Incorporation and Design of a New Facility in a Country-wide Logistics Network

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Abstract

This paper proposes a location and design warehouse methodology, starting from the premise that there's at least one existing distribution center (DC), in a manufacturing logistics network. The paper uses current methods with a new proposed integral methodology, that covers from a general diagnosis of the current state of the company, up to a validation phase for the network redesign. This structured guide aims to simplify the way companies research for and develop their expansion and warehouse design projects. Furthermore, it presents a method to take qualitative factors into account while deciding on the warehouse location and suggests a validation method that takes more than a single stock item's behavior into account, so results could be more accurate.

Keywords
Warehouse; location; simulation, network redesign, qualitative location index

1. Introduction

Patiño (2013) explains that Mexico, because of its geographic location, represents a strategic point to attend markets such as United States, Central America, and South America. Given this, the country's government has started the development of logistical, specific, and specialized cities, of which the following have been selected: Manzanillo, Lázaro Cárdenas, Querétaro, Ciudad de México, Guadalajara, and San Luis Potosí, cities belonging to the central point of the country. On the other hand, as stated by Morales (2013), the federal government selected 85 logistic platforms that will prioritize strategic projects for the growing and development of logistic infrastructure.

According to Forbes (2019a), DHL, 4th worldwide largest logistic company (PackTech, 2018), has four logistic hubs located in Mexico, three of them in the central region of the country. Notwithstanding, as said by Rodríguez (2019), Amazon, #1 worldwide biggest e-commerce (Forbes, 2019b), possesses three distribution centers in México located in the central region of the country, installations with more than 100,000 square meters for storage space. Also, according to (Huq et al., 2006), the quick response ability and client proximity has turned into a significant metric of performance and competence. Also, it demonstrates that a scenario with two warehouse replenishment systems, instead of one existing warehouse scenario, reduces significantly delivery lead times.

Mexico's logistic tendency points to companies to get closer to the country's logistic hubs, primarily located on the central region, therefore achieving to obtain a quick response to the consumer's necessities. This work seeks to address the initial situation described, using decision tools and a developed methodology, responding to the existing gap with current methods found in the literature.

The proposal outlined in this paper appears to offer significant advantages and contributions to existing literature in that in: 1) the location problem is addressed from an existing warehouse scenario; 2) a qualitative index for the location problem is presented; 3) a stage for validation-proofreading loop is suggested; and 4) a random-data-generated based simulation is constructed as part of an integral methodology.

2. Literature Review

The first problem that surges from the need for a faster response is the location of new installations. (Nekutova et al., 2015) addresses the location of a certain warehouse throughout classic mathematical models that pursue the minimization of transportation costs, usually reducing the distance between the distribution center and the client, departing from a scenario without prior warehouse consolidation. Although it further contemplates as part of its considerations for the location of a warehouse distinct qualitative elements such as access to roads and public transport availability, it lacks to deepen these aspects, neither it proposes methods nor methodologies for its evaluation. On the other hand, (Melachrinoudis and Min, 2007) addresses the localization problem with the redesign of an existing warehouse network, solving the problem through a mathematical model which consolidates an established number of warehouses into a fewer number of masters stocking points, eliminating redundant or poor efficiency points(Kuehn and Hamburger, 1963) approaches the warehouse location problem through a multi-plan mathematical model for a scenario without previous warehouse, only considering financial factors for decision making, without seeing any type of qualitative element. Contrarily, The World Bank (2018) presents the logistic performance index (LPI) as a tool to evaluate qualitative elements into international logistic market. Although it is developed for governments and macro-market studies, it exposes a clear idea as in a qualitative scheme of evaluation should look like.

The continued problem after localization is warehouse sizing, searching to define and delimitate the facility's size, as well as parking necessities. (Gu et al., 2010) proposes that warehouse sizing can be presented in two different scenarios: 1.) when inventory levels have been externally determined, and 2.) when the warehouse can directly control the inventory policy. Upholding this previous scenario, factors on consideration include seasonality, storage policy, warehouse construction cost and holding and replenishment cost, whose effects in the total storage capacity should be shown using a simulation, however, it does not deepen a methodology for this topic. (Nekutova et al., 2015), It also explains the importance of inventory policies, as it says customer demand is one of the attributes that can't be predicted with accuracy, thus, the storage has been turned into a fundamental part in a logistic system, inclining companies to keep an adequate service and inventory levels through supply channels and demand coordination.

