Chapter 6 Redesign of warehouse layout: Key piece in the supply chain

Capítulo 6 Rediseño de ubicaciones en el almacén: Pieza clave en la cadena de suministro

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J. Tolamatl, D. Gallardo, J. Varela y J. Méndez. (Dir.) Strategies and successful practices of innovation in the automotive industry, Science of technology and innovation. Handbooks-©ECORFAN-Mexico, Tlaxcala, 2018.

Abstract

The automotive sector has become one of the most important industries, its importance lies in the social and economic effect it causes in the regions it operates. The challenge is to maintain a sufficiently flexible and coordinated supply chain among the various participants, so that changing demands, delivery times and increasingly short life cycles can be met. Hence, warehouses are vital in the supply chain and have ceased to be only the facilities that are dedicated to store materials or products, now they have become centers of service and support of the organization. An efficient warehouse has an impact on the overall performance of the supply chain, for this it must be located in the optimum place, be designed according to the necessary operations, use the appropriate equipment for handling materials, and have an information system that support inventory control. The main objectives of the design of the warehouses is to facilitate the speed and precision in the preparation of orders, as well as the efficient placement of stocks, all this to enhance the competitive advantages of the organization. Through the Systematic Layout Planning (SLP) methodology, warehouses can be configured to achieve the aforementioned objectives. In this case of study, the poor location of the materials inside the warehouse generated excessive time in the preparation of orders (picking) of materials, which clearly affected the productivity of the supply chain, so it was decided to redesign the locations of materials within the warehouse through the SLP methodology, the results that were obtained from the implementation were significant, since it was possible to reduce the picking time of materials of 67 and 69 minutes of the front and rear products to 33 and 34 minutes respectively, and as a result, online stoppages, overtime hours, costs, among others, are reduced.

Automotive industry, Supply Chain, Logistics, Warehouses, SLP

1. Introduction

The automotive industry is the most relevant sector for many economies in the world and has been a source of innovation in the design of products and manufacturing technologies. In Mexico it is one of the most competitive and dynamic economic activities since it contributes with more than 3% of gross domestic product and generates around 900,000 jobs in the country (Mexican Association of Automotive Distributors [AMDA], 2016). For this reason, many organizations that are part of the Supply Chain (CS) of the automotive industry, have adopted different methodologies to improve logistics performance. It should be noted that the supply of automotive parts in many cases is through a Just in Sequence (JIS) or Just in Time (JIT) scheme, hence the interrelation and coordination of all members of the supply chain must be the basis for generating strategic procurement (Chiang et al., 2012) and competitive advantages that contribute to achieving the objectives and achieve the success of the organization.

In particular, logistics is what manages the flow of products between points of origin and points of consumption, this involves integrating information flows, handling of materials, production, packaging and packaging, inventories, transportation, storage, among others; while the administration of the supply chain is the one that strategically coordinates the functions and activities among the companies that make up a supply chain (Li, 2014).

The objective of this case study was to redesign the locations of materials within the warehouse of one of the suppliers of the automotive industry, in order to reduce picking times and consequently minimize overtime hours. In the first part of this chapter is the literature review, which addresses the importance of the distribution of warehouses, as it is considered vital in the supply of materials, since poor distribution can increase logistics costs, delivery times and decrease the level of customer service; In the second part, the three phases of the Systematic Layout Planning (SLP) methodology are described; in the third part, the development of the case study is described, starting by analyzing the problem, finding solutions and making decisions; in the last part the results obtained and the conclusions of the work are shown.

2. Theoretical review

The automotive industry is one of the most competitive sectors in the market, but demand, flexibility, quality and agility are the critical success factors (Caridade et al., 2017), that is, supply chains change every day, change of size and configuration (MacCarthyet al., 2016), and even more coordination, control and management also become dynamic. For this reason, the supply chain of the automotive industry has been the most studied (Xie, 2014), and in general the administration of the supply chain has received special attention from academics (Ou et al., 2010).

For the importance of the coordination and integration of the supply chain is essential to compete in the globalized world, however this has been characterized by the high degree of difficulty and complexity of the multiple relationships and interactions between the members (Kamariah & Mohamed, 2009), these interactions are not only complicated by their volume and variation in processes, but also by the complexity inherent in the existing dependency between the parties in time and space (Power, 2006). Therefore, it is necessary for the organization to have strategic collaboration with all members of the supply chain, both internal and external, in order to achieve effective and efficient flows of products and services, information, money and decisions, with the objective of maximizing the value to the customers at the lowest cost and faster (Zhao et al., 2008).

Logistics plays a very important role in any company, as it is responsible for managing, managing and controlling the inventory of materials, and is also responsible for providing materials to the production processes, however there are two important factors that have to be considered in the supply system, these are the time of collection of materials and location of raw materials in the warehouse. Currently successful organizations are increasingly characterized by the ability to abandon inadequate work configurations (Raguseo et al., 2016), for this case the proper distribution of the store can mark the success (or failure) of the business (Huertas et al., 2007; Frazelle, 2002).

It should be noted that warehouses are considered a vital part (Faber et al., 2013), since they are the intermediate and critical point of the members of the supply chain (Kiefer & Novack, 1999), since they can affect several aspects of the supply chain warehouse performance such as the cost of material handling, space cost and storage capacity (Rakesh & Adil, 2015). The main functions that warehouses must fulfill are: a) Maintain the flow of materials along the supply chain, b) Consolidate products from multiple suppliers and, c) add value to the activities of collection, labeling and personalization of the product (Horta, 2016).

While it is true that the most appropriate warehouse design depends on its operational conditions and characteristics such as modularity, adaptability, movement, accessibility and flexibility (Hassan, 2002), the design of the warehouse layout is a dependent problem, since there is no better design, due to the diversity of factors that influence the operation such as access, types of racks, racks levels, among others. (Tompkins et al., 2003; Carranza et al., 2004; Bartholdi & Hackman, 2005). The layout of the warehouses must consider a dynamic flow of materials, to minimize the cost, handling, transport of stored products (Gopalakrishnan et al., 2004), to improve the use of space (De Koster et al., 2007; Gu et al., 2007); and also must provide better working conditions (Richards, 2011).

Since years ago, the problems of designing the layout have been an active field of research, Vis & Roodbergen (2011) proposed three different concepts and procedures that can be used to design the layout of the warehouse; the first as a fixed layout, which is designed for a considerable period of time; the second layout based on categories, seeks to incorporate greater flexibility in such a way that it allows to categorize the materials according to the daily information; and the third as a flexible layout, this must allow daily changes.

There is also literature that divides the problems of layout design, algorithmic and procedural into two main categories. The algorithmic approach uses numerical calculations to optimize the system design, that is, it only implies quantitative data; whereas the procedural approach can incorporate quantitative and qualitative data (Liu, 2016).

Yang (2000) believed that the procedural approach was not enough to handle the problems of multi-objective layout planning, but through some evaluation functions these problems can be solved more effectively. The systematic layout planning (SLP) proposed by Muther (1976) is a relatively simple and procedural approach tool that has been proven in several organizations.

