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RESEARCH PAPER

Supplier assessment in a University Market: supply chain analysis and service delivery

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ABSTRACT

Goal: This study aims to model and analyze the supplier network of a university retail market to enhance supply chain efficiency, optimize supplier relationships, and improve service delivery to internal and external stakeholders. This study fills a gap in the literature by addressing the still underexplored context of supply chains in university markets, contributing new insights into the efficient management of supplier relationships and the provision of public services in academic environments.

Design / Methodology / Approach: The research employed a mixed-methods approach, integrating qualitative data from semi-structured interviews and document analysis with quantitative metrics derived from Social Network Analysis (SNA). UCINET software was used to calculate centrality, cohesion, and network density indicators. The network structure was analyzed based on a case study at the State University of Maringá (UEM), involving internal and third-party suppliers.

Results: The results reveal that the Focal Company (EF) occupies a central but vulnerable position, with high degree and betweenness centrality. Key suppliers, such as F12, show strong ties, while peripheral actors, like F3 and F4, exhibit weak and sparse connections. The network displays moderate density, suggesting potential for strengthening weak ties and diversifying sources. Identified challenges include supply irregularity, overdependence on specific nodes, and inefficiencies in logistics and inventory management.

Limitations of the investigation: The study is limited by its single-case design, which may constrain the generalizability of the findings. Additionally, the use of self-reported data may introduce subjectivity.

Practical implications: The findings support actionable recommendations, such as enhancing collaboration with peripheral suppliers, adopting AI-based forecasting tools, and expanding storage and transport capacity, contributing to greater supply chain resilience and service efficiency.

Originality / Value: This research offers an innovative application of SNA in a university retail context, providing a replicable framework for analyzing and improving supplier interactions and supply chain performance.

Keyword: Supply chain; Supplier evaluation; Customer-supplier interaction; Network modeling.

1 INTRODUCTION

Logistics gained prominence after World War II, focusing on activities such as supplying weapons and food, movement, rest areas, and transportation (BANDEIRA & PEINADO, 2010). In the 1980s, it began to operate in an integrated manner with other sectors of organizations, covering the entire process from the supplier, through production and distribution, until reaching the end customer (MACHLINE, 2011). Logistics is a set of processes that integrate the supply chain, aiming to plan, control, and organize the flow of storage of resources and services. It also plays a

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fundamental role in the management of product information, from the point of origin to consumption, to satisfy customer demands (CARVALHO JUNIOR; MACEDO, 2012).

The supply chain in retail companies plays an essential role in competitiveness and meeting consumer demands. In this context, efficient supply chain management allows for a quick response to market variations and greater integration between suppliers, distributors, and stores (BALLOU, 2020). With the growth of consumer expectations for quality products and constant availability, retail markets need to adopt modeling and optimization strategies to achieve efficient and profitable operations (CHRISTOPHER, 2016; CHOPRA & MEINDL, 2022). To contribute to the analysis, Ching (2010) says that the supply chain encompasses all efforts in the different business processes and activities that create value in the form of products and services intended for the end consumer, naming this process as Supply Chain Management, including all efforts related to the various business processes and activities that create value in the form of products and services for the end consumer.

SCM involves the integration of planning and control of the flow of goods, information, and resources from suppliers to the end customer, promoting cooperation and generating mutual benefits throughout the entire logistics chain. Barbosa and Musetti (2012) pointed to the importance of this exchange of knowledge and learning arising from partnerships between domestic and complementary foreign companies for the transfer of competencies, skills and logistical experiences, improving the performance of small and medium-sized domestic companies.

Supply chain modeling involves the use of tools and methods to represent and analyze the interactions between the different elements of the chain, promoting an integrated and strategic vision. In the retail sector, the adoption of modeling technologies such as neural networks and computer simulations has proven increasingly effective in anticipating demands, reducing costs, and improving relationships with suppliers and customers (IVANOV & DOLGUI, 2020; KOUVELIS, DONG, BOYABATLI, & LI, 2021). In addition, this approach allows identifying bottlenecks and proposing adjustments to the value chain structure, aiding in informed and assertive decision-making (SIMCHI-LEVI, KAMINSKY, & SIMCHI-LEVI, 2020).

In recent years, researchers have widely explored the role of tools such as social network analysis and specific software to map and visualize interactions within the supply chain, providing valuable insights for managing relationships with suppliers and efficiently coordinating information and product flows (Gephi and UCINET are examples of software with applicability in mapping and analyzing relationships in retail) (BRANDIMARTE & ZOTTERI, 2017; LEE & TANG, 2017) . In this context, this article proposes a model of the university retail supply chain, aiming to improve the chain's efficiency, optimize the relationship with suppliers, and enhance the end customer's experience, including professors, students, and the external community.

Although the literature on supply chains is extensive, there is a gap in the analysis of supply networks in public and educational environments, such as university markets, which operate under specific dynamics of demand, budget, and public service. This study offers an original contribution by mapping and evaluating the supplier network of a university market, with practical implications for similar institutions.

