Evaluation of The Feasibility of Centralization of Warehouses in The Construction Company VIDUSA.

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Abstract

This document presents a research project that consisted of verifying the logistical viability of centralizing warehouses in a construction company called Vidusa. The project was carried out in stages, the first stage consisted in structuring the statement of the problem by collecting as much relevant information as possible through interviews, observation and historical data such as volume flow of building materials, the location of the warehouses, the home construction projection, etc. in order to understand the processes of the company and how it operates; The next stage consisted in analyzing the information, first, to find out where to put the centralized warehouse, the median p model was used, which seeks to minimize the distance between warehouses taking into account the construction of houses per year in each construction site. This model was run in Python, in a Google library called Or-Tools, which allows to run Mixed Integer Problems (MIP). Once the location of the new centralized warehouse was selected, the Vehicle Routing Problem with Time Windows (VRPTW) was run to find out the route to follow to deliver the building materials to the construction site. In which the number of vehicles, the delivery time windows of each site, the daily volumetric demand and the volumetric capacity of the vehicle were taken into account. Restrictions were added so the model could decide whether or not to visit a construction site and for the number of vehicles to use. The model was also run in Python. Once done the analysis of the operations and the supplies used in the constructions of housing along with the results obtained in the mathematical model, the project proceeded with the design of the warehouse in FactoryCAD using as template an actual warehouse that Vidusa already owns. On this design were considered the changes the actual process will have, like the use of a loading dock for each of the routes the warehouse will have, this to facilitate the load of the trucks. Also, how the supplies will be transported and organized inside the warehouse. The feasibility of the project was determined by comparing the costs of the initial investment and the costs of the operations involved in the current situation versus the proposed solution. The costs compared were the price of the equipment required (e.g., cantilevers, vehicles, lift trucks, etc.), the maintenance, services, fuel, among others. The analysis was carried out by simulating 5 years of the two scenarios and verifying if the proposed solution would impact the operating and investment cost of the current situation by reducing them.

Keywords
Warehouses, financial, VRPTW, feasibility, households

1. Introduction
Vidusa is a Mexican company based in Monterrey that develops homes in economic segments (social interest or IS) and residential plus (medium interest or IM), throughout its history they have developed more than 88,000 homes, its process begins with the acquisition of the land, development of the project, the construction, and the delivery of the house to the client. In each of the constructions, a warehouse is built to store and protect the materials or supplies that are required until they are used.

Currently, the company has twenty-one warehouses and recognizes the need to improve inventory control, that is why is developing a project where the objective is to analyze the viability of the following points: centralization of warehouses, relocation of warehouses and reduce transfer times from warehouses to construction sites. Viability is defined in terms of cost reduction primarily. This document aims to formalize the investigation of the first point: the centralization of warehouses. An investigation is presented divided into stages where the problem statement is first presented, the current situation of the company is described and the problem is structured; theoretical concepts are described for a better understanding of the project; the methodology used to develop the project is also described; The information collected is presented as well as its analysis and the formulation of models that describe the problem; and finally a solution proposal for the problem is presented.

1.1 Objectives

The general objective of the project is: Verify the viability of the centralization of warehouses for optimal inventory control. This objective is supported by the following particular objectives:

- Verify that the centralization of warehouses allows the construction of houses in series.
- Design a replicable model to centralize warehouses.
- Define the financial evaluation in cost-benefit terms as part of the argument for the final recommendation of the feasibility of the implementation.

