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Methodological proposal for a feasibility study for the implementation of a vertical warehouse for a Manufacturing Company in Southern Sonora

Propuesta metodológica para un estudio de factibilidad para la implementación de un almacén vertical para una Empresa Manufacturera al Sur de Sonora

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Abstract

Inventory management has become a critical element in modern supply chains. Globalization has led products and services to travel longer distances at faster speeds, resulting in extreme variations in demand and putting pressure on production organizations to produce more and faster. This research proposes a methodology to guide the implementation of a vertical warehouse for a manufacturing company in southern Sonora. The organization aims to reduce material handling travel times, have materials closer to the point of use, and improve production efficiency. The methodology involves the combination of methods and tools such as ABC inventory classification, the use of the PUGH matrix, and the Analytic Hierarchy Process (AHP) to select the option that is technically, economically, and environmentally feasible for the project. The study also includes a review of the literature on vertical warehouses and their benefits. The practical implications of this work are that it provides a methodology for selecting a vertical warehouse that meets the needs of an aerospace manufacturing company. The proposed methodology can be used by other manufacturing companies to determine the feasibility of implementing a vertical warehouse and selecting the most suitable option based on their specific needs and requirements.

Vertical Warehouse, Logistics, Manufacturing

Resumen

La gestión del inventario es un elemento crítico en las cadenas de suministro. La globalización ha llevado a los productos y servicios a viajar más lejos y rápido con variaciones extremas en la demanda, estresando a las organizaciones productivas que se ven empujadas a producir cada vez más y más rápido. El objetivo es reducir los tiempos de recorrido de los manejadores de materiales, tener el material más cerca del lugar de uso y mejorar la eficiencia en la producción. La metodología involucra la conjunción de métodos y herramientas como la clasificación ABC de inventarios, uso de la matriz PUGH y el Proceso Analítico Jerárquico (AHP) para seleccionar la opción que resulte factible de manera técnica, económica y ambiental del proyecto. El estudio también incluye una revisión de la literatura sobre almacenes verticales y sus beneficios. Las contribuciones prácticas de este trabajo son que proporciona una metodología para seleccionar un almacén vertical que satisface las necesidades de una empresa manufacturera del giro aeroespacial. La metodología propuesta puede ser utilizada por otras empresas manufactureras para determinar la viabilidad de implantar un almacén vertical y seleccionar la opción más adecuada en función de sus necesidades y requisitos específicos.

Almacén, Logística, Manufactura

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Introduction

A supply chain is the set of activities, facilities and means of distribution necessary to carry out the process of transforming raw materials into products or services and marketing them to the end customer. The main objective of the supply chain is to ensure its profitability while meeting the needs of the end customer in the best possible way. This includes the following purposes: delivering goods and services on time, avoiding unnecessary losses or wastage, optimising distribution times, proper management of inventories and warehouses, establishing adequate communication and coordination channels, dealing with unforeseen changes in demand, supply or other conditions. [1]

Derived from various factors such as globalisation, nearshoring, the global pandemic of COVID, the low tolerance to waiting time by consumers, in recent years the economic and business activity is increasingly dynamic and therefore it is required to implement and integrate new technologies and disciplines that optimise processes and improve the results of the organisation. In this context, a critical element is logistics, which can be defined as the planning, organisation and control of a series of transport and storage activities that facilitate the movement of materials and products from their origin to their consumption. [2].

Warehouse management is one of the main activities involved in logistics, which we could define as a physical space where inventory is deposited, that is, where raw materials, semi-finished products or finished products are stored, waiting to be transferred to the next link in the supply chain. [3]

Order picking has long been identified as the most laborious and costly activity for almost all warehouses; Order picking cost is estimated to amount to 55% of total warehouse operating expenditure. Any poor order picking performance can result in unsatisfactory service and high operational costs for the warehouse and, consequently, for the entire supply chain. To operate efficiently, the order picking process must be robustly designed and optimally controlled. Research in this area has grown rapidly recently. Still, combinations of the above areas have hardly been explored. Order picking system developments in practice lead to promising new research directions.