The work will consist of sessions, being: 1. Introduction; 2. Bibliographic Reference; 3. Methodology; 4. Results and Discussions; 5. Conclusion.

2 BIBLIOGRAPHICAL REFERENCE

Supply chain modeling stands out for its emphasis on collaborative strategies and the use of information technologies to optimize processes. Ballou (2020) notes that an integrated and strategic approach to the supply chain is essential for creating value and operational efficiency, especially in a context where technology and data analysis play central roles in optimizing operations and increasing competitiveness. Christopher's work (2016) reinforces that chain flexibility and resilience are essential in highly uncertain scenarios, such as retail, where demand variation is significant and responsiveness becomes a competitive advantage.

Chopra and Meindl (2022) add that synergy between different chain partners can be greatly maximized with the adoption of information systems and modeling techniques, which not only promote coordination but also reduce operating costs. Similarly, Ivanov and Dolgui (2020) argue that with the advancement of digital technologies, retail companies can use simulations to predict and react to variations in consumer behavior and potential supply disruptions.

Lee and Tang (2017) address the use of software such as Gephi and UCINET, which facilitate network analysis and understanding of interdependencies between chain members, providing detailed mapping and the possibility of identifying areas that can be improved.

2.1 Supply Chain

According to Martins and Altuntas (2019), logistics has become a strategic function integrated into supply chain management, playing an essential role in balancing costs and service levels. The expansion of supply chains in the late 20th century was marked by significant growth in local and global markets, particularly in the automotive, textile and technology industries, with the aim of meeting growing consumer demands and reducing operating costs.

Christopher (2016) defines supply chain management as the effective coordination of relationships with suppliers and customers, aimed at optimizing material and information flows. This approach seeks to add value to the end customer while minimizing operational costs, strengthening organizational competitiveness. According to Lambert and Cooper (2000), the integration of logistics and supply processes, together with collaborative practices, contributes to efficiently meeting market demands, promoting efficiency and effectiveness in the supply chain.

Efficient supply chain management, as noted by Croxton *et al.* (2017), not only reduces costs but also improves the flow of information and products throughout the chain, ensuring greater customer satisfaction. Furthermore, the integration of suppliers and customers allows for greater flexibility and responsiveness to variations in demand, ensuring punctuality and quality in service delivery, a critical factor in academic-administrative contexts (Ramezani *et al.*, 2018).

According to Ching (2009), Supply Chain Management involves all efforts in the various business processes and activities that generate value in the form of products and services for the end consumer. SCM integrates the planning and control of the flow of goods, information, and resources, from suppliers to the end customer, promoting cooperation and mutual benefit in the logistics chain.

In a study carried out by Dias and Leite (2011), it is highlighted that SCM must meet two objectives, namely: a) promptly serve the customer, generating a competitive advantage; b) reduce financial costs, using less working capital, in addition to cutting operational costs, minimizing waste and avoiding as much as possible activities that do not add value to the product, such as waiting, storage, transportation and controls. For Martins and Laugeni (2006), the objectives are practically the same, namely: reducing the cost of supply and time; increasing production and product margins; and increasing the return on investment made.

The study by Borgatti & Li (2009) highlights the difficulty of collecting effective data in supply chain management, given the complexity of the various links (suppliers, distributors, customers, etc.). Despite this, the authors emphasize the importance of integrated management, which involves collaboration between areas such as logistics, production, marketing, and finance, to improve efficiency and decision-making in the supply chain. Studies suggest that dense and well-structured networks favor efficiency, as they facilitate information sharing and rapid problem-solving (LEE; KIM, 2008). One of these studies is that of Barbosa and Musetti (2012), who pointed out the importance of this type of network in the exchange of knowledge and learning aimed at transferring skills, abilities and logistical experiences, improving the performance of small and medium-sized Brazilian companies.

A network is formed by interconnected nodes, presenting several structural properties that can be explored (CASTELLS, 2003). Centrality in the network defines the position of an actor within it, reflecting how much it occupies a strategic position by being connected to multiple important links. Thus, the more central the actor, the greater its influence and role within the network (WASSERMAN; FAUST, 1994).

In a study conducted by Sacomano Neto and Truzzi (2009), where they investigated the concept of incorporation in the context of supply networks, they mention structural autonomy, where an actor connects two others, generating results like a centralized structure. Structural equivalence occurs when two actors have similar positions in the network, leading to similar actions, and cohesion refers to the strength of the links between the actors, affecting the sharing of information, knowledge, and reciprocity.

Nahapiet and Ghoshal (1998) studied the interactions between three dimensions of social capital: structural, cognitive, and relational. Although these dimensions can be analyzed separately, they are highly interconnected and influence each other. Thus, the dynamic interactions between these dimensions create a mutually reinforcing cycle, promoting collaboration and innovation within social networks.

Choin; Kim (2008) reinforce that a strong tie refers to a high degree of interaction between two companies, with an efficient exchange of knowledge and resources. A weak link is characterized by a more flexible relationship, with a lower frequency of interactions.

