Quality Tools, Modeling and Simulation: A case study on Supply Chain Management in the Footwear Sector

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Abstract

Supply chain management represents nowadays one of the main concerns with the continuous improvement of the quality of products and processes available in an organization. Due to the impact that processes related to Supply Chain have on the company, this management becomes vital. In this way, this article aims to propose tools to optimize, standardize and adapt the processes and procedures of the Supply Chain, specifically in the purchase and storage processes, in a large company in the footwear sector. For this purpose, quality and management tools integrated in Petri nets were used, which enabled the modeling and simulation of the production process. The analysis performed shows that it was possible to optimize the process through a mapping technique, and simulation tool. This approach was used to guide the decision-making process of a supply chain that had a production scenario of 6,937 types of products, with inventories that reach more than 600 thousand units.

Keywords: Supply Chain, Supply Chain, Quality Tools, Modelling and Simulation, Petri Net.

1. Introduction

According to ABICALÇADOS (*Associação Brasileira das Indústrias de Calçados* - Brazilian Association of Footwear Industries) (2021), which is a Brazilian association of the footwear industry, Brazil is the fourth largest producer and consumer of footwear in the world ranking, with 720 million pairs produced in 2020. The footwear sector is of great economic and social importance in Brazil, exporting 93 million pairs that represented a trade balance of 658 million dollars, generating approximately 247 thousand direct jobs in 2020. Therefore, it is evident the active participation of the sector in the Brazilian economy, being a relevant activity in Brazilian states, where the main productive centers of the sector are in Rio Grande do Sul, Ceará, São Paulo, Minas Gerais, Paraíba, Bahia, Pernambuco and Santa Catarina.

Therefore, in the face of the competitive and innovative market, consumers are becoming increasingly demanding, and on the other hand, the market demands increasingly qualified services and competition strives to be significantly differentiated. In view of this, concerns arise about the continuous improvement of the quality of products and processes offered within the organizations. For example, competitive advantage has been achieved through good practices in supply chain process management. According to Bertaglia (2017) supply chain management is a process-integration activity that involves the management of three flows: products, demand, and information. Good supply chain planning includes actions to reduce stock shortages and make purchases more advantageous, among others.

Thus, the organization is analyzed from the perspective of its capacity to generate value: activities that add value have their existence justified in the organization, whereas those that do not generate any value will only consume resources without the counterpart of increasing value for their customers (internal and/or external). According to Vom Brocke et al. (2021), effective process management identifies and analyzes the processes to be improved within the organization and promotes necessary solutions to ensure and improve the quality of processes.

Based on these premises, this research seeks to present a critical assessment of how the purchase of replacement goods is carried out, with the aim of optimizing and streamlining procedures and providing reliability to the data, in order to assist in decision making. To this end, in addition to demonstrating the application of organizational tools for procedural standardization, it is intended to present the use of the ABC curve to assist in the supply chain control process. Finally, an initial analysis process based on modeling and simulation introduces a Petri net-based discrete event tool to analyze the behavior of stock replenishment in a large company operating in the Brazilian footwear market. This research is justified by the fact that although the company has computational tools to aid decision-making, the reliability of the data does not portray the purpose of the tool.

2. Material and Methods

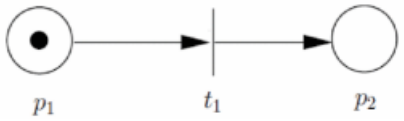
2.1 Theorical References

This study relied on fundamentals based on the history of the Brazilian footwear market. It was also analyzed the basic concepts of process management and supply chain, the definitions of the quality tools that were researched, together with a modeling and simulation process, and finally, an evaluation of works as related studies.

- **Process Management:** it is a set of practices focused on the continuous improvement of the organizational processes of a company or institution. According to Vom Brocke et al. (2021), the search for effective solutions has led companies to review their organizational structure and focus on the business processes of the organization.
- **Supply Chain:** seeks to integrate suppliers, manufacturers, wholesalers, and retailers, who interact by exchanging information and products until the needs of the final consumer are met (Ali et al., 2021).

- **Quality Tools:** are procedures whose application is intended to analyze, verify, establish, and help in decision-making tasks related to problems that affect the performance of work processes. For instance, some quality tools used in the development of this study are the organizational chart, flowchart, Ishikawa diagram, 5W2H, PDCA, and ABC curve (Nguyen et al., 2021; Shaffril et al., 2021).
- **Modeling and Simulation via Petri Nets:** According to Cassandras & Lafortune (2009), the Petri net can be interpreted as a bipartite directed graph with one or more initial elements used for the modeling and control of production systems. Figure 1 presents a Petri net, which is formed by transitions (active component corresponding to some action performed within the system, bar t_1), and place (passive and related to some system state variable, white circles p_1 and p_2).

