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# Logistic management and neural network maps: Keys to cost optimization in cardboard packaging manufacturing

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**C H R O N I C L E**

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**A B S T R A C T**

The focus of this research is to analyze how supply chains' management affects production costs in the cardboard and Packaging sector in Peru, specifically through the creation of artificial neural networks (ANN) to improve the logistical activities. Non-experimental quantitative design was applied, collected the data from the Year 2020 to the Year 2024 and sought to assess variables such as supplier capacities, stocks held, bottom line costs incurred and stock out ratios. The study revealed that there exists a proportionate inverse relationship between the logistical costs and production costs, proving that as the cost of acquiring goods needed for production as well as the cost of keeping and managing stock decreases, the overall production cost also decreases significantly. The ANN model was able to perform cost predictions with a high degree of accuracy which points out the relevance of sophisticated instruments in the shift of the supply chain. Also, it is important to note the core contribution of the research – effective logistics management is emphasized as a way of increasing competition in industries where supply chains are of critical importance. This research reinforces the effectiveness of designing ANN in minimizing costs, while adding knowledge to the reporting practice of the companies aimed at bettering their costs. The results are a good contribution in terms of technological change in logistics aimed at helping the organizations remain flexible in a changing economy.



## 1. Introduction

Procuring materials is closely linked to a company's logistics, as outlined by Tang (2018), who defines logistics as a concept tailored to meet customer demands and forms the bedrock of an organization's productive endeavors. At present, there is an enigma surrounding effective logistics management: on one hand, achieving optimal inventory levels is a common objective pursued by harmonizing initial supply and demand. In today's market landscape, characterized by swift globalization fueled by information and communication technologies, logistics is emerging as a fresh factor setting companies apart in the competition. Even locally, enterprises situated in remote locales have witnessed notable upticks in production and competitive capacity in services, largely attributed to robust logistics practices. A robust logistics framework doesn't just facilitate competitive forays into distant markets but also bolsters and elevates local market competitiveness. Hence, it becomes vital for companies not just to enhance their logistics for heightened competitiveness but to sustain it over the long term (Flores Vilcapoma, 2024).

Adeniran et al. (2024) point out that logistics is now a pivotal instrument for enhancing competitiveness. Well-structured logistics can confer substantial edges over other economies, effectively addressing scarcity issues and streamlining product transportation. Similarly, Mora (2024) underscores that modern logistics management is a key distinguishing factor for organizations. It's a core component of a systemic approach that links vital processes within the logistics system: procurement (purchasing management, storage, and inventory management), production, distribution or sales, and even

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reverse logistics. Flores-Vilcapoma et al. (2021) employed a linear regression model using the ordinary least squares method, demonstrating an inverse relationship between procurement, storage, and inventory management and production costs in the Peruvian paper industry. Ji et al. (2018) delved into the logistics scheduling problem in a three-tier supply chain involving suppliers, manufacturers, and customers. They demonstrated the correlation between inventory cost and workflow time—how long it takes for work to move from manufacturer reception to completion and departure (Chen & Bidanda; 2019). Similarly, Hur et al. (2018) investigated the management of spare parts inventory for aircraft at the end of an airline fleet's operational life cycle. With aircraft approaching their operational end, the supply chain management for spare parts becomes intricate and costly. In response, they designed an algorithm that fulfills the requirements for spare parts for aircraft components at the end of their life cycle, serving as an effective performance indicator during the management of spare parts supply chains in a performance-based logistics setting. Additionally, Wiecek (2016) proposed a fusion of fuzzy logic and genetic algorithms to manage a company's procurement process. The method and simulations unveiled by Wiecek underscore that in cases where demand, delivery times, and other uncertain factors significantly affect the supply system, traditional methods of determining inventory levels are ineffective and inefficient. The primary justification for this research lies in the aim to develop a schematic neural network map that facilitates the achievement of outlined objectives while optimizing processes related to logistics management, particularly in procurement, storage, and inventory operations. Under this approach, the study's objective is to analyze how logistics management impacts production costs in Peru's cardboard and packaging industry, employing a mathematical model based on neural networks. The research focuses on a private company located in the capital of Peru, highlighting the importance of efficient logistics management. This will enable the company to adopt a strategic tool that not only improves logistics management but also strengthens accurate and unbiased operational and tactical decision-making within its areas. Furthermore, it will significantly contribute to the continuous improvement of production costs within the organization.