Frazzon *et al.* (2019) indicate that smart supply chains take advantage of communication and technological advances to build an adaptive, efficient, and transparent network. However, the application of such a concept requires the development of knowledge, not only in the hardware and software fields, but also in the managerial field, to address the question of how to use information and communication to benefit stakeholders.

Industry 4.0 adoption improves traceability, transparency, and risk management. These mediating factors demonstrate the critical role of Industry 4.0 technologies in achieving superior supply chain outcomes (Khan *et al.*, 2025). For example, causal loop diagrams can be used to visualize and analyze the dynamic interrelations among these factors, highlighting feedback structures and systemic delays that influence supply chain performance (de Assumpção *et al.*, 2024).

2.2 Social Network Analysis (SNA)

The use of social network analysis (SNA) tools, such as UCINET software, has proven to be efficient in modeling relationships between actors, identifying central points and possible gaps in communication (Scott, 2017). According to Silva and Heber (2013), collaborative networks between suppliers strengthen the resilience of the supply chain, promoting an environment of innovation and reduction of failures.

Supplier network analysis that considers the interdependence between links in the supply chain allows for a more comprehensive view, identifying critical points and opportunities for improvement to increase operational efficiency (Ballou, 2018, p. 215). In social network analysis (SNA), structural properties (such as centrality, density, and cohesion) help to understand supplier performance by identifying the flow of information and the interdependence between the actors involved (CASTELLS, 2003). In addition, studies show that relational proximity between actors facilitates the exchange of information and the development of innovation, with a positive impact on the quality and speed of response of the system (FUSCO, 2005; GRANOVETTER, 1985).

Social Network Analysis (SNA) is a methodology that allows investigating social relationships and structures by mapping and measuring interactions between actors in a network (SCOTT, 2017). In the context of supply chains, SNA stands out for revealing patterns of collaboration, centrality and information flows, and is widely used to identify bottlenecks and optimize interaction between links in the chain (BORGATTI; LI, 2009).

SNA provides fundamental metrics for understanding supplier networks, such as centrality, which measures the strategic position of an actor in the network; cohesion, which indicates the degree of connection between actors; and density, which reveals the number of connections established out of the total possible. Such metrics are essential for analyzing the performance and resilience of the supply chain, since they show the ability of suppliers to adapt to changes and collaborate with each other (CROWE; ELKINS, 2010).

The application of SNA in complex environments, such as universities, allows us to identify not only direct interactions between suppliers and customers, but also the structure of influence between actors, revealing how connections can be optimized to increase efficiency and communication in the chain (JACKSON, 2008). As pointed out by Sacomano Neto and Truzzi (2009), a dense network, where actors have several connections between them, tends to be more resilient and innovative, as it facilitates the flow of information and cooperation.

Social Network Analysis (SNA) provides a useful framework for modeling and understanding interactions between actors in the supply chain, allowing the identification of focal points and potential gaps in communication (Scott, 2017). To this end, metrics such as degree centrality, betweenness centrality, closeness centrality, and density are often employed, especially through software such as UCINET, which facilitates the quantitative analysis of complex networks (Borgatti, Everett, & Freeman, 2018).

Degree Centrality measures the number of direct connections of an actor in the network, being essential to identify the most connected and influential "nodes". In a network with nnn actors, the degree centrality of actor iii is given by:

$$C_D(i) = \sum_{j=1}^{n} X_{ij} \quad (1)$$

Where X_{ij} is 1 if there is a direct connection between I and j, otherwise X_{ij}= 0. A higher degree indicates a central position and potentially greater influence on the network (Wasserman & Faust, 1994). *Betweenness Centrality* measures how often an actor is on a path between two other actors, acting as an intermediary. The formula is given by:

$$C_B(i) = \sum_{j<k} \frac{\sigma_{jk(i)}}{\sigma_{jk}} \quad (2)$$

Where σ_{jk} represents the total number of shortest paths between actors j and k, and $\sigma_{jk(i)}$is the number of these paths that pass-through actor i. This metric is useful for identifying actors that control the flow of information in the network (Freeman, 1977). Closeness centrality measures the "closeness" of an actor in relation to others, indicating its ability to communicate quickly with other nodes. The formula is:

$$C_C(i) = \frac{1}{\sum_j d(i,j)} \quad (3)$$

Where d (i,j) is the geodesic distance between actors i and j. This metric is often used to assess the efficiency of access to information within the network (Scott, 2017). Network density is a metric that describes the degree of connectivity between actors. It is calculated by:

$$D = \frac{\sum_{i \neq j} x_{ij}}{n(n-1)} \quad (4)$$

Where D is the density, ranging from 0 (completely disconnected network) to 1 (fully connected network). Network density provides an overview of how interconnected the network is and is essential for assessing supply chain cohesion (Borgatti *et al.*, 2018).

These formulas and metrics help to quantify and understand the relationship structures between supply chain actors, revealing who has the greatest influence or control over the flow of information and products. With the support of UCINET, these analyses offer valuable insights for the strategic management of complex networks (Borgatti *et al.*, 2018).