Figure 1: Petri Net



Source: (Lisboa et. al., 2019)

This research inspired the experiments in this study.

2.2 Methods

In the present work, quantitative and qualitative research was conducted in a multinational company present in the footwear market for more than 20 years, with more than 180 stores spread across the country.

A data collection process was carried out in the company, which was done using documentary data extracted from the processes of the company, considering the following parameters:

- **Period:** July-December 2021;
- **Sources:** Processes (interviews between September and October 2021 for the development of organizational charts, flowcharts, 5W2H and PDCA) and data (company management system, such as ERP - Entreprise Resources Planning - for ABC curve, and modeling and simulation via Petri nets).

Details of the actions relevant to the research were based on the following activities:

- Step 1 - Procedural Assessment: An organizational chart was used to define the hierarchical relationships existing in the company. A flowchart is also presented, which shows the entire process of making a purchase to replenish the distribution center.
- Step 2 - Inventory Management Classification through the ABC Curve: Through the data provided by the company, the ABC curve was used to assist in the supply chain control process, classifying the items of greater and lesser importance in the stock.
- Step 3 - Adequacy Recommendations: Organizational management tools were used to define the action plan and procedural standardization.

- Step 4 - Modeling and Simulation Proposal: A model based on Petri nets was developed to evaluate the stock replenishment flow.

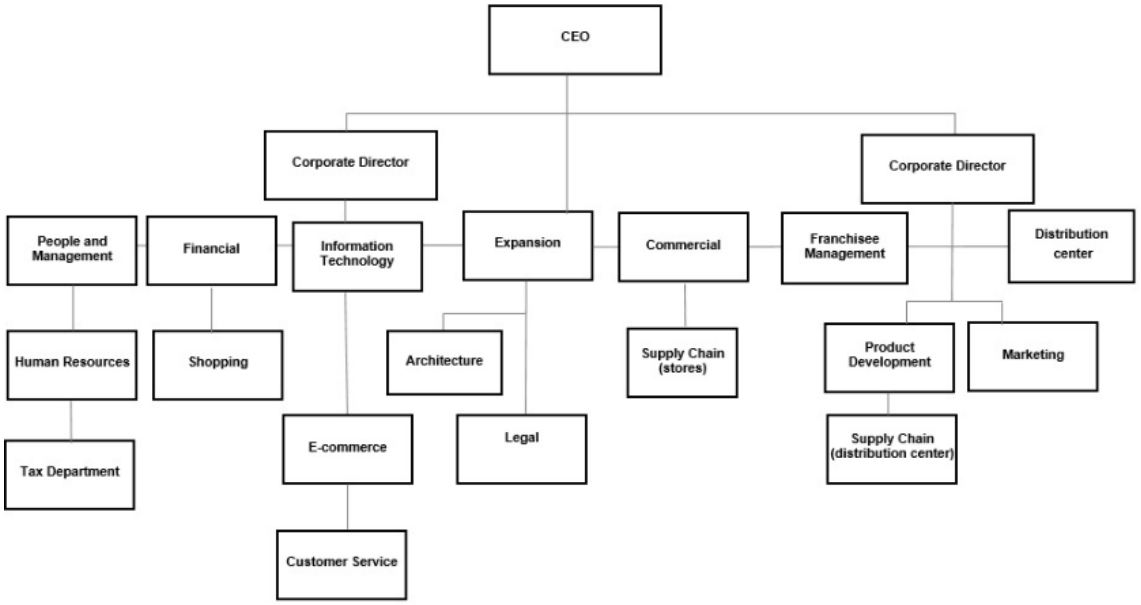
Finally, the application of quality and management tools was studied to contribute to the continuous improvement of the processes to reduce failures and increase productivity in the company.

3. Results

3.1 Procedural Assessment

To start a diagnosis, data collection was conducted in the company during the 2nd semester of 2021. Using the data provided by the company, an organization chart was prepared, and the flowchart is shown in figures 2 and 3. The organization chart presents the departments of the company, and this graphic representation is essential for defining the roles and departments that are interconnected in the organization. In figure 2, it is possible to visualize a graphical representation of the organization of the departments. The company is composed of three partners and legal representatives who represent the board. The CEO and corporate board of the company are responsible for the strategies and decisions that impact the entire organization. The people and management department are responsible for strategic planning, mapping of internal processes, and monitoring and defining the goals of the area managers. The human resources department is responsible for the entire recruitment and selection process, personal administration, labor and union relations, and training in accordance with legal requirements and company policies.