2. Literature Review

- ROI: return on investment, it is a performance measure used to evaluate the efficiency of an investment or investments through the relationship between the amount of return on a particular investment with the cost of the investment (Fernando, J., 2020).
- Location-Allocation: it is a model that aims to locate the facilities in a way that supplies the demand points in the most efficient way. Simultaneously locate facilities and assign demand points to facilities that minimize the distance between each point (ArcMap., w.d.).
- P-Median: it is a mathematical problem that helps to determine the partition of clients in *p* groups that minimize the cost. The problem considers the following: it is required to partition a set of clients into *p* groups. Each group is defined by its set of customers and the location of its median (facility that supplies it). Each customer can be assigned a median, usually represented by a network diagram. The median *p* is used to find the optimal locations, and it allows us to minimize costs and distance (Hernandez, L., w.d.).
- Python: It is a programming language that allows to work quickly and integrate systems more efficiently, it is used for multiple applications, such as modeling of optimization algorithms (Python Software Foundation, 2021).
- OR-Tools: python library that allows to solve MIP (Mixed Integer Problems) (Google., w.d.).
- VRP: The vehicle route problem is used to find optimal routes for a fleet of delivery trucks, the model allows restricting the capacity of the trucks in order to minimize the total distance. The model is built from one or more deposits and nodes that represent customers. Each customer has an order that can be fulfilled by inventory in the warehouse. A truck is then assigned to deliver orders to customers complying with the restriction of the capacity limit, according to a delivery route (Leelertkij, T., et al, 2021).
- Financial Analysis: It refers to the process of evaluating, in this case, a project to determine its profitability. It is useful because based on this analysis, decisions can be made or to review the past successes (Tuovila, A., 2021).
- GAAP (Generally Accepted Accounting Principles): They are a common set of accounting principles, standards, and procedures established by the Financial Accounting Standards Board (FASB) that U.S. companies must follow when they do their financial statements. Their objective is to improve consistency and make it clearer when a company communicates financial information (Fernando, J., 2021).
- Discount rate: It refers to the interest rate used when calculating the discounted cash flow in order to obtain the net present value (Hayes, A., 2021).
- NPV*:* It is the sum of the present value of the individual cash flows, that allows an investor to know the viability of an investment project. It consists of subtracting the amount initially invested with the present value of the flows that are expected to be received in different future periods. (Instituto Europeo de Posgrado, 2018).
- MARR: minimum acceptable rate of return, and represents the minimum return that an investor expects to obtain from an investment, considering risk, inflation, opportunity cost, etc. The MARR is obtained from the cash flows of the project and moving all transactions to the same point in time (present or future value), using the MARR as the interest rate. If the resulting value at that set point is zero or higher, the project will move on to the next stage of analysis as it is considered profitable. Otherwise, it is discarded (Sy, H., 2021).
- Certificates of the Treasury of the Federation (CETES): They are a debt instrument issued by the Mexican Federal Government used to raise funds over time and that generate returns to those who invest in them. Typically, it is used as a risk-free rate reference (BBVA, 2020).

3. Methods

The Dynamic Synthesis Methodology is a methodology that integrates theoretical concepts and allows the structuring of parts and elements of a research process or system over time to form a formal functional entity. The methodology is complemented by system dynamics modeling to help empirically explain and predict the behavior of problems or complex systems that are commonly observed in the performance of business processes (Williams, D., w. d) (Williams, D., 2005).

The methodology consists of six steps which are described below according to the same author:

- *Step 1: Problem Statement.* It is an important stage because you must declare the research question; the expected relationships between the research variables. As this methodology focuses on answering research questions rather than solving problems, it first starts with this question that must involve an empirical proof of the problem, the hypothesis.
- *Step 2: Field Studies.* At this stage, data collection methods are applied to provide invaluable insights and discoveries during system dynamics modeling. These methods can be through direct observation of the phenomenon under study, archived research, interviews, surveys, case studies, among others.
- *Step 3: Building Models.* The result of the field studies should be a descriptive model, at this stage a feedback structure is developed in the model turning it into a quantitative model of the research question. In this way, the model can be simulated, first the variables must be mathematically related and then propose scenarios.
- *Step 4: Case Studies.* It is an exploratory or explanatory strategy, which involves the empirical investigation of a phenomenon. This makes it possible to put theory into practice.
- *Step 5: Simulation of Experiments.* They are abstracts from a real system or problem that you want to solve. Simulation allows for trial-and-error experimentation to demonstrate the effects of certain policies, which must produce improvements to the model to be implemented.
- *Step 6: Use of Model and Theory.* As the structure of the methodology allows changes by feedback, at this stage is when, after model testing and simulation, the relevant changes are made according to the results that improve the model. In addition, it allows a dynamic hypothesis that can be tested by means of a causal loop diagram.

The methodology used in this project was selected because it combines system dynamics modeling and the case study research method. This allows the research question to be empirical (Williams, D., 2005)., in addition, it is composed of a flexible structure that allows feedback and changes to be made in the previous steps and also allows to combine descriptive mathematical models to quantitative models that can be simulated.

4. Data Collection

It was determined that it should first be analyzed which warehouses are active, how many constructions they will continue to build, closing date, etc., a database containing the projection of housing construction from 2021 to 2025 was analyzed. The database divides the projections by: Medium Interest (MI) and social interest (IS). After obtaining the elements of the total cost with the demand of each warehouse by year, which was obtained by knowing the operation of each and how many will operate per year and the total cost per year depending on the ones that are operating. With their locations, the distances in kilometers between them were obtained, by the largest road suggested by Google Maps.

To analyze the flow of material in the warehouses, the volume of the materials of the constructions that correspond to the projection of 2021 was analyzed, as well as their time of stay in the warehouse The given database had the units different: pieces, foot-plank, meters, etc. In order to be able to compare the materials with each other, to be able to estimate the minimum capacity of the warehouses in cubic meters and to be able to obtain the volume per house, it is necessary to obtain the volume of the materials. So, it was decided to visit Portales de Lincoln, because it handles a wide variety of materials. The visit consisted of measuring with a flexometer the dimensions of each input and recording its type of storage, that is, if it requires storage under lock and key or can be outdoors.