The SLP method is used to determine an efficient layout that:

1. It is based on the analysis of a logistic relationship between blocks and operating units.
2. Use a method of factor evaluation to evaluate the proposals.
3. Obtain the optimal layout (zhou et al., 2010). The main objective of the slp is to find a layout that minimizes the transport costs of the goods, in other words locate the departments as close as possible (Van Donk & Gaalman, 2004).

Although the relationship between the characteristics of the warehouse and the cost of maintenance is understood, little work has been done to evaluate the connection that the service level has with the distribution of the warehouse (De Marco & Mangano, 2011), as the interior distribution of the warehouse is to treat a very complex logistic process, since it has to be considered from the reception of the materials, handling of loads and storage, control and management of stocks, preparation of orders and delivery of material.

A well-managed and distributed warehouse gives balance to the company, because it is able to stabilize production with demand, since it tries to synchronize manufacturing and demand and also assumes a permanent supply. Therefore, the warehouse is considered a key element in the logistics network as it serves as a regulator of the flow of materials, and also must function and fit seamlessly throughout the supply chain to achieve excellence.

3. Methodology

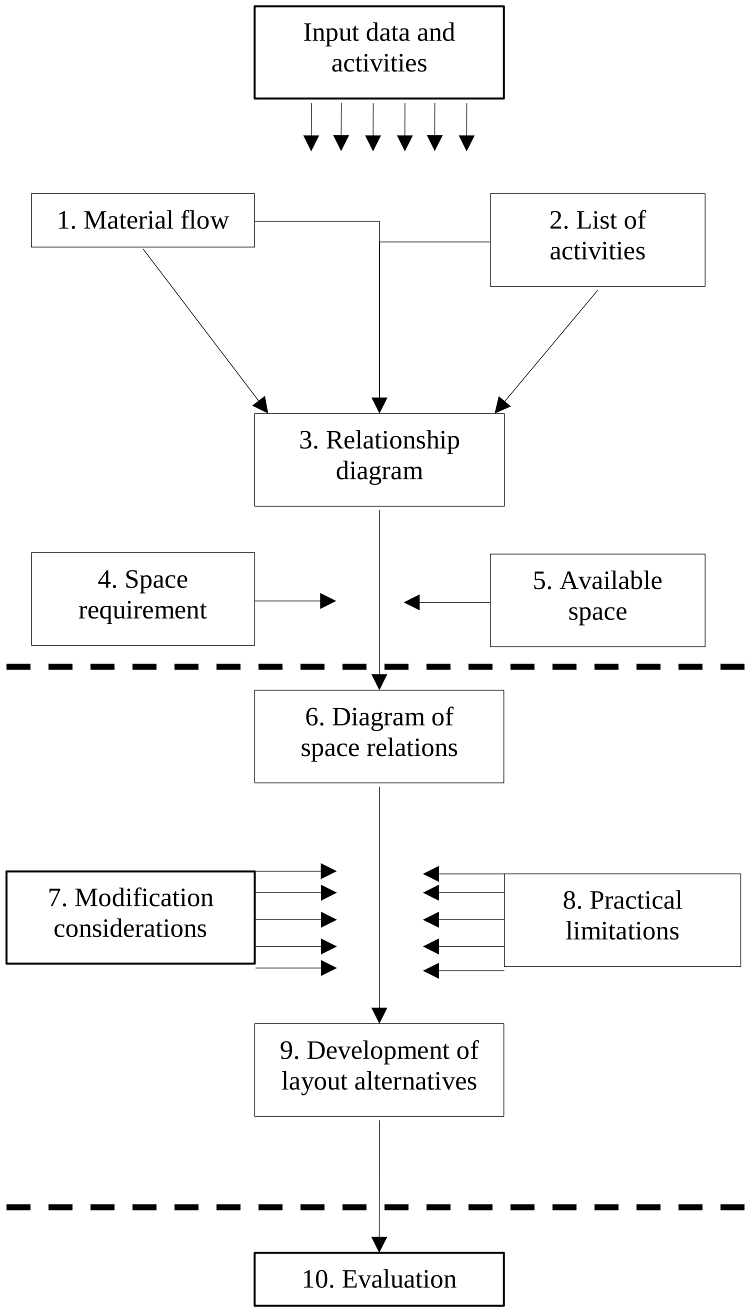
The objective of redesigning the locations of materials within the warehouse is to optimize the flow of materials, people and information (Monks, 1987). The SLP is a method widely used in companies due to accessibility (Gilbert, 2004), since it facilitates decision making in the redesign of facilities (Silva y Moreira, 2009). However, to initiate the application of this methodology it is important to identify the flows, procedures, activities and limitations of the distribution of the facilities (Trein & Amaral, 2001). According to Tortorella & Flogliato (2008), the SLP is divided into three major steps:

1. Analysis, is the collection of company data, flow and activities related to the process, resulting in the map of relationships.

2. Research, several alternatives are constructed considering the diverse characteristics and limitations.

3. Selection, the performance of the various arrangements is evaluated and the best one is chosen. This case study was developed with the methodology of the systematic layout planning (figure 6.1), it should be noted that the objective of this work is to minimize the picking time, because the excessive times have generated high labor costs extra.

Figure 6.1 Systematic Layout Planning (SLP)



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3.1 Analysis of the problem

To begin the analysis, information on the current system is needed to determine the relationship between departments, as well as the space required for these and the space available. The tools that are used in this stage are described below.

a. Flow of materials: The flow of materials includes all movements of raw material, product in process and finished product. To facilitate the analysis, the process flow diagram is used, which specifies the material route along the process and a diagram from-to, to know the distance between processes.

b. Relationship of activities: Consists of preparing a table of relationship of activities, developed by Muther (1976), this measures the importance of proximity between departments or processes. For this, all the departments in the table are listed, the importance of the relationship between them is determined, a criterion is defined to assign the importance of closeness, and the relationship value is established and the reason for which said value was assigned. The relationship value is usually expressed as follows:

A: Absolutely necessary
E: Especially necessary
I: Important
O: Ordinary proximity
U: Not important
X: Undesirable
XX: Highly undesirable

All those involved in the development of the table are allowed to have an opportunity to evaluate and discuss possible changes. In the table you can see which departments have to be close to each other so that material handling is efficient (Acevedo, 2001). With the flow of materials and the table of relationship of activities a relationship diagram is drawn up. This diagram shows if there is a flow of materials between each department as well as the relationship between these.

a. Space requirements: The space required for each department or process is determined, taking into account the dimensions of the machinery, the space necessary for the operators, for the inventory in queue and the inventory in process.
b. Available space: It is important that the space available is equal to or greater than the space required, in order to continue with the development of the SLP.

3.2 Search

In this stage the locations are redesigned taking into account restrictions and modifications, through:

a. Diagram of relationship - space: In the relationship diagram, the spaces required for each department or process as well as the location are added.
b. Modifications flexibility.
c. Practical limitations They can be of space and / or resources.

3.3 Evaluation

In this last stage the proposals are evaluated, for the evaluation criteria can be taken as the adjacency compliance between departments, the form of the departments, the cost of material handling, the total distance between departments, among others.

Proximity of departments: Consists in verifying the type of adjacency that is desired and in case of fulfilling said type of adjacency in the proposal a value is assigned. For this evaluation you have to consult the activity relationship diagram where the type of adjacency appears. Once the adjacency between all the departments is verified, the score is added, the highest being a better grade. Below is the value that is applied to each type of adjacency that is met.