2.3 Related Works on Supplier Relations

Studies have explored the relationship between the focal firm and its suppliers, addressing the importance of collaborative and long-term partnerships that promote the creation of shared value. Kouvelis *et al.* (2021) suggest that an efficient relationship between the focal firm and suppliers depends on clear performance evaluation criteria, which should include quality, response time, and innovation capacity. Recent literature also argues that supplier selection and evaluation should be based on a careful analysis of each supplier's capabilities, and how these capabilities can positively impact production and distribution processes (Simchi -Levi, Kaminsky, & Simchi -Levi, 2020).

Furthermore, authors such as Ivanov and Dolgui (2020) point out that maintaining open communication and developing a continuous feedback system between the focal company and suppliers allows both to adjust their processes in response to market changes. Through models based on social networks, it is possible to understand collaborative dynamics and identify possible weaknesses in the chain that may compromise the efficiency and resilience of the system (Christopher, 2016).

Successful retailers such as Walmart and Tesco prioritize partnerships with suppliers through collaborative arrangements that optimize the supply chain. This includes shared planning and technology integration, enabling faster responses to changes in demand and reducing operational costs (KIM; HOLCOMB; YU, 2022).

The implementation of digital systems, such as control towers, enables end-to-end traceability of the supply chain. These tools help markets predict disruptions and align promotions with available inventories, increasing efficiency and customer satisfaction. The practice is widely adopted in e-commerce and supermarkets (MCKINSEY, 2023).

Retail companies, such as Carrefour, use predictive analytics to adjust inventory allocation, prioritizing essential products during periods of high demand. This reduces losses and improves the end consumer experience by ensuring constant availability of basic products (RAPHAELY; XU, 2023).

Supermarkets and local businesses tend to establish long-term contracts with strategic suppliers, ensuring price stability and prioritization in service. This practice is especially useful in chains with seasonal fluctuations, such as food and beverages (MCKINSEY, 2023).

Retail markets avoid concentrating on purchases from a single supplier, mitigating the risk of shortages. In the food sector, for example, chains such as Kroger use multiple sources for perishable products, reducing logistical vulnerabilities (KIM; HOLCOMB; YU, 2022).

3 RESEARCH METHOD

The methodology of this study was structured based on two widely recognized approaches in the literature on supply chains. First, the methodological framework proposed by Leite *et al.* (2022) was used, which recommends the use of mixed methods in organizational research. This approach integrates qualitative and quantitative data, allowing the exploration of the relationships between actors and links in the university supply chain and the quantification of the impacts of these interactions. According to the authors, the use of mixed methods “enables obtaining deeper insights into complex organizational dynamics” (LEITE *et al*., 2022, p. 7).

Furthermore, the analysis was based on the analytical model of Croom, Romano and Giannakis (2002), which suggests a systematic framework for reviewing and evaluating supply chains. This model was adapted to map the university supply chain, identifying the flows of goods and information between suppliers and customers. According to Croom *et al.* (2002), the application of analytical frameworks allows understanding not only the efficiency of processes, but also the opportunities for collaboration and continuous improvement in the supply chain.

Data collection was carried out through semi-structured interviews with managers and those responsible for the university market supply chain, as well as regional suppliers. These interviews sought to explore aspects such as the frequency of interaction, the quality of deliveries, and response times. To complement the qualitative data, administrative documents, order records, and contracts were analyzed, allowing the incorporation of quantitative elements, such as the frequency and volume of transactions. The triangulation of qualitative and quantitative data was essential to increase the robustness of the analysis and the validity of the results (Yin, 2015).

In this study, SNA is used to model and evaluate the supplier network of a university market, with the aim of identifying collaborative patterns, bottlenecks, and opportunities for improvement, The internal stakeholders include professors, students, university managers, and those responsible for commercialization, while the external stakeholders are third-party suppliers of products and services. The UCINET software was chosen to perform this analysis, due to its ability to visualize the structure of networks and calculate centrality and cohesion metrics (Borgatti, Everett & Freeman, 2018; Borgatti & Li, 2009).

Using the data collected and the metrics generated by the SNA, comparative analyses were performed to interpret the supply chain structure and supplier performance. The analysis was based on performance metrics such as delivery reliability, quality, and responsiveness to the specific demands of the university market.

The graph, or network, becomes present in the work. As defined by Larson and Odoni (1981), it is a structure G (N, A) that consists of a finite set of N nodes (or vertices) and a finite set of A arcs (or edges) that connect pairs of nodes, where (i, j) ∈ A, with i ∈ N and j ∈ N. There are three types of graphs: directed, undirected, and mixed. The type addressed in this work is the undirected graph, which, according to Ahuja *et al.* (1993), can be described in a similar way to the directed graph, with the difference that the arcs are unordered pairs of distinct nodes. An undirected graph is classified as connected when there is a path between all pairs of nodes i and j ∈ N.

The validation of the results was done through feedback from university market managers and interviews with some of the suppliers involved. This process helped to verify the accuracy of the mapped information and the applicability of the proposed recommendations to improve the efficiency and quality of the supply network (MIGUEL, 2007).

