Routes Optimization with Cluster-Dependent Costs for Convenience Stores

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Abstract

This study is carried out in a commercial company with a chain of convenience stores. The initial phase of the diagnosis aims to introduce the problem, show the analysis made on the process, and finally the identification of the root causes of the problem. The key solution was to create a two-phase model which includes an allocation of stores by demand, vehicle capacity and a time optimization model of the routes. Vehicle Routing Problems (VRP) are usually optimized in function of the length of the resulting routes. These functions are expressed in terms of distance, time, fuel consumption, cost, emissions, etc. In this case, the cost of the route is given by the most expensive customer covered in such a route. In addition, the models proposed consider time windows constraints and heterogeneous fleet.

All the necessary documentation under the company's scheme to implement the two-phase model and reduce travel expenses was developed This includes the restructuring of the daily route calculation and planning process with new contract terms and conditions that ensure greater benefits for the company. The results after the pilot test and simulations were a 16% reduction in final travel expenses and vehicle occupancy increased from 63% to 85%.

Keywords
Vehicle Routing Problem, Optimization, Clustering, Convenience Stores

1 Introduction

The hectic pace of life for the inhabitants of the metropolises has forced the retail industry to innovate, change and transform the way it offers its services. Convenience stores today have increased their products and services, in turn increasing the number of customers they serve and their points of sale. To have the product that a client wants to get in a convenience store, there is a process of high importance in this industry, which is the distribution, which must supply the points of sale with the product needed to meet the demand of the final customer. As mentioned by Ahmad Khan (2014), in order to succeed in this very competitive environment of the industry, efficiency in the distribution process is necessary, since this, among other aspects, will allow for a higher profit margin.

The design and planning of transportation routes affects the performance of the supply chain because it establishes the infrastructure where decisions regarding distribution are made. An optimal distribution network enables the supply chain to achieve the desired degree of responsiveness with the minimum amount of cost. Optimization techniques play a great role when looking for an efficient supply, because thanks to these techniques it will be possible to make better decisions regarding factors that affect the distribution cost such as vehicles, quantity of goods to be transported and route order. (Ballou, R. H., 2004).

2 Routing Problem Definition

Companies belonging to the convenience store industry face the need to respond to a changing demand, so it is of utmost importance to have products to satisfy the customer, for this to happen you need to have a thorough planning of distribution and travel control, as this represents a large part of the costs.

This project was born from the need to minimize the distribution expense in a convenience store company. Currently, according to its national income statement of August 2020, distribution expenses represent 43% of total operating expenses. These distribution expenses have fixed and variable components. The variable expenses are made up of travel rates and tolls, while the fixed expenses are made up of administration, real estate, fleet and third party costs. The main focus is to reduce travel expenses since they represent 71% of total distribution expenses. In this case, customers are grouped into clusters with a common toll, travel expenses are defined as the sum of all trips, and one trip cost is defined by the toll of the most expensive customer visited in that trip.

3 Methodology

The present work was developed following the Plan, Do, Check, Act cycle (PDCA), also known as the Shewart - Deming cycle. The process was carried out fulfilling the stages of the methodology. The Operations Research methodology was used for the realization of an optimization model in the Do part of the PDCA cycle. Gutierrez, H. (2010) in his book Total Quality and Productivity states that the PDCA tool is very useful to execute and structure projects to improve the quality and productivity of the processes of an organization, in addition to generating more iterations of the cycle to always seek continuous improvement. In addition, successful implementations of this methodology in improvement projects have been documented (Aleu et al, 2020, Díaz-Ramírez et al, 2018, Chavero-Hidalgo et al, 2017).

4 "Plan" Phase

Within the Planning stage, the objectives and scope of the project were set, and a robust analysis of each part of the distribution process was conducted to document the most relevant findings and use the Ishikawa diagram tool to find the root causes.

4.1 Project Scope

The Mexican convenience store company has more than 20,000 stores throughout the republic, therefore, this project was limited to a single distribution center located in Leon, Guanajuato. This distribution center serves three locations with more than 400 stores each. The focus of the project will be only in one location with a total of 477 stores.

4.2 Objectives

The general objective of the project is to reduce travel expenses in the location by 11%, which represents a savings of 3.9 million pesos per year. The particular objectives are to increase to more than 65% the occupation of the vehicles of 12 and 16 pallets, as well as to eliminate the routes with 3 or more collection districts.

