

# Conceptual Model Based on Normative Multi-Agent System for Supply Chain Integration of Brazilian Gypsum LPA

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## ABSTRACT

The Brazilian gypsum has one of the highest levels of recognized mineral qualities in the world. Companies that operate in this sector support major economy-driving industries such as civil construction, architecture, medicine, and agriculture and are an input for the manufacture of paints, phosphors, and insecticides, among others. Most of the companies that constitute this sector are small and medium-sized enterprises (SMEs), which require supply chain solutions to maintain competition in market share. Supply chain integration as a collaborative solution has become a necessary strategy for enhancing SMEs decision-making capability. This study proposes a conceptual model based on a normative multi-agent system approach that offers a dynamic view about supply chain integration for managers and other stakeholders. From this contribution, it is possible to obtain constant information flow among stakeholders and build an effective strategic context for SMEs in the Brazilian Gypsum Local Productive Arrangement (LPA).

## KEYWORDS

Brazilian Mineral Industry, Communication Protocol, Local Productive Arrangement, Multi-Agent System, Normative Agents, Stakeholders

## INTRODUCTION

In emergent countries, the globalization incentives enterprises of the several market sectors to elaborate strategic actions to maintain their competitive business in a dynamic context and widely complex. In Brazil, the most of the enterprises is classified as small and medium-sized enterprises (SMEs) according to number of employees and annual gross revenues. SME need to be agile and have the ability to develop a high level of resilience, mitigate the consequences of managerial risks, and increase structural flexibility that enables them to respond quickly to the challenges of the competitive marketplace (Ben-Daya, Hassini & Bahrour, 2019). This SME are responsible for 25% of Gross Domestic Product (GDP) (SEBRAE, 2019) of the country, generating business opportunities and new job openings in various productive sectors. Among of the productive sectors, the mineral industry sector represents one of the main activities of the Brazilian economy. In this sector, SMEs are encouraged to play participatory roles the Supply Chain Management (SCM), such as suppliers, transformers and customers, to develop strategies and control over the information and products flows throughout the supply chain of gypsum industry.

SCM is a management model that requires organizational changes in order to develop cooperation, communication and trust, enabling integration among all chain stakeholders (Braunscheidel, Suresh

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& Boisnier, 2010). Supply Chain Integration (SCI) is a competitive business approach and provides the integration of cultural, operational and technological aspects considered by the stakeholders. However, SCI has not been implemented as widely as expected in SMEs, in many cases due to the lack of methodologies adequate of this type of enterprise (Palomero & Chalmeta, 2014) This is one of the factors which difficult the understanding about characteristics structural, conduct and performance of the market.

In each of the constructs of structure, conduct and performance of the market, stakeholders assume managerial roles to direct the actions of the different institutions that belong to the supply chain. However, the stakeholder's autonomy on decision-making requires that the norms, roles and responsibilities of each institution in SCI process are defined. So, some rules of behavior, relationship and communication must be followed to maintain the commercial balance between enterprises and government institutions, and to ensure the reduction of economic and social losses arising from the dynamism of the market. For this, Information Technology (IT) solutions can be support the description of SCI process for SMEs (Mishra & Mishra, 2009).

In this context, the public policies of the Brazilian government play an essential contribution in defining the guidelines for the mineral extraction market, and its inclusion as regulator of the SCI process is fundamental. The public policies define the regulated contributions of the behavior of each institution as agent of the market system. In this system, each agent exerts influence into interaction process and communication to ensure flow of information among different links in the supply chain, respecting the regulation of the public policies of the Gypsum Local Productive Arrangement (LPA), in context. However, the representation of this context can be complex. From this perspective, this work presents a conceptual model for the SCI of the Gypsum LPA using the normative multi-agent systems approach, considering the perspectives of communication, interaction and information flow to support the decision-making process of the main stakeholders.

## **Brazilian Gypsum LPA**

In Brazil, the exploration and commercialization of gypsum, as well the extraction, manufacture and distribution of products derived from gypsum, compose the productive activities of SMEs in the LPA of Gypsum in Pernambuco. LPA can be understood as a territorial agglomeration with a presence of economic, political and social agents that are involved in a constant transformation and a specific set of activities with common interests that communicate with each other. The Gypsum LPA is located in Araripe, far west of the State of Pernambuco, and it offers significant economic potential to the region. In this region, are registered more than 800 enterprises, including mines, calciners and manufacturers, since it is considered the largest set of mined deposits, representing 95% of the demanded gypsum in the country (FIEPE, 2017).

Nowadays, gypsum remains a mineral widely used in construction, architecture, orthopedic and dental medicine and agriculture and as an input for the manufacture of paints, phosphors and insecticides, among others (FIEPE, 2017; SINDUGESSO, 2019). Brazilian Gypsum has the best quality ore in the world, has an abundant reserve of gypsum, besides presenting excellent conditions for exploration of the material and geomorphologist of the deposit.