Figure 2: Company organization chart



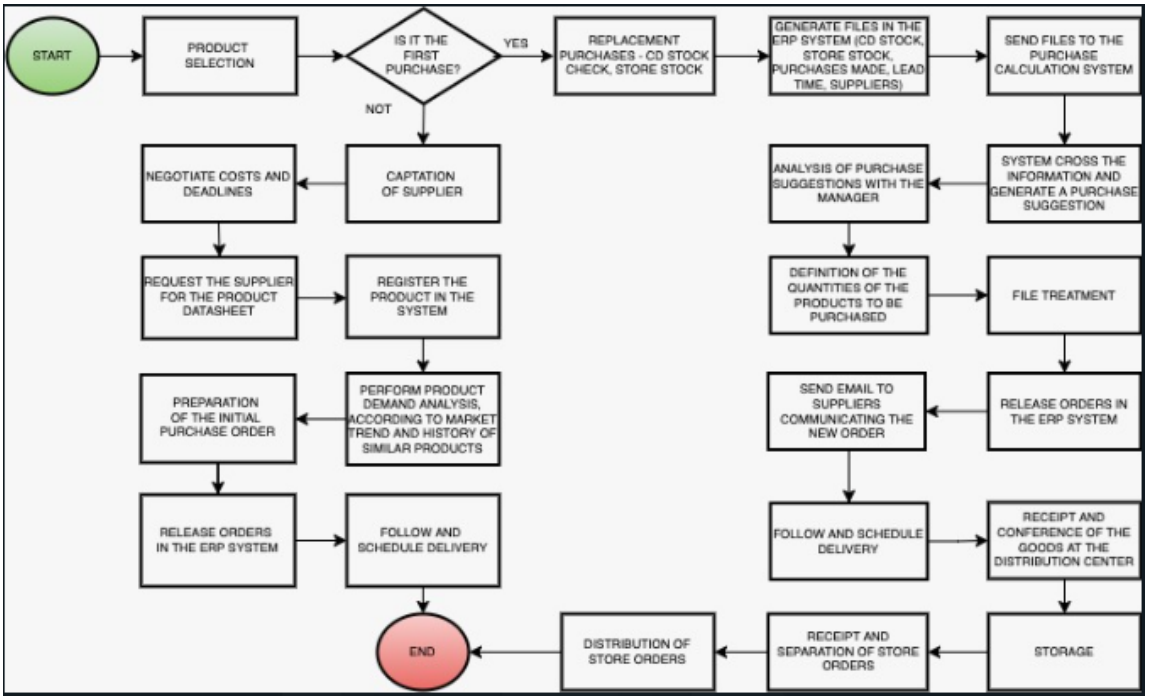
Source: (Authors,2022)

The tax department does the bookkeeping of all the financial activities in the company, determines taxes and legal obligations, and is responsible for internal accounting. Finance is responsible for controlling accounts payable and receivable, bank reconciliation, and managing information passed on to the board. On the other hand, purchasing considers the supply of internal inputs and the general flow of materials in the company. The IT (Information Technology) department is responsible for ensuring the security of information, the functioning of internal systems, and implementing the necessary infrastructure for the functioning of the company. E-commerce is responsible for the operation and management of the website. SAC (Customer Service) is a direct contact channel between customers and company to answer questions, solve problems, and propose improvements. Legal is responsible for all activities related to the legal aspects of the company. The expansion sector is responsible for capturing new commercial points, adding new franchisees, and storing the architecture.

The commercial department coordinates sales and customer relationship activities as well as the supply of all stores. Franchisee management is responsible for all necessary support for franchisees. The marketing department is responsible for all communications and media in the company, preparation of promotional campaigns, and management of social networks. On the other hand, the product development department is responsible for the entire product development process, from the study of trends to the approval of the product that will be sold in stores. The supply chain is responsible for managing the entire supply chain and, avoiding disruptions, excesses, and the lack of essential goods in the distribution center. The distribution center is where the receipt, storage, and distribution of all merchandises are carried out. The purchasing process begins after product selection, which is defined according to consumer needs, fashion trends, seasons, and functionality. The entire process is shown in the flowchart in Figure 3. From this analysis, it is identified whether the product is new, otherwise, the replacement process begins. This process is performed only for products that have good sales performance, which are considered in-line products. This process is carried out weekly, and the

product delivery schedule is carried out according to the capacity of the company and receiving flow.

