TPD3 - Pocinhos	PU1 – PB (Headquarters)	Dolomita
	PU2 – PB	
TPD4 - Cabo de Santo Agostinho	PU3 – RN	Argila Porto Rico
TPD5 - Aliança	PU3 – RN	Filito BA
TPD6 - Bom Jardim	PU1 – PB (Headquarters)	Cianito
TPD7 - Igreja Nova	PU3 – RN	Argila Porto Rico

Source: the authors (2024).

After supplying materials and inputs, ceramic products are manufactured at the focus company using the workflow shown in Figure 5.

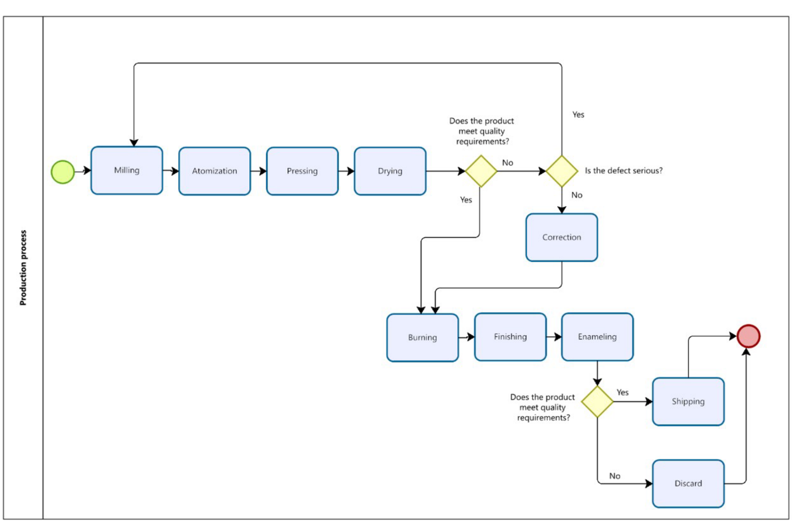

Figure 5. Ceramic manufacturing process.
Source: The authors (2024).

The process begins with grinding the stored ore, to reduce its particle size. Next, this material is then activated, a process that consists of mixing the grains with chemical additives, such as sodium silicate, which aim to give the clay ore the physical-chemical characteristics necessary for its conformation and mechanical performance. Once activated, the clay is then pressed into the desired shape and the resulting piece is left to dry. This phase is important for reducing the humidity of the piece and can be done outdoors or in greenhouses. After completion, there is the first quality analysis. If the piece does not meet the minimum quality requirements, it is not promptly taken to the next stage (burning). When non-conformity is identified, the severity of the occurrence is checked, so that if it is a very serious structural defect, the part is rejected and reused in the process as a bulk component. However, if there are minor modeling defects, cracks, or breaks, the part is corrected and reintroduced into the main process. It is important to highlight that the correction sub-process was not further detailed in Figure 5 because it depends on the type of occurrence presented, whose recovery techniques range from just sanding to the need for wet gluing, in which the broken area is moistened and a clay similar to that used in the piece is applied to join the parts.

The subsequent stage is burning, it is at this stage that the material acquires the hardness and other physical-mechanical characteristics of the product. After leaving the burning, the products are then finished, that is, polishing, cutting, and drilling are carried out depending on the specificities of each item. Finally, these are enameled and can also, following their specifications, go through an extra stage of decoration. Upon completion of these steps, the finished product is subjected to a new inspection. If it meets the quality criteria, it is transported for shipping; otherwise, it is discarded and reused in the secondary road base (burnt break).

4.2 Mapping and analysis of business processes

Although the LCP model proposes eight business processes for global supply chain operations, this article set out to map and analyze the supply processes, as defined in the research scope presented in the introduction of this study. Thus, Figure 6 presents the framework of the business processes of the aforementioned model in the logistical macro processes: supply, plant, and distribution processes defended by Amaral (2012).