These characteristics attract ore exploration enterprises and artifact manufacturers enterprises that use gypsum as raw material, to operate in the region in collaboration with the economic and social development of the APL. These different enterprises act as institutions, or stakeholders, in the supply chains responsible for supplying and generating value for the sector's business. These stakeholders are agents who are identified by the ability to change or be changed through achievement of objectives within a collaboration and information exchange network in the supply chain, having a direct and indirect interest in the business contribution.

According to (Freeman & Reed, 1983), defines the theory that stakeholders usually have limited focus on certain groups, such as financiers, labor, consumers, suppliers, local community, and others. On the other hand, (Kline & Mcdermott, 2016) state that stakeholders include all institutions that are

affected as well as those that may affect an enterprise. In this way, the stakeholders are all agents, target audience and institutions that cooperate, voluntarily or not, for the creation of wealth within the organizations, thus being the beneficiaries and/or potential people who are included and belong to a supply chain (Freeman & Reed, 1983; Post, Preston & Sauter-Sachs, 2002).

According to Harrison & Bosse (2013), consider that organizations that can generously refer their stakeholders can achieve higher levels of competitiveness by increasing company values. Show that when recognized stakeholders tend to be reciprocal in their attitudes, actively participate in the relationship of information and product exchange, seek alternative tax incentives and fundraising, among others, due to cooperation and integration of shared knowledge. Table 1 presents the main stakeholders and supply chain requirements of Brazilian Gypsum LPA.

**Table 1. Supply Chain Requirements of Brazilian Gypsum LPA**

Supply Chain Requirements	Description
Main actors/stakeholders	Customers, retailers, wholesalers/distributors, manufacturers, component/raw material suppliers, society, trade union, financial agencies, educational institutions, business consulting agencies, and government.
General objective	Actors are responsible for the increase of the enterprises' market share and for improving customer expectations of the supply chain.
Transformation process	Transformation of gypsum is the main aim of the companies. The outputs are finished products for several areas: health, agriculture, civil construction.
Environmental constraints	There are barriers set that the system can face such as economic situations, scarce raw materials and substitute products, among others.

The information presented in Table 1 was extracted from documentary analyzes about the Brazilian Gypsum LPA. From Table 1, actors are stakeholders or agents which exert an important role in ensuring that cooperation is efficiently achieved in the SCI process. Stakeholders influence the existed relationships in the market, and they are customers, retailers, wholesalers/distributors, manufacturers, component/raw material suppliers, society, trade union, financial agencies, educational institutions, business consulting agencies, and government. The general objective of these actors is improving the performance market, control the information flow and improving customer expectations of the supply chain. In additional, the SMEs of this LPA are classified as miners, calciners and artifact manufacturers, which deliver products to various industrial sectors such as health, agriculture, civil construction.

For the description of the supply chain integration context, it is important to describe the potential barriers and management difficulties faced by SMEs. These difficulties often impact economic aspects that evidence the increasing exploitation of raw materials, the relationship with financial and governmental institutions in relation to tax incentives, the interaction with market forces such as potential substitute products, among others. From this, the influence of each agent encourages the investment of the flow of information that aids in the decision-making of the SCI process.

According to Cadden, Marshall & Cao (2013), in SCI, collaborative practices should replace competitive structures, leading enterprises to obtain greater openness of information and decision-making jointly among the enterprises, such as SMEs in Gypsum LPA, that make up integrated supply chain management, considering the rules from market regulatory institutions. This openness will allow operational and managerial risks to be shared by providing a better understanding of the potential obstacles to be faced in the ICS process.

## DECISION-MAKING IN SCI PROCESS

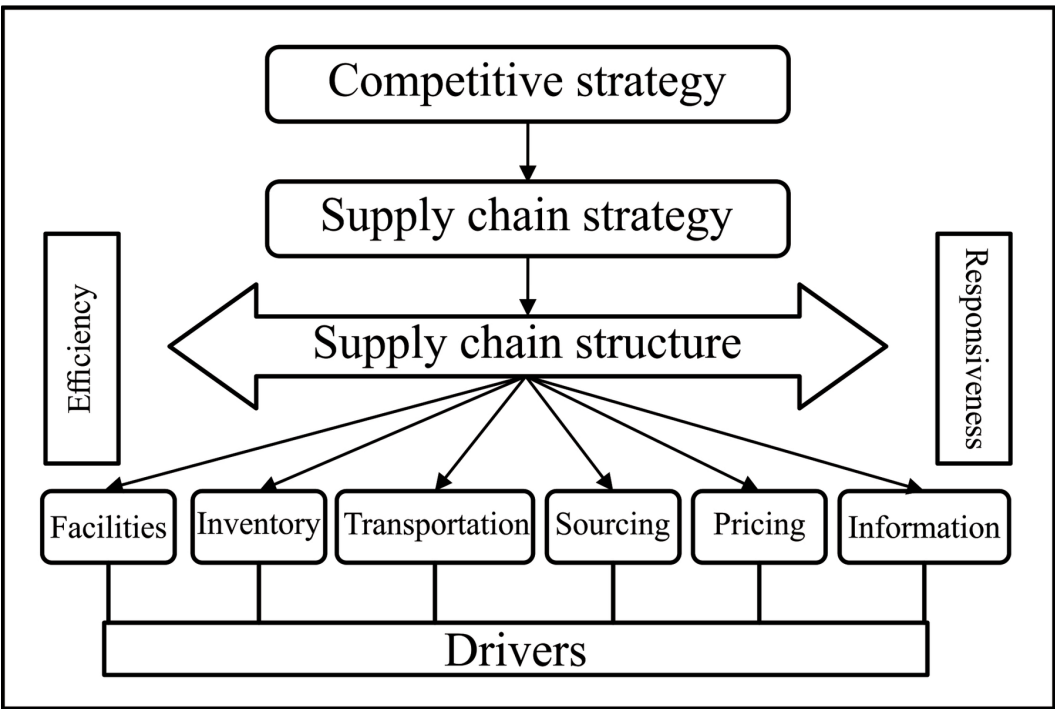
In the literature, SCI is a strategic multidisciplinary approach that consider several activities over purchases and sales of products and services, logistics operations, management information flow, financial flow, relationship among stakeholders and business partners, and others (Chopra & Meindl, 2013; Valmohammadi, 2013; Wu, Chuang & Hsu, 2014). SCI allows to ensure the formation of a value chain network represented by individual entities that are committed to providing both information and resources to efficiently achieve supplier goals and material flows (Bidhandi & Valmohammadi, 2017). In this context, there is a synchronization among all systems governed by the organization, allowing the generation of more efficient results in terms of performance, collaboration and information sharing to support the decision-making process (Schoenherr & Swink, 2012).