## 2. Literature Review

### *2.1 Artificial Neural Network*

As Krauss (2024) pointed out, neural networks are tools that use information processing inspired by the nervous system of a living being, aiming to mimic the human brain. According to Baleanu et al. (2023) they are powerful tools for analyzing signals and modeling systems, as they can solve highly non-linear functions quickly while processing complex mathematical data. Another concept, neural networks are like an “artificial brain” that can learn and solve complex problems in a way similar to how a human would (Yashchenko, 2023). As outlined by Batani (2018), ANNs are robust and proficient tools that possess intelligence, adaptability, and the ability to generalize to complex nonlinear systems. They can process data at high speeds and significantly contribute to informed decision-making. As noted by Goel et al. (2023), constructing an artificial neural network involves selecting input variables and determining the network's predictive structure through trial and error.

### *2.2 Procurement*

Vértice et al. (2010) contend that the terms procurement and purchasing are frequently perceived as interchangeable. While purchasing entails obtaining all necessary goods or services for a company, procurement encompasses a wider array of undertakings that includes purchasing. Among its principal tasks, we can identify activities like needs assessment, purchasing, storage, distribution of supplies, stock administration, and waste utilization. Gancedo and Vega (2017) underline that the meanings of procurement and purchasing are often erroneously interchanged. Purchasing denotes the act of acquiring something in exchange for money, whereas procurement entails furnishing the company with the essential goods or services to facilitate proper functioning. The overarching objective of a procurement strategy is to secure the supply of all requisite goods or services to facilitate the company's sound development, adhering to stipulated quality benchmarks, adhering to predetermined timelines, and achieving optimal costs, as articulated by O'brien (2024). Additionally, stored inventory constitutes an investment in fixed capital. Hence, from an economic perspective, it proves advantageous to align inventory levels with sales velocity or the quantity of each product essential for the company. Excessive inventory can entail elevated maintenance costs (covering space, storage, maintenance, and processing expenses) and undermine the company's competitive edge. Conversely, insufficient inventory can translate into missed sales opportunities, customer dissatisfaction, or such losses, as noted by Vásquez (2010). Efficiency, in terms of supply management, pertains to ensuring the prompt delivery of required products or services with suitable quality and necessary quantities. In the context of efficiency, supply management strives to minimize resource costs linked to the attainment of predetermined goals across various activities, as outlined by Shifino (2008). Moreover, Shifino highlights that the procurement function encompasses three pivotal elements: procurement, storage, and inventory management. To delve deeper into this topic, Shifino categorizes them as follows:

- The procurement management department is responsible for acquiring the products required by the production and sales departments, taking into consideration various factors such as price, quality, delivery time, payment terms, post-sales service, and more. This process involves making optimal supplier choices to leverage these variables that impact the purchasing decisions.
- Storage: A warehouse is established to house the products intended for future use by the production department. Once the products are manufactured, they are stored until the sales department sells them to customers. All of these activities necessitate a physical space where products can be easily organized and stored.

- Inventory Management: Developing an effective inventory management system is essential. Such a system is designed to determine the appropriate inventory levels and order rates required to meet both production and sales needs of the company.

### *2.3 Purchasing Managemen*

According to Lysons and Farrington (2020), the management of purchases is characterized as the commercial operation entrusted with the continuous and appropriate provisioning of all necessary resources for a company's production chain. This provisioning must occur within specified timeframes, while ensuring the highest achievable quality and the most economical price. To encapsulate, its primary objective is to fully meet the established standards of the company, thereby preventing any delays or impediments in the production process. Skillful management of purchases can yield a consistent supply of materials aligned with predetermined schedules, foster a robust rapport with a diverse array of suppliers, establish communication channels that facilitate smooth and reciprocal information flow, conduct perpetual supplier selection and assessment, maintain an ongoing dialogue for price, quality, presentation, and delivery times, guarantee suitable stock and inventory levels, and sustain a comprehensive record documenting the attributes of each requisite good or service.

#### *2.3.1 Stable and Continuous Flow of Materials*

Keeping a steady stream of materials flowing is absolutely essential for any company, whether it's the raw materials needed to make your products, the spare parts to keep things running smoothly, or even the finished goods ready to be shipped out (Picone, 2024). A good management system helps us figure out exactly what we need and when we need it, making sure our production lines keep humming along and our customers get what they ordered without any delays. It's all about staying competitive and making sure we deliver what our customers expect. (Jaramillo et al., 2024).

#### *2.3.2 Assessing and Evaluating Suppliers*

To obtain the best materials, we must choose reliable suppliers who meet our quality standards. It's important to evaluate suppliers continuously, not just at the beginning, to ensure they continue to offer high-quality products and adapt to our changing needs (Coşkun et al., 2022).

