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Optimization of space and flow of materials in a warehouse using SHA and SLP

BY

Ibarra Echavarria Juan Antonio [1], Jasso Guerrero Humberto [2], Reyes Gallegos María Magdalena [1], Medina Juárez Israel [1], López García Ricardo Daniel [2*]

[1] Postgraduate and Research Department, Tecnológico Nacional de México/Campus Cd. Victoria, Blvd. Emilio Portes Gil No. 1301 Pte., Cd. Victoria C.P. 87010, Tamaulipas México
[2] Department of Mechanical Engineering, Tecnológico Nacional de México/Campus Cd. Victoria, Blvd. Emilio Portes Gil No. 1301 Pte., Cd. Victoria C.P. 87010, Tamaulipas México

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Abstract

The efficiency and optimization of productive capital are characteristics widely studied in the business world. Any organization whose objectives include growth and financial success will seek the maximum use of its resources. In this way, this work presents the results from techniques and tools used to achieve the optimal management of two essential factors of any production process: the raw materials and the facilities. Tools included in the SLP and SHA methodologies were in this research paper used to obtain a logical and systematic flow of raw materials. This implementation included the analysis of the flow of materials through a raw material warehouse, looking to propose new routes and locations to reduce travelled distances and times, mainly on the most used materials. 140 m2 were from the space available saved for the future storage of new raw materials. The results reported in this paper demonstrate savings and cost reduction potential in any material control and warehouse layout design project when methodologies from SLP and SHA are applied.

***Keywords**- Layout, Raw material, Warehouse, Storage*

INTRODUCTION

The inventory control of raw materials and finished products would not be necessary if companies could deliver their production immediately and they could precisely know the specific market requirements. However, this is not possible since demand cannot be precisely predicted. A perfect match between offer and need implies that production facilities can respond immediately to any requirement, and the transportation of goods is 100 % reliable with ideal delivery times (Plinere and Borisov, 2015; Alfaro and Rábade, 2009; Ballard, 1996). Consequently, two factors are critical in a good raw materials supply process: product demand and logistics operations.

This research paper shows the case of a manufacturing company of electronic components located in Mexico. The company is dealing with an expansion process due to the fusion with the biggest manufacturer of electronic capacitors, which implies an increment in both production levels and facilities' capacity. To continue delivering positive results, this company is facing challenges that require improvements in several areas; in this case study, the focus will be on the warehouse's logistic operations. In addition, the changes impacting the global logistics operations due to the SARS-CoV-2 outbreak (COVID-19) two years ago made it necessary to redesign the raw materials warehouse for a better production process inside the company.

Two widely used methodologies for operative management of industrial facilities were to improve the warehouse selected: Systematic Layout Planning (SLP) and Systematic Handling Analysis (SHA). The first one aims to design productive areas; the second to design and implement material handling methods. SLP is an organized methodology that helps to lead the distribution design of any industrial facility (Khariwal et al., 2021; Liu et al., 2020; Wen and Bai, 2015). On the other hand, SHA is a technique that supports any project involving material handling processes (Su et al., 2010). The combined use of both methodologies has brought many positive results to many companies over the past years.

LITERATURE REVIEW

The plant layout problem, also known as the facility layout problem, can be observed in different study fields and is considered one of the most complex problems in the industry (Pillai et al., 2011; Palekar et al., 1992). A definition of plant layout could be the arrangement of the productive areas inside

*Corresponding Author: López García Ricardo Daniel a production facility and the interaction among them (Naik and Kallurkar, 2016; Yang and Hung, 2007). Several tools are used to solve productivity problems, such as Quality Control (QC), Pareto analysis, Total Quality Management (TQM), and Design of Plant Distribution. However, the Plant layout might deliver better results related to the manufacturing costs, including the enhancements of optimal routes for the flow of materials (Ali-Naqvi et al., 2016; Kovács, G. 2019; El-Baz, M. A. 2004).