This support provides greater competitive potential, greater knowledge related to the power of communication and the transfer of information among stakeholders, especially for SMEs which must face cultural, operational and technological obstacles (SEBRAE, 2019). These obstacles encourage studies on management alternatives that minimize negative impacts on the decision-making process.

In the supply chain, enterprises have several control points distributed in a dynamic environment, and each one has a specific objective, but they interrelate in order to solve tasks to cooperate in the market. This means that the collaborative relationships are related to the profits gained by each agent as a member of the chain and by the whole chain (Perales, Esteban, Díaz & Hernández, 2012) Figure 1 shows a supply chain decision-making framework based on logistical and cross-functional drivers (Chopra & Meindl, 2013).

Figure 1 shows the main management drivers: (i) Facilities, Inventory and Transportation are logistical drivers that make decisions about the assets that a company owns or outsources; (ii) Sourcing, Pricing and Information are cross-functional drivers that make decisions about how each logistical driver will be obtained, used, delivered and so on. All actions should be provided in the supply chain

Figure 1. Supply chain decision-making framework. Source: Chopra & Meindl, 2013.



strategy to answer to production capacity, demand forecasting and customer satisfaction, among others. These initiatives can be used to ensure market share, active communication, and compliance with rules and laws imposed by market regulatory institutions in supply chain structure (Chopra & Meindl, 2013). The competitive strategy is consequence of planning on management drivers in SCM. These drivers are important for description of the business power and business limitations, considering strategic perspective.

In general, the main management drivers show in Figure 1 exerts influence in SCI when the limitations of the business are considered. So, these limitations are related to potential obstacles which impede progress and it difficult the decision-making in the SCI process. Among the main obstacles, there is resistance in the organization regarding information sharing and of the knowledge about internal and external operations functions. These obstacles require from the enterprises the greater participation and efficient organizational leadership, in particular over the SMEs context in that resources of cultural, operational, and technological can be restricted.

### Obstacles and Barriers in The SCI Process

In SMEs, cultural resources define interactions among agents in enterprise environment and it describes the way how the business is managed. In this aspect are included relationship into staff context, strategic objectives, relationship among stakeholders, financial perspective for investments, rules and market' regulations, among others factors. The operational resources refer to operational methodologies used in the enterprise to determine it productive function. In this aspect are included trained staff, production cycle of products and/or service, and performance indicators to measure business evolution. As technological resources are included the IT solutions which support the management activities considering interactions, communication, and sending messages among stakeholders to maintain collaboration in SCI process. Table 2 presents main obstacles seen in SCI process of SMEs (Palomero & Chalmeta, 2014).

**Table 2. Main obstacles of supply chain integration**

Aspects	Main obstacles
Cultural	Lack of knowledge about benefits of organizational changes; Lack of trust among supply chain stakeholders; Lack of support and commitment from managers; Complexity of regulations or local laws; Imbalance between indicators of the financial area and those of other areas.
Operational	Lack of trained staff to manage SCI process; Inexperience in managing improvement programs; Lack of indicators to measure SCI; Poor quality of logistics services infrastructure.
Technological	Lack of knowledge or experience in new IT solutions; Lack of resources dedicated to internal and external communication.

Source: Palomero & Chalmeta (2014).

From Table 2, lack of knowledge about benefits of organizational changes, lack of trust among supply chain stakeholders, lack of support and commitment from managers, of regulations or local laws, and imbalance between indicators of the financial area and those of other areas are frequently related to cultural obstacles of the SCI process in SMEs. In many cases, the SMEs have not complete understanding about gains which the integration process can be offers to enterprise. Other relevant factor is the understanding on laws and regulations which regulate the productive activities in a market sector and it can be complex.