Figure 3: Purchasing Process Flowchart



Source: (Authors,2022)

The initial purchase of a new product is defined through the analysis of demand, market trends, and history of similar products. On the other hand, the replacement process is elaborated through average sales, seasonality, comparison of inventories, and product life cycle. The replacement process is performed using a few processes. First, an analysis of the stocks of the distribution center and stores is conducted to verifying the quantity of each product in stock. The next step is to generate reports within the ERP management control system (distribution center and store inventory information, purchase order report, supplier and sales lead time) and perform an analysis on each generated report, identifying possible errors, so that the reports are sent to the purchasing system. Within the purchasing system, which is a statistical system based on sales curves and trends, files with treated information are processed. The system analyzes this information and generates purchase suggestions. Then, a purchasing meeting is held with the manager to analyze, criticize and define the quantities to be purchased for each product according to previous market data. After defining the quantities to be purchased, this information is entered into the purchasing system, creating the distribution between the grids according to the sales analysis of each numbering.

The next step is to manually launch the orders within the ERP system and then send an email to the supplier to inform about the orders that have been processed for replacement. At this stage, the acceptance of the supplier is necessary to generate production orders. Follow-up on order deliveries ensures that the supplier meets the delivery deadline for the goods, thus avoiding stockout. After receiving the goods at the distribution center, the checking process for

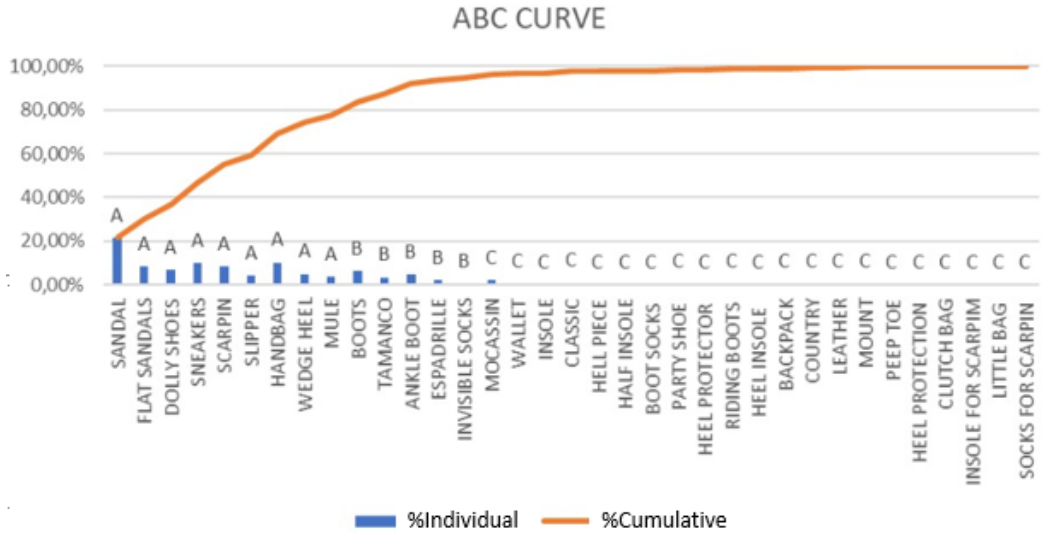
each product is carried out, verifying that the items highlighted in the invoice are in accordance with the receipt. At this stage, it is also verified that all products received are in accordance with the required quality standards. Subsequently, the products are stored according to the output flow of each product. The products are then sorted according to the orders received from the stores. The last step is the distribution of orders to the stores so that there is no stockout in the store.

3.2. Inventory Management Classification using the ABC Curve

Given the data provided by the company the inventory control of the organization is carried out through an integrated management system (ERP). Distribution center stock data were collected from the system in terms of sales quantity, average price, and sales value, referring to the last six months.

Currently, the company has 6,937 types of products divided into 35 categories, each of which has a specific purchase and sale value. The analysis consisted of classifying these products into different classes based on the values provided. A graph was generated that corresponds to the relationship between the percentage of sales value and products (Figure 4).

Figure 4: ABC curve



Source: (Authors,2022)

Analyzing the ABC curve, it can be noted that the products categorized as class A were identified in nine product categories, totaling 933,700 items, which corresponds to 78% of the total product transactions, and 26% of the total amount of items in stock, which can be considered the most important range of products for the company. As this class of products represents the largest volume of sales and billing within the organization, it is important for the company to maintain a good relationship with suppliers. Class B represents the intermediate items, which correspond to 17% of the product transactions in the period, and 14% of the total number of items, totaling 172,009 products, divided into five categories.

