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Diagnosis of physical conditions for the implementation of a reverse logistics management model in a supply chain

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Abstract. The objective of this research was to structure a Reverse Logistics Management model applied to the furniture sector in the city of San José de Cúcuta, Colombia, based on the identification and analysis of the current business practices adopted by the companies that are part of this sector. For this purpose, engineering methods and techniques were used to propose alternatives that contribute to achieve a competitive growth, a better use of resources and environmental impact through strategies for the reuse of products or materials that, based on their physical properties, represent the best feasibility conditions. The type of research used was descriptive, with a qualitative approach. The methods used for data collection were mainly surveys, interviews and direct inspection of the companies studied, which made it possible to evaluate the physical variables of the object of study. It was possible to demonstrate that furniture manufacturing companies can adopt better reverse logistics practices in the manufacturing processes through referencing and articulation with strategic allies in the distribution channels. It was possible to establish the importance of implementing this model as a strategy to diagnose physical conditions and improve production systems to achieve a more efficient use of physical manufacturing resources.

1. Introduction

The furniture industry is part of a traditionally dynamic sector, due to the increase in the construction of housing and real estate recently acquired in Colombia, this has produced greater consumption and growth in production, both to complete real estate projects and for personal consumption. There are different types of furniture depending on the need, among the wooden furniture most requested by customers 40% of the market is covered by furniture for living room, followed by furniture for rest or bedrooms with 33% of sales, we have that with 12% are the furniture for kitchen and 8% of furniture for office. In the city of San José de Cúcuta, Colombia, and its metropolitan area, this industry is one of the most important; currently, there are small and medium-sized companies dedicated to the manufacture and commercialization of furniture, being a source of manufacturing employment and contributing to the sustainable development of the region [1].

The hypothesis of the research was based on the assertion that the companies in the furniture sector in the study area do not implement any strategy aimed at the use and reuse of materials and inputs used in the manufacture of these products, and that all types of materials used are suitable for reuse. It is considered appropriate to demonstrate to what extent the physical conditions of the materials used in



the manufacture of furniture favor the application of reverse logistics and its impact on the management of the companies in the sector.

The main objective of this research article was to design a model of reverse logistics management in the furniture sector in the region of Norte de Santander. To achieve this, the existing companies in the furniture sector in the city of San José de Cúcuta, Colombia, were classified; a diagnosis of the current state was carried out to identify the logistic and production processes developed by the companies dedicated to the manufacture of furniture in the region; finally, alternatives for the implementation of reverse logistics practices in the distribution channels of the companies under study were identified.

2. Overview

Supply chain refers to the sequence of processes and flows that take place inside and outside the company and between different stages that combine to meet customer needs. It refers to the control and monitoring of all operations performed on the product, from the raw material until it is delivered as a finished product to the customer, as shown in Figure 1, the supply chain represents the articulation of different companies (suppliers, manufacturers, and distributors) that seek to ensure that the final product arrives in the minimum time established, in the right place and in the right quantities [2,3].

The supply chain arises from the need of organizations to coordinate different processes in an efficient way, becoming a key element that allows rethinking the delocalized production processes of companies with high demands of international markets that seek to give an efficient response to the consumer through physical distribution and transport [4].

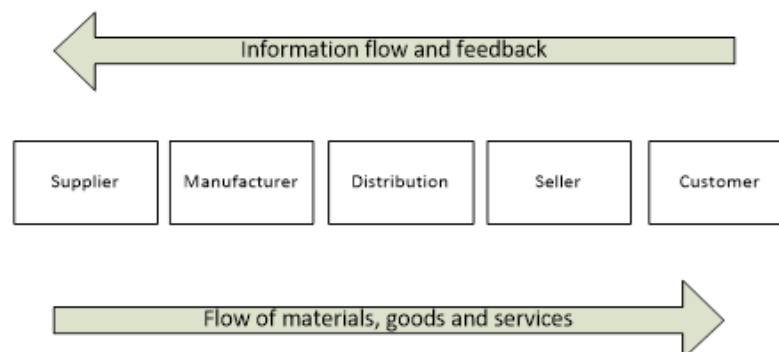


Figure 1. Supply chain management model.

Reverse logistics can be defined as a very complex process which requires the handling, transport, and control of products in the reverse direction that are generated by the final customers, the company, and the life cycle of the product, all this process is generated from the final point to a previous point to manage the products in a correct way [5]. Reverse logistics is understood as the process of managing customer returns with an impact on the service and recovery of product value, proper final disposal, and the development of environmentally friendly practices [6,7].