One of the storage systems that has seen remarkable growth in recent years is the so-called vertical warehouse. This system has gained popularity because it allows the storage of objects and materials using less floor space, as it extends vertically, allowing the storage to be placed next to the production line, having multiple benefits, such as saving space, improving organisation and consequently efficiency, as well as improving safety, and reducing the routes and movements of material handlers in the organisation.

However, decision-makers must also consider that its implementation requires a greater initial investment, due to the shelving, racks and in some cases automation, as well as less flexibility to deal with changes in load volumes, load limitations, derived from the height and restrictions on the amount of space for each material, among others.

In this sense, the objective of this research is to develop a methodological proposal to evaluate the feasibility of implementing a vertical warehouse to optimise space for the Multipin area within the facilities of a manufacturing company in southern Sonora, but which by its nature can be replicated in other productive and service organisations.

Background

Historically, inventory management has based its management models and policies on identifying the appropriate balance between the cost of holding inventory, the cost per order and sustaining the level of service agreed with the customer. While recent research evidence has established a correlation between the performance of a vertical lift module warehouse and order picking efficiency [4], the industry in general recognises the problematic costs and extreme risks of idling an asset that could be used in another operation that generates additional profit. [5]

In this context, it is the activities of the supply chain itself, which are presented as fundamental elements for companies to improve their relationships with customers and suppliers in the constant search for a competitive advantage.

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In other words, the supply chain proposes the integration and coordination of the company's internal activities and processes with external processes, to achieve a better use of resources and minimise operating costs, making it necessary for the multiple logistical processes involved to be increasingly faster and more efficient in order to reduce time and costs. [6]

This speed suggests relying on automation as a differentiating element, but also allows a greater number of operations per minute of work to be carried out. In Latin American countries, current logistics trends regarding warehouses are aimed at implementing automated processes that seek to minimise or eliminate human error, optimise storage areas, control inventory management, improve service times, and make operations profitable, among others [7].

In his publication "Warehouses as nodes of the logistics network" [8], he mentions that most of the volume in a warehouse is occupied by the so-called reserve storage, it is usual to expect that most of the manpower is in the picking activity. The separation of the reserve and picking areas can be done vertically or horizontally. Vertical separation is when the reserve area is located at the top of the racks and the picking area at the bottom. The product in reserve is stored above the picking product. When replenishment is required, a forklift is needed to lower the pallet with more product. This shows the complexity of optimisation in traditional inventory management models.

Optimisation of warehousing activities in supply chains is of significant importance to logistics operators. Technology enables the integration and coordination of internal company activities and processes with external processes to achieve better utilisation of resources and minimise operating costs. [6]

An automated warehousing system introduces modern technology to the manual production process and makes comprehensive changes to the structure and management of the process. Automated warehousing becomes a system for intelligent warehouse management, combining logistics technology and computer automation technology. Automation technology allows warehouses to logically allocate space to improve workflow and shorten production cycles, but this does not mean that warehouse chaos is completely eliminated.

It is for this reason that, in some cases, the introduction of scientific methods to increase management efficiency is recommended.

The automation of a warehouse, in its theoretical conception, does not present great difficulty, but the need to integrate all the operations can become a complex and costly problem, requiring careful planning and radical changes in the mentality and training of users and designers, and the appropriate selection of means of transport. [9]

Although there are specific differences depending on the line of business in which the companies operate, cost management plays a preponderant role in basically all of them; for example, in the aerospace industry the processes involved in inventory management include the costs of orders, the maintenance of stock, including the valuation of the product according to its nature (which can be: raw materials, consumption inputs, intermediate goods or final products necessary for the productive process of the company that concludes in the production of a good or in the offer of a service...). [10]

The global aerospace industry is worth around $450 billion. Its main markets are located in North America and Europe, with the United States leading the way, followed by France, the United Kingdom, Germany and Canada. [11]