4.3 Distribution Process

The distribution process has three main characteristics. The first one is that the demand of the stores which is measured in packages. For the company a package is a group of products without concerning the size or weight. This package can acquire the form of a basket with product or a group of products wrapped in plastic. The second characteristic is the vehicles, within the company there are three types of vehicles, which are distinguished by the 6T (6 pallets), 12T (12 pallets) and 16T (16 pallets) labels. The only difference between them is their capacity. Table 1 shows the capacities of each type of vehicle.

The third characteristic of the distribution process is the collection of the trips; an outsourcing company divides the stores by groups called districts. A district is made up of a critical mass of stores which share the same rate that depends on the district, the project's focus square has nine districts. The trip costs of each district by type of vehicle used are fixed and known but not shown for confidentiality reasons.

Table 1. Description of capacity by type of vehicle

Type of vehicle	Packages capacity	Weight capacity	Volume capacity
6T	400 packages	5,100 kg	14 m^3
12T	900 packages	10,200 kg	31 m^3
16T	1,300 packages	13,600 kg	42 m^3

In the end, the outsourcing company charges the convenience store company for the trip made. The travel fare acquires the fare of the most expensive district visited during the trip. The distribution process begins with pre-planning and ends when you return to the distribution center with store returns. This process consists of 6 key steps, which will be explained below.

4.3.1 Master Operations Plan

The Master Operations Plan, better known as PMO, is a route planning that is done on a semi-annual basis. This planning is done by the outsourcing company and is validated by the convenience store company to execute this fixed plan on a daily basis for six months. Within the PMO analysis corresponding to the period March to August 2020, it was found that the PMO planning in packages is 21% higher than the real demand in packages at the points of sale. Likewise, the planning of PMO in packages, differs statistically with the demands of the stores during the period of the PMO, this can be observed in Figure 1.

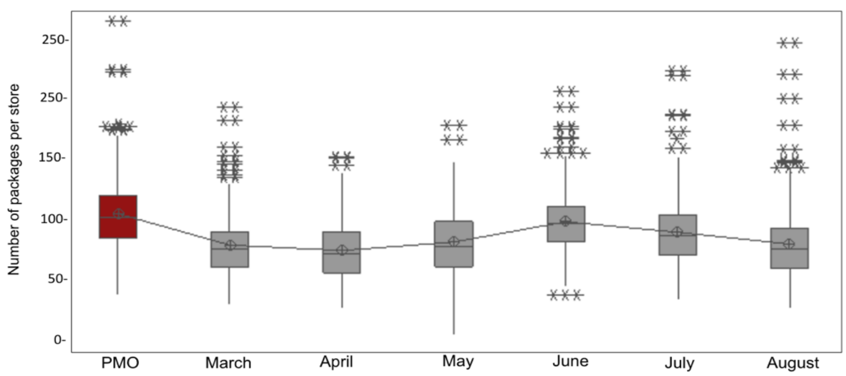


Figure 1. Planned packages PMO vs. Invoiced packages per store

4.3.2 In-Store Order Generation

The second step of the distribution process corresponds to the generation of orders by the stores. 89% of the stores are supplied twice a week, while 11% are supplied once or three times a week. The unit used to refer to the demand in the order of the stores is the package, which is not a standard unit of measurement and therefore its size and final weight is unknown.

4.3.3 Dynamic Routing

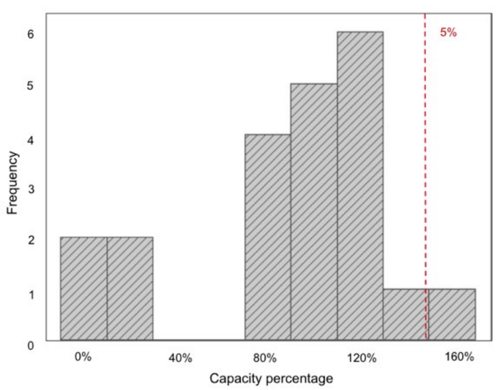
Dynamic routing is the next step in the distribution process, this routing is done based on the routes that were previously planned in the PMO and the amount of packages (demand) that the stores ask for. After having these two data, the analyst of the outsourcing company verifies the total load of the vehicles, if there is a possibility to fill the vehicle even more, a store is added under the analyst's own criteria. These changes are made manually, there is no record of the reasons why a change is made and no particular tool or rule is used. The intent of dynamic routing is to respond to changing store demand and increase vehicle occupancy.