Reverse logistics includes the set of physical activities of collection and dismantling of used products or their components, as well as materials of different types and nature, with the aim of maximizing the use of their value, in the broad sense of their sustainable use and, in the last case, their destruction [8]. Figure 2 shows the physical path of materials in a logistics chain on their way to the final consumer (direct flow) and the possibilities of returning materials or sub-parts to the organization through a reverse flow.

Reverse logistics comprises different actors that play a specific role in the reverse logistics cycle. These actors can be classified into main actors, specialized actors, and related actors [9]. There are different factors that are part of the reverse logistics process that allow optimizing its application, generating economic benefits for the organization, and improving the application of this strategy. These factors can be classified into: Administration and control, performance indicators and financial

aspects [10]. To carry out a return procedure, it is necessary that the company has established a procedure that allows it to maintain the company's standards and policies, so that at the time it is presented, it can be checked and allows it to carry out the corresponding procedures for this process [11].

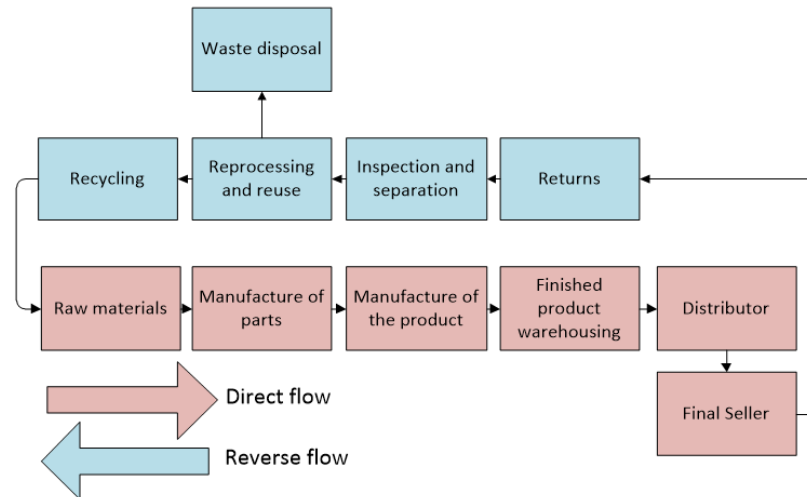


Figure 2. Relationship between forward flow and reverse flow in reverse logistics.

The reverse logistics cycle shown in Figure 3, establishes that this process begins with the physical return of materials, which may be classified according to the possibility of recycling and finally determine the criteria for use or reuse, as appropriate.

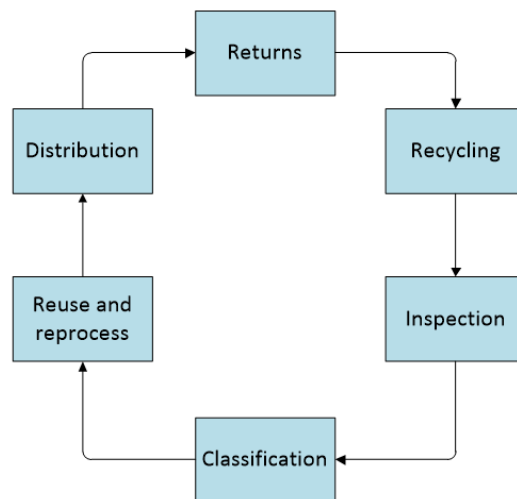


Figure 3. Reverse logistics cycle.

On the other hand, the products sold in this sector are usually made from conventional and non-conventional materials that vary among themselves, according to their characteristics and properties, which in some cases make them more easily reusable or recyclable. Within this group of materials, melamine, agglomerated materials, and solid wood stand out. For example, it is important to analyze the case of composite materials and their main properties. Table 1 compares the calculated density values of some materials commonly used in the industry, based on results obtained from previous studies [12].

Table 1. Thickness and density of some composite furniture materials [12].

N°	Type of panel	Thickness (mm)	Density (g/cm ³)
1	Medium density fibreboard (MDF)	MDF	0.757
2	Beech-faced MDF	BeV-MDF-BeV	0.799
3	Laminated MDF with High Pressure Laminates (HPL)	HPL-MDF-HPL	0.885
4	3-ply panel with MDF and plywood	MDF-PoPIW-MDF	0.776
5	Acrylic solid surface 6 mm	ASS-6	1.712
6	Acrylic solid surface 12 mm	ASS-12	1.709
7	Acrylic solid surface beech veneered	BeV-ASS-BeV	1.509
8	5-ply Acrylic solid surface beech veneered	BeV-ASS-BeVASS-BeV	1.577

3. Methodology

The type of research used in this project is descriptive, with a mixed quantitative-qualitative approach [13].

3.1. Application of instruments

The information was initially collected through surveys, these were applied to businessmen of this productive sector of the city; in addition to applying direct observation in the manufacturing processes of the finished product, to obtain information for the construction of a process diagram for reverse logistics.