The global aerospace industry originated and boomed mainly after World War II. One of the activities of the aerospace industry is to produce products and provide services for transport, communications, security and defence. The development of the aerospace industry is part of the new international division of labour, where countries tend to specialise according to their levels of capital possession, technological development, human capital, innovation capacity, extension of productive networks around the world and segmentation of productive value chains. [12]

The Mexican aerospace sector is made up of companies dedicated to manufacturing, maintenance, repair and operations services, engineering and design, and auxiliary services such as airlines, test laboratories and training centres, among others, and even for commercial and military aircraft. Mexico has established itself as a global leader in the aerospace sector.

Major companies, such as Bombardier, Safran Group, General Electric (GE), Honeywell and Eurocopter, have found in the country the conditions to develop design and engineering centres, laboratories and production lines.[13] The growing demand in the aerospace sector has led to a growing demand for aerospace products and services in Mexico.

The growing demand of the aerospace sector at a global level, has motivated the rapid implementation of various strategies to react to the dynamic context in which it finds itself, causing an increase in the volume of purchases so that for the manufacturing company in southern Sonora requires a greater volume (space) of storage in the multipin area, to support its operation, generating deficiencies in the administration and control within the warehouse.

Lack of space in organisations is one of the typical problems that can arise in logistics. The need to handle more part numbers causes them to accumulate making their management complex and the consequences of these practices can range from accidents at work to wasting time by not being able to find the item needed, thus delaying delivery times and hindering the efficiency required by the processes.

The following section describes the steps followed by this research in order to respond to the need to evaluate the feasibility of a vertical warehouse within a productive organisation.
Methodological framework

The methodological route followed for the elaboration of this research project is presented below, in which the way in which the company will carry out a feasibility study and implement a vertical warehouse within a manufacturing company in the south of Sonora is described in detail.

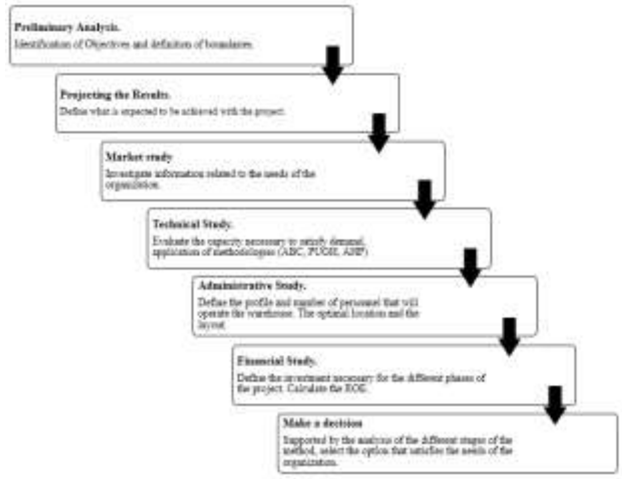

Figure 1 Methodology steps
Own Elaboration

Preliminary Analysis

In order to be able to define all the ideas and objectives that we want to implement in the project, a preliminary analysis was carried out in order to identify them separately and to determine whether they are possible or not. In addition, in this first step, the necessary limits are established so that the work plan does not deviate from its objective.

Projecting the Results

At this stage, it is necessary to define what is expected to be established from the budget and input capital, in order for the project to prosper. This will take into account what services are needed and how much they will cost, any adjustments to income, such as reimbursements, etc. The projection of results will be based on the following three activities: i) Projecting actual and accurate revenue to see if it is profitable or not; ii) Defining the benefits to be gained from the implementation of the automated warehouse; iii) Establishing budget and input capital.

Market study

Based on the preliminary analysis and the projection of the results, in order for the project to prosper, it is essential to carry out a market study. This will gather information from stakeholders including decision-makers and system users to understand the needs of the project, including an analysis of the competition or possible suppliers, as well as defining the advantages and disadvantages.