Once the general dimensions of the warehouse and its external areas are defined, it is required to determine the internal layout and the referent operation to the distribution center management. (Gu et al., 2007) propose a theoretical methodology framework for the configuration regarding operations of the distribution center along with a design guided structure, even though it lacks one last proposal validation stage. (Gu et al., 2010) express that internal configuration storage needs to be based on the behavior of the different stock keeping units of the business, even though further analysis on the subject hasn't been presented. (Huertas et al., 2007) acknowledges the distinct considerations during the selection of a layout design, that even though there is no particular methodology that solves elements under study, ongoing characteristics exist between the layout and the operation. As an example, it proposes as rule of thumb that a U shape layout is appropriate for warehouses with a strong ABC classification. Bentz (2017) defines what a strong ABC classification should be:

Once design proposal and warehouse tactical operation are defined, some authors suggest implementing a result validation phase through the use of simulation(Gu et al., 2010). (Huq et al., 2006) demonstrate through an analysis of variance that a scenario with two warehouse replenishment systems, compared with one existing warehouse scenario, indeed reduces significantly delivery lead times. These results have been told to be validated with the use of a simulation methodology even though this hasn't been presented. As reported by (Huq et al., 2006), distinct authors have explored the use of simulation for a single stock item inventory problem, nevertheless, it exposes the existent gap between theory and practice where advanced models present a construction flow far distant from real world situations and decision making. (Zhou et al., 2013) evaluate the warehouse operation throughout a simulation presenting a flow construction scheme; and though it's able to identify bottlenecks for their specific problem, the simulation limits to single stock item study.

After literature review over concern topics, a lack of an integral methodology for redesign logistics network and simulation validations on warehouses scenarios was identified. Therefore, this work aimed to develop a methodology that provides a guided structure for project enforcement and appraisal; both location and design problems, as well as validation phase, are included.

3. Designed Methodology and Methods

Two important sources root the development of this methodology: 1) (Gu et al., 2010) research and a companion paper (Gu et al., 2007), where a methodology framework for warehouse design and operation is presented; and 2) LPI from World Bank Group (2018), a reliable metric used to measure logistic performance around the globe (2018). The proposed methodology is divided into four different phases (Figure 1): appraisal, location, design and validation, which unite all the fundamental parts of the network redesign process, further suggesting a validation-proofreading loop on the resulting design.

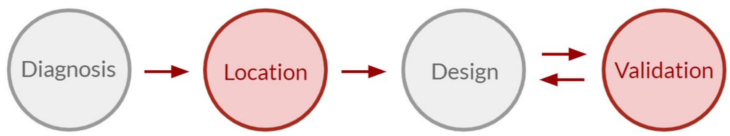

Figure 1: Methodology flow

The first stage, as a standard of classic engineering projects, represent the first diagnosis of the needs and problems to be solved. Throughout this phase, the current situation is defined, the general and specific objectives are established, most of the required information from the company is collected, and critical success factors are determined.

The second phase of location is divided in two major parts, quantitative and qualitative sides. Quantitative side is based upon a standard location mathematical method, seeking to determine a geographical spot that minimizes the distance from the new distribution center (DC) and the current delivery sites (locations/clients/customers). On the qualitative side, a developed qualitative method is presented. Quantitative literature research exhibited vast information regarding location problem. Otherwise, when it came to qualitative literature research, the main majority of articles suggest minor elements of support on the facility's qualitative evaluation, while bypassing further methods or methodologies. The Logistics Performance Index (LPI) was an initial reference that was taken into account but lacked as a flexible tool on different kind of projects. The proposed method, called Easy Consulting Qualitative Location Index (ECQLI) (Figure 2), considers six main factors to take into account: infrastructure, tax incentives, environmental conditions, security, workforce and proximity to relevant ports. Some of these contain elements that can be weighted based on decision-maker's preference and needs, with the intention of having higher flexibility as a tool. Look at decision maker's preferences was an aspect found on (Agrebi et al., 2017). Even though factors from the designed method are different from the existing factors in the LPI, results display is based on the LPI's radar result chart (Figure 3). Therefore, through a quantitative approach and a qualitative support, this phase gives solid results to continue to design stage.

