

Design of a reference architecture in intelligent warehouse supply logistics through the use of Industry 4.0 technologies. Case of retail Warehouses in the city of Pilar.

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ABSTRACT

The article presents a reference architecture for intelligent warehouse supply logistics using Industry 4.0 technologies in retail warehouses in the city of Pilar. The proposed architecture is based on the integration of information and communication systems, such as the Internet of Things, artificial intelligence and a DSS, to improve the efficiency and productivity of the supply chain. In addition, some case studies are presented that demonstrate the effectiveness of the architecture in optimizing lead time and reducing operational costs. Overall, the proposed reference architecture can be a valuable tool for companies seeking to improve their supply logistics and remain competitive in the marketplace.

Keywords: Industries 4.0; Warehouses; Procurement; Architecture; Logistics.

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Diseño de una arquitectura de referencia en la logística de abastecimiento inteligente de almacenes mediante el uso de tecnologías de la Industria 4.0. Caso Almacenes minoristas de la ciudad de Pilar.

RESUMEN

El artículo presenta una arquitectura de referencia para la logística de abastecimiento inteligente de almacenes, que utiliza tecnologías de la Industria 4.0 en los almacenes retail de la ciudad de Pilar. La arquitectura propuesta se basa en la integración de sistemas de información y comunicación, como el Internet de las cosas, la inteligencia artificial y un DSS, para mejorar la eficiencia y la productividad de la cadena de suministro. Además, se presentan algunos casos de estudio que demuestran la efectividad de la arquitectura en la optimización del tiempo de entrega y la reducción de costos operativos. En general, la arquitectura de referencia propuesta puede ser una herramienta valiosa para las empresas que buscan mejorar su logística de abastecimiento y mantenerse competitivas en el mercado.

Palabras clave: Industrias 4.0; Almacenes; Abastecimiento; Arquitectura; Logística.

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INTRODUCTION

This scientific paper deals with the design of a reference architecture in intelligent warehouse supply logistics, making use of Industry 4.0 technologies. In particular, it focuses on the case of retail warehouses in the city of Pilar. In these warehouses it has been determined that there is a problem of stock management and handling of goods with delivery logistics. The problem to be solved is what model or architecture based on these technologies should be developed to improve the stock management of these large warehouses. This research proposes a transformation of the current stock management models to improve the competitiveness of distribution logistics, using disciplines such as Data Mining and Artificial Intelligence to improve the information available for decision making. The implementation of this model could improve distribution and logistics in the sales chain, helping to reduce costs and distribution times of the final product in the region, which represents an important contribution to improve competitiveness in the storage and stock management of retail stores in the city of Pilar. Digital transformation is a trend that has been growing in the business world and Industry 4.0 has played a fundamental role in this process. This industry is characterized by the incorporation of intelligent technologies in the production process, which has allowed for greater automation and control in the management of operations. In this sense, the logistics sector has been one of the most benefited by the implementation of these technologies, as it has allowed a more efficient and effective management of processes.

In the case of retail stores in the city of Pilar, the implementation of a reference architecture in intelligent supply logistics through the use of Industry 4.0 technologies can be a solution to the problem of product stock management. The high level of product turnover, the large number of references and the need for rapid replenishment are some of the challenges faced by retail stores in this city. The implementation of an inventory management model supported by an intelligent decision making system can significantly improve process efficiency and market competitiveness. In this sense, the proposal of this work is of great relevance both academically and socially. From the academic point of view, the research proposes an innovative solution to improve inventory management in retail warehouses, through the use of Industry 4.0 technologies and the implementation of an intelligent decision making system. This model is supported by disciplines

such as Data Mining and DSS, which represents an important contribution to the development of new solutions in inventory management. From a social point of view, the implementation of this model could contribute significantly to improve distribution and logistics in the sales chain, reduce costs and distribution times of the final product and improve competitiveness in the storage and stock management of retail stores in the city of Pilar. This research is supported by similar analyzed works such as those of (González J. L., 2007) where logistics costs in Latin America are analyzed, with respect to other countries, and the lack of infrastructure that leads to an increase in operating costs and directly influences the competitiveness of products. The ABC model is a business management tool used to analyze and control a company's costs. It is based on the idea that not all costs are equal and that it is important to identify and control the most important costs in order to improve the company's efficiency and productivity. At (Arrieta Gutiérrez, 2018) details some important elements about this methodology that will be implemented in the research. We find in (Arrieta Gutiérrez, 2018) a study of the crucial processes demand/supply management, the research evidenced inefficient practices and recognized a problem in the control of projection against demand, generating planning errors, delivery at times out of budget, inventories in stocks generating additional costs and damage to goods in the Colombian textile sector. This material serves as a reference in the possible variables to be taken into account for the development of the model to be proposed for its application at the regional level in Paraguay. (Bartodziej, 2017) mentions a new performance of industries in the world, Industries 4.0; this paradigm deals with the combination of different physical forces with digital ones. Industry 4.0 technologies enable the adaptation of warehouses and stored products to changes in their