A quantitative analysis of these manual changes was carried out with the aim of verifying their effect on the daily variability of the routes. One of the most important findings in this analysis was that 12% of the routes experienced a manual change. Of this last percentage, 9% of the times, stores with a higher rate were added to the route established by the PMO and 12% of the times, stores with a lower rate were added to the route established by the PMO. It should be noted that since the PMO, 18% of the routes already contain more than one collection district.

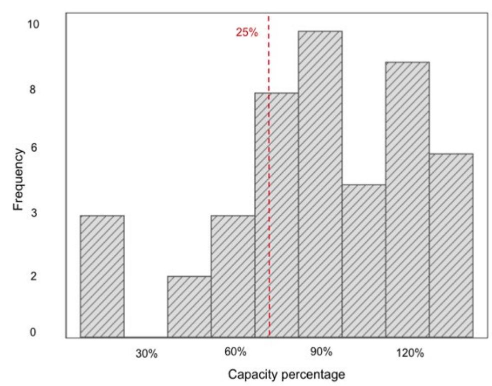
4.3.4 Vehicle Loading

As mentioned above, the loading schedule is done in packages, therefore, it would be expected that this schedule would be close to the capacity of the vehicle in packages to obtain a good performance. Subsequently, an analysis of programmed packages per vehicle among its total capacity was performed to determine its percentage of occupancy. This was done in order to ensure that in planning the PMO, the correct vehicle is being assigned with respect to store demand.

During the analysis, it was found that there is variability in the schedules of both vehicles. However, it can be seen in Figure 2 that most of the time the programmed capacity of the vehicle is greater than 70%, and there are even occasions when the programming is greater than 100% of the capacity of the vehicle in packages. The convenience store chain company justifies the planning in packages by arguing that this standard measure works for them to somehow ensure that the vehicle capacity. However, in Figure 2a, it can be seen that 5% of the 12T vehicles are planned with a bunk capacity for a 16T vehicle, while in Figure 2b, it can be seen that 25% of the 16T vehicles are programmed with a bunk capacity for 12T vehicles.



(a) 12T



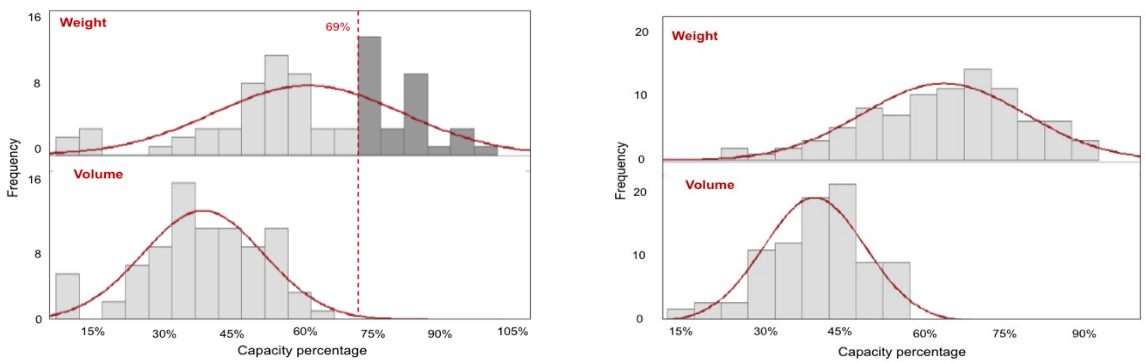
(b) 16T

Figure 2. Scheduled vehicle capacity

The previous analysis encouraged a second analysis of actual vehicle occupancy, but this time, the analysis was done on a standard measure. Due to the density of data involved in analyzing the weight and volume of each item requested by the store, only the first two weeks of August 2020 were analyzed. In terms of actual occupancy, a strong difference was detected compared to the schedule. In the first two weeks of August, 12T vehicles traveled at 63% of their capacity by weight with a 15% standard deviation and 40% of their capacity by volume with a 9% standard deviation, while 16T vehicles traveled at 62% of their capacity by weight with a 20% standard deviation and 40% of their capacity by volume with a 13% standard deviation, as shown in Figures 3a and 3b, 69% of the time a more expensive fee was charged for carrying a larger vehicle with less cargo. All trips that were made with a capacity of less than 75% on 16T vehicles could have been made on a 12T.