It will also take into account the geographic influence on the market, the demographics, the value of the market and whether the market is open to expansion.

The following 6 essential or basic steps can be used in the market study: i) Designing data collection instruments; ii) Segmenting the target audience; iii) Analysing the supply available in the market; iv) Checking the regulations that exist in the market; v) Checking compliance with production requirements; vi) Preparing a final report.

Technical study

In this stage, different tools such as the ABC methodology, PUGH Matrix and AHP will be used to carry out the feasibility study that will lead to a decision on the implementation of the automated vertical storage.

– ABC inventory classification method, this tool will be used to classify the part numbers used in the processes of the manufacturing industry under study. Also, at the request of the organisation, rather than prioritising costs, the work team has been asked to consider the intensity of use in the production lines by assessing the inventory turnover.

– The PUGH matrix is a tool developed by the British Stuart Pugh, which will help to compare and evaluate the different storage options available on the market in the first instance. To do so, it will precisely identify the alternatives and criteria used. Subsequently, a weighting will be assigned to each resulting dimension and finally the results will be ranked, the 4 most viable options will be evaluated in a subsequent step.

– Analytic Hierarchy Process (AHP) is designed to solve complex multi-criteria problems. This tool will allow us to evaluate the 4 alternatives that could be closer to satisfy the needs of the organisation, prioritising dimensions such as cost, life cycle, energy consumption, guarantees and after-sales services, operations per minute, among others, with the particularity that its evaluation of preferences measures in a global and objective way each of the decision alternatives.

Administrative Study

At this stage of the project, the organisation is expected to define the profile and number of personnel that will be required to operate the vertical warehouse, as well as the stages in which they will be hired and trained, in order to guarantee continuity in the manufacture and sale of components. It is important that the organisation defines the location and design of the installation and the method of negotiation that will be carried out with suppliers, as well as the definition of the budget to be used for the implementation of the warehouse.

Financial study

The financial study stage should be supported by the other stages in order to define the investment requirements and the timing of the funding required to start the project, and should consider, among other variables, cash flow, income and expenditure. Accounting runs should be prepared to calculate all the fixed costs and variable costs involved and from this establish a break-even point of monthly sales. An Internal Rate of Return should also be determined.

Analysis of Results

This chapter corresponds to the results obtained from the research project; it shows and explains the products resulting from each of the steps followed in the methodological route presented in the previous chapter.

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Preliminary Analysis

Being a productive organisation with direct competition in the region, we were limited in the information to be presented, however the procedure followed to define the budget and input capital to guarantee the viability of the project and to be able to meet the requirements of each of the processes to which the service will be provided, the decision-makers at the plant held several meetings to estimate the project budget and in this way the company will be able to have a solid idea of the return on investment, expected benefits, fixed and variable costs, thus making it possible to develop a growth plan on a solid basis that adapts to the reality and future needs of the company under study. It should be noted that after the analysis the organisation for this project decided to set a budget ceiling of around 150,000 dollars.

Market study

In order to be able to carry out the market study, the needs that covered the projections of the needs resulting from the previous stage were collected and which included the following points for the implementation of the vertical warehouse.

– Requirement 1. It must have integration to the SAP ERP system for the management and control of materials.

– During the purchase, care must be taken that the resulting investment already includes the installation within the budget, and that it does not exceed the budget ceiling.

– Preferably, the supplier should be located in Mexico, in order to be able to have close and quick contact in case of needing advice or maintenance.

– Other technologies such as laser pointer, alphanumeric bar, chain system speed, bay configuration can be integrated, as this presumably contributes to the automation process and also to improving the efficiency of the production processes to which the service is provided.

With these requirements, the search for options in the market began. A total of 20 storage systems were identified that meet the needs of the project and a table with the main options to be considered is presented below. See table 1.