The operational aspects are related to physical infrastructure and qualification of personnel belonging to enterprise. The lack of trained staff to manage SCI process, inexperience in managing improvement programs, lack of indicators to measure SCI and poor quality of logistics services infrastructure represent greater barriers to increase of the business and can be compromising for operations quality in a competitive market (Palomero & Chalmeta, 2014).

As technological aspects are considered the lack of knowledge or experience in new IT solutions and lack of resources dedicated to internal and external communication. The lack of business alignment with IT solutions can affect performance and at the same time not contribute to the internal process (Ataseven & Nair, 2017). However, some enterprises may have difficulty implementing IT solutions due to limitation of the knowledge and specific skills, so the decision to knowledge the capacities of IT services is a strategic decision for them. IT resources are capable to provide better integration, communication, information and visualization, data control, and obtaining of satisfactory outcomes in the internal and the external environments.

These obstacles can be identified mainly when there is no efficient control in the enterprise's processes, being factors responsible for great loss of competitive power. On the other hand, these can be corrected when identified, however their identification is a complex process that requires attention in understanding the relationships among stakeholders (Harrison & Bosse, 2013). In particular, for SMEs, addressing these obstacles is complex due to a lack of complete understanding of the business structure, conduct and performance of the market sector in which it operates, which inhibits the SCI process.

One of the approaches widely used to conceptualize and represent the influence of enterprises and institutions on the market is based on the Theory of Industrial Economics, which seeks to adapt to the internal and external forces required by the economic relations of the market. This approach is recognized by the Structure-Conduct-Performance (SCP) Paradigm which provides data from organizations, establishing an important relation among how enterprises are being conducted within their industry, their structures and their economic performance (Makate, Siziba, Hanyani-Mlambo, Sadomba & Mango, 2016).

### **Decision-Making In SCI Process Based on SCP Paradigm**

The SCP paradigm framework is widely adopted to evaluate the organizational competitively by investigating the structure of industry relates to the firm behaviors (conduct) and performance (Gavurova, Kocisova & Kotaskova, 2017). According to this paradigm, market structure is the decisive factor for a management and performance model of the enterprise. The approach seeks explaining the correlation between market structure, competitive behavior and operational performance among organizations in a sector (Lee & Yang, 2016), using a set of variables that serve as a starting point for problem assessment in a regression analysis (Stănciulescu & Molnar, 2017). Through analysis, the approach allows to explain empirical observations related to the development of market immersion strategies.

Over time, the SCP paradigm has received several methodological contributions that aim to represent the various factors that influence the structure of the market, including the emphasis on the perceived strategic aspects of networking. Finally, the crucial role related to public policy has been added by adding interactions where regulations and conduct policies can affect enterprise performance and market structure, as well as performance can have a direct impact on market structure without impacting directly in decision-making business strategies (Scherer, 1997).

According to Gavurova, B., Kocisova, K., & Kotaskova, A. (2017), the general framework suggests that basic conditions shape the structure of the market, while structure problems affect the conduct of the business, which in turn affects its performance. With the intervention of public policies, adjustments in structure, conduct and performance will be monitored interactively through rules and regulations to ensure the relationship among the various stakeholders. In the long run, performance affects conduct and structure, while structure affects basic conditions.

The SCP framework has devices that enable the identification of various scenarios presented in a supply chain. In addition, it can be adaptable and applied in various areas to describe problems related to understanding market structure. Table 3 presents some examples of its application.

**Table 3. Applications of Structure-Conduct-Performance Paradigm**

Application	Description	Reference
Economic education	This study investigates how many times the students have dedicate for seminal tests.	Ray (1992)
Service	This study analyses how SCP paradigm can be used in enterprises of service sector.	Britton, Clark & Ball (1992)
Telecommunication	This study seeks a relationship between the structure of the market and reforms to the telecommunications policy. To this end, the authors combined the model with a stakeholder analysis.	Mesher & Zajac (1997)
Financial market	Studies aimed at identifying changes in the structure of insurance markets that face constant cases of fraud, as well as analysing how their regularization impacts the conduct and performance of the market.	Cummins & Dionne (2008) Weiss & Choi (2008)
Civil construction	This study seeks to identify contractors' standards for R&D considering the structure of the Japanese construction industry.	Konno & Itoh (2018)
Supply chain integration	The authors used the SCP paradigm to explain the conduct of companies in investigating corporate strategies used for internal and external integration in enterprises.	Ralston, Blackhurst & Cantor (2015)

According to Russel & Norving (2016) the using survey data to show how companies can align business objectives with stakeholder interests to modify enterprises' responsiveness to customer demands, assessing the extent to which integration can affect organizational performance from a supply chain perspective. In addition, through the SCP paradigm it was possible to explain the conduct of companies by investigating the relationship between operational and financial performance.