4.3.5 Store Delivery

The next step is to deliver the merchandise to the store. Within this step, the time of stay of the vehicle in the store and the time of travel from one store to another were analyzed. The average stay in the store is 25 minutes and the average travel time from one store to another is 10 minutes.



(a) 12T (b) 16T

Figure 3. Real occupation of vehicles

4.3.6 Return to Distribution Center

To complete the distribution process, the last step is to return to the distribution center. Figure 4 shows the frequency distribution of the number of stores served per trip. On average, a vehicle of 12T visits 8 stores, while a vehicle of 16T visits 11 stores. However, the distribution curves of the 12T vehicles have a deviation of 2.5 stores while the 16T vehicles have a deviation of 3.5 stores. Eleven percent of the 12T vehicles made trips with fewer than five stores, while eight percent of the 16T vehicles made trips visiting fewer than five stores. More than 70% of the routes are planned with a cycle time of between 9 and 5 hours.

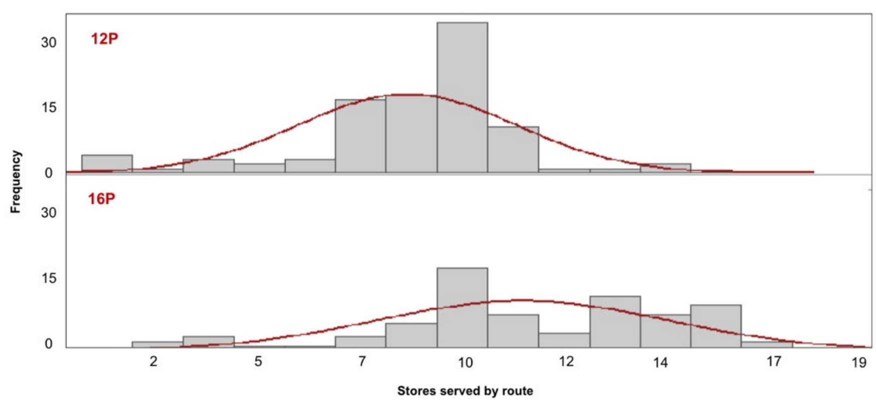


Figure 4. Stores served per trip

4.4 Root Causes

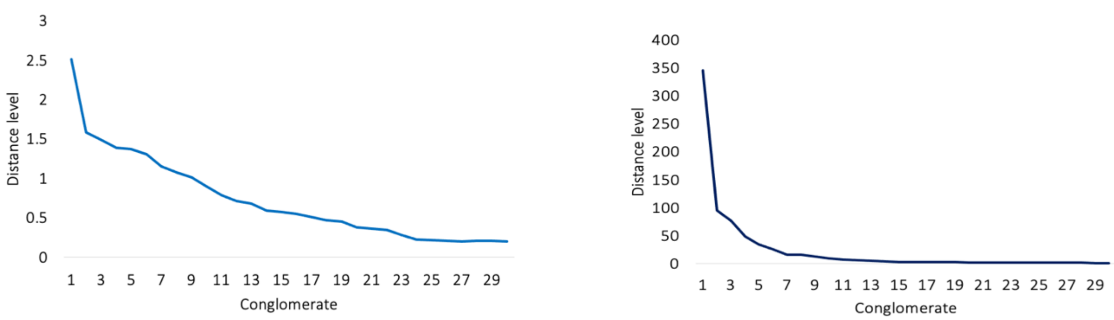
Throughout the research carried out, the symptoms that pointed to the current problems were collected. Ishikawa's graphic method was used to represent and analyze the relationship between the problem and its possible causes. At the conclusion of this method, the following 4 root causes were defined: 1: There is no adequate district grouping to support the fare, 2: A standard unit of measurement is not used to measure truckloads, 3: PMO does not respond to daily variability of demand, and 4: The contract does not ensure customer benefit. Attacking these root causes would help minimize cost variability to achieve an 11% reduction in travel expense. In response to the root causes found, it was decided to propose solutions to each of them, which will be described in detail below.

5 "Do" Phase

In this phase, solution strategies are proposed for the problems found in section 3.1, as well as the performance of each one of them is evaluated. The proposals covered in this section are the following: a) New proposal for store clustering: as a response to root cause 1, which speaks to the lack of an adequate district cluster to support the tariff. b) Proposal for a standard measure: in response to root cause 2, which speaks of the lack of a unit of measurement that states exactly what the vehicle's load is. c) Proposal for an optimization model: in response to root cause 3, since the PMO does not respond to the daily variability of demand and d) Corresponds to root cause 4, which is outside the scope of the project.