On the other hand, the facilities represent a crucial part of the capital investment made for any company. If these facilities are correctly planned and used, they contribute positively to the operative costs. Consequently, the operative capacities and profit will increase. As it was by (Bordia et al., 2004) stated, companies are currently facing a changing and uncertain business environment. Therefore, projects of redistribution of plants are more common. Identifying the issues in the current distribution process is the first step for getting an efficient distribution so that productivity increases with a minimum investment (Suhardini et al., 2017).

According to (Klausnitzer and Lasch, 2018), the design of manufacturing facilities and material handling often affect the productivity and profit of any company, even more than any corporate decision. Moreover, the layout of facilities affects not only the cost and quality of products but the proportion of supply and demand (Hossain et al., 2014). In the same way, optimization is a constant factor in any project of redistribution of productive areas. According to (Heakal and Adi-Prasetio, 2020), minimum distance, flow of materials, and occupied volume are some of the main factors to be optimized.

There are documented cases related to the redesign of layouts and improvement of the flow of materials using SLP and SHA. For instance, (Aguilar, 2017) presents, in a research paper, an infrastructure design for a truck production line. He mentions that "the automotive industry is requesting changes in the productive processes, from new product assembly to changing or expanding production lines. In this regard, Dina Camiones SA de CV introduces two new truck models, Buller and Linner 12, which brings the need to increase production capacity. One can conclude that it is possible to design truck production lines that accomplish construction norms and industrial safety regulations using SLP and official norms.

In a second example, (Reyes, 2013) developed a project where SLP and SHA are combined to improve the material's movement in a textile company. He describes that "the research's purpose is to suggest a plant distribution for a new building. Since current facilities may not support the production and sales objectives, the convenience of a new plant was evaluated.

His project proposes up to 16 % savings on movement reduction against the current plant layout. Also mentions that results from the marketing analysis supported the exportation opportunities and improvements in plant distribution. After the new plant distribution, production capacity increased by 400 % against the previous plant distribution.

Another example of the adoption of the SLP methodology is by (Zambrano, 2018) reported, which details the installation of a new processing plant for alcoholic beverages. In his work explains the use of the methodology, highlighting the results obtained through the application of tools like the relationship diagram and dimensionless block diagram. Moreover, he explains the decisions taken based on the SHA methodology; he details the acquired equipment for handling materials and their characteristics.

Finally, projects like the one developed by Paz and Segura, 2021 in a Fruit Logistics Centre in Colombia present improvements using the SLP methodology. For this case, a 13 % reduction in distances and a 31 % increase in available spaces.

Section 2 presents the theoretical and referential framework. Section 3 presents the method and tools used in the research. Section 4 presents a description and analysis of the results obtained. Section 5 presents the analysis and conclusions.

METHODS

CLASSIFICATIONS OF MATERIALS

For defining the best handling methods, SHA methodology proposes a deep understanding of the materials, which means knowing everything that will be moved, handled, and transported. According to (Richards, 2014), the best solutions for material handling involve the minimum level of manipulation and handling.

The classification of materials allows us to know the individual characteristics of each item for grouping them into classes or categories, which simplifies the analysis of problems like the one covered in this research work. When a significant number of variants of items need to be analyzed, each material is within a group or category assigned along with other materials that share similar characteristics. Two fundamental characteristics make possible the classification of any material. First, the physical condition of the material, which means if it is solid, liquid, gas, or any other state; finally, what is its storage condition, which means if it is storage single or bulk. SHA methodology uses the physical characteristics of materials to classify them, such as size (long, wide, high), weight, form, risk of deterioration (weak, explosive, corrosive), and physical state (hot, unstable, wet). In addition, other characteristics could be considered, like quantity, time (stational, urgent, regular), and particular controls (appropriate dispositions, applicable norms). Based on the previous characteristics, the most significant distinctive shared by the group's members serves for arrangement purposes.

Time is also during this process considered. Fast and urgent movements are more expensive and require different storage methods than those used for other materials. Exclusive controls may determine the classification of materials too. Drugs and munitions are typical cases of materials controlled by government dispositions (Muther and Haganas, 1969).