A = 20
E = 15
I = 10
O = 5
U = 0
X = 15
XX = 20

Geometric space: The shape of the departments determines a better functionality of the departments. The desirable form of a department is the one that most resembles the perfect square, or if it is a rectangle that is not thin. For this evaluation, the area and perimeter of each department must be calculated. Once you have these data the following formula is developed:

$$\boldsymbol{F} = \frac{p}{4\sqrt{A}} \tag{1}$$

Where:
p = perimeter
A = area
F = department shape coefficient
If $1 \leq F \leq 1.4$, The shape of the department is acceptable

Costs: The total cost for material handling and is calculated with the following formula.

$$C = \sum_{i=1}^{m} \sum_{j=1}^{m} c_{ij} f_{ij} d_{ij} \quad (2)$$

Where:
C = total cost
c_{ij} *= cost of material handling between department i and department j.*
f_{ij} *= flow of materials between department i to department j.*
d_{ij} *= distance between department i and department j.*
m = number of departments.

The desired alternative in this evaluation is the one with the lowest total cost for handling materials

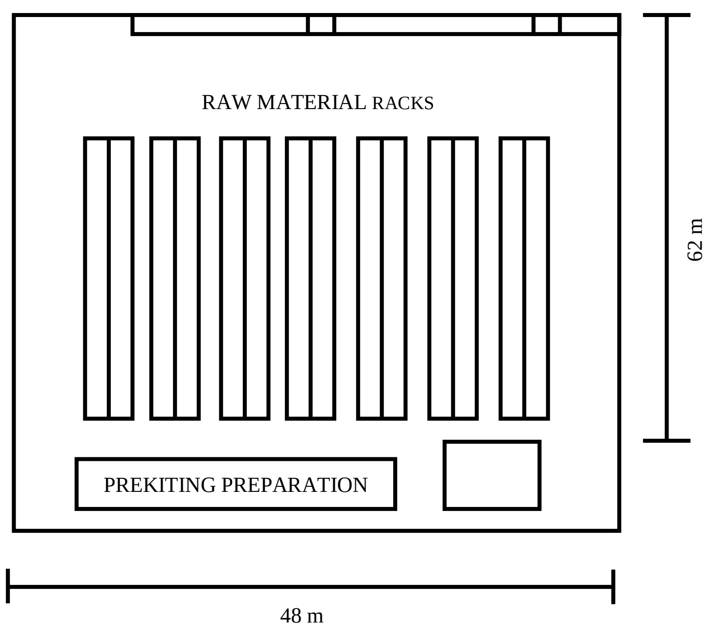
Simulation: According to Kelton (2004), simulation refers to a wide collection of methods and applications to mimic the behavior of real systems, usually on a computer with the appropriate software.

5. Development

5.1 Analysis of the problem

This study was carried out in a company that manufactures components for the automotive industry, and specifically analyzed the physical distribution of the raw material warehouse locations of the front and rear products, which has an approximate area of 3000 m^2; in this space there are 7 ramps, 15 racks of 3 levels, area of order preparation and a quality release zone (figure 6.2).

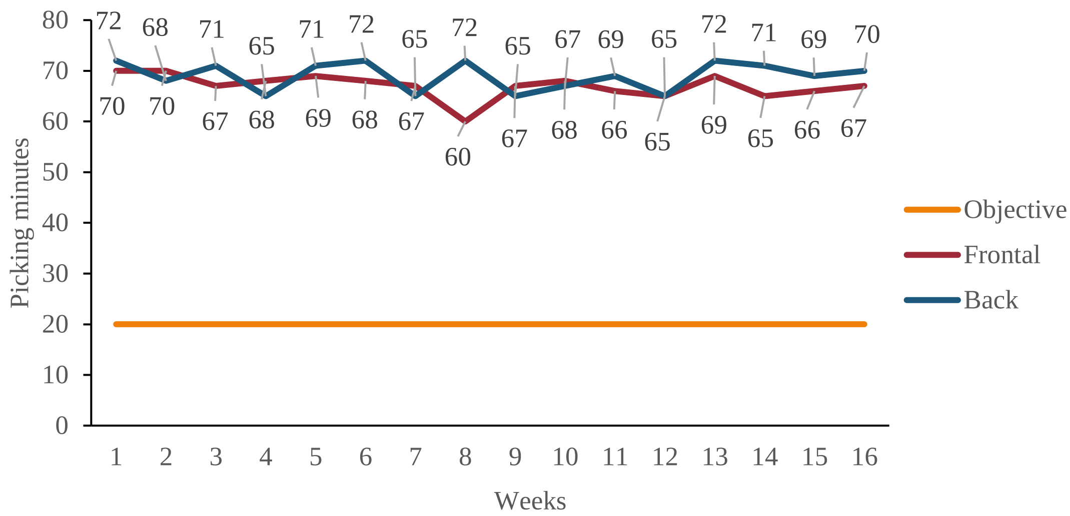
Figure 6.2 Current layout of the materials warehouse



Source: self made

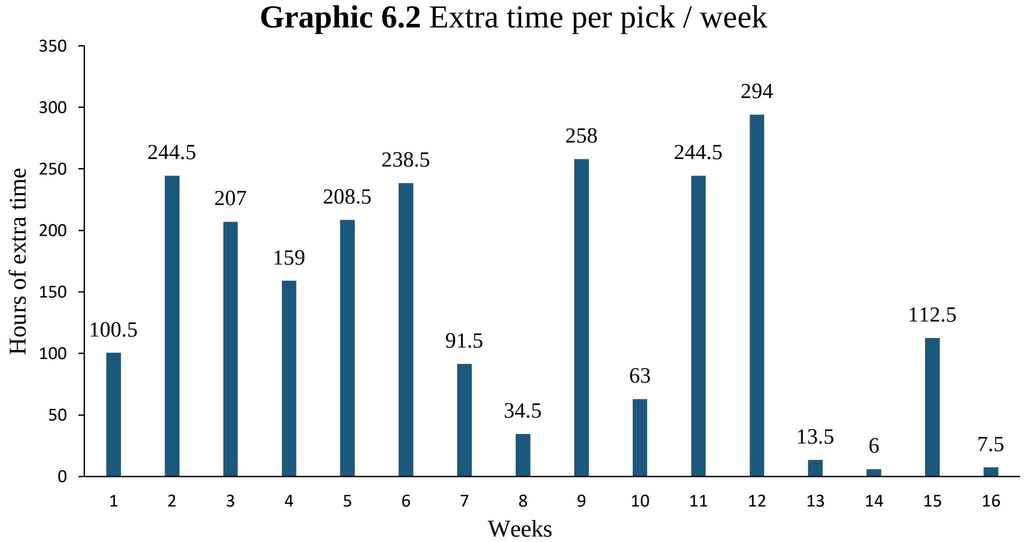
Although the physical facilities of the warehouse currently meet the basic needs in terms of space for the dimensions of inventory that are handled for the short and medium term, the distribution of the warehouse has led to the times of the total flow of the picking exceeding 20 minutes of time customer's touch (graphic 6.1), which has generated that the preparation of orders for the materials to be used for the production of front and rear products, are made in advance through extraordinary work days (Graphic 6.2) to satisfy 100% of customer requirements.