5.1 Clustering Proposal

For the development of the new proposal for the grouping of stores, a multivariate analysis was carried out in order to group the stores by similarity of location. The different methods of clustering were explored, the methods used were evaluated and finally a new store clustering was proposed. During the exploration of clustering methods, two types of methods were found in the literature; hierarchical and non-hierarchical. The hierarchical method is characterized by not knowing the initial number of groupings. The non-hierarchical method starts from an initial number of groupings. After trials with several clustering methods, the hierarchical methods that best suited the problem were Ward's and Centroid. Figure 5 shows their behavior under different number of conglomerates. Ward's method tends to minimize the sum of the squares within each cluster and Centroid's method seeks to join clusters by the similarity of their centroids. The sum of squares calculates the square distance between each data point and its nearest cluster centroid (Abu-Jamous, et al. 2015).



(a) Centroid Method (b) Ward Method

Figure 5. Elbows from two clustering methods.

The Elbow Method is a visual tool that allows you to appreciate the level of similarity within each grouping. We chose to use this tool in both Ward and Centroid methods in order to delimit the iterations of number of partitions to be made. As you can see in Figure 5b the Ward's Jambu elbow presents a more abrupt change in the distance level than Centroid (Figure 5a), this change can represent an adequate cut point for the final partition. Therefore, partitions from 7 to 15 clusters were used to further analyze the difference between clusters.

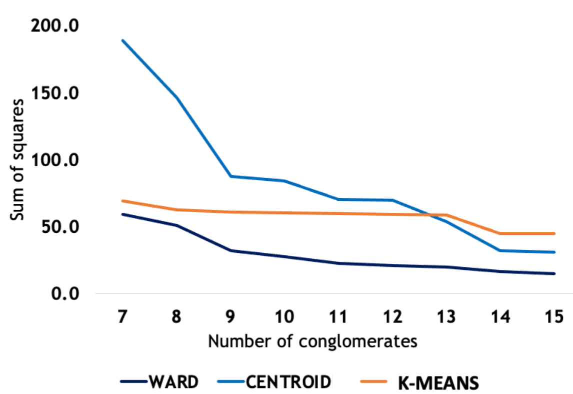


Figure 6. Convergence of three clustering methods, measured in sum of squares

In addition to these two methods, it was decided to add a non-hierarchical method, which is the k-means. The k-means algorithm is the most common, its main function is to obtain the partition with the minimum sum of square errors for a given number of clusters (Abu-Jamous, et al. 2015). After experiencing the iterations of 7 to 15 clusters with the above methods, the sum of squares in each iteration was compared as can be seen in the following Figure 6.

This type of proposals tends to be defined by the sum of squares and criteria of the analyst, therefore it was decided to stop at 13 clusters. Taking into account this last partition, the sum of Ward's squares was chosen, which is less than the other methods.

After analyzing the results, it was decided to apply Ward's method for the new store clustering proposal. Figure 7 shows the changes compared to the current store clusters, with the stores grouped in 13 clusters (districts) with the Ward's method.

(a) Original (b) Ward Method

Figure 7. Clustering results

In the illustration of Ward's method, it is noted that districts 1, 2, 3 and 6 surround the distribution center, which in the current grouping are considered as one district. For the new proposal districts 1, 3 and 6 were considered with the same rate. The calculation of the new rates was done through an interpolation that depends on the travel time to the centroid of each district.

5.2 Standard Measurement Proposal

The proposal of the standard measurement aims to change the information and indicators of the convenience store company from packages to weight, this in order to improve the accuracy of the loading of the vehicles and their performance. The pertinent bases of the analysis were documented in order to formally initiate the change of indicators in the company. However, the final decision depends on the company and its stakeholders.

5.3 Optimization Model Proposal

In addition to the above mentioned proposals, there is the proposal of a mathematical model in order to decrease the distribution expense by optimizing routes. Based on Baldoquín et al (2020), at the beginning, we started with the elaboration of a complete model based on the VRP, however, the complexity and execution time exceeded the analyst's time limit to define the daily routes in the company. Therefore, after a large number of iterations on the model was chosen to divide it into two phases. The first phase consists of a vehicle store allocation model to minimize the total cost of travel rates and the second phase consists of VRP model to minimize the total route time.