From the perspective of supply chain participation, organizations seek to add competitive advantages to their business by investing in communication and exchanging experiences among the stakeholders involved. In this context, one of the main opportunities for business development is the process of cooperation among the parts of the same system (Mishra & Mishra, 2009). The setting up of a cooperative system that allows interaction between different agents in the supply chain is an approach capable of returning varied management benefits.

Based on this objective, the computer sciences approach techniques and theories aimed at the cognitive representation of active agents in the same cooperative environment (Russell & Norving, 2016; Günay, Winikoff & Yolum, 2015). In this representation, the definition of the roles and responsibilities of each agent must meet the context description requirements and maintain the constant flow of information to ensure the best performance of the system interaction. In particular, this representation is appropriate for supply chains, where several stakeholders assume different responsibilities that contribute to the market evolution.

In the distributed Artificial Intelligence discipline, one of the most commonly used approaches to represent interactive systems is the Multi-agent Systems Approach (MSA). This approach uses the

conceptual mapping technique to define responsibilities and roles of agents in an integrated system, allowing the explanation of concepts, applications and particularities of relationships among agents, and it has been incorporated for the representation of complex systems, as SCM and SCI process (Munroe, Miller, Belecheanu, Pěchouček, Mcburney & Luck, 2006; Pěchouček & Mařík, 2013). However, is important consider that public policies define laws and regulations that ensure the economic incentive and regularization of productive activities carried out by enterprises in a supply chain. The legislative aspects are fundamental to defining the behavior of the agents and should be incorporated into the conceptual model for the SCI process, in specially for SMEs. From this perspective, it is pertinent the application of Normative Multi-agent Systems Approach which apply sociological theories in multi-agent systems, using agent theory and the social sciences to describe interactions in a system.

### Normative Multi-agent Systems Approach

The normative multi-agent system definition can be understood as combined concepts about normative systems and multi-agent systems (Shoham & Tennenholtz, 1992). Norms are essential to conduct human social behavior and is a fundamental element to describe artificial agents' performance that simulate and collaborate with humans. Norms are implemented in multi-agent systems to provide models for cooperation and co-ordination among artificial agents that represent the human intelligence rationale in social context.

By integrating norms and multi-agent systems, is possible build and implementing Normative Multi-agent Systems with specific instructions to solve group decision problems, regulated societies, multi-agent organizations structuring, among others cases. The normative term highlights the insertion of normative behavior or normative judgments, like as social laws, to describe multi-agent autonomy based on sociological theories in contexts that the regulation process assumes fundamental roles (Shoham & Tennenholtz, 1992). Table 4 presents some applications of Normative Multi-agent Systems approach.

**Table 4. Applications of Normative Multi-agent Systems Approach**

Application	Description	Reference
Supply chain planning	This study proposes a methodology for development of an environment to design and test distributed advanced planning and scheduling systems in supply chain.	Ferreira & Borenstein (2011)
	This study presents a framework which explicit the modelling the actors involved in the regulation of SCs to evaluate the potential benefits of alternative strategies for planning.	Braggins, Ilie-Zudor & Monostori (2009)
Project management	The purpose of this study is to present a model to select partners in the supply chains, considering a quantitative framework to support the decision-making process on project management.	Garcia, Giret & Botti (2016)
Business process	This study approaches a methodology to the development of normative open virtual enterprises.	Huhns & Stephens (1999)

A normative system is identified if there is at least one normative correlation among set of sentences that result in normative consequences in specific case (Shoham & Tennenholtz, 1992). The normative consequences are outcomes of specific roles' implementation, that describe or bound the



agent behavior in the computational environment. The agents interact with the normative system being able to create new norms, update or maintain norms, and enforce norms (Shoham & Tennenholtz, 1992), using regulation rules, legislators or other government force, and they can use those rules to determine the constraints and conduct equilibrium of social behavior. In normative multi-agent system, the agents use the norms to define their autonomy as decision maker in a dynamic system.

From Table 4, the normative multi-agent approach is commonly applied to respond to the behavior of different agents in a cooperative environment such as a supply chain. In order to analyze and design systems of this kind this approach seems suitable because it offers a specific solution for supporting the social and contractual relationships among enterprises and for formalizing their business processes. For SMEs public policy representation tends to facilitate understanding of the interactions between companies and regulatory organizations so that business expansion incentives contribute to the economic and social development of a region.

There is an increasing interest on developing SMEs in order to deal with the globalization of the economy, the rapid growth of information technologies and the increase of competitiveness. In order to design context of this kind, this study propose a conceptual model based on normative multi-agent approach to support the social and contractual relationships between enterprises and for formalizing their business processes. The case study is applied in Brazilian Gypsum LPA, focusing only on the cities of Pernambuco that stand out in gypsum production activities and enterprises profiles.

### **Conceptual Model of Supply Chain Integration of Brazilian Gypsum LPA**

In the Araripe region, in the far west of the state of Pernambuco, is located one of the largest and most promising LPA in Brazil. The Gypsum LPA encompasses ten municipalities, accounting for about 95% of the product produced throughout the country (FIEPE, 2017) Gypsum is treated as white gold in Araripe because it has potential and for being used in various areas, such as agricultural products, the jewelry industry, automotive, healthcare (medicine and dentistry) and the construction industry featuring A cost-benefit ratio for being a material that has characteristics of thermal insulation, stability, lightness and high quality of chemical components.