Graphic 6.1 Average picking time / week



Source: Self Made

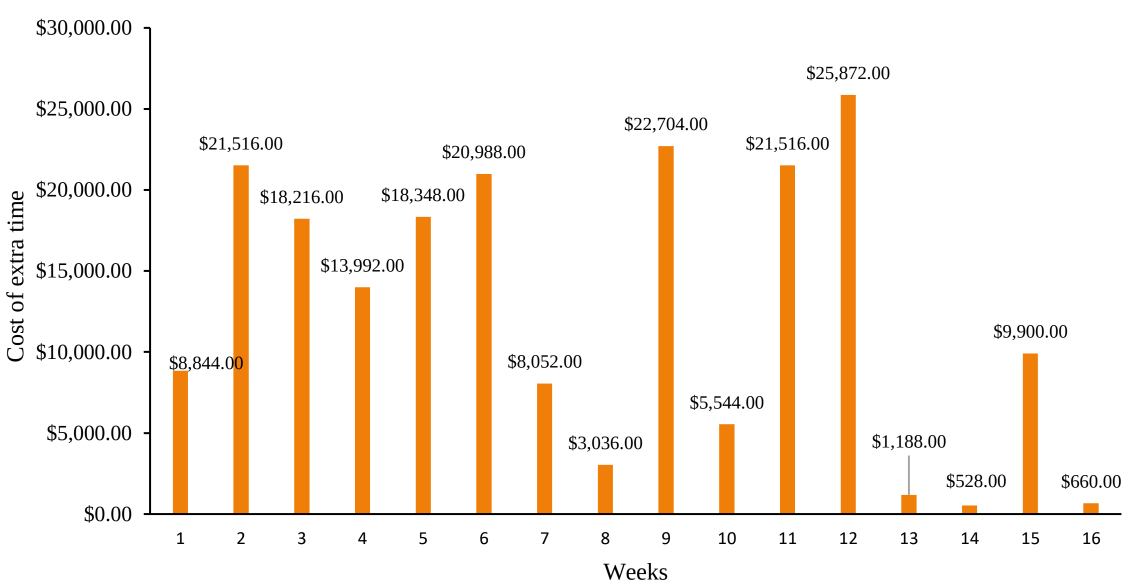
Graphic 6.2 Extra time per pick / week



Source: Self Made

This increase in hours represents a high economic impact within the company, since it is allocating non-budgeted resources for the payment of payroll for the concept of extra time (Graphic 6.3).

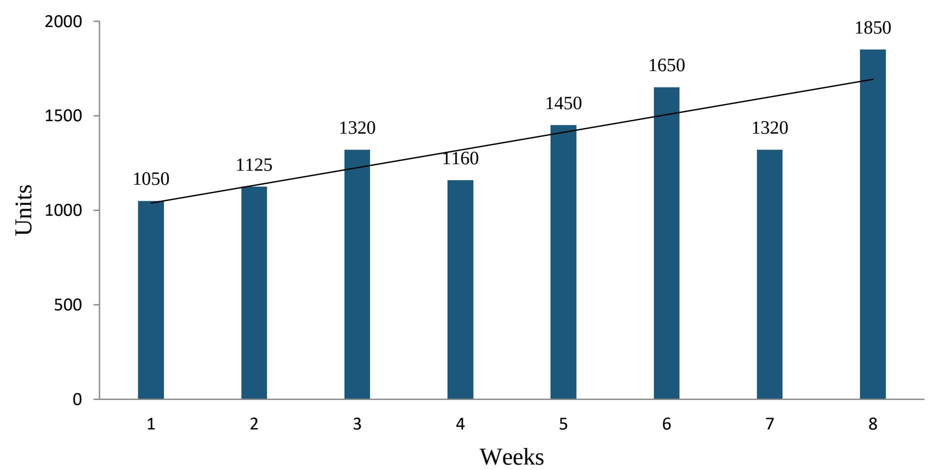
Graphic 6.3 Cost of extra time / week



Source: Self Made

From this problematic was made the analysis of the picking process times to be able to satisfy the customer demand, it was as well as it was detected that the times and movements were very high, that is, the route of the operators are a bottleneck in the operation, for this reason it is necessary to re-configure the locations of the materials of the front and front products within the warehouse through Strategic Layout Planning (SLP), in such a way that the distances traveled from the picking, take advantage of the spaces, save energy, and identify areas of opportunity that allow the organization to be channeled towards competitiveness. One of the important aspects for the sizing of a warehouse is the volume needed to protect the materials, since the total production volume of the last periods has been increasing (graph 6.4), which is why it is necessary to plan the resources for the Following periods, for this reason and under the JIT scheme, the locations of the raw materials warehouse have to be adjusted to reduce picking times, operating costs and optimize labor.