Figure 1 is a Pareto graph of the materials that can be centralized, in dark blue is the volume of the materials of IM and light blue color those of IS:

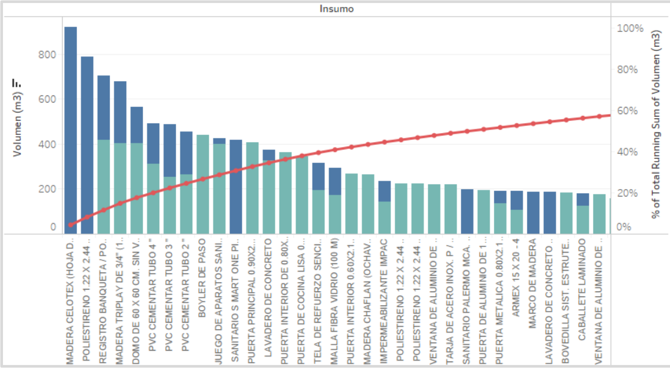

Figure 1. Pareto of the materials *divided by IS/IM.*

In Figure 1 it is observed that the most important input in volume is wood, followed by polystyrene and so on. Analyzing the behavior by IS and IM, it is observed that there are some materials that only belong to IM, others to IS and others to both. 80 percent of the volume of materials is covered by 49 materials out of a total of 638 materials. 8% of the materials are significant in terms of volume.

5. Results and Discussion

5.1 Numerical Results

Continuing with step 3 of the methodology: Model Construction, the location-allocation model was built, it was used to find the optimal location of the possible centralized warehouses and then analyzed in different scenarios.

5.1.1 Location-allocation model

Location-allocation is a long-established research problem. The overall objective of this problem is to position a certain number of facilities in optimal locations, so that they are able to serve specific demands or customers in an optimal manner (Vafaeinejad, A., et al, 2020). The best location of the warehouse must be the closest to all other warehouses, in addition to the distances, this location must be weighted according to the demand of materials of each warehouse to give more importance to those that require a lot of volume shortening its distance to the centralized warehouse, considering this, first the warehouses that have demand from 2021 to 2025 were obtained which are 24 , plus other possible locations which are the Taller Mecánico, so *I=25*, *J=25*.

The variables of the model are:
x_{ij}: 1, if the warehouse *i* distributes to warehouse *j*, 0 in any other case.
y_i:1, if the centralized warehouse is located in the warehouse *i*, 0 in any other case.

The parameters of the model are:
d_{ij}: Distance in km from warehouse *i* to warehouse *j.*
D_i: Projection of housing from 2021 to 2025 of warehouse *i.*
P: Number of warehouses to be centralized, where $P \in Z\{1,3\}$ *varies according to the scenarios

Considering that the objective of the model is to minimize the distance between the possible centralized warehouses and take into account the demand of all the warehouses, the following objective function was defined:

$$Min \sum_{i=1}^{I} \sum_{j=1}^{J} D_i * d_{ij} * x_{ij} \quad (1)$$

subject to the following restrictions:

- $\sum_{i=1}^{I} x_{ij} = 1 \quad \forall j \in J$ (2)
- $\sum_{i=1}^{I} y_i = P$ (3)
- $\sum_{j=1}^{J} x_{ij} \leq y_i \quad \forall i \in I$ (4)
- $x_{ij}, y_i \in \{0,1\} \forall i \in I, j \in J$ (5)

The restriction (2) ensures that all stores are visited, restriction (3) ensures that P centralized stores are opened, restriction (4) assigns to a single centralized store, and restriction (5) defines variables as binary. It was modeled and run in python using a library called OR-Tools, "an open source software for combinatorial optimization, which seeks to find the best solution to a problem among a large set of possible solutions" (OR-Tools, w.d.).

Continuing with step 4 and 5 of the methodology: Case Studies and Simulation of Experiments respectively, two scenarios were proposed to compare them with each other. In the first scenario the model is run assuming the opening of 3 centralized warehouses. The location of the centralized warehouses are in Arbado Monarca, Parque Zafiro and Valle de Oporto, the cost of the target function is $390,620 and the assigned distance is 414.6 km. The second scenario assumes the opening of 2 centralized warehouses. The location of the warehouses are in Parque Zafiro and Valle de Oporto, the cost of the target function is $565,455 and the assigned distance is 611.7 km. It can be observed that the greater the number of centralized warehouses, the cost of the target function is reduced, this is because the cost by km decreases when there are more warehouses, which makes the construction closer to it. The target function just takes in consideration the cost per km, not the cost of se services and the employees. In the next section will be describe with more detail the economic impact.