The roster method call, as proposed by Morrison and Rabellotti (2009), is widely used in studies that aim to map networks of interaction between actors in a system. This approach consists of asking participants to identify the individuals or organizations with whom they have significant ties, allowing for detailed mapping of formal and informal connections. This method proved to be relevant for this research, as it makes it possible to capture the structure of relationships in the university market supply chain, identifying interaction flows between suppliers and customers, such as professors, students, and the external community. Accuracy in data collection, especially in limited networks, is one of the main benefits of using this technique.

The choice of the ordinal scale in this research was based on its suitability for measuring qualitative variables that have an implicit order, such as the level of interaction between network actors. This scale was developed with categories ranging from "low interaction" to "high interaction", allowing for a structured analysis of the data. Furthermore, the compatibility of this type of data with software such as Gephi and UCINET further justifies its adoption, since it enables effective network analysis.

In this research, the use of directed and weighted graphs was adopted, given the objective of analyzing specific flows and the intensity of relationships between actors in the supply chain. According to Borgatti *et al.* (2002), directed graphs are essential to capture the direction of interactions (e.g., supplier to customers), while weighted graphs allow incorporating the magnitude of these connections, such as the frequency of transactions or volume of services. This approach enriches the analysis by providing not only the structure of the networks, but also their density and relative importance.

4 RESULTS AND DISCUSSION

4.1 Case Details

The case study in question addresses a project carried out at the State University of Maringá (UEM), which includes the production and marketing of inputs grown on regional campuses, such as vegetables, fruits, legumes, honey, and eggs. In addition, the project operates a Micro Bakery that supplies the University Restaurant (RU) with breakfast products daily. It also holds a weekly market that offers third-party products, such as pastries and sugarcane juice. The analysis sought to identify improvements in supply chain efficiency, reduce the risk of disruptions, strengthen relationships with peripheral suppliers, and optimize service delivery.

The main objective of the marketing activities is to serve the internal community (students and staff) and supply the RU. The UEM Fish Farming Station, through its research and experiments, supplies carp and other species of fish to a municipal park, serving as an attraction for the regional community.

The main problem of the project is the production system, characterized by a variable and irregular supply, imposing significant management challenges in the supply chain. The random nature of the supply of products can generate operational problems, such as a lack of products at the point of sale or the accumulation of perishable items, requiring effective strategies to minimize waste and ensure adequate meeting of internal demand.

The problems observed arise from small-scale, domestic production, as in the case of vegetables, where new crops are sown after harvest. This process requires a new cultivation cycle, resulting in a waiting period until the next harvest, when the market is deprived of these products. The central issue of this study is to identify how the different actors involved in the production and supply process should interact to avoid product shortages and ensure adequate supply, thus preventing losses.

The data was collected through the management system used by the market, although with some limitations. The problems were identified through an interview with a responsible employee, in addition to direct observation of the production dynamics on each campus.

In this context, social network analysis (SNA) was applied to map and evaluate the project's supply chain, with the aim of understanding the interactions and performance of internal suppliers and third parties involved. SNA allows identifying patterns of collaboration and interdependence between the different actors in the system, providing support for more agile and effective commercialization strategies.

4.2 Characterization of network participants

The network analyzed in Table 1 is composed of a Focal Company (FB), which acts as the central point of coordination and integration between several suppliers and partners involved in the supply and delivery of products and services. Participants were categorized based on their main functions, ranging from food production and delivery to the provision of specific services. Suppliers are segmented into outsourced production lines, fresh food deliveries, and marketing of prepared products, offering diversified support to the FB's operation. This structure reflects the complexity and interdependence of the supply chain, essential to meet the demands of FB and its customers.

Table 1 - Each Indicator with its respective Characterization

Indicator	Characterization
EF	Focal Company
F1	University Restaurant
F2	Municipal Park
F3	Outsourced production line
F4	Outsourced production line
F5	Outsourced production line
F6	Outsourced production line
F7	Delivery of products (vegetables, legumes)
F8	Delivery of products (vegetables, legumes)
F9	Delivery of products (vegetables)
F10	Delivery of products (fish)
F11	Delivery of products (vegetables, eggs, milk)

F12	Delivery of products (vegetables, eggs, milk)
F13	Sales of outsourced products (sugarcane juice, pastries)
F14	Bakery (breads, savory snacks, sweets, among others)

Source: Authors 2024.

After analyzing Table 1, it is possible to observe a well-defined division between the network participants, highlighting the critical links in the delivery of fresh products, such as vegetables and fish, in addition to the integration of outsourced production and marketing services. This segmentation allows EF to manage both the quality and efficiency of operations, optimizing internal and external processes through strategic partnerships with suppliers. The diversity of participants also reinforces the resilience of the network by mitigating risks associated with dependence on a single supplier or category.

4.3 Degree of Cohesion

Wasserman and Faust (2007) define actors as social entities, which can be individuals, groups or institutions. Social network analysis investigates the links between these actors and their implications, highlighting friendship ties, commercial transactions, message exchanges and social movements.