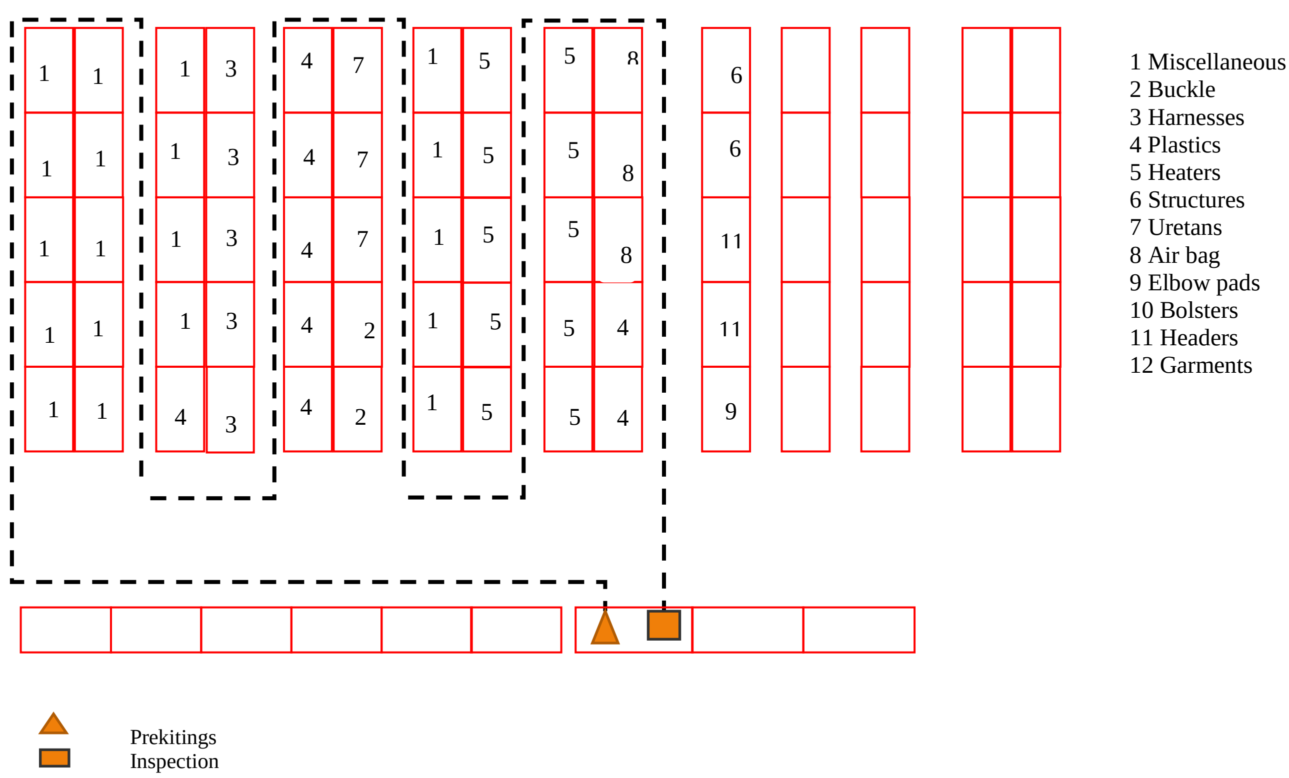
Graphic 6.4 Total production volume



Source: Self Made

That is, each flow added to the work system is one more cost that is added to the process within the raw material warehouse, the picking operations are those that have the greatest weight in the total amount of the operation, so the importance of analyzing by means of a flow chart of materials the routes and times (figure 6.3), in this the location of each of the materials is indicated, currently there are empty spaces, however it is important to relocate the materials, in such a way that the picking times be minimal. It should be noted that each location is a 3-level rack and applies to the front and rear products.

Figure 6.3 Flow chart of the raw material warehouse



Source: Self Made

In the following multiproduct diagram (figure 6.4) the times of travel for the picking of the front and rear products are observed, on average they are 67 and 69 minutes respectively, while the expected is 20 minutes, this imbalance has been compensated with extraordinary days, as already mentioned above with the explanation of graphs 6.2 and 6.3.

Figure 6.4 Multi-product diagram

Operation / material	Product			
	Frontal		Back	
Prekitings	△		△	
Miscellaneous	1	2	1	2
Vestments	12	13	12	13
Bolsters			10	4
Plastics	4	1	4	1
Harness	3	2	3	2
Plastics	4	3	4	3
Urethanes	7	2	7	2
Miscellaneous	1	3	1	3
Buckle	2	1	2	1
Heaters	5	2	5	2
Structures	6	3	6	3
Air bag	8	1	8	1
Headers	11	6	11	6
Plastics	4	8	4	8
Elbow pads			9	3
Inspection	100	20	100	15
Time (minutes)		67		69

Source: Self Made

The relational diagram was also made between each of the activities involved in the picking process (Table 6.1), this applies both to front and rear products, considering the proximity between each of the materials and the basic safety restrictions of the materials sensitive or explosive.

Table 6.1 Relational activity diagram

Activity	Importance of closeness													
0. 0. Pre-kiting														
1. Miscellaneous	E													
2. Buckle	I	I												
3. Harnesses	O	X	U											
4. Plastics	I	U	O	U										
5. Heaters	U	X	O	E	O									
6. Structures	I	U	I	O	I	O								
7. Urethanes	I	U	O	U	U	I	O							
8. Air bag	XX	X	U	A	U	O	U	U						
9. Elbow pads	O	O	O	O	I	O	I	U	I					
10. Bolsters	O	U	O	O	I	O	O	U	E	A				
11. Headers	O	U	U	O	O	U	O	U	I	E	A			
12. Garments	X	U	U	O	I	U	O	I	I	I	E	A		
13. Inspection	A	U	U	U	U	U	U	U	U	I	I	E	A	
	14. Pre-kiting	15. Miscellane	16. Buckle	17. Harness	18. Plastics	19. Heaters	20. Structures	21. Urethanes	22. Air bag	23. Elbow pads	24. Bolsters	25. Headers	26. Vestments	27. Iinspection

Nomenclature

A:	Absolutely necessary
E:	Especially necessary
I:	Important
O:	Ordinary proximity
U:	Not important
X:	Undesirable
XX:	Highly undesirable

Source: Self Made

5.2 Search

The necessary space for each bay was determined, without forgetting the restrictions of relations and proximity allowed by type of material, it is also necessary to consider that each rack is composed of three levels, each level of 5 bays, each bay has an approximate space of 3.5 m long, by 1.5 m high. It is important to consider the number of part numbers by ABC classification, the amount contained in a standard pack of the supplier and their dimensions. Tables 6.2 and 6.3 show the spaces needed to store the materials.

Table 6.2 Spaces required for the storage of materials (Frontal)

Commodity	Frontal Units	Space m^2	Classification	Type of storage	Space in number of bays
Plastics	119	81	A	Paperboard	23.1
Vestments	109	75	A	Paperboard	21.4
Harness	49	56	B	Paperboard	16
Headers	110	75	B	Paperboard	21.4
Miscellaneous	38	26	B	Paperboard	7.4
Structures	26	17	C	Plastic	4.8
Heaters	25	17	C	Paperboard	4.8
Urethanes	26	17	C	Plastic	4.8
Air bag	15	10	C	Paperboard	2.8
Buckle	5	3	C	Plastic	0.8

Source: Self Made

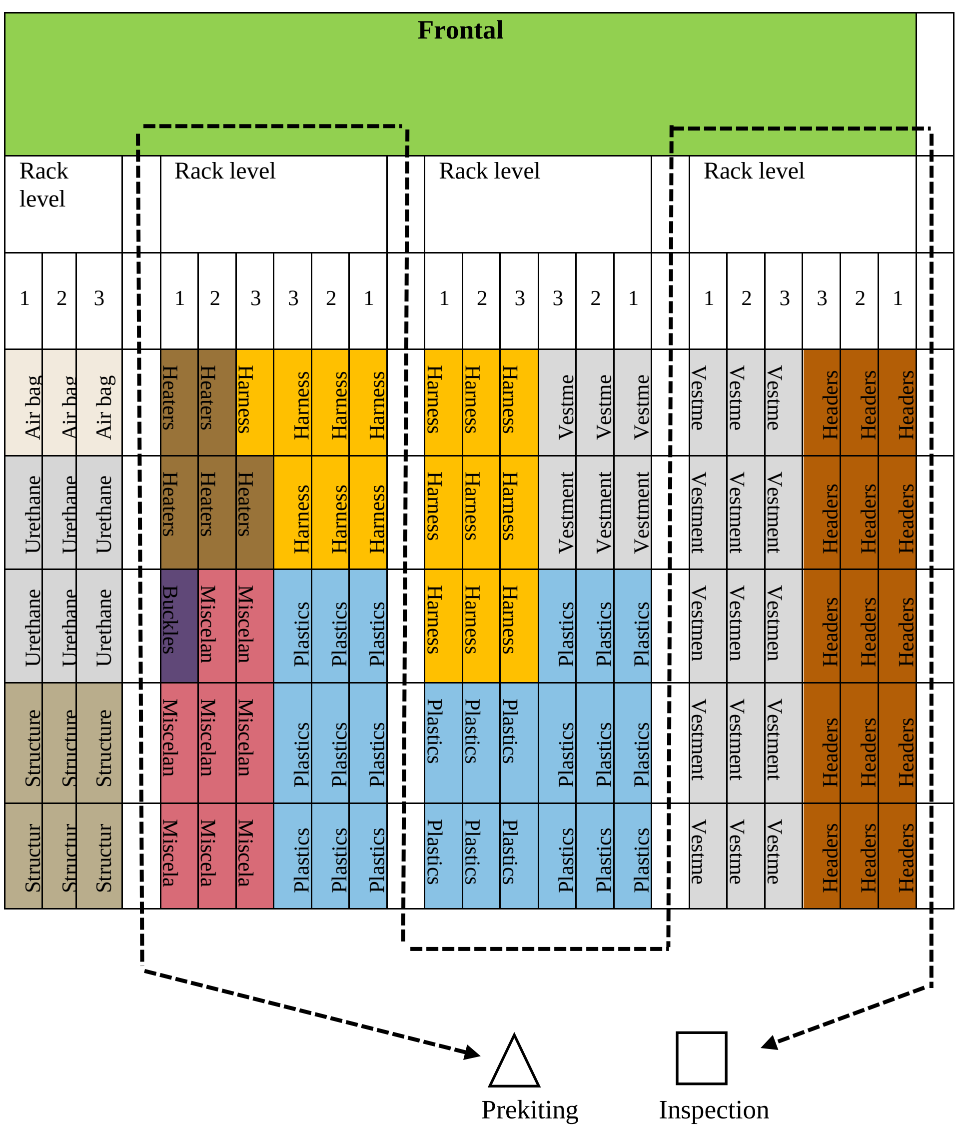
Table 6.3 Spaces required for storage of materials (Rear).