In a meeting with the manager, it was agreed that the second scenario would be the one that will be analyzed in detail, for reasons of time of the project, it was agreed to work only on the design proposal of Parque Zafiro and replicate this model in the other warehouse adapting it to their needs. When reviewing the location, it was found that it is closer to the Taller Mecánico, as it already has warehouse infrastructure, it was determined that the centralized warehouse of Parque Zafiro should be considered to build it in the Taller Mecánico.

5.1.2 VRPTW

Based on the previous assumptions, the following VRPTW model was built. The VRPTW is a generalization of the well-known VRP. It can be reviewed as a combined vehicle routing and scheduling problem which often arises in many real-world applications. It is to optimize the use of a fleet of vehicles that must make several stops to serve a set of customers, and to specify which customers should be served by each vehicle and in what order to minimize the cost, subject to vehicle capacity and service time restrictions. (Liong, et al, 2008).

The allocation model shows which warehouses will be supplied by the Taller Mecánico, during several interviews with the warehouse manager to see the planning of the routes and based on the above assumptions' modifications were made that are described below. As Cari, T., et al. (2008) say, changes needed to be made for the real-world application that solves VRP, it is essential to perform a fast selection of methods which produce the desired improvement of the objective function. Pilares and Privada Victoria are located a long way from the workshop, so it was decided that these two constructions continue to operate as they currently do, that is, that they have their own warehouse. While with the other warehouses it was decided that they will be supplied by the workshop.

In the first instance it was decided that each warehouse has its own route, which involves a large investment in the vehicles that transport the material from the workshop to the warehouses since each warehouse would have to have at least one vehicle. The purpose of this proposal is to comply with the window of delivery time to work without committing those in charge of the constructions to arrive earlier than usual in case of making a route that supplies, for example, three warehouses in a single lap. However, as part of the project, a scenario was added in which routes can be made and some warehouses can be put together on a route that is close to each other in order to minimize the investment. To do this, the VRPTW model was used. A parameter of the model, is the cost per kilometer of each truck, that is, for each kilometer how many liters it consumes multiplied by the price of gasoline, this parameter was calculated as follows: the price of gasoline, which is $20.9 mxn and the average consumption of the truck, which is 14.8 km/lt, were obtained, then the price is divided between the performance to obtain the kilometer cost, which is 1.412 $/km. With this data you can obtain the cost of transport once the routes are obtained using this model.

These are the model assumptions: the route has a single depot; there are different clients that are nodes, which have a different volumetric demand; each customer must be visited once per vehicle, if not visited, it is punished with a high cost; each route starts and ends at the depot; the total cargo of each vehicle must not exceed its capacity; each vehicle has the same capacity, all are trucks of the same dimensions; the most important thing to minimize is the distance of the routes; each customer must be given the material before their time window to receive it is finished; the unloading time was the same for all clients, being 30 minutes; the time window is the same for all customers, 120 minutes from the start of the tour; the centralized warehouse was moved to position 1 to facilitate its mathematical modeling.

1. Mathematical formulation.

The mathematical model represented by the VRPTW is formulated as a mixed integer linear programming (MILP). The model uses the following notations.

I: set of clients. $I = \{1,2,3,...,N\}$
I_2: set of clients except the centralized warehouse. $I = \{2,3,...,N\}$
V: set of vehicles $V = \{1,2,3,...,5\}$
N: number of clients N = 11

2. The parameters of the model are:

d_{ij}: Distance by road in km from origin *i* to destination *j*.
t_{ij}:Time by road in minutes from origin *i* to destination *j*.
D_vol_j : Daily volumetric demand by destination
a_i:Start time window
b_i:End time window
K: Number of vehicles to be centralized, where *K* Z{1, 5}
C: Cost per km
Cap: Vehicle capacity.

3. The decision variables of the model are:

x_{ijv}:1, if vehicle *v* travels from origin *i* to destination *j*, 0 otherwise.
S_i: variable used to avoid subtours, interpreted as the position of the node $i \in I_2$ in the route.
$Visita_j$:binary variable where 1 is if you visit node *i*, 0 if you do not visit.
u_v: binary variable where 1 if the vehicle *v* is used, 0 if not used.
w_{jv}: variable used for each origin *i* and each vehicle *v* and denotes the time in which vehicle *v* begins customer service *i*.