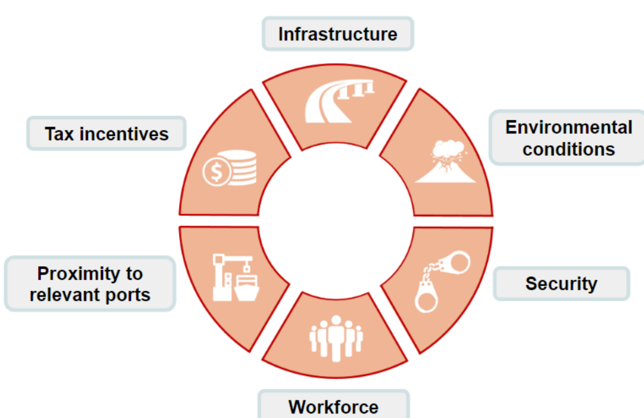

Figure 2: EC Qualitative Location Index

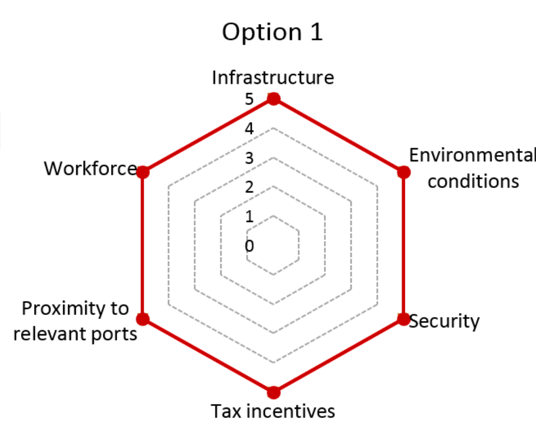

Figure 3: ECQLI radar result chart

For the third stage of the methodology, the design phase, a reliable reviewed framework (Figure 4) is proposed as the go-to execution method given its thoroughness. The Framework separates all major concerns on warehouses' development into two major parts: 1) warehouse design (functional elements) and, 2) warehouse operation (operational elements). According to project's outputs and terms, the decision maker can decide the detail level that's needed to carry out this phase and continue with project's last stage: validation.

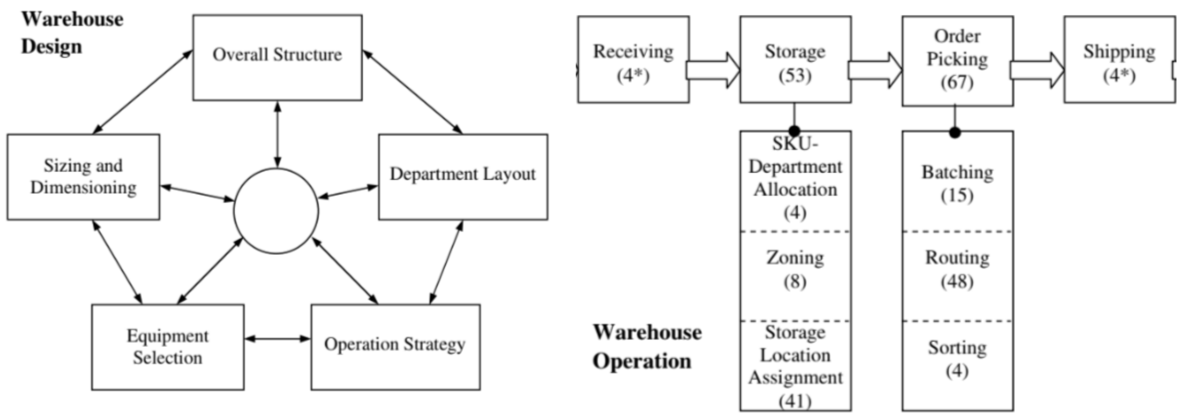

Figure 4: Framework for warehouse design and operation problems

The last part of the methodology is the validation phase. Though few sources suggested a validation stage, no method nor structure was further explored on how to deliberate a design validation. Authors have inquired into single stock item simulation, attempting to agree on the design proposals. Nevertheless, real world problems include greater infrastructure and operation degrees, where more than a single item behavior must be studied. The validation simulation used in this project was developed in a specialized software called ProModel. It looked at different product-family's behavior, and its occupation ratios according their physical dimensions regarding truck-type loading and internal storage; furthermore, it took into account families and product distributions for random-generated demand, and truck-type usage distributions.