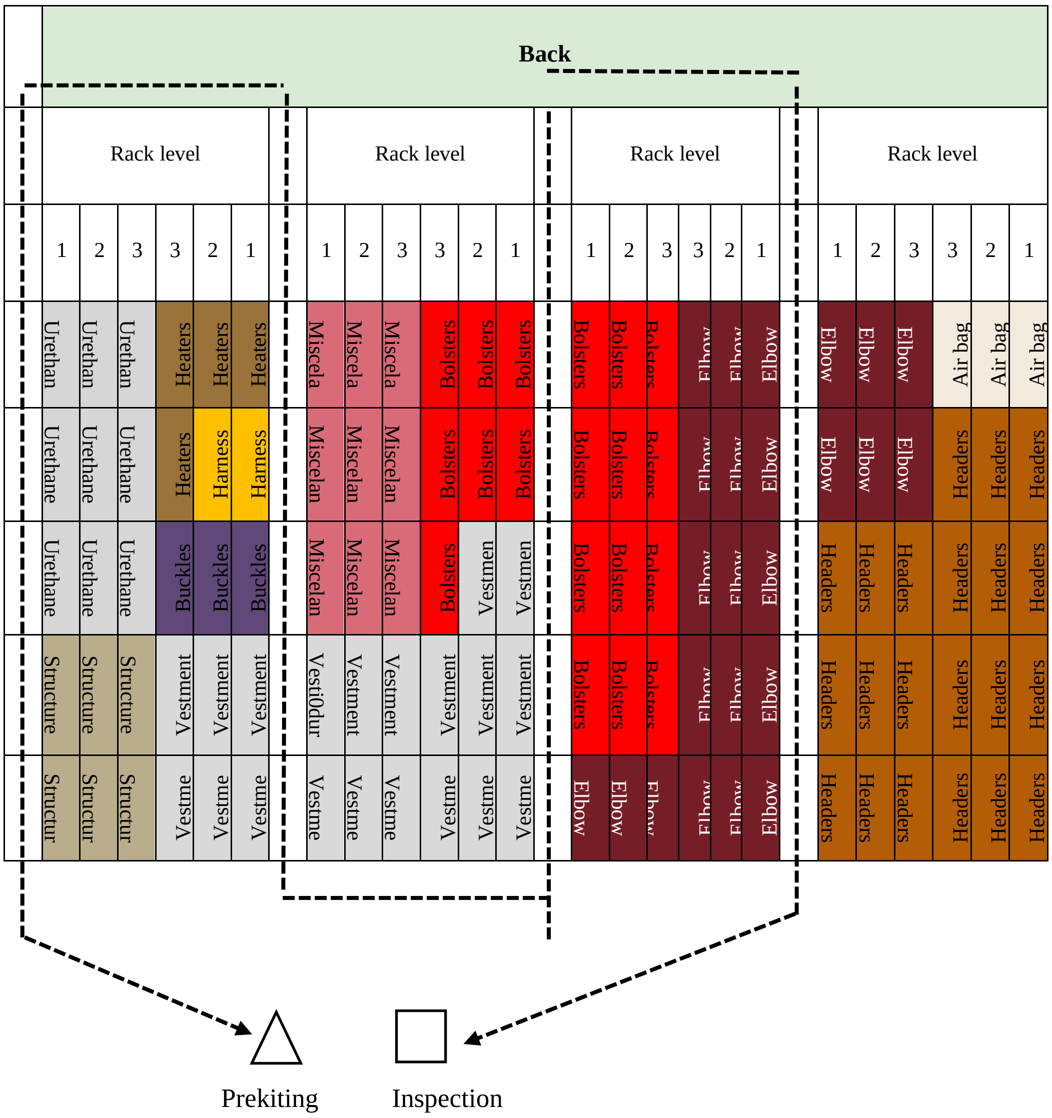
Commodity	Back Units	Space m^2	Classification	Type of storage	Space in number of bays
Vestments	102	70	A	Paperboard	20
Plastics	30	20	A	Paperboard	5.7
Bolsters	102	70	B	Paperboard	20
Elbow pads	102	70	B	Plastic	20
Headers	102	70	B	Paperboard	20
Urethanes	50	34	B	Plastic	9.7
Buckle	13	8	C	Plastic	2.2
Heaters	15	10	C	Paperboard	2.8
Structures	30	20	C	Plastic	5.7
Air bag	10	60	C	Paperboard	1.7
Harness	5	3	C	Paperboard	0.8
Miscellaneous	50	34	C	Paperboard	9.7

Source: Self Made

The general distribution of the warehouse was divided into two sub-warehouses, the left zone assigned to the materials of the front line and the right side to the materials of the rear line (figure 6.5). In this way, the spaces available for each production line are specialized.

Figure 6.5 Relocation of materials of the front and back products inside the warehouse





Source: Self Made

6. Results

The implementation of the redesign of the locations of the materials within the warehouse was carried out in a period of 2 to 3 months, mainly due to the needs of physical adjustments that imply that the operations are totally suspended, the changes were developed in three phases:

a. Classification of raw materials: Identification of racks for each part number; indicating part number, quantity of standard pack and location of the bay
b. Physical inventory: separation of nonconforming materials was made, obsolete and not corresponding to the location. This process, in addition to being a corporate requirement per semester, was essential to purge the warehouse.
c. Creation of sub-warehouses. The redesign of the material locations within the warehouse was implemented.

Once the physical reconfiguration of the warehouse was put into operation, the times of travel and operation for the picking of the products were taken. The results are shown in figure 6.6.