4. Objective Function

Considering that the objective of the model is to minimize the distance of the routes, the following objective function was defined:

$$Min \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{v=1}^{V} d_{ij} * x_{ijv} * C + \omega_1 \sum_{v=1}^{V} u_v + \omega_2 \sum_{j=1}^{J} (1 - visita_j) \qquad (1)$$

subject to the following restrictions:

$$\sum_{i=1}^{I} \sum_{v=1}^{V} x_{ijv} = visita_j \qquad \forall j \in I_2 \qquad (2)$$
$$\sum_{i=1}^{I} x_{ijv} = \sum_{j=1}^{J} x_{jiv} \qquad \forall v \in K \qquad (3)$$
$$\sum_{i=1}^{1} \sum_{j=2S}^{J} x_{ijv} \leq 1 \qquad \forall v \in K \qquad (4)$$
$$\sum_{i=1}^{1} \sum_{j=1}^{J} x_{ijv} \leq u_v * N \qquad \forall v \in K \qquad (5)$$
$$S_j - S_i \geq 1 - (n(1 - \sum_{v=1}^{V} x_{ijv})) \qquad \forall i \in I_2, \forall j \in I_2 \quad i \neq j \qquad (6)$$
$$\sum_{i=1}^{1} \sum_{j=1}^{J} Dvol_j \; x_{ijv} \leq Cap \qquad \forall v \in K \qquad (7)$$
$$w_{iv} + t_{ij} + td - M_{ij}(1 - x_{ijv}) \leq w_{jv} \qquad \forall i \in I, \forall j \in I_2, \forall v \in K \qquad (8)$$
$$a_i \leq w_{iv} \leq b_i \qquad \forall i \in I_2 \qquad (9)$$
$$x_{ijv} \in \{0,1\} \qquad \forall i \in I, j \in J \; \forall v \in K \qquad (10)$$
$$visita_j \in \{0,1\} \qquad \forall j \in J \qquad (11)$$
$$u_v \in \{0,1\} \qquad \forall v \in K \qquad (12)$$
$$w_{iv} \in Z \qquad \forall i \in I, \forall v \in K \qquad (13)$$
$$S_i \in Z \qquad \forall i \in I \qquad (14)$$

The objective function (1) minimizes three things, the total distance traveled by all vehicles, the number of vehicles to operate as little as possible and the number of customers not visited. Restriction (2) considers that all destinations are visited and punishes if not visited. Restriction (3) ensures that if a *v* truck reaches a customer, it must leave that warehouse, it is of flow of movement. Restriction (4) ensures that each vehicle only leaves the depot once. Restriction (5) allows all nodes to be visited if the truck is used, if not used, it must be equal to zero. The restriction (6) is the elimination of subtours proposed by Miller Tucker Zemlin. Restriction (7) limits the load of each vehicle with its capacity. The restriction (8) establishes the relationship between the departure time of a vehicle and its immediate successor. Restriction (9) states that time windows are observed. The constraint (10) - (14) specifies the type of decision variables.

Python was used for the mathematical model, like in the previous model. This made it easier to move information from one model to another and its interpretation. The result that the model yielded, meeting all the constraints of time windows, stake capacity, flow, etc. Talking to the client, he mentions that the route for each stake is adequate.

- **Route 1:** The estimated arrival times to each of the constructions, considering 30 minutes of unloading and departure at 6 am from Taller Mecánico are: 6:13 am to Adara ➞ 6:51 am to Samsara ➞ 7:25 am to Altrysa with 20 km of total travel.
- **Route 2:** For the second route considering that the vehicle leaves at 7 am from Taller Mecánico: 7:10 am to Parques Zafiro ➞7:51 am to Portales de Lincoln with 29.8 km of total travel.
- **Route 3:** The estimated arrival times to each of the constructions, considering 30 minutes of unloading and departure at 6 am from Taller Mecánico are: 6:26 am to Solana ➞ 7:00 am to San Gabriel ➞ 7:35 am to San Manuel with 38.7 km of total travel.
- **Route 4:** For the fourth route considering that the vehicle leaves at 7 am from Taller Mecánico: 7:15 am to PH Linces ➞ 7:52 am to Arbórea with 20 km of total travel.

5.2 Proposed Improvements

First, the capacities in m^3 of the warehouses that Taller Mecánico will supply must be estimated. For this purpose, these warehouses were obtained, each one was registered with its type (IM /IS), its capacity in m^3, its demand of 2021 and its volume per house was calculated dividing volume by demand. This information was not complete, this is due to the problem with the flow of information mentioned above. To obtain the information of all the warehouses it was chosen to estimate that of the missing ones, the only thing missing is the capacity in m^3. What was done was to calculate the average volume per house of IS and IM; 0.10 m^3/house and 0.43 m^3/house, respectively. Then the corresponding average was multiplied with the demand of the missing warehouse. This information was used to estimate the capacity of the centralized in Taller Mecánico, it is obtained by adding all the capacities of the warehouses to which it will supply, the estimate of the capacities of the remaining warehouses suggest an increase of 24.53%. Subsequently, the maximum weekly volume of each subcategory is obtained, multiplied by two (15 days). The total volume is 80.85 m^3, multiplying it by two obtains 161.7 m^3, to this amount is added the 24.53% increase in estimation of the missing warehouses and 20% of clearance to support the increases in demand. Thus, obtaining an estimated capacity of 241.64 m^3 (considering only the volume of materials).