Despite the great productive potential, Araripe's gypsum production has received significant influences from the country's economic changes. Many companies are unable to maintain their activities due to the financial crisis, the informality rate increases, and the lack of logistic structure is maintained for production to be distributed to customers in the country and exported to other countries. About this, (Valmohammadi, 2013; Günay, Winikoff & Yolum, 2015) characterize the Araripe region as a poorly diversified production base presenting a large turnover of SMEs that ends up damaging the innovation and learning process of the APL. Regarding the growth and development of the APL, a technical study was conducted by FIEPE (2017) in which it was observed that high tax burden, lack of knowledge of regulatory public policies and inefficient communication among supply chain stakeholders are factors that inhibit development of SMEs in this region.

In the SCI problem of Gypsum APL, several stakeholders influence the generation and transfer of useful information for process maintenance. One of the first concerns of this study was to identify who are the stakeholders that can be included in the perspective of supply chain representation under analysis. For this, it was considered a survey in which in the relationship between stakeholders, trust is an essential part for the improvement of production and growth of the organization, because it is possible to invest in strategic actions to overcome the main obstacles presented in Table 2.

In this context, the formulation of information management-based strategies to support decision-making processes that promote the return to growth and commercial expansion of the APL is extremely important. Moreover, considering cultural aspects, it is possible to develop actions that improve the relationship between the different stakeholders of the supply chain, since the objectives of each agent will be clearer to identify. Stakeholders include customers, suppliers, political and/or educational public bodies, and society at large. Regarding the operational aspects of organizations, stakeholders can efficiently encourage collaborative work across all sectors, engagement within the organization

and the way they are open to possible change, and the provision of logistical support for transporting products, materials, raw materials and information. Regarding the technological aspect, organizations acquire greater ability to adapt technological innovations thus promoting greater integration between sectors beyond the standardization of operations and qualification of the workforce.

### Market Structure of Brazilian Gypsum LPA

From an economic perspective, the SCP paradigm uses theoretical instructions to assist in describing the composition of a market. In the construction of the market structure of the Gypsum APL, the main components that lead the understanding of how interactions occur between the productive agents of a market are indicated. Among the particularities are described the characteristics that define the quantity, size and type of productive operation of companies, the demand for products and services of the various stakeholder groups, the technological conditions, the ease of entry and exit of companies in the market and geographical proximity of the organizations.

These elements influence the conduct of the companies while also suffering interference from the elements of conduct, performance and the framework regarding the elements identified for public policies.

**Table 5. Factors which describe Gypsum LPA Structure**

Aspects	Factors
Cultural	Closely localization of the Gypsum industry with input suppliers Predominant road mode of transport
Operational	Competition among the LPA enterprises
Technological	Desertification of the region Restricted power supply options for energy matrix

### Market Conduct of Brazilian Gypsum LPA

The conduct of SMEs is a response to the characteristics observed in the market structure, while the role of stakeholders is to recognize these characteristics and adapt to environmental factors. In this sense, Table 6 presents the instructions regarding the conduct of the SMEs of the Gypsum LPA, which should be implemented to increase the enterprises' participation in the market in order to obtain competitive advantages in the SCI process. Among the strategies, the growth of companies depends on how much is invested in improving their processes, the quality of products, and the price offered to the consumer. For this, it is important to plan how to capture investments and how they will be allocated to the various needs of the company.

Investing in professional qualification is another aspect to be considered because in order to achieve internal integration and improve relationships with all links in the supply chain, all stakeholders

**Table 6. Factors which describe Gypsum LPA Conduct**

Aspects	Factors
Cultural	Participation in associations and unions Marketing strategies Communication (internal and external)
Operational	Cooperation through partnerships, mergers and alliances
Technological	Partnerships with education and research institutions

use work in synergy as well as knowing how to implement the process. The development of new products, such as marketing strategies and the search for partnerships between companies in the sector, are also measures that contribute to the transformation of the market structure. This interaction is perceived through the recurring process in the SCP paradigm.

### **Performance of The Brazilian Gypsum LPA**

Recursively, the performance of organizations affects the structure and conduct of the market. Market performance analysis should be multidimensional. For this, in addition to financial considerations, stakeholders should consider measures related to the efficiency of organizations, such as product and service prices, process and inventory efficiency, profit margin; and aspects of social interest, such as employability rate, salary range, among others.

From the research conducted, the performance expected by stakeholders for companies to be able to develop and advance the process of supply chain integration is focused on improving the efficiency of SMEs internal activities, including better communication between all sectors of the company, reduction of rework, and waste of labor and raw material. In addition, improve communication with other links in the supply chain, especially with customers, by aligning their desires and offering innovative and quality products. In the social aspect, we seek to increase the generation of jobs, increasingly providing the economic growth of the region.

Influential on the conduct and performance of the market is the normative force governing the national competitive market. This force is configured in public policies that should be related to a better understanding of the interactions experienced in the studied market.