4. Application Case

The group on which this application case was made, consists of 4 manufacturing companies and 1 trading company. This group is dedicated to the manufacture and marketing of equipment for food processing. In January 2019, it consolidated its operations in a DC located in an industrial city of Nuevo León, México, and is in charge of distributing the products to the entire country.

4.1. Diagnosis

In the diagnostic stage, a preliminary analysis of the company was carried out, in which the sales volume that each of the five companies that make up the group was determined. These percentages indicated that about 90% of sales are from equipment and the other 10% is focused on the market of accessories and spare parts for the same equipment. The application approach of this case was carried out only on the equipment given the proportions and since the spare parts follow a completely different process.

The group's product range can be divided into 33 different families. The family criterion was defined by the similarity in dimensions and operation. Sales behavior is similar in all families, where one or two products cover about half of that family's sales volume.

The group has a total of 144 clients throughout the republic, however only 40 of them represent 80% of the total sales volume, which indicates that some are more important than others. On the transport issue, the group uses four different types of transport: 53-foot box truck, moving truck, 3.5-ton truck and torton truck. With the current DC location, the first two types of transport make 80% of the trips. Group sales are divided into four regions throughout the Mexican Republic and with their respective sales percentages: North 26%, Center 32%, Pacific 31% and

Southeast 11%. It is evident how most of the sales are focused in the central region of the country and in the states closest to the Pacific, which is directly related to the use of the biggest transportation given the need to travel long distances from Monterrey to the central region.

4.2. Location

The localization stage was based on the measurements obtained in the diagnosis. As a first exercise, a center of gravity or COG model was developed. This model considered each of the 144 customers of the group with their respective coordinates and demands in sales volume. As a result of the model, the coordinates of the new location were obtained given the locations of the customers that were introduced to the model. The optimal point for the location of the new DC was the x: 20, y: -100.1 coordinates. Such coordinates are referring to the city of Temascalcingo in Mexico City. The transportation cost associated with the solution was $ 17, 553,489 considering T1 (Transportation supply cost from factories to DC) and T2 (Transportation distribution cost of DC to customers). Based on the results of the location obtained by the COG model, a study of the region surrounding the city of Temascalcingo was made and nearby cities were selected to compare transportation costs individually. The variation in transportation costs of all cities was not more than 5%, so this variable becomes irrelevant for the decision on the final location point. Figure 5 shows the location of the considered locations.