This is the first sketch of the layout. To do this, a satellite view was first obtained through Google Maps to be able to size the terrain, it is approximately 9,380 square meters. The warehouse has an approximate area of 1,027 square meters. That is the space that is available for the design of the warehouse, in addition, during the visit to the workshop it was agreed that, if necessary, the warehouse could still be extended to the front a few more meters. The minimum space required for each subcategory is based on the maximum weekly volumes per subcategory. First, the materials of each subcategory were analyzed to identify what type of storage they require or some specific structural element. When performing this analysis, it was found that some subcategories contain small materials that are used for plumbing and electrical equipment, the supplier delivers them in boxes of approximately 30 by 30 cm, therefore, it was decided that these subcategories should be stored in racks to facilitate their access and optimize the space. Other subcategories are large and heavy to be placed in racks, such as floors, adhesives and buckets of paint, so it was decided that they should be stored on pallets. Subcategories that are long or cannot be stacked on pallets such as doors and some plumbing pipes will be in a cantilever. Pulverized includes materials such as sand, soil, etc. so it was decided that these inputs will go directly to the construction as mentioned before.

Based on the visit to the workshop and agreeing with the manager it was determined that the materials that are high in value must remain locked, in rooms on the left part, the space of the workshop is large enough to be able to store these inputs inside, one room per warehouse that the workshop will distribute. Figure 2 shows the sketch of the warehouse. It was considered 3 meters wide for each corridor as they will be two-way. As mentioned before, on the left wall there will be a closed room to protect supplies that need to be locked, the other materials that require to be in racks but not necessarily locked will be placed by the wall of the warehouse to the bottom, these weight the least, therefore it is more convenient to move them greater distance than the heavier ones.

Figure 2. Design proposal of the Mechanical Workshop.

In the middle will be the pallets separated by subcategory for quick access since they are of daily movement, these include the buckets of paint, powders, floors, tiles among others, the stacking of the materials will not be greater than 1.5 mts in height. Entering the warehouse on the right the cantilevers with the tubes, doors, windows, etc. will be placed since the cantilevers require more space and have greater height, in addition, they will be located near the exit of the internal staff to facilitate the transfer to the bays this in order that when moving other supplies prevent them from being damaged. The technique used to locate all products inside the warehouse is the fixed location, allowing time saving in the storage process, creating order, location of products all these because the employees are already familiar with the location of the input or product. (De Koster & Neuteboom, 2001).

The design proposal includes an inventory management proposal, from planning the arrival of suppliers to delivering materials to on site. All the process and distribution of the warehouse is designed considering the human factor as key for the order picking. Once you create specific routes, a specific space for every material it increases the efficiency of the order picking (Grosse, et al, 2015). It was determined that there should be one warehouseman per warehouse supplied by Taller Mecanico. In the sketch it is observed that there are some tables attached to the wall where the entrance is located, those tables will be the offices of the warehousemen. The average of the maximum daily volume of the warehouses is 3 cubic meters, this means that a small cargo truck can be used. The administration process of the inventory is divided into two sub processes, the first is all the supplies that enter the warehouse.

The process starts with the arrival of the suppliers at 9:00 hrs. 5 at most. once they arrived the landing starts, when completed, it begins the registration of the supplies on the inventory system where are involved the 11 warehouse employees, this way the landing is more efficient. Next, all the supplies are stored in the correspondent place. There are also intern warehouses, all supply that is stored in here is first packed, this idea was replicated from one of the visits to the PH Linces warehouse, this process made the delivery process more efficient. For this process it was designated a packaging station. every warehouse is assigned to an intern warehouse,

The second process is where all the supplies are moved to the correspondent bay. First the receipt of the order for each of the works enters through the system, sent by the work resident at 5:00 p.m., this way is delivered the next day. Then the manager proceeds to prepare the order, taking the requested inputs to the bays corresponding to the route, carried by a forklift or a platform cart. The third and last sub-process consists of leaving the warehouse at 6:00 a.m. to deliver on site no later than 8:00 a.m., with the VRPTW these time windows are ensured. It begins by receiving the stakes with their designated drivers, each of the drivers together with the storekeeper arrive and park in their corresponding bay according to their route, they review the order made the day before and that all the supplies are in the bay and from there proceed to be loaded to each of the corresponding stakes.

Once it is verified that the order is complete and the truck has been loaded, the driver and warehouseman sign the receipt which is filed in the system, then the truck begins its delivery route. Within this process, the case of missing material upon delivery is considered because it was necessary to order this input a day before. For this, within the process, there is the possibility of giving a second round by ordering the input by the warehouse manager before 11:00 hrs. in order to have time for the storekeeper to receive the order, prepare it and the driver can return. to the warehouse to pick up the order and deliver it to the work site at 3:00 p.m. In order to start the warehouse process, the work manager must review the TAKS to be carried out the next day in order to order the necessary supplies to work the next day. Once the work manager reviews this, he proceeds to generate the order for the supplies so that it reaches the warehouse directly through the system. Once this order reaches the warehouse, the manager reviews the order and proceeds to prepare it.