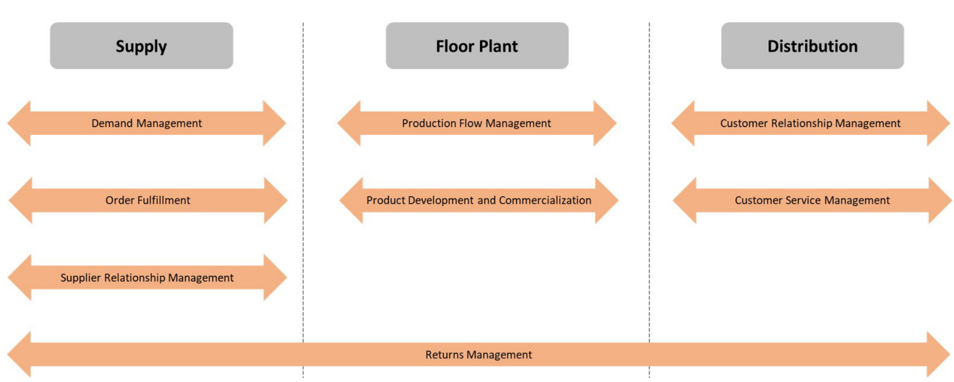

Figure 6. Logistics macroprocesses and the LCP model.
Source: The authors (2024).

Based on the responses from the research instrument applied to the production manager of the company under study and the evaluation matrix proposed by Drohomeretski et al. (2012) it was possible to evaluate the supply chain business processes, as shown in Table 6.

Table 6. Assessment of supply chain processes.

Business processes	Company Analyzed					
	Yes/No	1	2	3	4	5
Demand Management	S				x	
Order Fulfillment	S			x		
Supplier Relationship Management	S				x	
Returns Management	S				x	

Source: The authors (2024).

In Table 6, the applicability of the process was assessed by assigning “Yes” to indicate that the process is applied in the organization, and “No” to indicate that it is not applicable. The scale used to measure the degree of use of the process is as follows: 1 – very incipient process, 2 – functional process, however, requires significant improvements, 3 – functional process, requiring few improvements, 4 – meets expectations, 5 – exceeds expectations. It is worth mentioning that the results expressed in the aforementioned table represent the perception of the person responsible for production when asked using the aforementioned instrument regarding compliance with the aforementioned business processes and the degree of adherence of these to the ceramic chain.

It is noted that all business processes evaluated are observed in the case under analysis, and these are well-defined in the operationality of the analyzed supply chain. However, when evaluating the consistency and integrity of the processes according to the proposed scale, it is highlighted that the order fulfillment process presents a small lag concerning the others. This finding is justified by managers when they state that the greatest difficulty would be checking the physical entry of stock and managing the fulfillment of purchase orders (over or under fulfillment, in the latter case requiring additional supply).

Furthermore, the non-attribution of the maximum score on the scale (grade 5) is due to inefficiencies found in the processes, which for the evaluating manager, assigning a score of 4 implies recognizing the possibility of improvements in the processes. In the case of demand management, the company uses electronic spreadsheets to tabulate and quantify sales projections, which are based on managers' feelings and as discussed above, do not always lead to correct forecasts, bringing negative consequences to the supply chain.

In the relationship with suppliers, the focus was on the supply of ores because it is the main input of the product and because of its criticality and need for management. From Figure 4, it was possible to highlight the multiple supply points, while Table 4 showed that the supply of a given ore can be exclusive to a single deposit, as well as deposits can supply one, two, or all three units productive, thus demanding integration and coordination of supply operations.

Regarding return management, despite internal policies for reusing ceramic waste, the supply chain under analysis does not have major reverse logistics policies that ensure returns beyond internal waste, with this practice being a necessity incorporated into the configurations of modern supply chains, by including the environmental dimension in known sustainable supply chains (Gurzawska, 2020; Junge, 2019; Madronero-Díaz et al., 2012; Mc Loughlin et al., 2021; Pimenta & Ball, 2015; Purnomo et al., 2020; Vafaei et al., 2019).