3.2. Data analysis

Valid and reliable bibliographic sources and databases were used, related to the management models of reverse logistics, supply chain and procurement; these tools were used to have a reference for the development of the project.

3.3. Validation of material properties

A bibliographic review of the physicochemical variables of the materials that have been used in the manufacture of furniture was applied to compare and demonstrate the feasibility of their application in reverse logistics models that are feasible in the industrial sector.

4. Results and discussion

Previous studies have shown that the decomposition of materials such as wood, caused by the action of weathering containing ultraviolet radiation, can affect the surface of this material, being a visible aspect after a few years; likewise, the fungi present in the decomposition processes modify the entire wood and destroy it in a few years.

4.1. Considerations affecting materials reuse

The process of degradation is reflected in the loosening of the fibers of the surfaces, erosion, the generation of cracks and raised grains [14]. A clear example of these degradation processes can be seen in Figure 4, showing a wood surface eroded by the sun and rain.

Reverse logistics strategies should consider the state of the materials in terms of their level of degradation, which may limit the feasibility of their implementation. Likewise, as a previous review aspect, the relationship between cost, thickness and density of some composite materials was analyzed. According to the behavior of Figure 5, the background of previous research [12] shows that wood-based materials have lower density and cost, but higher thickness (Figure 5(a)). MDF laminated with HPL (HPL-MDF-HPL) has excellent flexural strength. In contrast, acrylic-based solid surface materials have lower thickness and higher mechanical properties, except for beech-veneered 5-layer acrylic solid surfaces (BeV-ASS-BeV-ASS-BeV), but their cost and density are very high (see Figure 5(b)).



Figure 4. Weather-degraded wood [14].

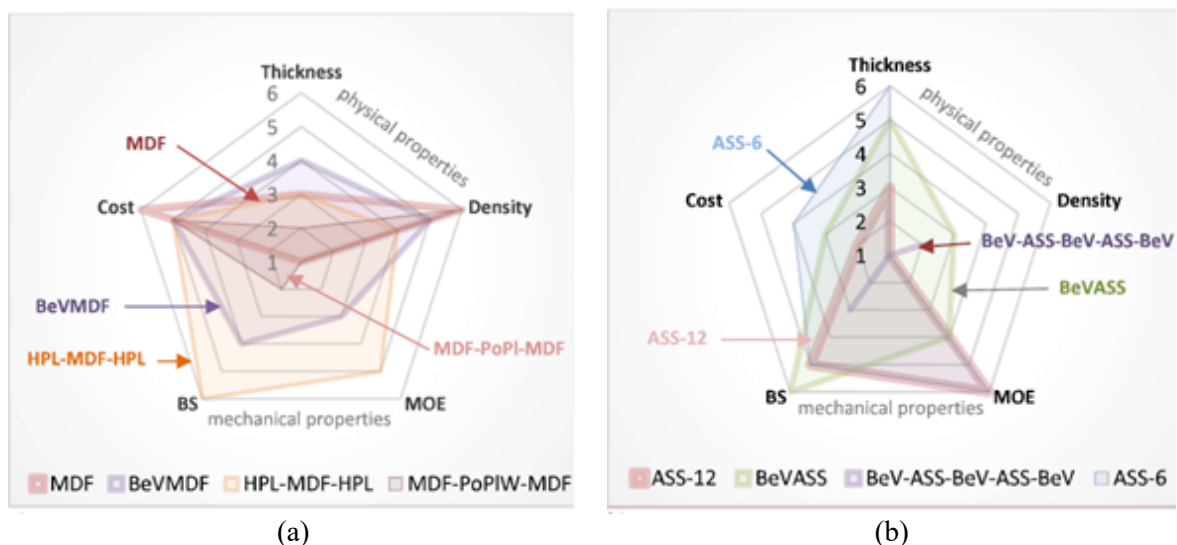


Figure 5. Radar chart for the evaluation of furniture materials with respect to thickness, density, mechanical properties, and cost: (a) wood-based materials, (b) non-wood-based materials [12].

4.2. The behavior of the sector under study

The industries dedicated to the manufacture of furniture in the city of San José de Cúcuta, Colombia, and its metropolitan area have been characterized according to their size, the scope of their market projection and the type of products they sell. When investigating the raw materials used in the furniture manufacturing processes, it was found that in all the companies, the main material used is wood in its different presentations and classifications. Although other materials are used in the manufacture of furniture, they are complementary, and the amount invested is proportionally less than that of wood derivatives.

Within the furniture sector, different types of products can be produced depending on the determination of each company, most companies produce furniture for resting, which means that this type of furniture has a higher demand from customers and a higher penetration in the market. To a lesser extent, the companies in this sector produce box furniture, table furniture or other types of furniture which are also needed and required by the customers; however, their frequency and volume of purchase is lower than the rest furniture.