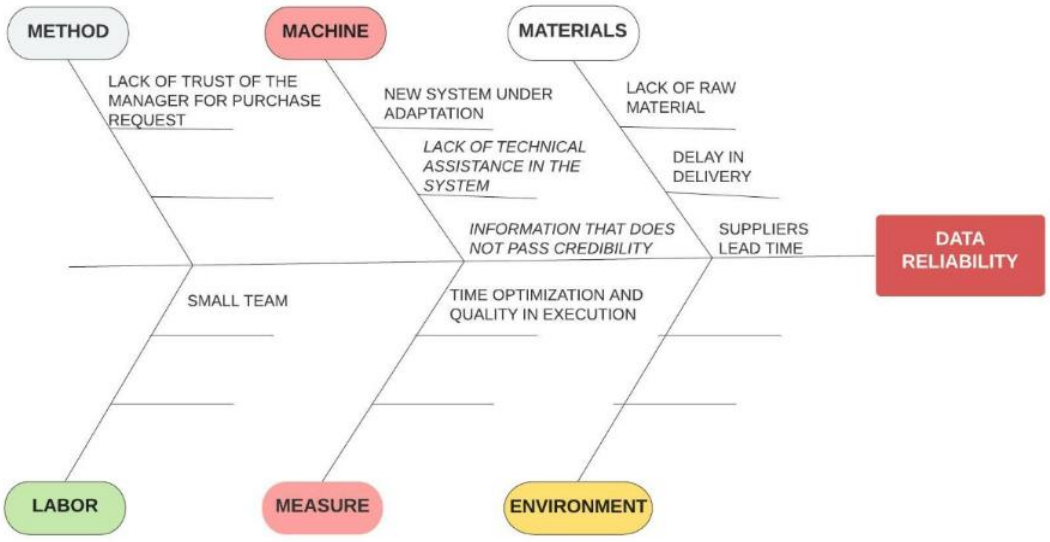
Products classified as class C have a greater volume, but little monetary value when compared to other products, corresponding to only 5% of the total product transactions. However, they represented 60% of the entire stock, totaling 73,842 products. Therefore, these products require special analysis because they need a large storage space in stock, but they do not have a significant impact on revenue.

It is worth mentioning that the products of classes A and B play an important role in the financial stability of the company, considering that the idea is to offer a mix of products to meet customer needs. Therefore, based on these results, it can be seen that the analysis of the ABC curve provides information about the most relevant items, in relation to the total cost, that requires greater prioritization in relation to the other items. This analysis also helps the development of a stock planning strategy according to demand, generating more assertive purchases and consequently helping to reduce stockouts.

3.3. Adequacy Recommendations

The purpose of the Ishikawa diagram was to map the root causes of the problems present in the processes of the company. Figure 5 shows a graphical representation of the tool that identifies the main bottleneck present in the company, which is the inappropriate use of the new distribution center stock replenishment system. After mapping the flow and applying the diagram, it was identified that divergence in the generation of the purchasing process is linked to the new system in the adaptation phase. As this process is executed manually, the defined procedures require extra attention from the person executing the task to avoid errors.

Figure 5: Ishikawa



Source: (Authors,2022)

In view of this, it was possible to organize the reasoning on the possible causes of the problem related to the distribution center and the resulting effects. To seek alternatives to minimize the issues found, the causes were listed and labelled as probable and unlikely.

For better visualization, an illustrative explanation of the 5W2H action plan was provided with the alternative solutions presented in this study. The supply chain sector will be responsible for applying and evaluating the actions listed in Table 2.