The Focal Company has a degree of connection of 1 between its own components, acting as a receiving and sales center. Its connection with F1 is classified as degree 2, since it supplies certain products for the students' meals. In contrast, the relationship with F14 is considered degree 3, due to its importance as a supplier. The connections with F3 and F4 are degrees 1 and 2, respectively, indicating a low level of interaction.

Regarding all direct suppliers, EF is characterized by a degree of connection of 3, since these establishments are the direct suppliers of the products. F12, where sugarcane juice and pastries are sold by third parties, establishes a degree 3 connection with EF.

F14 maintains a degree 3 connection with EF and a degree 2 with F1, providing bread for students' breakfast. On the other hand, F3 and F4 have no direct connection with F1 and F14, presenting variations in strength between 1 and 2. The relationship with F7 and F11 is analogous, while F12 has a direct connection, classified as degree 3.

Additionally, F9 supplies products to EF with grade 3 and delivers fish to the Municipal Park, establishing a grade 1 relationship. F12 stands out as the largest supplier, presenting a wide variety of products and frequent deliveries, with binding strengths ranging from 2 to 3, consolidating itself as the most relevant actor in the project.

The analysis of the degree of cohesion in the project's supply chain revealed important aspects about the integration and strength of connections between the different actors involved. Cohesion measures how well connected the network elements are and is essential to ensure that the flow of information and goods occurs efficiently. The greater the cohesion, the stronger and more resilient the chain will be, facilitating collaboration between those involved and reducing the impacts of possible failures.

It was identified that EF occupies a central position, being the most connected and influential actor in the network. It depends on many suppliers to maintain their operations, but it is also the convergence point for the distribution of products. This makes EF essential for the functioning of the chain, but also vulnerable, as any problem in this node can cause major disruptions. Other actors, such as F1, also play important roles, with strong connections, especially with suppliers of essential items, such as F14. On the other hand, smaller suppliers, such as F3 and F4, have few connections and interact in a limited way with other links in the chain, reducing the strength of the network.

Connections in the network vary in intensity. Some ties are strong, represented by frequent interactions and high dependency, such as the connections between EF and F12 or F9. These ties are essential to ensure a regular supply. However, other ties are weaker or infrequent, such as the relationships between F3, F4, and F1, compromising the integration of the network. This difference in the strength of the connections creates areas of vulnerability, where the lack of direct or efficient interaction can generate delays or failures in supply.

Network cohesion is also affected by the lack of alternative connections. In many cases, there is an over-reliance on a few suppliers or intermediaries, which reduces the flexibility and resilience of the system. For example, if F12, a major supplier, experiences problems, the network as a whole may suffer from a lack of products. In addition, the low connectivity of some actors prevents a faster exchange of information and resources, making collaboration and agile problem-solving difficult.

4.4 Characterization of the Supplier Network

The graph in Figure 1 illustrates the supplier network of a supply chain, highlighting the interactions and the degree of interdependence between the different links. Each node represents an actor in the chain, such as production units, farms, markets, and food services, while the connections (edges) indicate the intensity of the relationships between them, marked by a scale of values (1, 2, 3) that symbolizes the level of interdependence. The thickness of the lines also reinforces the strength of this interaction, with thicker lines representing more intense interactions. This visual model helps to identify bottlenecks and opportunities for optimization in the chain, where weaker connections can signal areas for improvement, and stronger ones demonstrate critical interdependencies that support the operational flow.

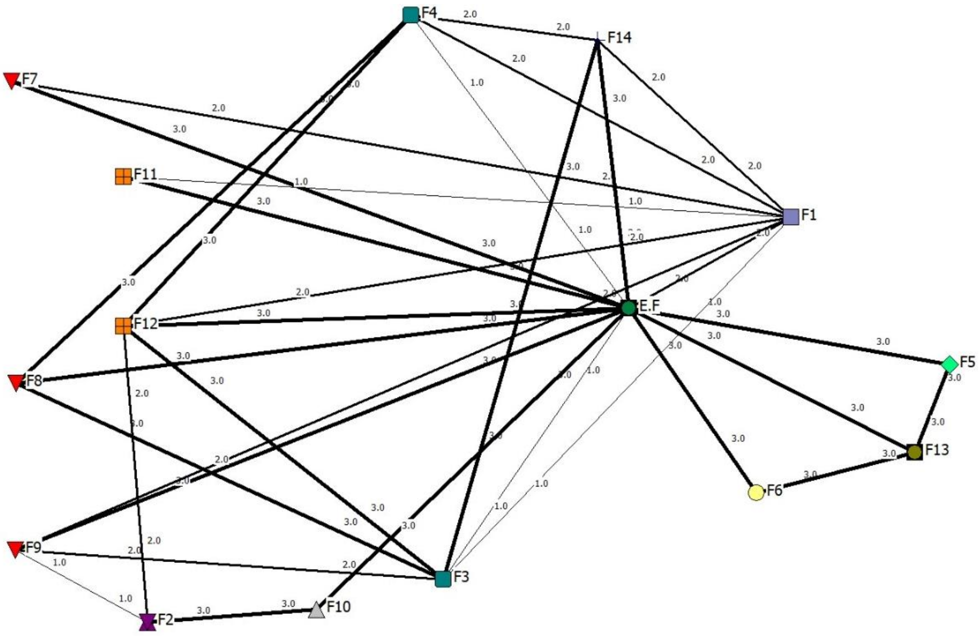

Figure 1 - Supply Chain simulation
Source: Authors,2024.