FLOW OF MATERIALS

A critical factor for any handling material or layout design project is the movement of materials. Kay (2012) mentions that the optimum flow of materials involves short distances inside the manufacturing facility; through efficient handling and control of materials, it is possible to add value to the final product. Through records and graphical formats, the movement analysis identifies how materials change their location inside the facility; this information helps to propose more efficient motions. Therefore, data about the route and flow need to be known, along with the material's characteristics and classification. Thus, information about the origin, path, and destiny is necessary to define the route; similarly, for the flow, knowledge about the conditions and intensity of the flow is essential.

Routes are the origin and final destiny of the materials. Consequently, route data must show information about the distance, physical condition of the route, existing congestions like physical obstructions, weather conditions, and surroundings. About the flow, one should consider that any movement has an intensity of flow. SHA methodology defines this intensity as the quantity of material moved on a route during a time. The measurement of this intensity is tons per hour, batches per week, among others. The number of materials transported, the frequency of movements, and the conditions and speed of the moves, are unique characteristics of the flow.

The Eq. 1 for the intensity of flow is shown below:

$$I = \frac{nP}{t} \qquad (1)$$

where
I = intensity of flow
n = number of material units
P = measurement unit
t= time range

SHA methodology makes the following question to perform the flow of materials analysis: how varied are the materials analyzed? Process diagrams are the correct selection when a few materials are analyzed. This type of diagram uses the information collected from the process during a specific period. For the case of a greater number of materials, SHA recommends an origin-destiny diagram, known as a route sheet. The information collected on each movement's origin and destiny supports the elaboration of the route sheet. Data is from the route analyzed during a time, acquiring evidence about the class of materials flowing on that route.

Thus, to decide the best handling methods, this case study used flow diagrams, which show the material's movements on the routes, the type of material, distance, and the movement's intensity and direction. The flow diagrams are drawn on a layout plane indicating the distance and direction of the moves on each route. Since the flow diagram may contain many data, it is critical to follow up a standard. Figure 1 depicts an example of how a flow diagram looks based on the SHA's recommendations with the main elements included. Likewise, the three routes with more intensity of flow were for this case study picked up for analysis.

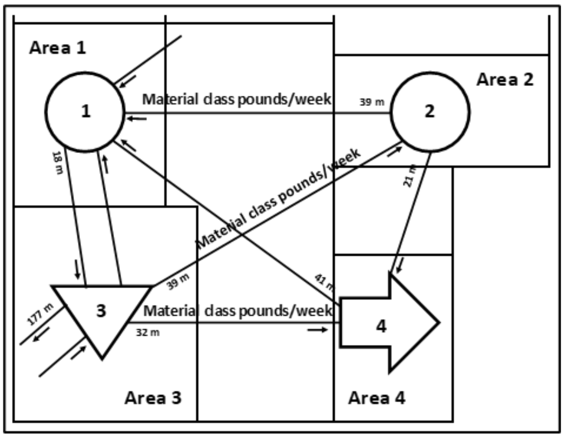

Figure 1. Example of a flow diagram. Source: The authors.

Generally, during the layout design process focus is on the product's flow among the related areas; nevertheless, SLP methodology points to other factors, such as the location of supporting areas and administrative departments. Even though these areas are not part of the flow of materials, they are part of the layout. For instance, in the jewellery industry, the flow of material is not so critical since the quantities moved do not impact the facilities' distribution. However, supporting areas could be decisive within this industry.

The relationship diagram is the tool that SLP proposes to analyse the relationship and level of closeness among areas. The final goal is an optimum area distribution, considering legal and safety restrictions. This diagram shows the relationship among areas through two indicators; the first indicator displays the importance of the relation, and the second the reasons for the first one. The final aim is to indicate how far or close the areas should be among them. Figure 2 shows a relationship diagram based on divided boxes, where the analysed spaces converge in a specific box; the upper division of the box contains the first indicator, and the lower division the second one. In addition, SLP methodology proposes a valorisation of closeness using a code constructed by colours and letters. Each of these codes includes a description indicating the degree of importance. The code and description combined provide the closeness' importance.