Table 2: 5W2H

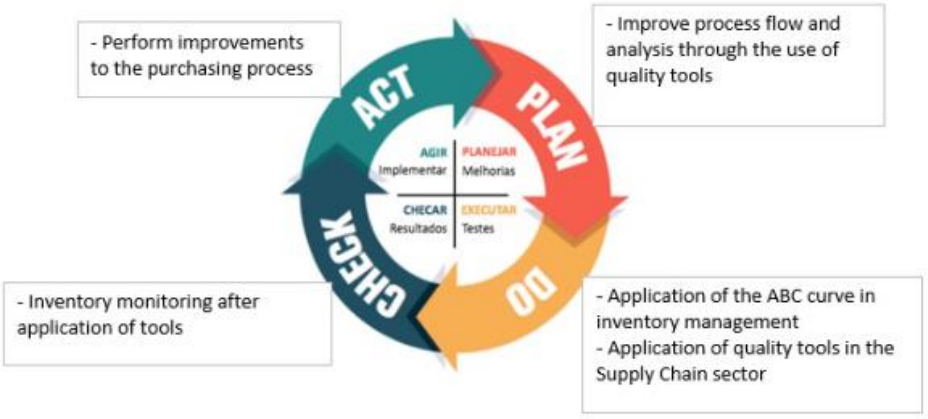
N	Cause	WHAT?	WHY?	HOW?	WHO?	WHEN?	WHERE?	HOW MUCH?
1°	Lack of trust from the Manager to request purchases	Adapt the purchasing system.	To know when and how much to buy	Improve quality tools, assemble staff, apply training and verify effectiveness.	Supply Chain Manager	From Nov 2021	In the meeting room	Free
2°	Small team	Analyze the demand of each collaborator	To verify the possibility of hiring and the overload of employees	Redistributing tasks and hiring interns to assist with demands	Human Resources	From Nov 2021	In the meeting room	In case of hiring BRL 1,000.00
3°	New system undergoing adaptation	Analyze quality tools and their performance	To measure your level of success or errors and thus relieve the manager	Develop an analysis using the Petri Net	Supply Chain Analyst	From Ouc 2021	In the training room	Free
5°	Information that gives confidence							
4°	Lack of technical assistance in the system	Operator training and support	To avoid not using the system	Develop training that demonstrate the importance of using the platform and the importance of the data entered	IT Team and Supply Chain Team	Establish monthly from Dec 2021	In the training room	Free
6°	Optimization of time and quality in execution	Supply Chain Control	To keep the exact amount of product in stock, it must not be missing or accumulating.	Using the quality tool (ABC Curve)	Supply Chain Analyst	Establish monthly from Dec 2021	In the meeting room	Free
7°	Lack of raw material	Routine alignments	To improve communication between buyer and supplier	Performing clear and objective communications, aligning demands and commitments with deliveries to adjust the process and industry times for each product.	Purchasing team, Supply Chain Analyst and Supplier	Establish fortnightly from Dec 2021	In the meeting room	Free
8°	Delay in deliveries							
9°	Suppliers lead time							

Source: (Authors,2022)

The action plan involved four sectors: HR, purchasing, supply shain, and IT. Most activities do not generate costs, as they are developed by the employees that the company already has, as it

refers to some alignments and improvements of the processes that already exist within the organization. The sectors were responsible for solving the tasks listed, with deadlines to be met. Therefore, to mitigate the problems caused by some sectors, it will be necessary to better align the expectations of the organization and establish new procedures and strategies to improve the purchase and storage flow of the company. PDCA is one of the key tools of this work, and in order to achieve the goals and to provide continuous improvements to the processes of the company, the steps shown in Figure 6 were proposed.

Figure 6: PDCA Cycle



Source: (Authors,2022)

After some observations and surveys were carried out in the purchasing department of the company, it was found that its problems were not limited to the high stock levels of some raw materials. The company also faced other types of problems related to the sector, such as failure to replenish stocks in a timely manner due to the lead time of the products, high expenses for the transportation of purchased goods, few distribution centers, and high stock of some products from past collections. In summary, the company faced more department-related problems than was realized. Therefore, improvements must be made in the processes and these actions should be closely followed.