On the other hand, to better explore the supply chain, the processes were analyzed at a more granular level of their nature, that is, their activities. To this end, the aforementioned processes were rearranged into four other processes that describe the criticality of the supply chain, they are the demand and order management process, the raw material extraction process, the inventory management process, and finally, the process of transporting the raw material. Figure 7 summarizes the activities of these processes throughout the chain.

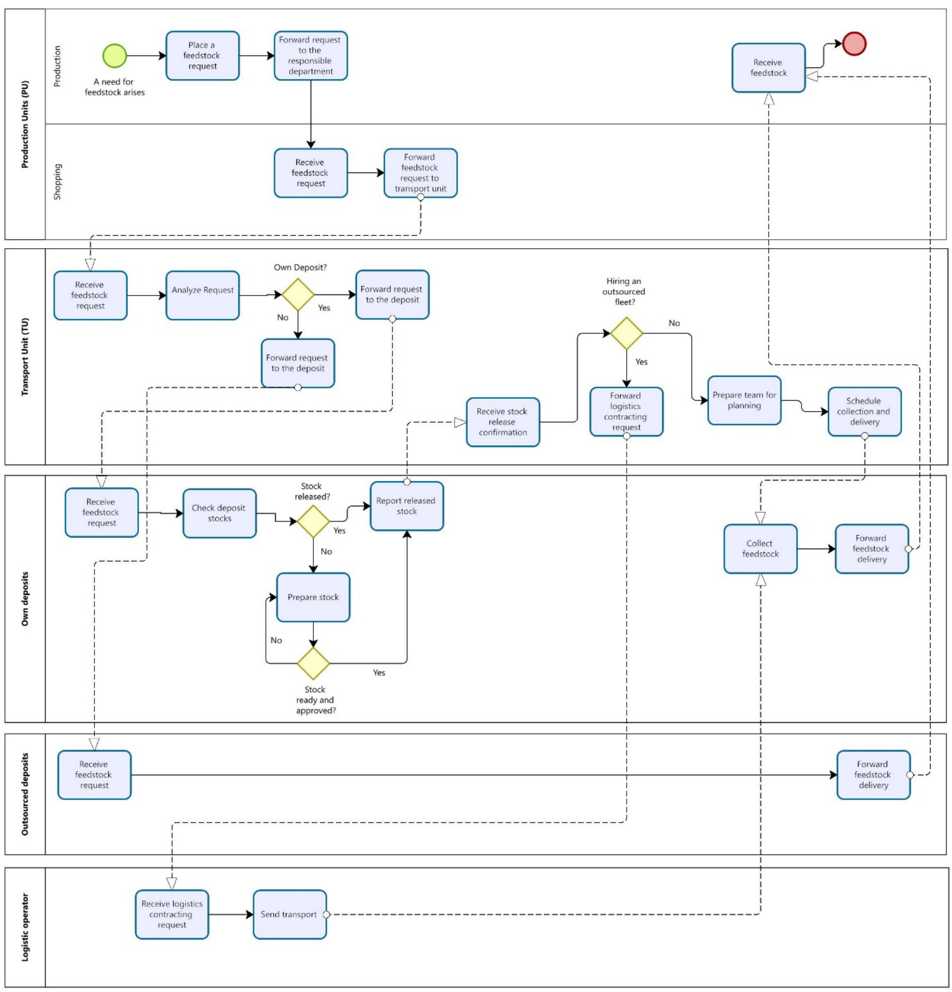

Figure 7. Supply activity flow.
Source: The authors (2024).

From Figure 7 it is possible to see that this is a complex process, whose activities require not only a flow of information but also documents in tune with the flow of material. In this regard, it is important to highlight that information and documents in transit in the process happen virtually through emails, phone calls, and messages via smartphone applications that integrate all employee communication, from operational to supervision and management.

4.3 Assessment of management components in business processes

As for the management components, which are part of the last dimension of the LCP model, the company under study and its supply chain present strong evidence of the practice and consolidation of these components in the organization's day-to-day operations.

