Analysis of the distribution of medicines using VRP with time windows: VPRTW

Guadalupe Canuto1, Alberto Ochoa2, Alberto Hernández3 & Carolina Guzman.
1Instituto Tecnológico Superior de Naranjos.
2 Masters in Applied Computer UACJ.
3FACel, Universidad Autónoma de la Ciudad de Morelos.

Abstracs. This article presents an analysis of the distribution of medicines Farmacia del Ahorro, which raises pharmacies in the chain are stocked in a timely manner, by the store located in Civac, Jiutepec, Morelos, taking into account the density population that concentrates the city, for this distribution strategies for their respective delivery vehicles are proposed; considering a deposit associated with 17 branches and a defined number of vehicles; which creates a problem of VRP type, with restricted ranges, since it leaves the store until it reaches the end customer. Which is developed by applying the VRPTW (Vehicle Routing Problem with Time Windows), it is focused primarily on the available range of time that the vehicle should visit their clients and they are available to receive pharmaceutical products with good service. To do this, the execution of a mathematical program developed in MATLAB in order to show the best feasible routes to optimize the total distance by supporting a pseucodigo and application of an algorithmic code shown nearest neighbor. Likewise the C ++ software was employed for the experimental design, where the algorithm of ant colonies is used, resulting in optimization time in several tests a percentage of 100%, 80% and 60%.

KEY WORDS: Programming of vehicles with Windows of Time, drugs, Matlab and distribution routes.

Introduction

In this article is about problems of vehicle routing, focus mainly on the distribution of orders, through an analysis and implementation of tools that allow you to resolve any event that has relation to the logistics branch

These requires, have basic understanding of VRP (Vehicule Routing Problem), and solves any problems, both simple and complex, in relation to the distribution of any type of product to provide good service. This mathematical model has three main characteristics that take into account to resolve any difficulties that may have an organization of transport; customers, the deposit and the vehicle fleet. The customer is the number one entity , which will provide some demand for goods , so the deposits is the supply center where the fleet leaves for delivery orders.[19] This type of problem is handled on a road network that is also called graphs [7] it represents the roads and junctions whose vertices ways to store locations and customers; It is considered much the arches because it depends where the vehicle is traveling in the same direction or in both directions. Since each arc is represented by its length, costing and travel times. [1]. As increasingly larger number of clients, vehicles and tanks the problem becomes more complicated. The VRP solution by scheduling can reap many benefits in a distribution company as feasible data throws the driver to choose the shortest route, in order to provide good service to a number of customers.

In the last four decades they have seen a huge effort to solve these problems, such as in 1959, Dantzig and Ramser [19] they first conducted a formulation of the problem for a fuel distribution application. Five years later, Clarke and Wright, [4] they proposed the first algorithm was effective for resolution: the popular algorithm Savings. From this work, the Vehicle Routing area has grown significantly. On the one hand, towards models increasingly incorporating features of reality [13] and secondly, in finding algorithms to solve problems efficiently. There are very few accurate methods for solving the VPR, due to the difficulty of the problem as it takes to solve small instances of 25 or more than 50 customers.[17]

These types of problems constantly cause a bankruptcy in the organization due to poor organization, planning and control of distribution strategies delivery of products by vehicles. That's why VRP model resulted in many variants evolved from the general model (GVRP). For example one of the most studied variants is VRPTW, Vehicule Routing Problem with Time Windows is a model of problems vehicle routing but with an additional restriction in time, called time window associated time interval defined by the customer it has to be stocked, it is considered the time interval in the reservoir, which is characterized primarily by the use of vehicles based on the same store that is directed optimally to supply power to customers. [3]

Ever you have been asked : How necessary is to know how long a vehicle is to reach the first point of delivery ?, what specific time we have for each client ?, What is the minimum and maximum attention service delivery of the order ?, What strategies do quickly if the operation amid public somewhat unexpected occurs as a mechanic ? Sometimes not only has to be limited to the vehicle must be well maintained so you can reach the consumer , but should also analyze how long

the trip will take place approximately equally distance including possible obstacles , order quantity , type of goods to be transported . Likewise, the outlets have to visit and the cost incurred by this operation. [22]

But nevertheless , there are few organizations that the time to analyze the main parameters to properly take their logistics operations are taken ; perhaps some choose to hire an outside firm as a logistics consultant, who provide acceptable proposals for a better distribution in the market. Clear as everything you need to identify the market size to measure customer service [8]. Allowing better decisions to transportation to services or products with a high value of time, so you need to be delivered within a time window, to avoid generating high costs. [10] a clear example is when in supermarkets and / or distribution centers, may be that an earlier arrival involving greater vehicle waiting for care and lack of space for arranging cargo in it, or the lack of stock for which it charged.