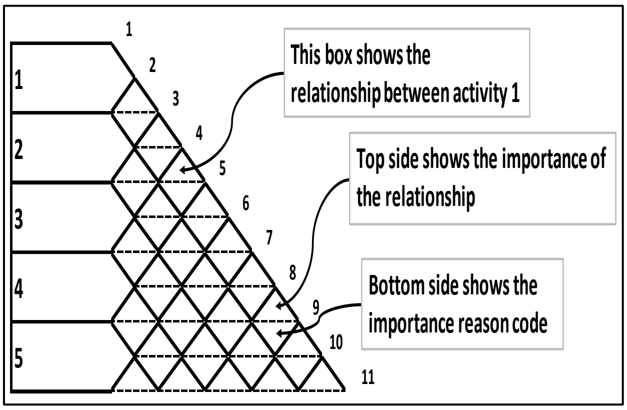

Figure 2. Structure of boxes on a relationship diagram.

Finally, to justify the valorization made previously, SLP recommends using reasons; for greater practicality, are between eight and ten reasons recommended. Figure 3 depicts the whole valorization process described.

Once the construction of the diagram finishes, Eq. 2 determines the potential number of relationships:

$$TR = \frac{N*(N-1)}{2} \qquad (2)$$

where

TR = total number of relationships

N = number of areas analysed

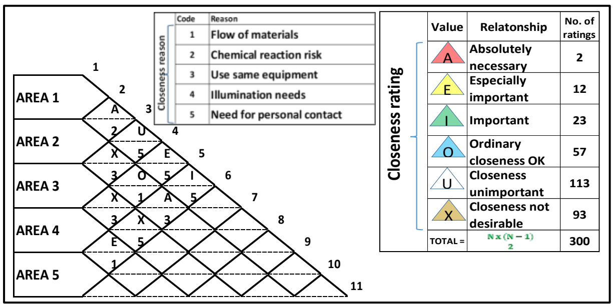

Figure 3. Example of relationship diagram. Source: The author.

RESULTS AND DISCUSSION

CLASSIFICATIONS OF MATERIALS

The materials used by the selected company for this research were, using SHA methodology, classified. Since the packaging information from the materials in the warehouse grants the most relevant information, this was the classification criteria chosen for this step. Past experiences in this company suggest that packaging conditions are related to improved handling methods in its warehouse.

Following the SHA methodology's recommendations, the packaging characteristics of each material supported a classification based on these data. Figure 4 shows the results of this step.

FLOW OF MATERIALS

As stated before, the flow of materials analysis covered the three materials with the higher intensity of flow: the leadframe, the carbon, and the spare parts. The first two are part of the final product, and the last one supports the manufacturing operations; the intensity of flow is using Equation 1 calculated. Table 1 lists the results where the letters (variables) were previously defined.

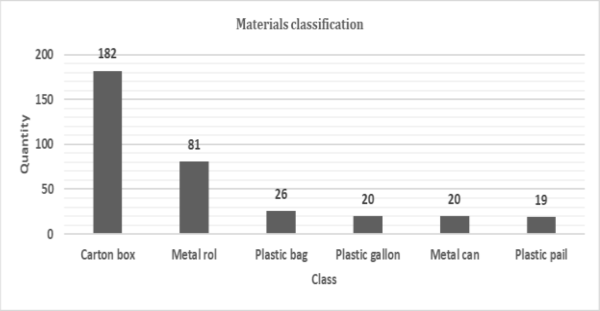

Figure. 4 Classification of materials based on packaging conditions.

Table 1. Intensity of flow for each route.