5.3 Validation

In order to validate that the proposed design will improve the operation, a financial analysis (Tuovila, A., 2021) was made. Following the GAAP (Fernando, J., 2021), but approaching it from a cost reduction perspective, the costs of the actual situation were obtained. To accomplish that, the production costs of all the warehouses were obtained, to compare the design proposal it was considered only the warehouses that the workshop will supply. The annual cost was broken down into five components: Salaries, Guards & K9's, Uniforms, Light plant and Diesel. Their respective costs were tabulated, this information was the starting point of the financial analysis. Then, the years that each warehouse will operate was obtained to get the cost per year depending on the warehouses that are operating. Table 1 shows the breakdown of costs by year adding the warehouses that are operating in that year, this represents the operating costs per year of the Taller Mecánico.

Table 1. Operating costs per year of Mechanical Workshop.

Production Costs	2022	2023	2024	2025
Salaries	$2,983,500	$2,983,500	$2,709,720	$1,818,180
Guards	$6,387,660	$6,387,660	$5,638,961	$3,392,863
Uniforms	$182,081	$182,081	$158,331	$102,915
Light plant 7000 watts (rent)	$30,000	$30,000	$27,000	$18,000
Diesel (light plant)	$816,092	$816,092	$734,483	$489,655
Total	**$10,399,333**	**$10,399,333**	**$9,268,495**	**$5,821,613**

In order to compare them with each other, the discount rate (Hayes, A., 2021) must be made by converting all costs to present value in order to add up the total costs. The formula to get the NPV, in this case, is as follows:

$$NPV = \frac{F_{2022}}{(1+i)^1} + \frac{F_{2023}}{(1+i)^2} + \frac{F_{2024}}{(1+i)^3} + \frac{F_{2025}}{(1+i)^4} \quad (1)$$

The cash flows F_n are the total costs shown in table 1. The cash flows are divided by $(1+i)^n$ where i is the interest rate. The interest rate represents the minimum acceptable rate of return (MARR). This rate is composed of three elements: the return on a low-risk investment, inflation, and a return-on-investment risk. For the calculation of the MARR in this case the estimate of inflation in the next 4 years was consulted which is 3% per year. As a low-risk yield was considered the yield of the CETES (BBVA, 2020) whose estimated yield per year is 4.75%. Finally, the company told the team that the risk premia they take by making investments in projects like this is 13%.

$$MARR = risk\ free\ investment + inflation + risk\ if\ the\ investment \quad (2)$$
$$MARR = 4.75\% + 3\% + 13\% = 20.75\% \quad (3)$$

In the previous equation it is observed that the MARR is 20.75%, with this interest rate, the annual costs of equation (1) are converted into present values. The substitution of equation (1) is as follows:

$$NPV = \frac{\$10{,}399{,}333}{(1+0.2075)^1} + \frac{\$10{,}399{,}333}{(1+0.2075)^2} + \frac{\$9{,}268{,}495}{(1+0.2075)^3} + \frac{\$5{,}821{,}613}{(1+0.2075)^4} \quad (4)$$
$$NPV = \$23{,}747{,}384 \approx \$23.7\ millions \quad (5)$$

Equation (5) shows that the NPV is $23.7 million, that is, if the company continued to operate as it currently operates until 2025, this value was used to compare it with the value of the operating costs and investments of the proposal in order to analyze the financial viability of the project. Further is the financial analysis of the proposal.

In the section of Warehouse Design, it was described the necessary equipment for its internal management. The company already has many tools and equipment that will be reused. The ones that do require investment are trucks, forklifts, industrial skates and lamps. The NOM 025-STPS-2008 standard establishes a minimum requirement of luxe for different work areas depending on the activities carried out in that space. The level of lighting required for circulation areas and corridors was considered to be 100 luxes. To know how many lights are needed according to the NOM, a type of lamp was first considered as an example to have its lighting flow as a reference. it was obtained that 15 lamps must be purchased to satisfy the lighting with a total cost of $28,705. The manager estimated the cost of installing the lamps, air conditioners and security cameras, (the last two are already own by the company) as $ 5,000 each.

The maintenance of the forklift was consulted on by a company that offers this service, estimating $211 thousand per year for the five forklifts. With the calculated kilometers per year per truck the required maintenance was obtained depending on the mileage, according to Nissan the NP 300 gasoline truck requires maintenance every 10 thousand kilometers. The consumption of each truck is 14.8 km/l, if the total km per year is divided this number to obtain the total liters of gasoline consumed per year. The total of liters was multiplied by the price of magna gasoline and thus the annual cost of gasoline was obtained for the 4 trucks.