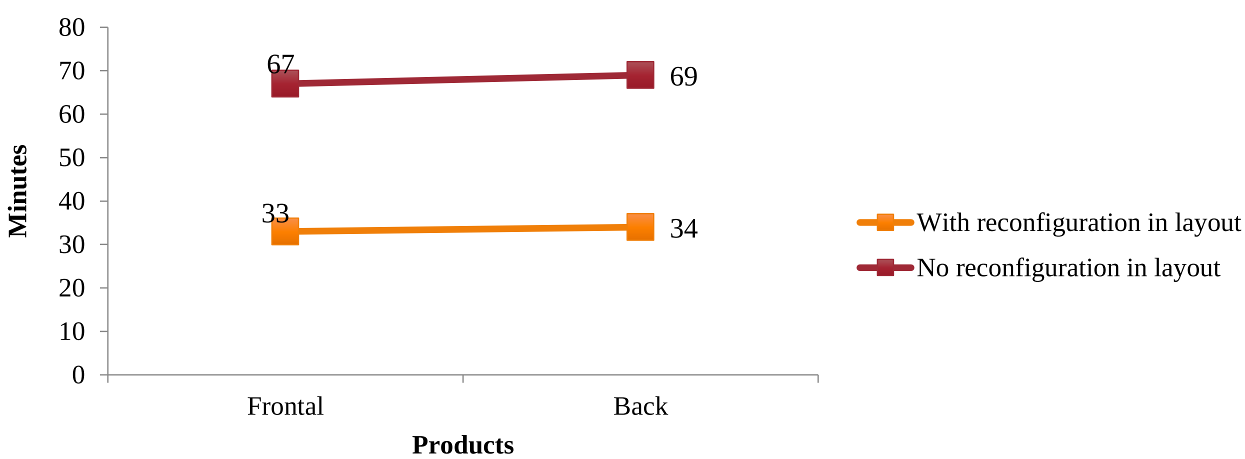
Figure 6.6 Multi-product diagram (redesign layout)

Operación/material	Producto				Operación/material
	Frontales		Traseros		
Prekitings	△		△		Prekitings
Estructuras	6	2	6	2	Estructuras
Misceláneos	1	2	7	3	Uretanos
Buckle	2	2	5	2	Calefactores
Uretanos	7	3	1	2	Misceláneos
Air bag	8	1	3	2	Arneses
Calefactores	5	2	2	2	Buckle
Arneses	3	2	12	3	Vestiduras
Plásticos	4	3	10	3	Bolsters
Vestiduras	12	3	9	3	Coderas
Cabeceras	11	3	4	3	Plásticos
			11	2	Cabeceras
			8	1	Air bag
Inspección	100	11	100	6	Inspección
Tiempo (minutos)		33		34	Tiempo (minutos)

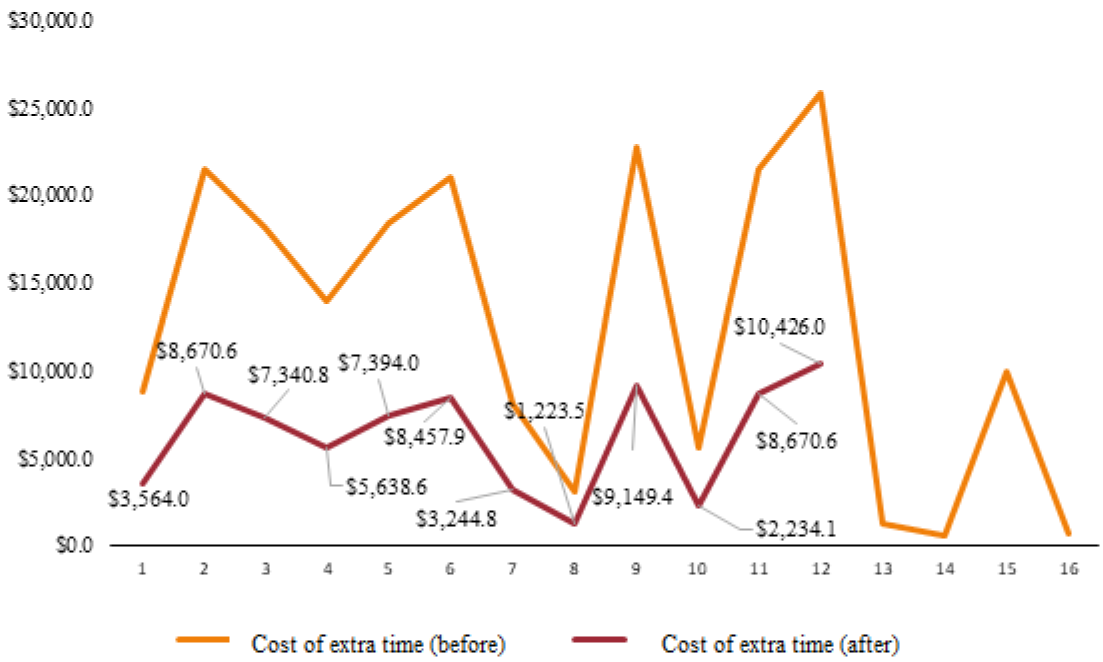
Source: Self Made

The following graph shows the comparison of prekiting times (minutes) before and after the redesign of warehouse locations. As can be seen in figure 6.6, the picking times were reduced by 51% for front products and 50% for rear products, which will be reflected in the costs of extra time (graphic 6.6).

Graphic 6.5 Comparison of results (minutes)



Graphic 6.6 Comparison of results (Costs of extra time)



Source: Self Made

8. Conclusions

The daily competitiveness in which companies are immersed leads them commonly to the idea of investing in new resources, whether human, technical, physical, etc., however, it is important to know that there are tools and methods that allow facing the problems of orderly and measurable way. The benefits of the practical integration of different tools in the analysis of data, decision making, and proposals of alternatives lead to achieving important objectives in the company, such as: increase productivity, efficiently use resources, maximize profitability, eliminate waste, among others.

One of the key pieces to plan the supply chain is to redesign the locations of the materials within the warehouses, as it optimizes the activities and generates a greater guarantee in the logistic services that the company can offer the client, for this it must be taken into account. account the strategy of inputs and outputs of the merchandise, the type of storage, the internal transport system, the frequency of rotation of the products, the level of the inventory, the guidelines of packaging and preparation of orders, among others. By taking into account these elements the operations of the warehouse will be more efficient as they will achieve faster order preparation and a decrease in errors. This translates into a better flow of materials, lower cost and greater customer service, in addition to offering workers a suitable and safe work environment.

In this case the reconfiguration of the material warehouse distribution in an automotive JIT plant through the SLP, provides the flexibility to adapt the tools to very specific and specific processes, to improve the process flows that allow to satisfy the client's demands in the agreed times, which generates competitive advantage by reducing time, distance, energy, labor, material handling and also contributes to the traceability of materials.

9. References

Acevedo, J. A., GÓMEZ M. I. (2001). Diseño del servicio al cliente, Habana, Cuba: ISPJAE.

Asociación mexicana de distribuidores de automotores A.C. (AMDA) (2016), Diálogos con la industria automotriz 2012-2018. https://www.amda.mx/wp-content/uploads/2018/02/Dialogos01-12-16.pdf

Bartholdi, J.J. & Hackman, S.T. (2005). Warehouse and Distribution Science. The Supply Chain and Logistics Institute. Atlanta, GA.