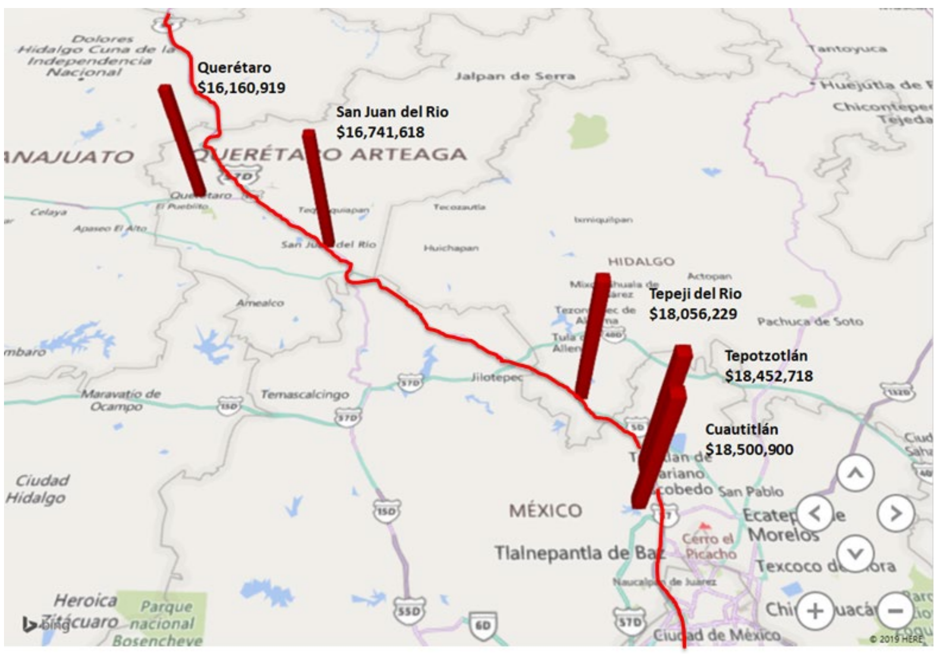

Figure 5. Considered locations surrounding the optimal COG model.

Subsequently, the qualitative analysis of the EC Qualitative Location Index tool was carried out. The categories that were considered for comparison were: Infrastructure, Fiscal incentives, proximity to international ports, Human Resources, security and environmental conditions. Adjustments were made in some categories of the tool given the specifications of the clients where it was sought to highlight for each of the categories some relevant indicators were investigated in the country, especially in the Infrastructure category that turned out to be of great interest to the company by corporate strategic plans. The result of the comparison indicated that the most suitable cities to locate the DC were San Juan del Rio and Queretaro, both in the Querétaro state as shown in Figure 6. The final decision of the group was San Juan del Río as a starting point for the construction of DC.

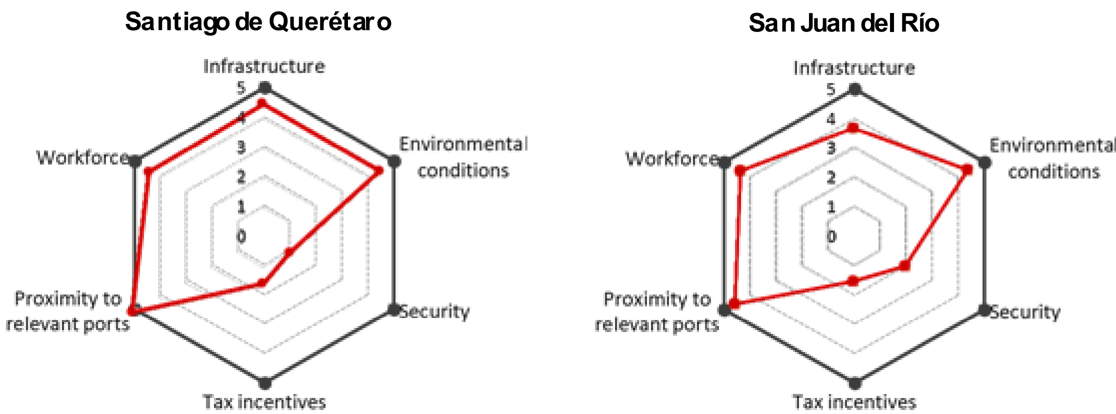

Figure 6. Qualitative Location Index for the two best locations.

4.3. Design

Once the location was selected, a demand allocation model was carried out, which indicated the optimal combination between the DC, customers and the type of truck that should be used, minimizing the total transportation cost. The results of the model indicated that San Juan del Río would be left with approximately 70% of the company's clients and 76% of the demand proportion, while Monterrey was left with only 30% of the clients and with 24% of the demand proportion. Figure 7 shows the covering map per DC.