Its physical and technical components are evident in the planning and control of supply operations and their flows, through its ERP (Enterprise Resource Planning) system in conjunction with Business Intelligence systems that allow the survey, treatment, modeling, and analysis of production data, generate useful insights for business units, thus guiding management decisions in a Data-Driven Management model.

In addition to production management activities and their flows, it is also possible to highlight its organizational, leadership, and power structure, consolidated in a Human Resources management model, focused on integration and professional development through training and internal marketing practices.

Thus, it is noted that the supply chain under analysis, based on its structural dimensions, its business processes, and its management components, is integrated into a value generation unit for the final customer, as shown in Figure 8, ratifying the principles that advocate and justify the need for this type of organizational structures given the specificities of the market in which they are inserted.

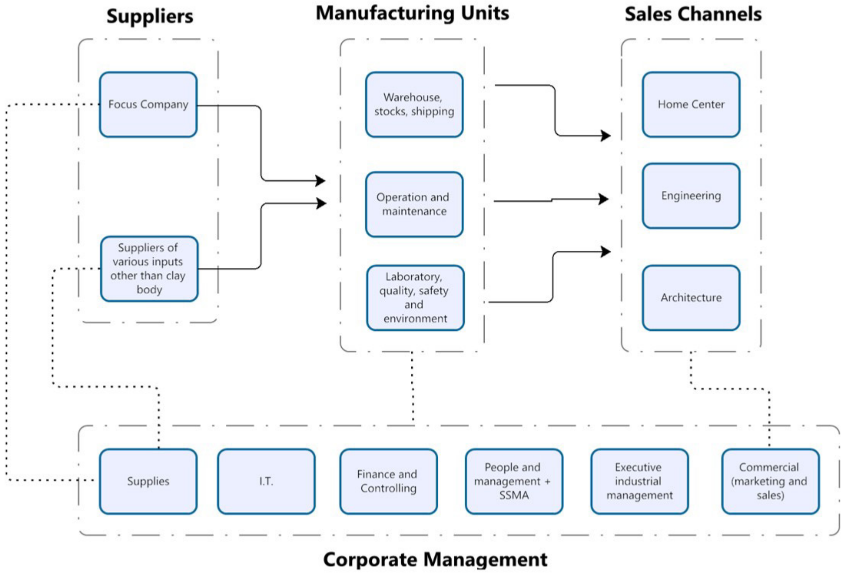

Figure 8. Value chain of the chain under study.
Source: The authors (2024).

Given the above, Table 7 summarizes the points of analysis and the main problems identified, as well as offers points for improvements for the chain in question.

Table 7. Problems identified and proposed solutions.

Business process evaluated	Identified Problems	Suggestions for improvements
Supplier Relationship Management	Low strategic integration with suppliers	Creation of actions to strengthen ties with suppliers and creation of a collaborative supply network. To this end, it is suggested the establishment of strategic partnerships, the development of transparent contracts and agreements, the sharing of strategic information, and the proposal of a supplier performance evaluation system.
Demand Management	Inefficiency in demand and order management	Creation and implementation of mechanisms for forecasting and monitoring demand from internal (production sector) and external (downstream members of the chain) customers. Here, we suggest the adoption of more robust and quantitative methods to predict demand and, consequently, improve order fulfillment, such as Time Series and Models based on Artificial Neural Networks.
Order Fulfillment		
Returns Management	Lack of reverse logistics policies	Creation and implementation of ceramic waste collection policies from the consumer market, such as clear returns policies, registration, and analysis of reasons for returns and feedback with customers.

Source: The authors (2024).

5 Final considerations

This article aimed to study the business processes of a supply chain based on the LCP model, a methodology used in analyzing and managing supply chains. A particular case of the ceramic sector supply chain in northeastern Brazil was studied, the analysis of which was based on the understanding of its processes, how they are managed, and the relationships between the different agents that make up the dimensional structure of the chain in question.

As a result, the application of the LCP model allowed, from chain mapping, to identify inefficiencies in business processes through understanding its members, how they relate to generating value for the customer and the management components used in the processes and their activities, thus presenting potential opportunities to improve the production system and, consequently, the operational efficiency of the chain.