### **Normative Aspect For Brazilian Gypsum LPA**

For SMEs of the Brazilian Gypsum LPA context, the strong influence of normative instructions, such as laws and regulations, are guidelines imposed by the public power in order to guide the actions, rules and procedures for the relationship and behavior of the main actors in this market. Among the guidelines, the competitive strategies are related to the economic model, technological innovations, productive restructuring and the effects of job creation and reduction of social inequality in the local region.

For the LPA studied, it is perceived the strong influence of normative instructions, such as laws and regulations, which govern the behavior of companies as market players. These normative instructions are formalized by the public policies, which are guidelines presented by the public power with the purpose of guiding the actions, rules and procedures for the relationship of these entities with society. The strategic dimension is linked to the economic model and should consider technological innovations, productive restructuring and the effects they can have on job creation to reduce social inequalities.

In general, the actors who develop the guidelines are represented by educational institutions, business consulting agencies, trade unions, financial agencies and government that highlight tax incentives, the legalization of informal enterprises, the provision of managerial and technological knowledge and financial support from APL to continue contributing to the revenue generation and labor absorption. From this, it is possible to consider that these agents exert influence in the decisions based on logistical and cross-functional drivers in the SCI process.

Decision-making process require an active flow of information to ensure control and interaction among different agents in the market. Figure 2 represents the role of normative agents highlighting the flow of information developed for the Brazilian Gypsum LPA context.

Figure 2 shows the interaction among the stakeholders from the normative perspective. These are represented by governmental and non-governmental institutions, which foster industry growth and managerial and technological knowledge in enterprises. These are Federal, State and Municipal Government, trade union, Financial agencies, business consulting agencies and public and/or private educational institutions.

Figure 2. Normative agents in Brazilian Gypsum LPA

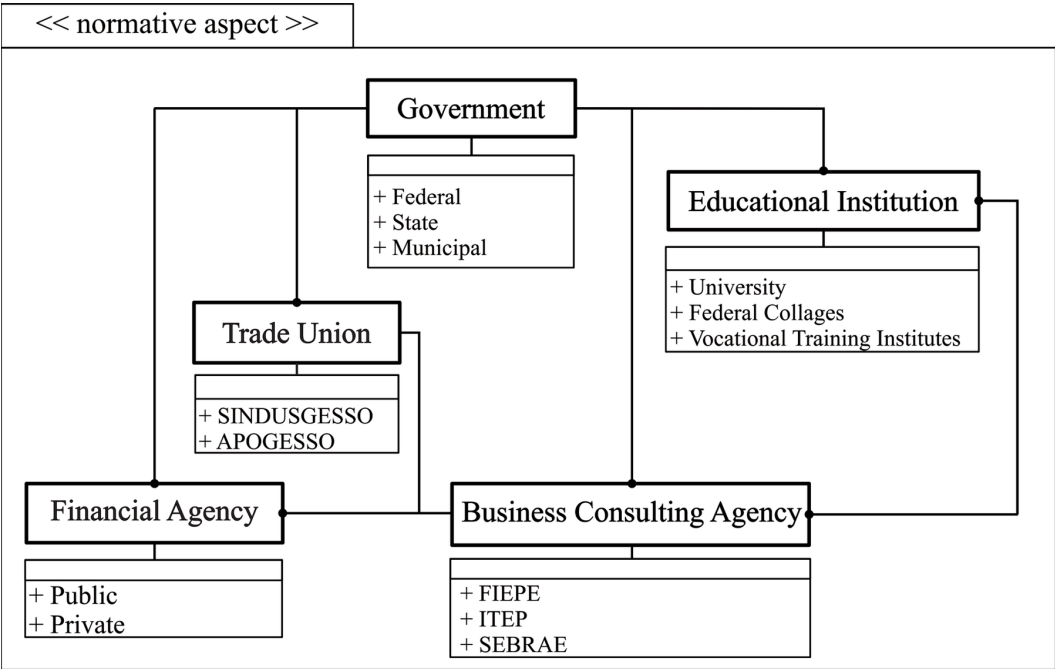
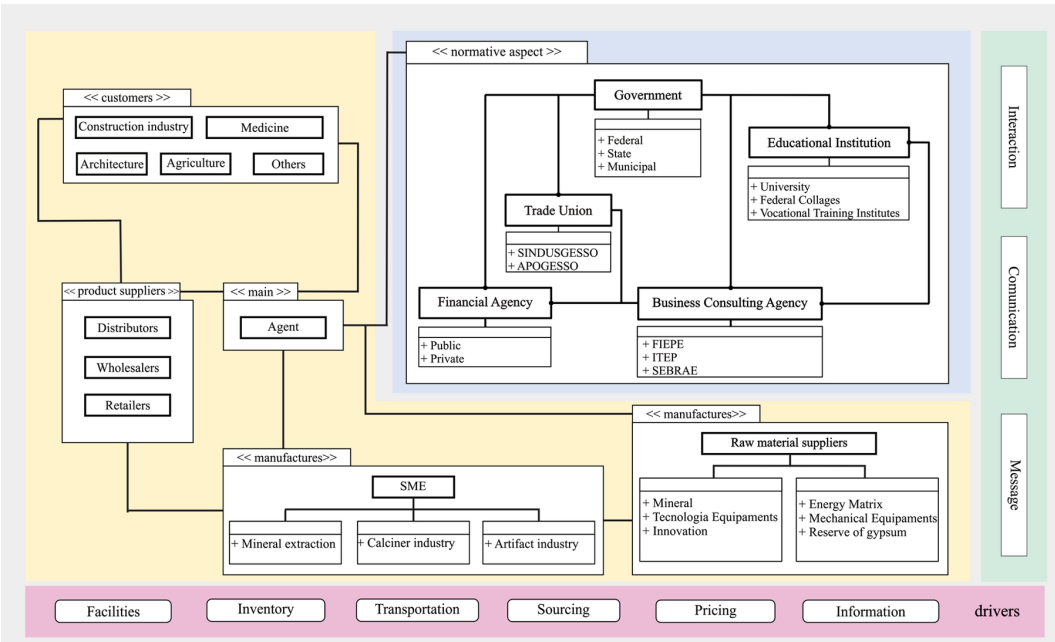