5.3.1 Assignment Model

Indices

i=stores 1,2,3…|I|
f=fleet 1,2,3…|F|
d=district 1,2,3…|D|

Parameters

N_d: Travel time from the distribution center to the centroid in district *d*.
W_f: Vehicle *f* capacity.
e: Time spent in store.
$Tmax$: Maximum route time.
De_i: Demand in kilograms per store *i*.
A_{if}: Binary matrix to define if vehicle *f* can visit store *i*.
C_{df}: Fare to district *d* by vehicle *f*.
B_{id}: Binary matrix identifying whether store *i* belongs to district *d*.
G_{dd1}: Travel time from district *d* to district *d1*.

Variables

X_{if}: 1 if store *i* is assigned to vehicle *f*. 0 if not.
Y_{fd}: 1 if vehicle *f* is assigned to district *d*. 0 if not.
Tar_f: Rate per vehicle *f*.
V_{dd1f}: 1 if vehicle *f* visits district *d* and *d1*.0 if not.

Model

$$\min\ z = \sum_{f\in F} tar_f \quad (1)$$

subject to

$$\sum_{i\in I} de_i * X_{if} \le W_f \quad \forall f \quad (2)$$
$$B_{id} * X_{if} \le Y_{fd} \quad \forall i,d,f \quad (3)$$
$$\sum_{f\in F} X_{if} = 1 \quad \forall i \quad (4)$$
$$\sum_{d\in D} Y_{fd} \le 2 \quad \forall f \quad (5)$$
$$Y_{fd} + Y_{fd1} - V_{dd1f} \le 1 \quad \forall d,d1,f \quad (6)$$
$$\sum_{i\in I}\left((r+e) * X_{if}\right) + G_{dd1} * V_{dd1f} \le tmax - N_d * Y_{fd} - N_{d1} * Y_{fd1} - N_{d1} * \left(1 - V_{dd1f}\right) \quad \forall f,d,d1 \quad (7)$$
$$tar_f \ge C_{df} * Y_{fd} \quad \forall f,d \quad (8)$$
$$X_{if} \le A_{if} \quad (9)$$
$$X_{if} \in \{0,1\}\ \forall i,f, Y_{fd} \in \{0,1\}\forall f,d, V_{dd1f} \in \{0,1\}\forall d,d1,f, Tar_f \in \{0,1\}\forall f \quad (10)$$

Equation (1) minimizes the sum of the most expensive fees, charged by each vehicle. Constraints (2) assure the demand of the stores has to be less than the capacity of the vehicle; Constraints (3) that vehicle *f* goes to district *d* only with stores that belong to that district. Equation (4) that all customers are visited by one vehicle. Constraints (5) assure that one vehicle can visit maximum 2 districts. Constraints (6) make that variable *v* is 1 when there is a change of district. (7) limits the route time, (8) keeps track of the rate cost per vehicle, (9) is an upper bound on *X*, limited by the capacity of the vehicle *f* to visit store *I*, and (10) establishes the domain of the variables.

Together, all the elements of the model generate a solution which is an input for the routing model, which seeks to minimize the routing time. This model is explained below following the structure of the previous explanation.

For aspects of the work we had access to a GAMS license, this software served to validate the results of the model, as well as to observe the operations that were made. The above to have a better comprehensive validation. However, the deliverable to the client must be in a software that can be used freely and for free, so having validated the model with GAMS, we proceeded to program it using the Python programming language with the OR-Tools library.

5.3.2 Routing model

Indexes
i, j=stores 1,2,3…|I|
f=fleet 1,2,3…|F|
The following sets were also defined:
ic, jc: = clients,
io, jo: =origin
id, jd: =destination

Parameters
R_{ij}: Travel time from i to j.
Y_{fj}: If store j is assigned to vehicle f. 0 if not.
e: Time of stay.
$Tmax$: Maximum route time.
De_i: Demand in kg of store i.

Variables
X_{ij}: 1 if store j is visited after i. 0 if not
G_{jf}: Time of arrival to node j by vehicle f.