#### *2.3.3 Bidirectional Information Flow*

Open and transparent communication with our suppliers is essential. Systems like SGA allow us to share important information, such as inventory levels and security needs, so our suppliers can adjust their deliveries and ensure we always have what we need, at the right time (Oguchi & Yuen, 2024; Geissdoerfer et al., 2017)

### *2.4 Warehousing*

According to Jarašūnienė (2023) warehousing is not just a space where things are stored. It's a crucial area that ensures all the materials a company needs are available in an organized, safe and efficient manner, without being altered or modified. According to Ahmad et al. (2023) it's no longer just a simple depot where things wait to be shipped. Today, good warehousing management is essential for optimizing resources, reducing costs and improving customer service quality. The goal is to optimize space, reduce inventory holding costs, streamline the product picking process and continuously improve how materials are handled. All of this helps to avoid shortages of raw materials and other essential items for the company.

#### *2.4.1 Types of Warehousing*

When it comes to storing things, we have a few options. We can keep products safe inside, protected from the weather, temperature changes, and even bright lights. Or, we can store them outside, as long as they're in a secure area with a fence or other barriers. We can also organize our storage by what kind of products we have. We might have a section for raw materials, another for things that are still being made, and another for finished products. We can even store chemicals and other special materials separately. And then there's financial storage, which is like a special kind of warehouse for imported goods. It allows companies to bring things into the country while delaying paying taxes and making sure they follow all the rules. We also have transit storage, which is like a short-term parking lot for products. It helps to make transportation more efficient and keep trucks moving (Flores, 2024).

### *2.5 Inventory Management*

According to Nwaiku and Ejechi (2022) effective inventory management is key to keeping production running smoothly. Inventory management is crucial for any company's success. It's all about keeping a detailed record of all the materials stored in the plant, from raw materials to finished products. Efficient inventory management means carefully tracking each item, preventing shortages that could bring production to a halt. Perkumienė (2022) highlights that inventory is a dynamic process, with the amount of materials in a warehouse constantly changing due to the company's daily operations. In other words, an inventory snapshot taken at one point in time won't accurately reflect the warehouse's inventory at another point in time.

### *2.5.1 Types of Inventory*

Rao (2023) indicates that inventory types can be classified as follows:

- Raw material inventory: includes all items intended for the transformation and production of finished products that have not yet been processed.
- Inventory of spare parts for equipment and industrial supplies: encompasses secondary raw material inventories and consumable items.
- Finished product inventory: comprises storage of all finished products derived from the production area, which will soon be distributed in the market to meet customer demand.
- Work in progress inventory: consists of items in an intermediate stage of processing, stored for subsequent completion of their transformation process.
- Forecast inventory: encompasses products intended to meet future needs.
- Safety stock inventory: represents a minimum reserve quantity of raw material that can prevent any shortage.

### *2.5.2 Inventory Policy*

Esrar et al. (2023) inventory policy is a vital tool for any business, determining how much stock to keep and when to replenish it. This strategy needs to be carefully crafted to ensure it doesn't negatively impact the company's finances, avoiding excessive inventory that leads to unnecessary storage costs. At the same time, it needs to guarantee enough products are available to meet customer needs. In other words, a good inventory policy aims to strike a balance between profitability and customer satisfaction, as highlighted (Framinan, 2024).

### *2.6 Procurement Objectives*

Flores-Vilcapoma et al. (2021) points out that achieving optimal supply management requires companies to focus on several key objectives:

- It's crucial to identify the organization's needs and ensure adequate inventory to prevent shortages of raw materials and other supplies.
- Efficient inventory management should reduce inventory investment and minimize storage costs, especially due to damaged, obsolete, or perishable goods.
- Having an effective information system is essential, providing relevant departments with inventory status and reporting the monetary value of stocks to the accounting department.
- Finally, collaborating with the purchasing department is key to achieving cost-effective procurement while maintaining efficient transportation, including shipping and receiving activities.

While these objectives are important, they cannot always be achieved simultaneously, and conflicts or unforeseen circumstances may arise. Therefore, it's necessary to find a balance that minimizes the costs associated with each objective while maximizing customer service.