processes. Industry 4.0 technologies can move to an inclusive robotic technology. This enables automated systems to solve problems that occur when working with people through current technological innovations. (Gonzalez, 2021) applies data mining techniques to determine the behavioral patterns of retail store customers. These patterns can later be used for intelligent replenishments and avoid unnecessary stocks in the company. This research serves as a reference for the analysis of purchases, so, unlike it, the research work conducted in the stores of the city of Pilar focused on the location of products in the warehouse, its impact on delivery logistics and

the improvement of waiting lines through the construction of a reference model for its application and the improvement of the search and delivery processes. (**Abad, 2020**) we analyzed the possible techniques and algorithms to be used for the desired purpose. A detailed review of the algorithms used by the selected software for the implementation of Data Mining has been carried out. The techniques used are fully tested throughout different situations so they guarantee a reliable result.

This research work makes a significant contribution to retail stores in the city of Pilar, as it provides a product management model based on AI and supported by a DSS that can improve the product storage system and processes taking into account the sales season.

The main objective of the work is the intelligent management of large retail stores in the city of Pilar through Decision Support Systems and Industry 4.0 technologies, leaving as a legacy a reference model or architecture for the precise implementation of the same.

METHODOLOGY

With regard to the research, based on the object of study, the problem posed and the objectives set, this work was carried out quantitatively, developing theoretical models and measurable variables for the formulation of a hypothesis and its subsequent validation.

The universe is composed of resources and processes of the current inventory distribution systems and the logistics chain of retail warehouses located in the southern region of Paraguay, specifically in the city of Pilar, department of Ñeembucú. The unit of analysis is composed of the current distribution systems of the logistics chain of retail stores in the city of Pilar and the management models of large warehouses. We work with the scenarios indicated in the specific objectives.

The work carried out is of a theoretical type in the stage of development and verification of the current models. Once the method has been identified, a decision support scheme with computer support was sought to validate and improve the suggestion made to achieve the objective proposed in this research. As a consequence of the analysis, it was necessary to modify the proposed decision models, which started a new cycle of validations.

During the research process, different data collection and analysis techniques were taken into account, it was necessary to consider the methods, techniques and instruments as those elements

that make up the empirical fact of the research, that is, the basic phase of the research experience. A systematic inquiry was made to study the significant aspects of the facts and situations that occur in the current context of distribution and organization of product inventories in warehouses. The advantage of this data collection methodology was that the data were studied as they occur at the time and without intermediaries.

This technique made it possible to obtain bibliographic data on current models applied in other regions in similar processes. The documentary compilation made it possible to study the inventory organization methods and schemes used by companies in other countries or regions to improve the cost of the product through inventory management.

The documentary collection helped us to detect and consult other materials based on other knowledge and/or information of any reality, so that they can be useful for the purpose of the study.

Due to its technical characteristics, this type of technique does not take into account the possible reactions of the subjects under investigation.

Simulations were carried out with the proposed decision models and the computer decision models to analyze the result of the suggestions and whether they met the necessary conditions for their subsequent application. The simulations showed that the proposed model can be applicable and would help to improve the entire logistics chain management process, thus reducing the current distribution costs to the points of sale.

Data Mining was used as a tool for the analysis of the information. The proposed technique is intended to be applied to any item of retail warehouses in Pilar or in any city and organization with the same characteristics.

Data mining helps to deal with a large amount of information that is produced in different areas, in this case, we deal with the information produced from the sales of retail stores and the outputs that they cause in their warehouses. This information is important because it generates patterns of customer behavior and specific products (sales, seasonal changes, sales decline, sales peaks, etc.). We call this type of analysis descriptive mining, since it analyzes and describes a situation found in a group of data. On the other hand, also thanks to Predictive Data Mining and Artificial Intelligence we have determined the different situations that can be foreseen for the location of products in a given warehouse. Through descriptive mining we obtain behavioral information and through predictive mining we propose results to improve the current situation of retail stores in the city of Pilar.

RESULTS AND DISCUSSION

In order to carry out the proposals and analysis of the methodology to be implemented, the current situation of the retail stores in the city of Pilar was verified and the following results were obtained:

- Retail logistics warehouses in the city of Pilar currently lack an intelligent merchandise location system.
- Nowadays, the location is favored by the moment and the free spaces.

This information is verified through observation and data collection by means of an interview and a simple questionnaire to the owners of retail stores in the city of Pilar.