4.5 Relational Analysis between Actors

The relational analysis between the supply chain actors aims to understand the interdependencies and the strength of connections between the participants involved. From the graph generated, the intensity of the relationships between the different points in the supply chain, such as the market, production units, and regional suppliers, can be observed. The relationships are represented by lines of varying thickness, where stronger connections suggest a high degree of exchange and dependence, while thinner connections indicate less intense or sporadic interactions.

At the center of the network, actors such as EF and F1 stand out, presenting several robust connections with different suppliers, such as production units and farms. This suggests that these actors play central roles in the coordination and distribution of resources, acting as convergence points in the supply chain. The presence of multiple high-intensity interactions (represented by the value 3) between these actors and their suppliers indicates a significant mutual dependence on ensuring the efficient flow of products and services.

Furthermore, other actors such as F14 and F5 present moderate connections (values 2) with several production units, which may indicate stable but less interdependent relationships. This relational analysis allows us to identify potential bottlenecks, where excessive dependence on a few suppliers or intermediaries can compromise the efficiency of the chain. At the same time, it points out opportunities to strengthen strategic relationships and diversify supply sources, promoting a more resilient and efficient chain.

Table 2 - Relational analysis

Node	Degree	Closeness	Betweenness
EF	34	15	54.11
F1	14	20	8.08
F2	6	22	1.75
F3	13	22	2.92
F4	11	23	1.54
F5	6	27	0.00
F6	6	27	0.00
F7	5	26	0.00
F8	9	26	0.20
F9	6	26	0.20
F10	4	27	0.03
F11	4	27	0.00
F12	3	22	0.00
F13	9	26	0.50
F14	10	25	0.20

Source: Authors,2024.

1. Degree Centrality (Degree Centrality)

- The Market has the highest degree of centrality value (34), indicating that it is directly connected to more nodes than any other, suggesting that it is a central point in the network and likely has a large direct influence on interactions.
- F1 also has a significant degree (14), followed by F3 (13) and F4 (11). This suggests that these nodes play important connecting roles in the network.
- Other points, such as F13 and F14, have intermediate degree values, showing relevance in the connections, but with less direct influence than the main nodes.

2. Closeness Centrality (Closeness Centrality)

- The node with the highest proximity value is F5, F6, and F10 (all with 27), indicating that they are "closer" to all other nodes in the network, facilitating access and dissemination of information.
- Then, nodes like F7, F8, F9, F13, and F14 have close values (25 and 26), suggesting that they also have good network accessibility.
- Nodes with a lower proximity value, such as EF (15) and F12 (22), are further away in the network, making them difficult to reach compared to the main nodes.

3. Betweenness Centrality (Intermediation Centrality)

- EF has the highest betweenness centrality value (54.108), indicating that it acts as a crucial gateway for interactions between other nodes. This means that, in the network, it facilitates communication between different areas, being a strategic link.
- F1 has a high intermediation (8,083), reinforcing its role as a relevant connection point.
- Other nodes such as F3 (2,917) and F4 (1,542) also have some levels of intermediation, but on a much smaller scale.
- Most other nodes have very low or zero betweenness centrality, indicating that they are more peripheral and have little or no influence in mediating connections.

A significant problem was identified related to the irregularity of product supply and inventory management, which directly affects the efficiency of customer service. This problem is in line with the observations of Dias and Leite (2011), who highlight the need to reduce waste and optimize inventories to avoid supply failures. During the analysis, EF was identified as the main point of convergence of the supply chain, occupying a central and strategic position. However, this position also highlights a critical vulnerability, since there is a high dependence on specific suppliers, such as F12. This situation is in line with the considerations of Sacomano Neto and Truzzi (2009), who point out that excessive dependence on a few suppliers increases the risk of supply disruptions.

Network density is based on the coefficient of connectivity between the network's authors

(MASQUIETTO; SACOMANO NETO; GIULIANI, 2011). The density, which measures the level of interconnection between actors, is moderate, indicating that there is still room to improve relationships and strengthen ties in the supply chain. As Borgatti and Li (2009) argue, denser networks, with multiple strong connections, are more resilient and favor information sharing. However, the study identified several weak links, with low degrees of connection (1 or 2), especially in the relationships between F3, F4, and other actors. This reveals an opportunity to strengthen partnerships and diversify suppliers. Granovetter (1973) suggests that strengthening weak ties can increase the chain's resilience, in addition to reducing dependence on central actors.