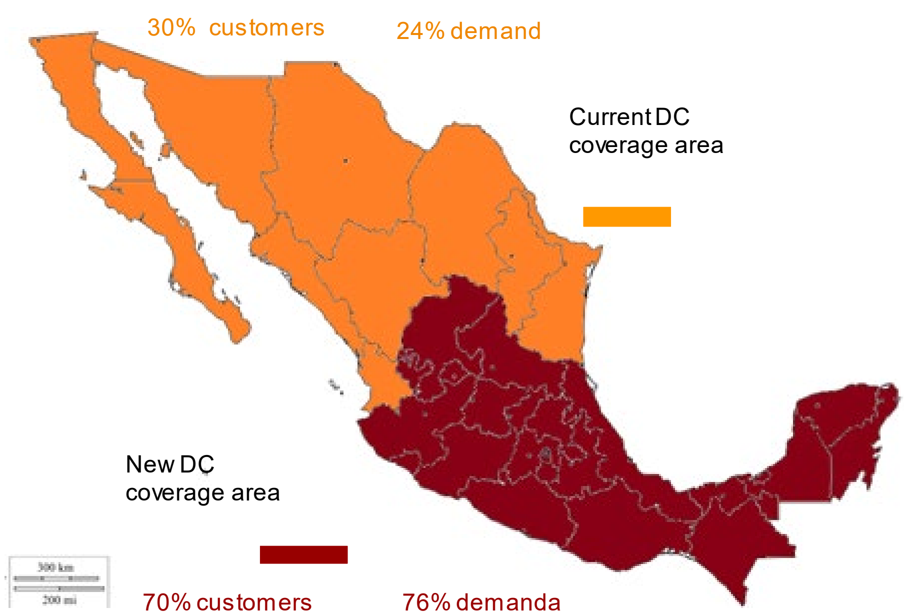

Figure 7. Results of the allocation model. Covering areas per DC.

Once the demand for the operation of the DC was distributed, the maximums in inventory were determined according to an inventory policy. For this, it was decided to carry out an ABC analysis of the demand corresponding to the San Juan del Río DC, with the purpose of determining the appropriate inventory policies for the different product groups and their respective behavior. Group A of the analysis was treated at the SKU level, products that represent 80% of the group's income. Two statistical tests were performed for each group: Equal variances test, and correlation test. This in order to understand their behavior, and according to this define a generic assumption of demand behavior to determine the appropriate inventory policy. For group A it was decided to work under a stable demand assumption, using the EOQ inventory policy for stable demand. Group B of the analysis was worked by families, constituted by the SKUs that represent 15% of the sales revenue. For these group two different methods were used: Silver Meal and EOQ. The decision is based on the coefficient of variation of each family. For a coefficient of variation less than or equal to 0.2, the EOQ method for variable demand is used; otherwise, for the coefficients greater than 0.2, the Silver meal inventory policy is used. For group C, the EOQ policy for stable demand was used. Silver proposes that within an ABC analysis, the elements belonging to group C are elements of low dynamics and low economic contribution, so the inventory method or policy used is indifferent.

Once the inventory maximums were obtained, the general dimensions in racks and floor necessary for the storage of the different products were determined. from the numbers obtained from the inventory policies and according to the type of storage required for each product. The result of the analysis showed that 2,125 rack spaces and 623 m^2 of floor space were needed. Detail design specifications are not provided for confidentiality reasons.

The planning horizon for this DC was 5 years. The reason for this time is due to strategic aspects of the company where the corporate objective is to grow twice every five years; however, given the factors of national GDP that this type of product has and background in the growth of the group, an intermediate scenario in which the DC design will be able to withstand a 45% increase in demand in the same five years.

Among some other steps of the design phase, aspects were defined as the general structure of the warehouse where it was determined that the internal flow of products that the DC will have as well as technical aspects of the Layout where the number of loading and unloading doors was determined that the warehouse must have given the demand it would receive. The adjustment of the office area was carried out in proportion to that of Monterrey.

4.4. Validation

To validate the design a simulation was carried out from an external file of arrivals with random numbers, which was prepared with a database with the actual orders of the company for three full months, in order to generate the same effect on the simulation as in the current process and get the results that most closely resemble reality. The period in which the simulation was carried out was in the month with the highest demand of the fifth year; or in the planned intermediate scenario with an increase of 45% of the current demand.

Among the final results that the simulation shows a 30% in the use of the loading doors, which indicates that the number of doors that the warehouse has is sufficient and is capable of supporting a greater demand for which it was designed. The forklifts used in the process have a 65% utilization. The average number of trucks to be loaded per day is 14 with 85% of its capacity which is very efficient given the variety in product dimensions.

The simulation gave us the opportunity to make important decisions on issues that concern and impact the company as well as operational processes, money and time. For this reason, it is essential to continue exploring simulated scenarios together with the client to obtain more findings and make better decisions.

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Biographies

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