Figure 3. UML Diagram for SCI process in Brazilian Gypsum LPA



Based on Figure 2, the multi-agent systems approach is able to represent cognitively active agents in the same cooperation environment. In this environment, the roles and responsibilities of each agent are defined and maintain the constant flow of information to ensure the best performance of agents. Figure 3 shows a diagram of the SCI process considering SMEs in the context of Brazilian Gypsum LPA.

As illustrated in Figure 3, the provision of models, tools and collaborative technologies will enable a more effective business strategy for handling the products and agents service perspective of key SMEs in the SCI process. In this case, the supply chain structure is represented by customers, product suppliers, manufacturers, raw material suppliers and normative agents. Raw material suppliers provide active and passive resources to the manufacturers, which provide finished or semi-finished products to retailers, wholesalers and/or distributors. The product suppliers deliver the output to the different customers. All agents assume a specific role determined by normative aspects.

### **Multiagent Communication For Brazilian Gypsum LPA**

The functional requirements in the conceptual model correspond to the interaction, communication and sending of messages to support the decision-making process based on logistical and cross-functional drivers. Thus, this conceptual model presents an adequate contribution for the SCI process in the Gypsum LPA context.

From Figure 4, each agent has the capacity for perception, processing and performance, in addition to having internal representations in the system. Because of this, communication between agents is considered complex due to the languages used and the role that each agent plays in the environment. The communications' functionality must be directly related to the central module of the agent allowing it to have access to the messages received and to define which messages to send among the stakeholders.

The communication architecture assisted by facilitating agents partially solves the problem of coordination of communication and considerably reduces the complexity in carrying out communication, as agents do not need to store detailed information about all other agents. Huhns & Stephens (1999) define the assisted communication architecture in the context in which the System incorporates facilitating agents responsible for communicating with other agents. That is, if a given SME wishes to send a message to a government organization, for example, it will have to send the message to the facilitating agent who will forward it to its final destination. However, if the facilitating agent ceases to function, the communications' system also ceases to function. In this way, the facilitating agent is represented by the decision-making process that will process all requests for messages.

The conceptual model developed for SCI process of the Brazilian Gypsum LPA enables the specification and edition of interaction protocols for the specific identified process. The model can also be used as a repository of interaction protocols, assisting in the analysis and design phases of a Normative Multi-agent System, in which interactions among different agents are defined.

### **CONCLUSION**

The Brazilian Araripe region is responsible for an expressive volume of production and commercialization of gypsum and its derivatives throughout the nation' territory. Therefore, studies on the SCI process are significant in providing opportunities for internalization of regional public policies. From this work, a conceptual model based on the normative multi-agent system approach represents the SCI process of the Brazilian Gypsum LPA, which includes normative instructions, such as norms, laws and regulations, about stakeholders' market share to define their behavior in this context.

In order to analyze and design complex systems the normative multi-agent approach offers a specific solution for supporting the social and contractual relationships among enterprises and for

formalizing their business processes in SCI process. In particular, some methodologies for SMEs management are considered strategic when incorporate regulation role, whether issued by a government agent or by a national institution to describe the real market context. The stakeholders modelling involved in the regulation of Gypsum LPA using normative agents allowed to evaluate the potential benefits of alternative strategies for planning of this region.

Due to a scarcity of bibliographic references, this study contributed to the literature about the studies of Gypsum LPA and encourages new studies that can be performed in the sector. The conceptual model presented for the SCI process is the first stage of the implementation of the IT solution. The initial results are satisfactory and offer an improvement regarding Brazilian Gypsum SCM that can be considered a collaborative solution for competitive strategy and for enhancing the decision-making process for SMEs in the LPA. Thus, the model will be used to support different decisions and to indicate the best recommendations for maintenance of interaction, communication and flow of information among stakeholders, and it can be adapted for other contexts.

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