Route	Item	n	P	t
Leadframe	38241014	2,625	pounds	month
	38241600	7,875	pounds	month
	38241618	3,000	pounds	month
	38241626	4,875	pounds	month
	38241634	1,875	pounds	month
	I =	**20,250**	**pounds**	**month**
Carbon	A02413N5	740	pounds	month
	A02898N0	480	pounds	month
	A02916N3	400	pounds	month
	A02897N9	300	pounds	month
	02040020	663	pounds	month
	I =	**2,583**	**pounds**	**month**
Spare parts	XV000042	2,200	pounds	month
	A04809N0	180	pounds	month
	YY0262	6	pounds	month
	I =	**2,386**	**pounds**	**month**

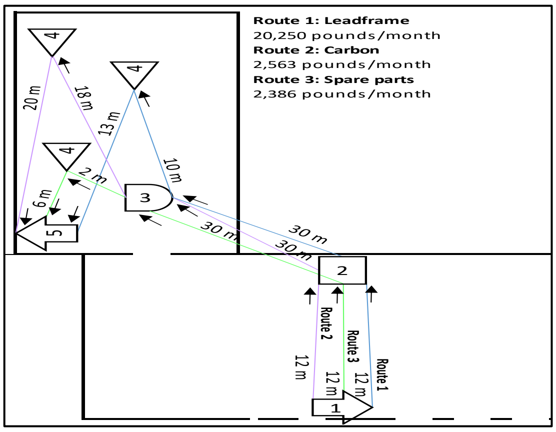

Figure. 5 Current flow of materials.

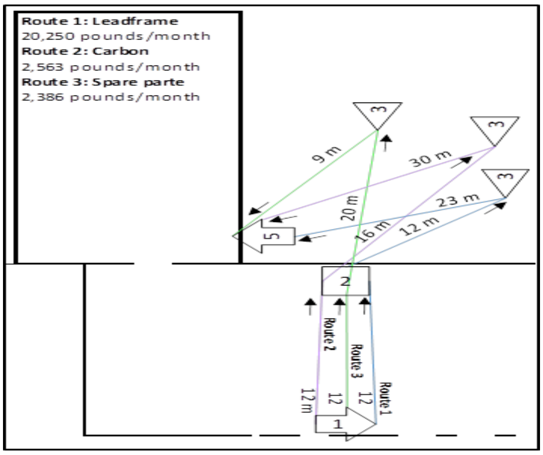

Figure. 6 Proposed new flow of materials.

Regarding the visualization of movements, based on the recommendations made by the SHA methodology and already explained, the routes of the three picked materials for this analysis were on a flow diagram drawn. This flow diagram reflects the actual situation since it uses the current layout.

Figures 5 and 6 show the original and new layouts for the three considered materials within the plant's warehouse.

With the new flow of materials finished, it was possible to estimate the distance saved between both options; Figure 7 shows the distance reduction of the analyzed materials' routes.

Moreover, the new layout showed time reductions in other operations impacted; Table 2 lists these results. These reductions were possible since these operations were part of the routes of the analysed materials.

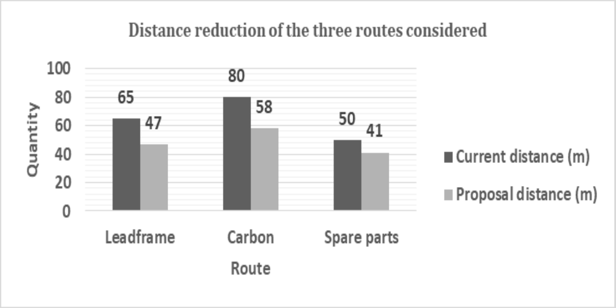

Figure.7 Reduction of distance.

Table 2. Reduction time of main warehouse activities.

Activity	Current time (h)	New time (h)	Reduction
Receiving	1.00	0.83	-17%
Shipping	1.50	1.10	-27%
Cycle count	7.00	3.90	-44%
Storaging	2.00	1.40	-30%
Picking	0.15	0.13	-13%

ACTIVITY RELATIONSHIP DIAGRAM

Each area inside the warehouse was for the level of closeness analyzed; compatibility restrictions, legal requirements, and environmental storage conditions, among other criteria previously mentioned, were for this activity studied. Figure 8 shows the outcomes of this analysis in the form of a relationship matrix, which makes possible the relocation of some areas.