## 3. Methodology

The research adopted a quantitative, longitudinal, and non-experimental design approach, aiming to determine how logistics management has an inverse influence on the production costs of packaging and cardboard packaging in Peru through a neural network-based map. To carry out this study, the following key steps were established:

a) logistics needs

b) Identify supply sources

c) Efficiently manage purchases

d) Properly manage storage

e) Monitor and optimize inventory management

The sample used was based on data collected from a Peruvian cardboard manufacturing company, with monthly records spanning from January 2020 to July 2024. In total, 80 observations corresponding to each variable involved in the study were analyzed.

| Variables | Dimensions | Indicators |
|---|---|---|
| Procurement Management | ✓ Purchasing management | • Number of Local Suppliers (SUPP_LOC)<br>• Number of Foreign Suppliers (SUPP_FOR) |
| | ✓ Storage management | • Stock (STOCK)<br>• Balance (BAL) |
| | ✓ Inventory Management | • Inventory Turnover (INV_TUR)<br>• Merchandise Value (MV) |
| Production Costs | ✓ Direct Production Costs | • Raw Material Costs (RMC) |
| | ✓ Indirect Production Costs | • Expenses on wages, maintenance, and general expenses (EWM) |

Knowing how the variables are formed, through their dimensions and indicators, the research hypothesizes the following:

General Hypothesis: Supply management has an inverse influence on the production costs of packaging and cardboard packaging in Peru.

To validate the proposed hypothesis, the use of neural networks employing the backpropagation algorithm as a statistical method is proposed, with the aim of identifying and estimating future production costs through procurement management. In this way, it relies on a correlational analysis that evaluates the relationship between the dependent variable and its indicators, aiming to determine the level of association between these variables.

## 4. Results

### *4.1 Preliminary Analysis of Variables*

Table 1 demonstrates the summary of some based analysis such as min, max, etc.

**Table 1**
The summary of the basic statistics

| | SUPP_LOC | SUPP_FOR | STOCK | BAL | INV_TUR | MV | PC |
|---|---|---|---|---|---|---|---|
| **Min.** | 3.135 | 3.178 | 8.826 | 7.685 | 8.315 | 12.81 | 12.77 |
| $Q_1$ | 3.401 | 3.296 | 9.097 | 7.929 | 8.688 | 13.23 | 13.13 |
| **Median** | 3.569 | 3.401 | 9.191 | 8.003 | 8.832 | 13.5 | 13.35 |
| **Mean** | 3.541 | 3.406 | 9.194 | 7.993 | 8.832 | 13.51 | 13.37 |
| $Q_3$ | 3.644 | 3.504 | 9.332 | 8.097 | 8.988 | 13.81 | 13.64 |
| **Max.** | 3.829 | 3.689 | 9.474 | 8.231 | 9.156 | 14.11 | 13.92 |

### *4.2 Neural Network Design*

We use an Artificial Neural Network (ANN), with this we are able to learn to theoretically perform any operation, without the need for us to provide its mathematical formulation. You just need us to provide you with several examples of the output that is produced from certain inputs. If the procurement management examples are sufficient and representative of the problem, after learning the neural network will be able to carry out said operation with high precision.

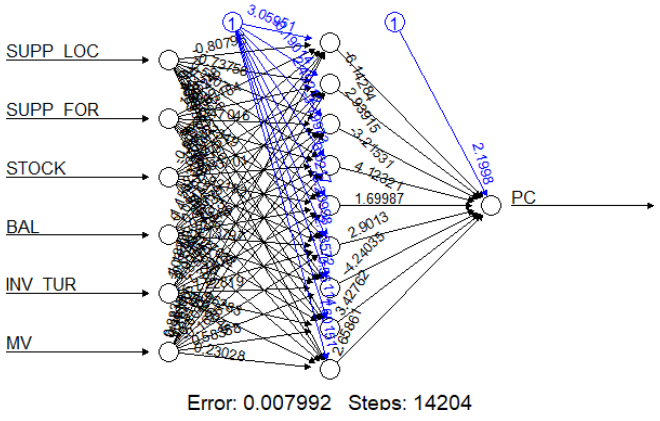


**Fig. 1.** Neural Network Map

Fig. 1 directly represents the data contained in the variables used, we could take any values as legs and follow their evolution step by step through the ANN. First you would have to multiply these values by the weights indicated by each of the links. Next, we would add up all the inputs that reach each hidden neuron. A function would be applied to this value, the activation function of the neuron, which will generate an output value. By default, we use a logistic or sigmoidal activation function. In this way, an output is obtained from each neuron in the hidden layer. All of them act as input to the output neuron, whose value is calculated as the weighted sum of all those inputs. This output neuron does not carry out any processing on said value, nor do the input neurons.

In addition to the network diagram with its connections and weights, we also obtain a representation of the Generalized Weights (GW) of each of the input variables with respect to an output variable. This allows us to determine which variable contributes more weight to the prediction of an output. In our ANN, after learning the hypotenuse function, it is not surprising that all the predictor variables have a very similar contribution to the only existing output, as shown in Fig. 2.