Another critical point identified was the variability in product supply, especially due to the seasonal and small-scale nature of domestic production. This variability results in periods of product shortages or surpluses, which often leads to waste, especially of perishable items. The situation is aggravated by limitations in storage capacity and inefficient transportation logistics, making it difficult to meet demands within the appropriate timeframes. This situation highlights the need for stricter control of product stocks and volumes, as recommended by Ballou (2020), through the implementation of tracking and monitoring systems.

Furthermore, the centrality of EF, which acts as an essential intermediary point, makes it vulnerable. Its intermediary position is important for connecting different actors in the network, but it also creates significant dependency, which can lead to disruptions throughout the chain if there are problems in this link. Other actors, such as F1, play relevant roles, but their connections with suppliers, such as F3 and F4, are limited, reducing their relevance in strengthening the network.

To mitigate the problems identified, several recommendations were proposed. The first is to strengthen connections with less integrated suppliers, such as F3 and F42, promoting greater collaboration and frequency of interactions. This would reduce dependence on central suppliers, such as F12, and make the chain more balanced and robust. Another important action would be to diversify the supplier base, including new regional partners, to create alternatives and ensure a more stable supply, reducing the risk of disruptions.

Furthermore, the adoption of advanced technologies is essential. Demand forecasting software, based on artificial intelligence, could help anticipate seasonal variations and adjust production and inventory levels. Tools such as UCINET and Gephi can be used to simulate scenarios, identify bottlenecks, and improve the allocation of resources and transportation routes. It would also be essential to invest in expanding storage capacity, prioritizing perishable products, and creating a dedicated fleet to improve transportation efficiency.

Another recommendation is to adopt collaborative strategies, such as creating long-term agreements with strategic suppliers, as suggested by Kouvelis *et al.* (2021). These agreements can ensure greater supply stability and minimize the risk of disruptions. In addition, providing training for supply chain stakeholders can improve communication and encourage collaborative practices.

To improve the degree of cohesion of the project supply chain, some actions can be taken. First, it is important to strengthen connections with smaller suppliers, such as F3 and F4, by increasing the frequency of interactions and collaboration. This would help to reduce dependence on a few suppliers and make the network more balanced. In addition, it is necessary to create new connections between actors that currently depend on intermediaries, such as F7, F8, F9, F10, F11, and F12, with F1. This type of direct link can relieve pressure on the market and diversify flows within the network.

The project study illustrated the challenges faced by supply chains in university settings, highlighting both strengths and weaknesses. The analysis revealed that, although EF plays a strategic role in the chain, its high centrality is also a factor of vulnerability. Implementing the suggested recommendations, such as diversifying suppliers, adopting advanced technologies, and strengthening weak ties, can make the chain more efficient, resilient, and sustainable. These actions provide a solid basis for future interventions, contributing to improving supply chain management and ensuring more efficient service to system demands.

5 CONCLUSION

This study highlighted the importance of strategic and integrated supply chain management in a university retail environment, focusing on the analysis of interactions between suppliers and the focal company. Through Social Network Analysis (SNA) and network modeling with UCINET software, it was possible to identify central points, weaknesses, and opportunities for improvement in the chain structure, promoting an in-depth understanding of interdependencies and information and product flows.

The application of centrality metrics revealed that actors with a higher degree of connection and proximity occupy strategic positions in the network, facilitating the efficient flow of goods and information. Actors with high intermediation centrality were identified as critical points of communication and distribution, essential for the resilience and effectiveness of the chain. The analysis of network density indicated the need to strengthen some relationships and diversify supply sources to reduce vulnerabilities and increase the robustness of the supply network.

Therefore, this study contributes to supply chain management in a retail context by offering a model that can be adapted to different organizational contexts. The analyses performed with UCINET and the insights obtained from SNA metrics provide a solid basis for interventions aimed at increasing the efficiency, flexibility, and resilience of the chain. Thus, it is expected that the recommendations presented can be implemented to strengthen collaborative partnerships and improve the quality and agility of demand fulfillment.

The proposed objectives – mapping the supplier network, identifying bottlenecks, proposing improvements, and assessing risks – were achieved through the analysis of centrality and cohesion metrics. The vulnerability associated with the excessive centrality of a single actor and the presence of weak ties reveal critical points and opportunities for diversification and improvement.

For future research, it is recommended to expand the scope of the study, exploring the application of other network modeling and analysis methodologies, such as machine learning algorithms. learning, which can improve demand forecasting and inventory optimization. A longitudinal analysis that allows observing changes in the relationships between actors over time would also be valid, providing a more dynamic view of the supply chain. The application of other software tools, such as R and Python for modeling and programming, could complement the analyses performed with UCINET, offering new perspectives for the management and visualization of interactions and interdependencies in the chain.

It is recommended to conduct research in collaboration with a group of universities to develop a multiple case study or a replicable framework that enables the analysis and improvement of interactions with suppliers, aiming to contribute to the performance and resilience of the supply chain. This approach could enhance the generalization of the results and offer adaptable guidelines for different industrial contexts.

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