Caridade, R., Pereira, T., Pinto L. & Silva, F.G. A. (2017). Analysis and optimisation of a logistic warehouse in the automotive industry. Procedia Manufacturing. Vol. 13, pp. 1096-1103.
Carranza, O., Sabria, F., Resende, P. and & Maltz, A. (2004) Logística: Mejores prácticas en Lationamérica, Thomson, Mexico City.

Chiang, C.Y., Kocabasoglu-Hillmer, C. & Suresh, N. (2012). An empirical investigation of the impact of strategic sourcing and flexibility on firm's supply chain agility. *International Journal of Operations & Production Management*, Vol. 32 No. 1, pp. 49-78.

De Koster, R., Le-Duc, T. & Roodbergen, K.J. (2007). Design and control of warehouse order picking: a literature review. *European Journal of Operational Research*. Vol. 182, pp. 481-501.

De Marco, A. & Mangano, G. (2011). Relationship between logistic service and maintenance costs of warehouses. *Facilities*. Vol. 29 No. 9/10, pp.411-421.

Faber, N., De Koster, M. B.. M & Smidts, A. (2013). Organizing warehouse management. *International Journal of Operations & Production Management*, Vol. 33 No. 9, pp.1230-1256

Frazelle, E.H. (2002), World-Class Warehousing and Material Handling, McGraw-Hill, New York, NY.

Gilbert, J. (2004). Construction office design with systematic layout planning. 15th Annual Conference on POM. Cancun, May 15-18

Gopalakrishnan, B., Turuvekere, R., & Gupta, D.P. (2004). Computer integrated facilities planning and design. Facilities, Vol. 22 No. 7/8, pp. 199 – 209.

Gu, J., Goetschalckx, M. & McGinnis, L.F. (2007). Research on warehouse operation: A comprehensive review. *European Journal of Operational Research*. Vol. 177, pp. 1-21.

Hassan, M.M.D. (2002). A framework for the design of warehouse layout. *Facilities,* Vol. 20 No. 13/14, pp. 432-40.

Horta, M., Coelho, F. & Relvas, S. (2016). Layout design modelling for a real world just-in-time warehouse. *Computers & Industrial Engineering.* Vol. 101, pp. 1-9.

Huertas, J. I., Díaz, J. & Trigos F. (2007). Layout evaluation of large capacity warehouses. *Facilities*, Vol. 25 No. 7/8, pp.259-270.

Li, X. (2014), Operations management of logistics and supply chain: issues and directions. *Discrete Dynamics in Nature and Society*, Vol. 2014, pp. 1-7.

Kamariah, N. & Mohamed, Z. (2009). Supply chain technology adoption in Malaysian automotive suppliers. *Journal of Manufacturing Technology Management*, Vol. 20 No. 3, pp. 385 – 403.

Kelton, W., Sadowski, R. & Sturrock, D. (2004). Simulation with Arena. 3rd ed., McGraw-Hill, Boston.
Kiefer, A.W. & Novack, R.A. (1999). An empirical analysis of warehouse measurement systems in the context of supply chain implementation. *Transportation Journal*, Vol. 38 No. 3, pp. 18-27.

Liu, K. H., Hwang, S. L., Hsieh, M. H., Liang, S. F. M & Chuang, C.F. (2016). Systematic layout planning in human–system interface: An evaluation of alarm displays with spatial proximity for accidents diagnosis of advanced boiling water reactor. *Industrial Ergonomics.* Vol. 51, pp 30-42.

MacCarthy, B. L., Blome, C., Olhager, J., Singh J. & Zhao, X. (2016). Supply chain evolution – theory, concepts and science. *International Journal of Operations & Production Management*. Vol. 36 No. 12, pp.1696-1718.

Monks, J. (1987). Administração da Produção. McGraw-Hill, São Paulo.

Muther, R. (1976). Systematic Layout Planning. Cahners Publishing, Boston, MA.

Ou, C. S., Liu, F. C., Hung, Y. C. & Yen, D. C. (2010). A structural model of supply chain management on firm performance. *International Journal of Operations & Production Management*. Vol. 30 No. 5. pp. 526 – 545.

Power, D. (2006). Adoption of supply chain management-enabling technologies in SMEs: the view from the top vs the view from middle. *International Journal Value Chain Management,* Vol. 1 No.1.

Raguseo, E., Gastaldi, L. & Neirotti, P. (2016). Smart work: Supporting employees' flexibility through ICT, HR practices and office layout. *Evidence-based HRM: a Global Forum for Empirical Scholarship*, Vol. 4 No. 3, pp.240-256.

Rakesh, V. & Adil, G. K. (2015). Layout Optimization of a Three Dimensional Order Picking Warehouse. *International Journal of Industrial Ergonomic.* Vol. 51, pp. 30-42.

Richards, W. (2011). Warehouse management: A complete guide to improving efficiency and minimizing costs in the modern warehouse. Kogan Page.

Silva, M. & Moreira, B. (2009). Aplicação da Metodologia SLP na Reformulação do Layout de uma micro empresa do Setor Moveleiro. XXIX Encontro Nacional de Engenharia de Produção. Salvador, October 7-10.

Tompkins, J.A., White, J.A., Bozer, Y.A. & Tanchoco, J.M.A. (2003). Facilities Planning. Wiley, Hoboken, NJ.

Tortorella, G. & Fogliatto, F. (2008). Planejamento sistemático de layout com apoio de análise de decisão multicritério. *Produção*. Vol. 18 No. 3, pp. 609-624.

Trein, F. & Amaral, F. (2001). Aplicação de Técnicas Sistemáticas para a Análise e Melhoria de Layout de Processo na Indústria de Beneficiamento de Couro". Encontro Nacional de Engenharia de Produção. Porto Alegre, October 10-14.

Van Donk, D.P & Gaalman, G. (2004). Food Safety and Hygiene: Systematic Layout Planning of Food Processes. *Chemical Engineering Research and Design*. Vol. 82 No. 11, pp. 1485-1493

Vis, I. F. A., & Roodbergen, K. J. (2011). Layout and control policies for cross docking operations. *Computers & Industrial Engineering*. Vol. 61 No. (4), 911–919.

Xie, Z., & Miyazaki, K. (2014). Heterogeneity and typology of product innovation in embedded software: The case of Japanese automotive software. *Asian Journal of Technology Innovation*. Vol. 22 No. 1, pp. 33-53.
Yang, T., Su, C.T. & Hsu, Y.R. (2000). Systematic layout planning: a study on semiconductor wafer fabrication facilities. *International Journal Operations Production Management*. Vol. 20 No. 11, pp. 1359-1371.

Zhou, K.Q., Zhang, R.J., Wang, Y.D. & Wang, B.J. (2010). Study on Workshop Layout of a Motorcycle Company Based on Systematic Layout Planning (SLP). Conference on Image Processing and Pattern Recognition in Engineering, Available: http://proceedings.spiedigitallibrary. org/proceeding.aspx?articleid¼724158

Zhao, X., Huo, B., Flynn B. B. & Yeung. J. H. Y. (2008). The impact of power and relationship commitment on the integration between manufacturers and customers in a supply chain. *Journal of Operations Management*. Vol. 26, pp. 368–388.