Model

$$\min z_f = \sum_{jd \in L} G_{jdf} \quad \forall f \tag{11}$$

subject to

$$\sum_{jc \in L} X_{0\,jc} = \sum_{ic \in L} X_{ic\,n+1} \tag{12}$$
$$\sum_{jd \in L} X_{ic\,jd} = \sum_{jo \in L} X_{jo\,ic} \; \forall\, ic \tag{13}$$
$$\sum_{jd \in L} X_{ic\,jd} = 1 \quad \forall\, ic \tag{14}$$
$$\sum_{jo \in L} X_{jo\,ic} = 1 \quad \forall\, ic \tag{15}$$
$$e + R_{io\,jd} \leq G_{jdf} + M * \left(1 - \left(X_{io\,jd} * Y_{f\,jd}\right)\right) \; \forall\, io,\, jd, f \tag{16}$$
$$\sum_{jd \in L} G_{jdf} \leq tmax \; \forall\, f \tag{17}$$
$$X_{ij} \in \{0,1\} \; \forall i, j, G_{if} \in \{0,1\} \forall\, i, f \tag{18}$$

The objective function (11) is to minimize the route time per vehicle f. This model is solved F times. (12) and (13) are flow balance equations, equations (14) and (15) assures 1 route. Constraints (16) track the arrival time to node j, and (17) track the maximum route time. Finally, (18) set the variables domain. The model was run and tested in the GAMS software, however, it was also implemented in Python for the company.

6 "Check" Phase

6.1 Process Automation

Next, the different process automation strategies that were carried out with the objective of facilitating the implementation to the client are addressed. Firstly, a database macro was made in Excel that works as an input for the assignment model that is run through Python. Within this database, each store is introduced with its respective demand to automatically make the matrices and parameters of the allocation model. The Excel macro has the option to modify the parameters if is necessary. Then, the allocation model is executed and finally the routing model is executed in Python, taking as input the results of the allocation.

6.2 Simulations

Three scenarios with the following characteristics were taken into account to carry out simulations:

1. Original district configuration, default vehicles and demand in kilograms: by default, it refers to the original PMO configuration that indicates the type of vehicle (16T or 12T) that is assigned to the store.
2. Original district configuration, change flexibility and demand in kilograms: the district configuration established by the company is left, but the possibility of changing the vehicle, for example from a 16T to a 12T, is enabled.
3. 13 district configuration, changeover flexibility and demand in kilograms: proposed 13 district configuration and like the second scenario, vehicle changeover flexibility.

To test the allocation and routing model, the daily demands of the months of August as the high season and October as the low season were taken. A total of 144 runs were made in a time of more than 48 hours to test the 3 scenarios. Likewise, the main indicators to be analyzed in the results of the simulations were: total travel expenses, number of trips, vehicle utilization and maximum route time. They were compared with the real figures obtained by the company in the same period (August and October, 2020).

Beginning with the total travel expense within the first scenario, an improvement of 8% was obtained with a significant difference between the means, this improvement is merely due to the change in the allocation of packages to kilograms. On the other hand, the standard deviation was reduced by 52%, which means that there is less variability in routes due to periodic deliveries and constant vehicle configuration. In the second scenario, by enabling the possibility of changing the type of vehicle (12T or 16T), there is a 16% reduction in travel expenses, with a significant difference between the means and a 18% decrease in standard deviation. Finally, the third scenario, which tests the proposal for a new grouping of stores, shows an 18% improvement in distribution spending, as well as a significant difference between the means and an 18% reduction in standard deviation. Within this scenario we can see how fare interpolation further lowers total travel spend.

Within **the total number of trips**, in the first scenario a total of 2 average trips per day are reduced and the variability is reduced by 45%. On the other hand, in the second scenario, an average of 3 trips per day are reduced and the variability is reduced to 20%. Finally, the third scenario reduces a total of 2 average trips per day and the variability by 25%.

The third evaluation of the scenarios was **the use of vehicles**. In the first scenario, the 12T and 16T vehicles are used in the same way 45% and 45% respectively. This occurs because there is a pre-established configuration by the PMO. Then, in the second scenario where the option of type of vehicle is enabled, the utilization of 12T vehicles increased to 72%. Finally, in the third scenario, the use of 12T vehicles is increased by 74%. 12T vehicle utilization is higher because rates are lower and vehicle capacity is sufficient to meet store demands.