According to the data obtained, it can be concluded that most of the companies belonging to the furniture sector have a production capacity that does not exceed 100 units per month to cover the required demand; to a lesser extent, there are companies whose maximum monthly capacity is between 200 and 300 units per month. These values determine that the production capacity of this

sector is relatively low, this could be since the demand for this type of products is small, or that the number of companies belonging to this sector covers the quantity demanded by the clients.

On the other hand, it was considered that having control over the raw material inventory is of great importance for all companies, as this factor depends on the adequate supply and distribution of what is available without generating excesses or shortages in the quantity of raw material. The relationship between the quantity of products manufactured and the level of inventory must be equitable. In the sector, it was found that half of the companies have an inventory level of raw materials that does not exceed 15% of their production, 37% of the companies have an inventory level of less than 5% of their production and a smaller proportion of companies have an inventory level that exceeds 30% of their production. In relation to finished product inventory, Figure 6 shows that at present, the companies that manufacture furniture in the region do not have a finished product inventory or this percentage is less than 5% of production, this is due to the fact that the production of these companies is low and therefore, the inventory index is also low or null; only 12.5% have an inventory of between 10% - 15% of their production and the remaining 12.5% have a finished product inventory greater than 30% of total production.

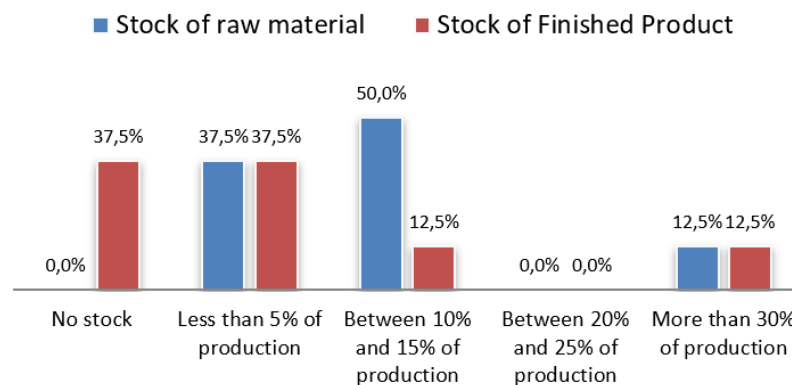


Figure 6. Amount of stock used.

During the production process, companies emit a large amount of waste of different characteristics. As explained in Table 2, 50% of these wastes are fabrics, leathers, and foams, used especially in the manufacture of rest furniture such as couches, sofas, chairs, among others; as mentioned above, this is because most of the companies in the region are engaged in the manufacture of this type of product. This is followed by 25% of the waste generated from raw materials, and the remaining 25% is divided between sawdust and other types of inputs.

Table 2. Types of waste generated.

Waste material	Percentage (%)
Fabrics, leathers, and foams	50.00
Raw materials	25.00
Sawdust	12.50
Other	12.50

This is contrasted with the volume of waste generated, where it is reflected that approximately 87% of the companies do not know or have not measured the amount of waste or residues, they produce during the manufacturing process of their products, only 13% measure the amount of this waste and it is between 1 to 2 tons in the year. It is worth noting that all the companies studied stated that they do not have constant product returns from customers, which is a positive indicator in terms of quality.

When 50% of the companies receive returned products from their customers, they dispose of them without carrying out any kind of process. 37% carry out a transformation and disassembly process to recover the parts that are still in good condition and the remaining 13% repair the defects and put them

back on the market. The reverse logistics strategies that could be adopted to promote the use of materials with a long-life cycle can be established according to the recyclability of the materials used. On the other hand, it is essential to implement mechanisms for separation of materials at source, to classify potentially usable materials. Sawdust management is also a problem that can be addressed under the reverse logistics paradigm, seeking to be marketed to organizations in other sectors such as agriculture and livestock.

5. Conclusions

It is feasible to reuse and recycle materials that demonstrate very good mechanical properties and a good weight-to-cost ratio, such as MDF and acrylic-based materials.

It was possible to establish that reverse logistics is a field of business and production management that has a wide scope of intervention in highly relevant production sectors such as the furniture manufacturing and marketing sector, since throughout the supply chain, materials and inputs are handled and wasted that have the potential to be linked again to cycles of use in society.

The furniture production sector in the city of San José de Cúcuta, Colombia, recognizes reverse logistics tools as a determining factor for competitiveness and sustainable development, even though most of the companies have not implemented them, they have a basic knowledge that would imply the willingness of this sector to develop specific research under the paradigm of the circular economy to adapt their operational processes to this new approach.

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