Model	Dimensions in mm.	Useful capacity in tons.	Software
Modula LIFT	Height: 3,300 – 16,000 Broad1,900 – 4,100 Depth4 a 857	50 – 90	Own software compatible with SAP
Modula Synthesis1	Height: 2,600 – 7,100 Broad11,300 – 1,700 Depth654	25 – 30	Own software compatible with SAP
Modula One PICK	Height: 3,300 – 16,000 Broad11,900 – 4,100 Depth 4 a 857	Maximum weight is 25 kg, per load unit	Own software compatible with SAP
LOGIMAT	Height: 2,450 – 23,850 Broad11,900 – 5,200 Depth15 a 1000	Net payload25 – 60 .	Integrated into SAP system regardless of the level of automation
Kardex Megamat 180	Height: 2,200 – 7,500 Broad11,870 – 3,870 Depth1441 a 1671	6	Own software compatible with SAP
Ferrerto Group Vertimag	Height: 3,200 – 12,000 Broad11,870 – 4,275 Depth1441 a 1671	70	Own software compatible with SAP
Fismash Vertical lift module	Height: 3,800 Broad13074mm	4.2	Own software compatible with SAP

Table 1 Comparison of options

The search for options during the market study also made it possible to learn more about the vertical storage systems, as well as to identify the load capacity, the space occupied by each option, their geographical location, after-sales services, the technologies they use and those with which they could be compatible in their automation process. It should be noted that the table omits the level of automation, integration of technologies and hourly capacities according to the size of the components to be handled.

Technical study

During this stage, quantitative analyses were carried out to support decision making regarding the relevance of the options and, above all, to serve as differentiators that would discriminate between the different options.

ABC analysis

Firstly, the ABC method was used to organise the distribution of the different goods within the warehouse according to their relevance for the company, their value and their rotation. However, in this case, the company considered replacing the value of the product by the number of times the product is used per day and the total value by the annual use of the product, as these indicators are aimed at guaranteeing efficiency in the supply of materials, an aspect that is a priority for the organisation. The study was limited to 2 production lines that would be served by the same vertical warehouse. The accounting concentrates 270 part numbers. After classifying according to the requirements of the organisation, the results can be seen in table 2.

Classification	Part numbers	Average usage per day (in times of usage)	Accumulated percentage by volume of use
A	65	780	74.04
B	88	345	94.08
C	117	180	100

Table 2 ABC classification by part number

The figure shows the number of part numbers classified as A, which equals 65 and represents 74.03% of the cumulative volume of components used in the operations. The B classification contains 88 part numbers, representing a cumulative 94.58%. Finally there is category C which completes the remaining 100% with a total of 117 part numbers.

PUGH Matrix

After obtaining the organisation of the products with the ABC method, a PUGH matrix was made to compare options with each other using a multidimensional array in order to select the warehouse that meets the needs of the company such as SAP integration, whether the warehouse meets the budget, maintenance or technical support, import costs, storage capacity, additional technology (laser pointer, alphanumeric bar, etc.). Table 3 presents a summary. See Table 3.

Criteria	Factor	A1	A2	A3…	A20
SAP Integration	10	1	1	1	1
Meet the budget	9				
Maintenance/technical support	8	1	1	1	0
Costs and import	7				
Storage capacity	6				
Laser Pointer	5	1	1	1	-1
Bay configuration	4	1	1	1	1
System speed	3	1	1	1	0
Technology integration	2	1	1	1	1
Alphanumeric bar	1	1	1	1	-1
Punctuation		33	33	33	10

Table 3 PUGH matrix

In table 3, a fragment of the multidimensional array of the study is shown to show the filling of the PUGH matrix. In the matrix we can identify the criteria to be evaluated, the weighting factor on a scale of 1 to 10 and the alternatives were listed (A1, A2, A3...A20) resulting in the identification of the warehouse alternatives that meet the customer's requirements and correspond to alternatives 1,2,3 and 9.