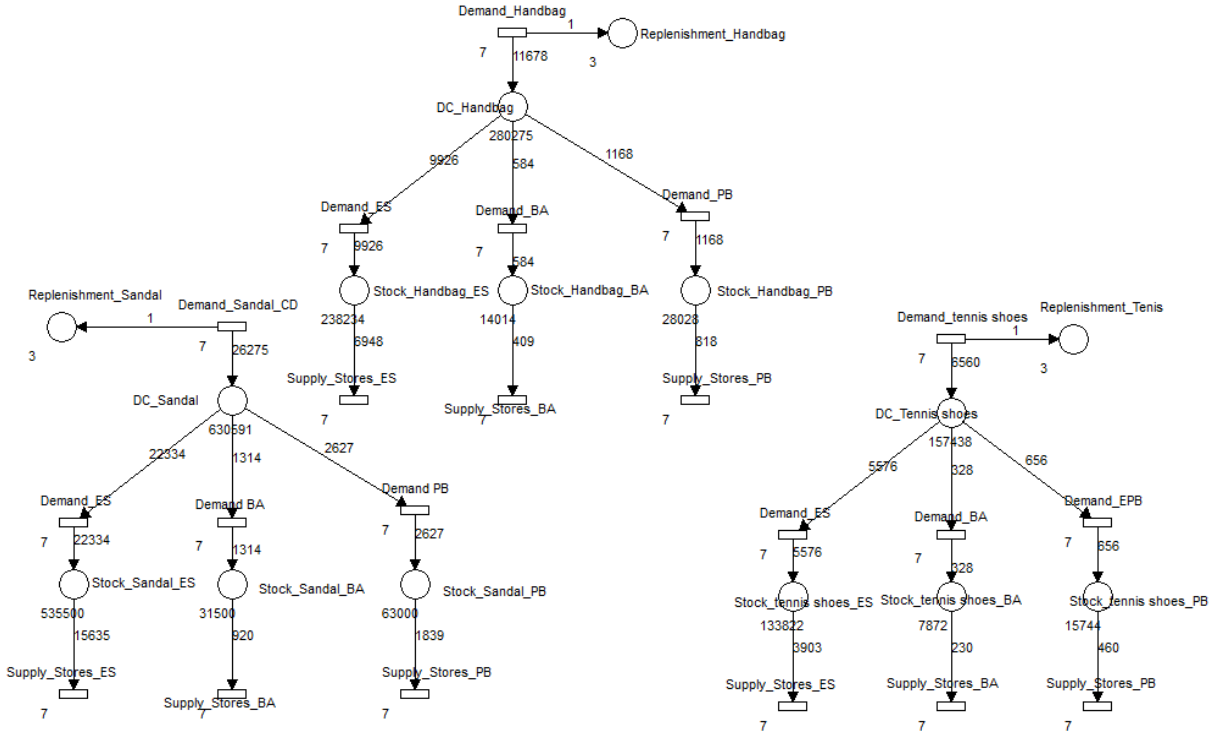
3.4 Simulation via Petri nets

Based on the data collected, a method of modeling and simulating the supply process of the distribution center was developed to verify, via Petri nets, whether it would be possible to identify the main bottlenecks or if there will be a rupture in the stock. The company has three distribution centers. The main distribution center is located in the state of Espírito Santo, where all purchased products are received, and then distributed to the other distribution centers considered auxiliary, located in the states of Bahia and Paraíba. To begin the simulation, the three most relevant products of category A, classified in the ABC curve, were used. Therefore, for the construction of the reference simulator, a dataset was obtained from the last six months of purchases, considering the half-year average of 630,591 pairs of sandals, 280,275 bags, and 157,438 pairs of sneakers.

The distribution center in Espírito Santo consumes an average of 85% of storage, that in Paraíba consumes 10%, and that in Bahia consumes 5%. Based on this, the weekly consumption of each product was analyzed, which may vary according to the seasonal period. Figure 7 shows the modeling via Petri nets, where transitions represent resource consumption, and places represent stock capacity. It can be seen that the purchase value of the last six months was used as a basis, and this value was then converted to represent the value within seven days, so that a more reliable simulation could be possible.

These values were distributed according to the demand capacity of each distribution center (DC). To reduce the risk of stockout, the safety margin for the stock was considered to be approximately 30% of the total stock, where 70% of the stock was used to replenish the stores. The distribution center in Espírito Santo consumes an average of 85% of the storage, which corresponds to a weekly consumption of approximately 22,334 pairs of sandals, 9,926 bags, and 5,576 pairs of sneakers. Considering 70% replenishment of stores, this corresponds to 15,635 pairs of sandals, 6,948 bags, and 3,903 pairs of sneakers.

Figure 7: Petri Net (Sandal, Bag and Sneakers)

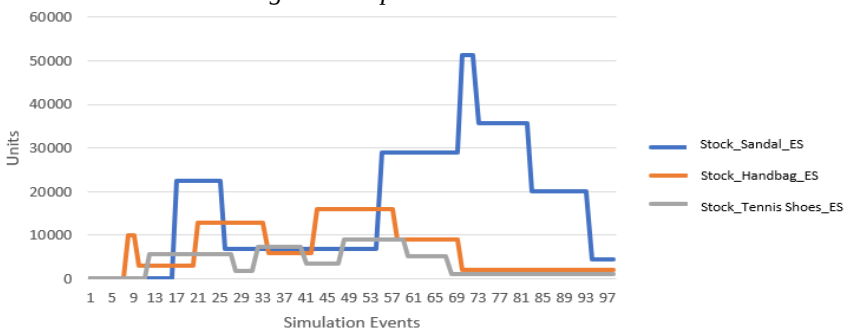


Source: (Authors,2022)