This questionnaire is a set of questions designed to collect information from stores in the city of Pilar. Questionnaires can be used in a wide variety of contexts, from market research and customer satisfaction evaluation to worker performance evaluation and business decision making, in this case it was structured to know exactly what is the real situation and how warehouse managers organize their warehouses.

How do you classify the storage of your products?



By order of arrival By available spaces By sales priority By ABC method of classification None of the above

Illustration 1. Representative graph of the results of the questionnaire to warehouse managers. Own source The results of this interview indicate that 53.3% of retail store managers classify according to the order of arrival of items, 33.3% do so according to available space and 13.3% do so by determining priority products.

None of the warehouse managers use the ABC method for product classification and organization. This information was collected through visits to retail stores in the city, identifying those that actually have product warehouses with stock and their location in an area larger than 100 m2. During the visit to the warehouses, the products and their classification in the inventory were observed. In addition, the following survey was made to the warehouse managers.

The brief survey was conducted in the city of Pilar, targeting retail warehouses located in the area. This survey was applied in order to obtain data on the current situation of product storage in the warehouses located in the city of Pilar.

Taking into account the data collected, the information was analyzed and a reference model for intelligent stock management was developed using Industry 4.0 tools.

It is then determined that the products with the greatest movement should have a privileged location. This will allow a quick and smooth reaction from the stocker.

Response time in the distribution chain is paramount, every second counts and adds up in the final calculation of time spent on delivery to the customer or carrier. The less downtime in the search and replenishment of the product, the lower the cost charged to each sale.

The ABC inventory management model is a method of categorizing inventories, used as a rudimentary prioritization mechanism to concentrate efforts and resources on items that are most important to the business (Vermorel, 2020) mentions that this method is based on the empirical observation of a small fraction of items or SKUs that generally represent an important part of the business. It is also mentioned that since 2000, this method is mainly used as a data visualization method and as a way of prioritization for supply chain managers who must regularly review their replenishment configurations.

If we add the technological features of Industry 4.0, such as AI and DSS, to this proven method, which is already widespread worldwide, we have a great opportunity to improve on current inventory management standards.

Artificial Intelligence can predict the items with the best movement in certain months of the year, thus leaving aside the fact that items are static for a long period of time, as currently analyzed. This methodology aims to dynamize and provide intelligent management of Pilar's retail stores. The ABC model is normally prepared on the basis of 1 year of consumption or movement of items in the warehouse.

The premise that we put forward is differentiated by means of an aggregate plus with the implementation of Artificial Intelligence as sales data analysis, thus forming the following model:



Illustration 2. Seasonal ABC Inventory Management Model with AI applied.

Essential tables and basic data structure.

The following list of fields is an example of the data that the database must necessarily have for

standard operation. To the list below, the particular fields of each warehouse must be added.

Article master	
SKU	Numeric or Alphanumeric
DESCRIPTION SKU	Alphanumeric
ITEM	Alphanumeric

 Table 1. Proposed table for article master. Own source

Stock of items]
SKU	Numeric or Alphanumeric
Current Stock	Numeric
Average daily sales	Numeric
Average seasonal sales	Numeric
Fully variable cost price	Numeric
Sales price	Numeric

 Table 2. Proposed table for the stock of articles. Own source.

Process Description:

- Preparation of the stock list of retail items
- Preparation of the daily sales list for at least 1 year
 - This time period will be able to guarantee the AI's path through the entire sales process and relate them to the seasons.
 - \circ The longer the period of time, the better the result of the analysis.
- Categorize the company's most profitable items. This will allow identifying them as a select group in the analysis process.
- Categorize the list of items by items (if they are of different colors, different sizes or different styles).
 - Ex.1.: Category Polo shirts: Red polo shirt Black polo shirt White polo shirt.
 - Ex.2.: Categroy Shirts: Green Shirt White Shirt Pink Shirt

The determination of the seasons will be established according to the existing relationship with the products sold in the retails, in this case, the seasons are: spring, summer, autumn and winter. We also present some tests carried out to validate the proposed model.

Test 1 - Sales scenario by line of business - 1 year period.

- a) Breakdown:
- List of stock items. Demo-simulations
- Consumption of items by season (spring, summer, fall, winter). Demosimulations

b) Proposal of product classification zones in the warehouses.



Illustration 3. Proposed LOCATION ZONES for products, according to their priority. Own source

The GREEN ZONE is the zone of filler products, which have no priority, the YELLOW ZONE is the middle zone and corresponds to products with medium demand. However, the RED ZONE is determined by the season and corresponds to the high priority products, which normally comprises 20% of them.

Test results:

The tree resulting from this test with real data is a tree with too many nodes, due to the amount of information we loaded into the analysis tool, which is why we will proceed to analyze the most relevant ones.

In the case of a decision tree with many leaves, we are talking about a tree with a large number of branches representing different possible outcomes or classifications. This type of tree can be useful in situations where detailed and precise classifications are needed, although they can also be more difficult to interpret and analyze than simpler, more representative trees.