Hierarchisation of the alternatives with AHP

The Analytic Hierarchy Process (AHP) method, proposed by Thomas Saaty in 1980, is a quantitative method for multi-criteria decision making that allows the generation of priority scales based on expert judgements expressed through pairwise comparisons using a preference scale. [14]

In the present study it was used to identify or select the proposal convenient to the organisation, according to the criteria evaluated in the PUGH matrix, but knowing that the four alternatives meet the technical requirements, now the criteria related to price, useful life, maintenance cost and energy consumption were compared. In this article we present as an example the matrix corresponding to the weighting made in the criterion of useful life of the equipment in relation to the planning horizon of the project considering four alternatives better positioned in the PUGH matrix. See Table 4.

Criterion: Useful life					
	A1	A2	A3	A4	Vector
A1	1	9	5	3	0.53
A2	1/9	1	1/7	1/7	0.55
A3	1/5	7	1	1/3	0.04
A4	1/3	7	3	1	0.04

Table 4 Comparison Matrix Useful Life Criteria

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For this scenario, the criteria table assesses that the storage system corresponding to alternative number two results in a better position than the rest of the options analyzed. It is important to note that this ranking exercise must be repeated for all the dimensions to be evaluated. How is it possible that different criteria may result in differences in the selection of alternatives. The method proposes to create a pair comparison matrix that allows ranking the criteria per se. See table 5.

Comparison with even criteria (CCP)					
	Price	Useful life	Mtto Cost.	Energy consumption	Vector
A1	1	1/5	5	1/3	0.14
A2	5	1	9	1	0.46
A3	1/5	1/9	1	1/5	0.05
A4	1/3	1	5	1	0.35

Table 5 Pair Comparison Matrix

Finally, the method compares the resulting vectors of each evaluated criterion and weights it according to the comparison matrix of even criteria, resulting in Table 6. See Table 6.

Critero: Useful life					
	Price	Useful life	Mtto Cost.	Energy consumption	total points
A1	0.12	0.25	5	1/3	0.34
A2	0.53	.55	.04	.04	0.35
A3	0.31	0.10	0.62	0.15	0.17
A4	0.04	0.10	0.12	0.26	0.15
CCP	0.14	0.46	0.05	0.35	

Table 6 Decision matrix

In this table it can be seen that after ranking the options and multiplying them by their pair comparison criteria, the closest alternatives are alternative one and two. In this case the decision is practically indistinct, since the alternative with the highest score must be selected, which in this case means that option or alternative number two is the storage system that received the best rating, being the option that meets with the requirements of both the production area and the financial area since it adjusts to the budget assigned for the execution of the project.

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Conclusions

The objective of this research was to show the procedure followed for the analysis and choice of a vertical storage model that contributes to having more efficient processes in the organization. This objective was met with the development of a methodology that allowed a reliable study to be carried out for the implementation of a vertical warehouse for the optimization of spaces for the Multipin area within the facilities of a manufacturing company in southern Sonora.

All the requirements that arose in the results projection stage for the planned useful life horizon for the storage system were met. Likewise, the analysis allowed the decision makers to allocate a sufficient budget to respond to the needs detected by the organization and finally the use of three tools was defined that would serve as technical support to have a starting projection of the requirements of warehouse capacity, such as compatibility with the SAP system, the dimensions it will occupy within the facilities and its levels of integration or automation.

For this case, the alternatives identified during the market study were listed and in the first instance they were classified using the PUGH matrix to guarantee that the selection of an alternative met all the requirements requested by the users of the project, resulting in 4 alternatives. Of the 20 evaluated, they met the characteristics.

In the next stage, these four resulting alternatives were evaluated with the help of the AHP tool. From this analysis it was possible to assist decision makers by identifying alternative 2 as the one that best satisfies each of the requirements established by the organization.As future work, it is recommended that the organization, once the project is implemented, measure the impact on operational efficiency, to evaluate the relevance of continuing to rely on this type of storage systems. In the event that, if it is necessary to continue implementing this strategy, the organization can replicate the methodology proposed in this research for future selections of storage systems.

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