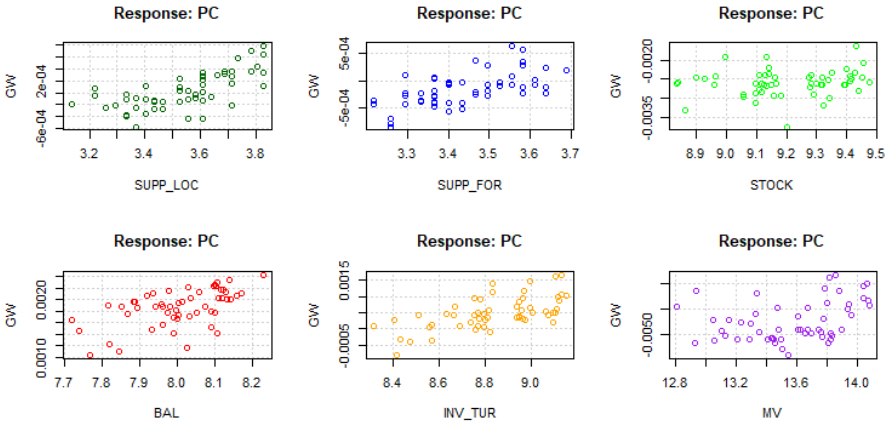


**Fig. 2.** Neural network map

### *4.3 Prediction*

**Table 2**
The summary of desirable parameter estimation

| Indicator | Result |
|---|---|
| **RMSE** | 0.0005 |
| **NMRSE** | 0.0200 |
| **$R^2$** | 0.9962 |
| **ME** | 0.04052 |
| **MAPE** | 0.0014 |
| **MAE** | 0.0192 |

Table 2 presents the summary of the desirable parameter estimations.

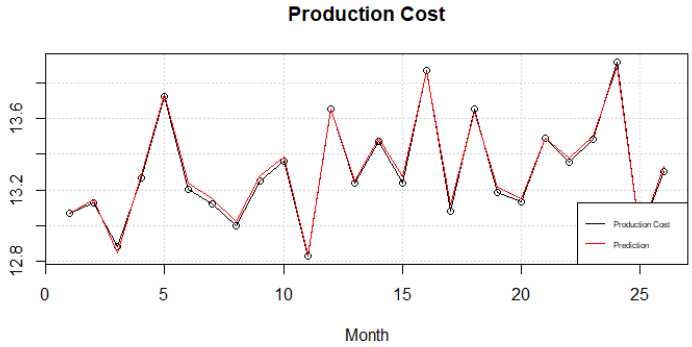


**Fig. 3.** Production Cost Forecast

With the network already trained, we can give it new inputs not with the aim of continuing learning, but to obtain a prediction of what the resulting value of the learned function should be. To do this, we will provide the variable containing the ANN configuration, with the values for the input variables and, optionally, we will indicate which of the ANN repetitions we want to use. Fig. 3 indicates that our prediction is very similar to the costs used, so the prediction error is minimal.

## 5. Discussion and conclusion

*Answer to general hypothesis*

Inverse Relationship Validated: The study employed artificial neural networks (ANNs) using a backpropagation algorithm, correlational analysis, and predictive modeling to assess supply management's impact on production costs. The results confirm that better supply management leads to reduced production costs.

The research confirms that efficient supply management significantly reduces the production costs of cardboard packaging in Peru. By examining the different processes of procurement, storage, and inventory management, the research highlights the importance of balancing each of these components to optimize costs. Modeling with artificial neural networks revealed that improving procurement practices, including supplier selection and purchasing efficiency, clearly impacts the reduction of raw material costs and other production-related expenses. The inverse relationship between supply management and production costs underscores the potential of logistics as a competitive tool in Peru's packaging industry.

The use of artificial neural network (ANN) algorithms proved to be a consistent tool for predicting production costs with high accuracy. Metrics such as RMSE, MAPE, and correlation coefficients provide reliability for the ANN model in decision-making processes. This approach offers a scientific foundation for companies in this sector to enhance their supply management systems by identifying critical variables, such as inventory levels and stock turnover, which directly influence production costs. Furthermore, the ability to incorporate complex data into practical strategies underscores the importance of advanced analytics in optimizing supply chains.

Finally, it can be concluded that the findings highlight the strategic value of supply management as a driver for cost optimization and competitiveness in Peru's cardboard packaging industry. Efficient inventory and storage management can ensure a steady flow of materials, thereby minimizing excessive inventory costs and production disruptions. These insights are significant for companies seeking to leverage logistics and technological innovations to maintain competitive advantages in a constantly globalizing market.

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