Regarding improvement points, it is possible to highlight the improvement of the demand forecasting and management process, being able to use, instead of the subjective method adopted, quantitative models such as time series analysis or even through mathematical techniques and contemporary statistics within the context of the rise of Big Data and Data Science, such as the work of Farias et al. (2016) who proposed a predictive model based on Artificial Neural Networks to optimize the accuracy of demand forecasts in a supply chain.

Furthermore, the criticality of raw material transport operations and the exchange of information and data between agents in the supply process is also noted. In response to such problems, it is suggested to adopt tools from the PRR group (Quick Response Programs), for example, the Electronic Data Interchange and the Continuous Replenishment Program, which seek cooperation and information sharing to improve the operational performance of organizations, in particular supply chains, as discussed in the article by Pacheco et al. (2011).

It is important to highlight that all these analysis points and their suggestions for improvements were compiled in a management report and presented to the organization's director for his consideration and evaluation of the possibility of implementing the proposed corrective actions.

There are some limitations to this study, including the global pandemic caused by the COVID-19 virus, which prevented on-site visits to the company under analysis in this paper. As an extension of this study, it is suggested, in addition to the improvements listed, to increase the cost dimension in the analyses, to evaluate not only the company's operational efficiency but also its financial efficiency and the impact that each business process has on the structure costs in the supply chain. An analysis of the supply chain is also recommended, encompassing the supply of other inputs required by the production system, as a way of better portraying the dimensionality and complexity of the supply chain, as well as expanding the scope of evaluation for other business processes predicted by the LCP model.

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Statement on Data Availability

The authors declare that all data used in this article are fully available in the manuscript, with no restrictions on their use and dissemination.

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Authors contribution

Jailson dos Santos Silva was responsible for designing and writing this study. Maria Silene Alexandre Leite supervised the study.

Appendix 1. Data Collection Instrument.

Objective

To understand how activities occur in the raw material extraction process up to the manufacturing process of the products, highlighting the following aspects: extraction process, intermediate processes, quality control, fleets, transportation services, storage, and machinery used.

PART 1: RESPONDENTS IDENTIFICATION

Respondent:

Position:

PART 2: PRODUCTION PROCESS

1. How many deposits exist and where are they located?

2. Are the deposits owned or does the company have only the exploration rights to the area?

3. Regarding the extraction and preparation process of raw materials, mark with an “X” the operations that are part of the production process and indicate the responsible party for the operation:

Clay extraction from deposits ( ) - Responsible: Supplier ( ) Company ( )

Clay disaggregation ( ) - Responsible: Supplier ( ) Company ( )

Clay milling ( ) - Responsible: Supplier ( ) Company ( )

Particle size classification ( ) - Responsible: Supplier ( ) Company ( )

Clay purification ( ) - Responsible: Supplier ( ) Company ( )

4. Which sectors are responsible for the steps described in the previous question?

5. If the company is NOT responsible for the extraction in the deposits, who performs the mentioned operation? How many companies are involved in the extraction operation?

6. How many and what are the additives used in the preparation of the clay?

7. Mark with an “X” the type of clay used in the manufacturing process of ceramic products:

Slip - suspension clay ( )

Dry or semi-dry clay ( )

Plastic clay ( )

Other: ____

8. Mark with an “X” the techniques used in shaping the pieces:

Casting - gluing ( )

Extrusion ( )

Pressing ( )

Turning ( )

9. Is there any protocol to be followed for receiving the material at the factory, which will certify that the raw material meets the required quality standards for product manufacturing?

10. If yes, how much time is spent on this testing? Is the load only released after this process?

11. Is there transfer of loads between factory units? How is this procedure done? Is there any check-in/audit to ensure a standardization model?

12. What are the metrics involved in the supply logistics (delivery lead time, frequency of transporting cargo from the deposit(s) to the factory)?

13. Regarding the listed production processes, mark with an “X” those that are part of the company's production process and briefly describe how they occur:

Drying ( )

Firing ( )

Finishing (polishing, cutting, drilling) ( )

Glazing and Decoration ( )