Finally, with the routing model it was evaluated that the routes did not exceed **the maximum route time**, within the first scenario it was found that only 3% of the routes exceeded the time. In the second scenario it was found that 5% of the routes exceeded the time and finally the third scenario only 4% of the routes exceeded the time. However, it should be considered that the store-to-store travel matrix used in the routing model considers a constant speed which was set at 50 km/h and the common denominator of the routes that exceeded time was that they belonged to very distant districts, in real practice a vehicle travels at 80 km/h on the road so this time could be compensated.

6.3 Randomized testing

In addition to the simulations, it was decided to test the model with random demand cases. A sample of 30 stores was used, of which 90% followed a normal distribution, under this finding the assumption that the demands of the rest of the stores followed a normal distribution.

As a result of the tests with random demands by scenario, it was observed savings of 8%, 21%, and 26% in total travel expenses, per scenario, respectively. In the first scenario a similar saving was observed as in the simulations of the months of August and October, while in the following two scenarios a greater saving was observed.

6.4 Results

The general objective set at the beginning of the project was to reduce 11% of travel expenses in the square. Within the first scenario, an 8% reduction of the distribution expenditure was achieved, achieving an impact of 2.8 million pesos per year. In the second scenario, travel expenses were reduced by 16%, which represents a savings of 5.7 million pesos per year. Finally, in the third scenario, which shows the new grouping of districts that will be considered in 2023 by reevaluating the contract, travel expenses were saved by 18%, representing 6.4 million pesos per year.

Compared to our particular goals of increasing 12T and 16T vehicle occupancy to more than 65% and eliminating routes with 3 or more collection districts, the second scenario shows that 12T occupancy increases from 62% to 85% and 16T occupancy from 64% to 84%, this is because stores are now allocated to the appropriate vehicle according to demand. Finally, within the allocation model, district changes are limited to a maximum of 2 changes.

7 Act

At this stage, pertinent actions were taken to continuously improve the development of the processes, these actions consist of documentation and training to carry out the implementation and future iterations of the PDCA cycle.

7.1 Documentation

Firstly, the necessary documentation of the proposal for the grouping of stores was developed, it was done under the scheme of the planning area of the company. Within this document, the analyses carried out on the groupings, the new proposal of districts and the calculations of interpolation of tariffs were expressed. The intention of the documentation is to reevaluate the district tariffs once the contract established by the convenience store company and the outsourcing company has ended. Regarding the proposal to change the indicator from packages to weight, the pertinent documentation was made showing the findings found and referring to the need to change the indicator for the company to begin the change process.

As for the proposal of the optimization model, an operational manual was made that explains step by step the necessary actions to run the assignment and routing models, as well as the instructions for downloading the programs and tools used. In the case of this proposal, a job profile was also made with the activities to be carried out in relation to the new optimization tool. The person who will carry out the deployment of the implementation of this tool is the Coordinator of Management and Distribution of the convenience store company. In addition, the process was developed with a flow chart that indicates in detail the activities that must be performed in the distribution center to run the optimization tool before the outsourcing company and thus prevent them from performing routes with greater expenditure than proposed by the model.

7.2 Training

The company's Management and Distribution Coordinator was trained for the correct execution of the models. During the deployment of the tool in the distribution centers, he will be in charge of training the systems analysts and thus be able to evaluate the routes before they are carried out by the outsourcing company. The Management and Distribution Coordinator carried out the one-week pilot test considering scenario 2 and obtained a 12% saving, which was satisfactory for the company and starts the deployment of the tool in the distribution center.

8 Conclusions

Within the planning stage, a robust, data-intensive analysis was conducted to determine the root causes of the problem. In the second stage, the complexity of the optimization model was addressed, with a review of routing literature where none addressed the problem of routes that do not depend on the client but on the cluster to which the client belongs. Then in the verification stage, the model was successfully developed and the objectives above five percentage points were met. Finally, all the pertinent bases were established for the following iterations of the PDCA cycle, which is the implementation and deployment of the tool.

Throughout the project, different challenges were presented, firstly, learning a programming language from scratch, which involved a lot of study and practice time. On the other hand, the current world situation regarding covid-19 has led companies and universities to carry out their processes remotely, so it was necessary to create and adapt work strategies such as training, meetings with the client, data analysis, etc., 100% virtually. The development and growth of this project was of great interest and complexity, coupled with a great sense of satisfaction on the part of the team for all the knowledge acquired and enriching for each of the members. It can be concluded that each of the proposed objectives was satisfactorily fulfilled. In addition, there were proposals, tools and additional benefits that were of great help to the client. For this reason, the client was satisfied with the work done.

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