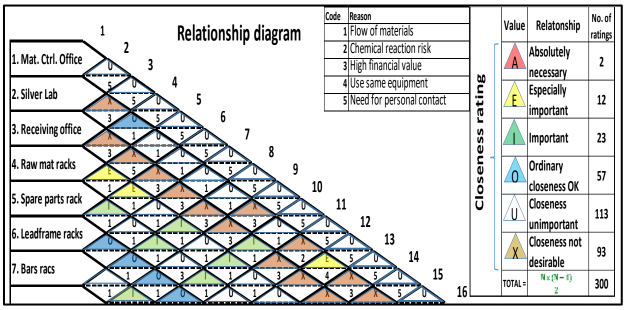

Figure. 8 Relationship diagram for the warehouse areas.

Table 3. lists the potential relocations and the final decision for each case.

Area 1	Area 2	Distance between A1 and A2 needs	Was the change possible?
1. Mat. Ctrl. Office	All areas	Increase	Yes
2. Silver Lab	12. Cool room	Reduce	Yes
5. Spare parts rack	25. User's picking area	Reduce	Yes
6. Leadframe racks	25. User's picking area	Reduce	Yes
8. Tool crib racks	25. User's picking area	Reduce	Yes
11. Hotbox	13. Nitrate area	Reduce	No
18. Anode storage	2. Silver Lab	Reduce	Yes
20. Drawer for chemicals	2. Silver Lab	Reduce	No
21. Powder keg	2. Silver Lab	Increase	Yes
22. Safety Room	2. Silver Lab	Increase	Yes
24. Scrap drums	23. Shipping platform	Reduce	Yes

*Corresponding Author: López García Ricardo Daniel

Table 4. Area reduction in the warehouse.

Area	Current m^2	New m^2
Reels	120.00	54.00
Mat. Ctrl. Office	30.00	0.00
Waiting for storage area 2	24.00	0.00
Receiving office	7.50	0.00
Safety room	31.20	25.00
Wip area	15.75	12.00
Scrap drums	24.00	21.00
Raw mat racks	36.00	36.00
Spare parts rack	6.00	6.00
Leadframe racks	9.00	9.00
Bars racks	6.00	6.00
Tool crib racks	12.00	12.00
Tool crib carousel	46.00	46.00
Hotbox	8.75	8.75
Gas cylinder area	17.50	17.50
Waiting for storage area 1	24.00	24.00
Anode storage	49.00	49.00
Shipping platform	22..50	22..50
User's picking area	2.25	2.25
Nitrate area	9.45	9.45
Powder keg	7.80	7.80
Incoming inspection area	12.00	12.00
Drawer for chemicals	8.50	8.50
Cool room	66.50	66.50
Silver Lab	97.50	97.50
Forklift traffic area	190.00	190.00
Total m^2	**883.00**	**743.00**
% of space used	**100%**	**84%**

Once the potential relocations pointed out by the relationship diagram were implemented, the distribution and dimensions of the working areas changed. Consequently, the warehouse area decreased, supported by optimum use of space and removal of unnecessary spaces.

As a result of the improvements, the saved warehouse's area was 140 m^2, which means 16 % of the total area. This additional space is available for other projects, in this case, for the expansion of operations early mentioned. Table 4 shows the areas within the warehouse before and after the analysis.

Once the movement analysis pointed out by SHA methodology was finished, the opportunity to reduce the distances travelled by high-volume materials came out. Likewise, the relationship diagram recommended by SLP methodology showed that the location of some operative areas generates flow saturation in the main routes of entrance and exit of materials. In the same way, the results showed that the Material Control office, currently inside the warehouse, makes no sense in its current location due to the lack of relationship with other warehouse areas.

CONCLUSIONS

The new layout design showed 16% of freed space inside the warehouse; new raw materials use this space currently. In addition, the reduction of the travelled distances in the routes with the highest flow of materials improved by 24%. Based on the new classification of materials, the company acquired a three levels drive-in-rack type rack for storage. It is possible to conclude that the application of SHA and SLP methodologies, in this case, study allowed us to find opportunities inside the warehouse of the analysed company. Even though the previous layout and material flow delivered acceptable results for a while, once new requirements appeared, also room for improvement appeared. It is logical to think that electronic companies facing similar challenges may find opportunities for improvement using the two methodologies applied in this case.

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