Illustration 4. Resulting node corresponding to the adjustable items. Own source

The resulting tree of the fitted sheets gives us a classification where it is interpreted that sales in the spring season are less than 88 units, however, in summer are the highest sales, therefore, we have an idea of the season of highest sales in units of fitted sheets, and the season of highest movement of this same product.

This tree indicates that 56% of spring sales were less than 88 units, however, 46% of summer sales were greater than 88 units. It is important to clarify that this information indicates that there were more sales tickets in the spring season, thus defining the adjustable as a product with a lot of movement in this season.



Illustration 5. Node resulting from the analysis of the Basic item. Own source

The analysis of Basic sheets shows that during the spring, 59% of the sheets are sold in units less than 31, however, the summer season stands out with 57% of sales between 31 and 85 units and in winter with 26% of sales greater than 85 units.

Although in the spring season they are sold in smaller quantities, there are more movement tickets, therefore, in this season the Basic sheets should be in a high demand or red zone. During the summer season in the medium demand or yellow zone and in the winter and fall, in the green zone.



Illustration 6. Node resulting from the clasic sector. Own source

The analysis of the classic products node show us that in the spring season there are the highest ticket movements for these products, with 57% of the tickets reaching almost 95 units; however, summer and winter sales indicate higher quantities, but less movement.

This result indicates that clasic products should have a privileged location in the spring season.



Illustration 7. Node resulting from the Duvets. Own source



EM clustering with the same data. 8,583 actual sales records.

Illustration 8. Comparison of Clustering by EM Clustering method. Own source

Green Zone - Non-priority	Red Zone - Priority Zone
- Bags	- Adjustable
- Curtains	- Pillows
- Covers	- Quilts
- Necessaires	- Blankets
- Shopping Bags	- Sheets
- Quilts	- Towels

Table 3. Product classification table according to EM Clustering results. Own source.

According to the resulting grouping, it is easy to differentiate the items that will NOT be a priority in each season, marked in "green" color, and those that, due to sales excellence, should be significantly closer to the Red Zone of product location, marked in red color in the graph.

Through data mining and artificial intelligence applied with Weka, we obtain important information for the identification of products and their peak seasons.

The J48 and Clustering EM algorithms are very useful artificial intelligence tools for classifying products and sales in retail warehouses. These algorithms are particularly effective in the context of the city of Pilar, as they allow classifying and analyzing large amounts of data quickly and efficiently.

These two tools are very effective in classifying products and sales in retail stores in the city of Pilar. These algorithms allow analyzing large amounts of data quickly and efficiently, which can help stores improve their inventory management, optimize their marketing strategies and improve the customer experience.

The file structure needed for the analysis has been established and we have determined that the relationship of the season and the sale of the star products of the retails in the city of Pilar is demonstrated through the analysis carried out with the information added to the system.

This analysis is extremely important to determine the actions to be taken when determining the location of each product and its priority on the warehouse shelves.

The same data analysis has been performed using logs generated by IoT tools and the results have been similar, thus proving the performance and feasibility of application of the proposed model for AI-assisted seasonal product storage improvement.

The following Use Case and DFD proposal is also presented for DSS guidance that will support decision making, subsequent to the analysis of the Data Mining tool.



Illustration 9. Use case for a DSS applied to seasonal sales. Own source.

Data flow diagram for a zoned product storage management system.

The base DFD should contain the following processes and movements to fit the proposed definitions and architectures. In the following, we describe a series of processes that should be contained in the DSS systems that help decision making for the reference architecture in intelligent warehouse supply logistics through the use of Industry 4.0 technologies.



Illustration 9. DFD level 1, proposed basis for the DSS to be developed. Own source

CONCLUSIONS

Industry 4.0 emerges as a revolutionary method of implementing technological tools for process improvement, production and sales know-how. The retail stores in the city of Pilar do not escape this innovative regime of new technologies that involve the use of knowledge, science and data. It is precisely the data that provide the trend towards the use of modern industry ingenuity and that is combined with the use of new software along with traditional models

For the implementation of this architecture or model we suggest the use of emerging technologies in Industry 4.0 such as: Weka, for Big Data analysis and Python for DSS.

The implementation of tools such as Weka in this study makes it possible to classify product items by their average sales. The average sales and seasons will determine their location in the storage areas.

This relationship is the fundamental premise of the architecture presented and its existence confirms that the use of Industry 4.0 tools such as Data Mining, Artificial Intelligence and Decision Support Systems provide a competitive advantage to those who take advantage of it and apply it in their storage and product replenishment operations.

This competitive advantage provided by these tools and the proposed reference architecture model positions the organization at a higher level than those who do not use it and ensures customer loyalty.

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