The distribution center in Paraíba consumes an average of 10% of the storage, and its weekly consumption of stock corresponds to approximately 2,627 pairs of sandals, 1,168 bags, and 650 sneakers. Considering 70% for the replenishment of stores, this corresponds to 1,839 pairs of sandals, 818 bags, and 460 pairs of sneakers. On the other hand, the distribution center in Bahia consumes an average of 5% of the storage, and its weekly consumption of stock corresponds to approximately 1,314 pairs of sandals, 584 bags, and 328 pairs of sneakers. Considering a safety stock margin of 30% of the total stock, 70% of the stock was used to replenish the stores,

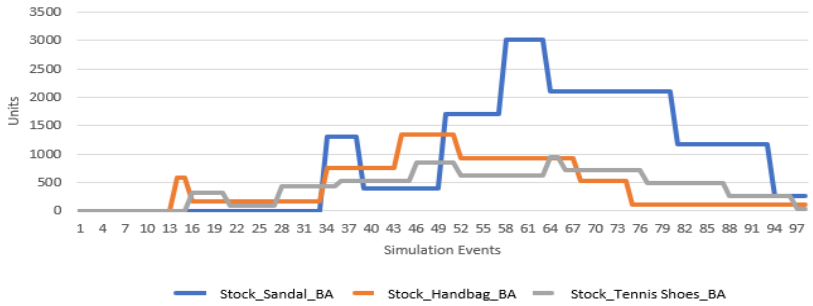
totaling 920 pairs of sandals, 409 bags, and 230 pairs of sneakers. After performing the simulation, according to the graphs in figures 8, 9, and 10, it is possible to see the stocks of products in each distribution center. It was noted that in the stock of the three distribution centers, the sandal is the product that has a high turnover in stock, followed by the bag and the sneaker category.

Figure 8: Espírito Santo DC Stock



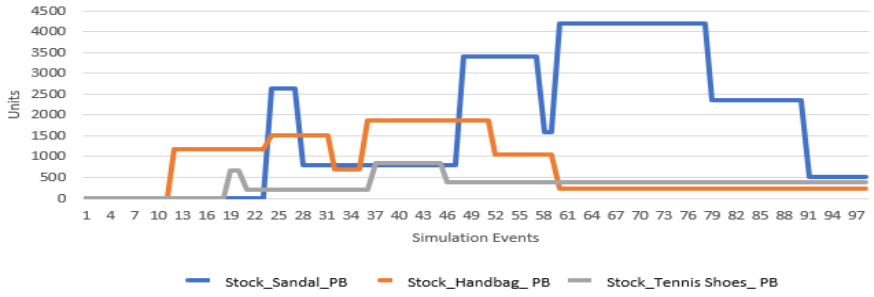
Source: (Authors,2022)

Figure 9: Bahia DC Inventory



Source: (Authors,2022)

Figure 10: Paraíba DC Inventory



Source: (Authors,2022)

A behavioral analysis of the distribution centers can be visualized on figures 8-10. During the simulation process, it can be seen in figure 8 that during the simulation, Espirito Santo DC Stock, during its storage process, reached a peak of approximately 50,000 units of sandals, which impacts not only the planning of distribution but also the storage of this amount of input. However, both the Paraiba and Bahia DC Stocks had maximum amount of 4,000 and 3,000 respectively (more than 90% less than the first). In addition to peaks in storage demands, it is also possible to verify that the handbag stock presents a product availability for a longer

sequence of events (i.e., more product in stock at a given time) in Bahia than the others (i.e., the product tends to remain in stock for longer in Bahia). On the other hand, tennis shoes tend to have more stock in Bahia, but with a behavior that may require a strategy from managers in Paraíba, since the product tends to be in a minimum stock much faster than the other DCs.

4. Conclusion

This study analyzes the supply chain process in a large company operating in the Brazilian footwear market. The application of organizational tools for process standardization was proposed, and an analysis based on modeling and simulation via Petri nets of the distribution center stock replenishment process was conducted. In this way, a procedural evaluation of the analyses made by the organization chart, flowchart, Ishikawa diagram, 5W2H, PDCA cycle, ABC curve, and modeling and simulation via Petri net were carried out. Petri net simulations provided a visualization of the behavior of the stock replenishment process of the evaluated company. It can be understood that there are several parameters that can influence stockout, some of which are the lack of raw material generated due to Covid-19, lead time of production and delivery of the goods, and erroneous generation of demand forecast, which can also cause a high product index in stock.

Therefore, it is concluded that the objective of this work was accomplished, because it was possible to demonstrate through this study that with the application of management tools, it is possible to obtain a significant improvement within the organization and standardize and optimize the purchase process.

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