The light was estimated by applying the GDMTH rate of the CFE, which is $514,825 per year. Finally, there are the costs of staff salaries. A warehouseman's salary is $2,700 per week. In addition, it was considered to hire two assistants to support the warehousemen, their salary is $1,700 per week. For the security of the warehouse will be hired 2 guards and a dog K9, the salary of the guard is $ 13,572 monthly and the dog is $ 5,500 monthly, apart from an annual investment of $ 15,833 per year must be made for the uniforms. Also, 4 drivers will be hired to handle the stakes, their weekly salary is $1,500. Table 2 summarizes warehouse operating costs, initial investment, and additional expenses. To the salaries were added 35% to consider the benefits since what should be considered in the expense of the salary is what it costs the company, not the free salary:

Table 2. Total costs per year and initial investment.

	2021	**2022**	**2023**	**2024**	**2025**
Warehouseman		$1,895,400	$1,895,400	$1,895,400	$1,895,400
Auxiliary		$1,193,400	$1,193,400	$1,193,400	$1,193,400
Guards & K9s		$1,043,132	$1,043,132	$1,043,132	$1,043,132
Drivers		$421,200	$421,200	$421,200	$421,200
Electricity		$514,825	$514,825	$514,825	$514,825
Gasoline		$83,431	$83,431	$63,596	$44,047
Trucks		$461,700	$1,044,600	$485,800	$674,700
Forklifts		$211,200	$211,200	$211,200	$211,200
Trucks	$1,551,600				
Forklifts	$1,850,000				
Industrial skates	$90,000				
Lamps	$28,705				
Lamp installation	$5,000				
Air conditioner installation	$5,000				
Security cameras installation	$5,000				
Total	**$3,535,305**	**$5,824,289**	**$6,407,189**	**$5,828,553**	**$5,997,905**

The total costs of table 2 as well as the initial investment were converted to present value so that they can be compared with each other and then compared against the current operation, using the same equation with the same MARR of 20.75%, but now adding the initial investment, the equation for the net present value of the total costs of the proposal is as follows:

$$NPV = \$3{,}535{,}305 + \frac{\$5{,}824{,}289}{(1+0.2075)^1} + \frac{\$6{,}407{,}189}{(1+0.2075)^2} + \frac{\$5{,}828{,}553}{(1+0.2075)^3} + \frac{\$5{,}997{,}905}{(1+0.2075)^4} \quad (8)$$

$$NPV = \$18{,}869{,}923 \approx \$18.8\ millions \quad (9)$$

Recalling that the net present value of the current operation in equation (5) of this section is $23.7 million, it is observed that this scenario of the proposal would positively impact costs reducing from $23.7 million to $18.8 million, this represents a 20% reduction in costs. It should be noted that the costs are based on estimates, due to the problem of the flow of information, however it is a scenario with estimates that were made together with the people of Vidusa to be as close to reality as possible. Leaving that detail aside and based on the results of the model, this proposal verifies that it is feasible to centralize warehouses since it would help to reduce costs in a great way in the short term.

6. Conclusion

The Dynamic Synthesis Methodology facilitated the process of analysis, giving the structure necessary for the project. In the first step the establishment of the objectives was crucial, this way the range of the project was delimited. Also, it was possible to identify where the problem was and be able to structure it. The second stage of the project consisted of analyzing the information collected and building the models in order to determine a solution proposal. The most important thing in this stage was the establishment of the assumptions since the solution depends completely on them. At this stage, all relevant aspects that affect the operation of the warehouses were identified and analyzed to obtain the cost of the current operation of the company, salaries, infrastructure, security, among others. The next stage is the design proposal, after several visits to warehouses and to Taller Mecánico, the best practices of each were determined to be replicated, a first sketch was worked which began as a replica of the Taller Mecánico warehouse, during the process requirements were added according to the result of the models and the assumptions that were established. The most important part of this stage is to be able to design a proposal considering all the points of view, from the people who are on the construction site, the architects who plan the taks, the managers of the warehouses, etc. The first two objectives were accomplished in this stage, the centralization of warehouses allows the construction of houses in series and the replicable model was realized.

Another important part is to verify the financial viability, the improvement should be reflected in an increase in profits, which in this case is due to cost reduction. In the financial analysis, all the factors that generate expenses were identified, either for initial investment or for operating expenses. In the end, the expenses per year are converted to present value in order to be able to be compared with each other and to determine a decision. The result of the simulation showed that the centralization of warehouses is feasible because there is a cost reduction of approximately 20%; This is based on the estimates described in the previous sections as well as the established assumptions. The last objective was accomplished, the implementation is feasible in cost-benefit terms. This is unique research because it involves multiple analysis, first the location-allocation model, then the VRPTW. It's important to mention that these models were run in python. And finally, a complete financial analysis in order to decide the best option for the company.

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Biography

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