For these types of vehicle routing problems it requires the use of combinatorial optimization. According to Diaz et al (1996) " A heuristic is a procedure to solve a well-defined using an intuitive approach optimization problem, where the structure of the problem is used intelligently to get a good solution " [16], They belong mostly to the NP-hard class whose complexity to solve is that it is not possible to construct in polynomial time algorithms that solve any instance of the problem so it takes effort reasonable computation. [15]

In recent years they have made the importance of developing algorithms based on heuristics as Metaheuristics; metauristicos are some of the simulated annealing (SA), Genetic algorithms, taboo search, memetic, Ant Systems (AS) or Ant colony [17]. Simulated annealing search and taboo start working from an initial known solution, and each iteration move from one solution to another in the same neighborhood until a given condition is met. In systems of ants in each iteration several solutions using information from previous iterations are created. According Taillard et al. (1998) said that the tabu search, and ant systems are methods that store information about the solutions found and used to find even better solutions [18]. These types of algorithms facilitates the operation of any problems to be solved by your code to make a good program that in times of seconds yields data that allows a more acceptable optics.

That is why every time you need the support of technology, because in a given time is funadamental the help of this tool and equipment easier everyday human life. This article describes a problem which is solved by applying the mathematical formulation that identifies the parameter of the problem is shown, themselves an algorithm that facilitates the development of results by choosing pseudocode or coding and programming is done in a software called Matlab based data to throw the bodies we have.

MATLAB is very useful mathematics, was initially developed by Cleve Moler between 1977 and 1984 as a teaching aid. The first version was written in Fortran , and since 1985 have been written in C.Creada order to resolve difficult situations that require computer systems, so it is originally created to perform numerical calculations with vectors and matrices, this software also is called Matrix Laboratory, it is composed of applications especially to carry out projects which are elevated mathematical calculations , so too , the graphical display thereof; such as , matrix computation , signal processing , numerical analysis and graphical visualization of the environment that is the problem.[2]

Tabi has specialized support program , called Toolboxes , which significaticvamente incorporads extend the number of functions in the main programs ; they cover practically almost all major areas in the world of engineering and simulation, among them the image processing toolbox , signal , robust control , statistical , financial analysis , math, symbolic networks neural networks , fuzzy logic, identification systems , dynamic systems simulation , among others.

Below describes the procedure for solving the problem, the code used; experimental design, designed to test the model on the network, considering different levels of routing and analysis of the results of the priebas made . At the end of this article is the outcome of the results, according to the problems.

Background.

Farmacias Del Ahorro, is born in Tuxtla Chiapas, with the vision of being the best drugstore chain in the country through continuous improvement of technology and service offered to its customers, started operations in August 1991 Company, only 2 shops and 30 employees. In his 22 years have been distinguished by the consistency with their customers, it is number one in the marketing of pharmaceuticals. Today serves more than 769 own and 167 franchise pharmacies through six distribution centers located throughout the country. It also has more than 14,000 employees of which 700 work daily in one of its distribution centers. [25]

This company is characterized by having achieved their success because of several factors that can be a competitive organization, providing excellent customer service, maintaining a wide range of products, grant access to the customer through the location of its pharmacies, handle fair prices and ensuring the continuous development of its personnel. Also, its distribution strategy and intelligence of managers to take advantage of the crises that have occurred in the country

taking them as opportunities to invest and innovate, have made Farmacias Del Ahorro a true icon to follow in the pharmaceutical industry. [26]. Today Farmacias del Ahorro distributed accurately and efficiently about 15 million pieces monthly to 967 pharmacies from its 6 distribution centers which, according to the service indicators, have placed the company as the best supplier of pharmacies group compared with major wholesale market presence.

It has been highlighted by the implementation of projects for evaluation 10 different platforms between ERP'sy WMS's, some variables considered were taken: technical and functional measurement application (RFP and RFI), demonstrations and tests implementation, analysis and investment costs, Base installed in Mexico in companies with a similar operation to ours, strong presence and representation in the Mexican market, professional experience of implementation, implementation methodology, positioning the application within the industry WMS according to analysts at software, and service levels offered hosteo scheme, etc. Also visit references to distribution centers and implemented the technology and operating with measurable results. Some benefits are an increase in the overall productivity of the operation, significant reduction of errors in the assortment. Vision, control and reliability in inventories. Establishment of specific metrics for employee benefits to them directly proportional to productivity. Reducing staff turnover by 90%, staff come to work motivated and satisfied return. Expiry dates and batch control in detail. 350 pieces were produced in the first year to 600 parts per hour range.

Description of the problem

The franchise called Pharmacy Savings has identified the need to increase the level of customer satisfaction , because the competition has grown and is slowly influencing this company , which has been losing some customers since the service it provides; Added to this , more people tend to have a constantly growing at an average annual rate of 0.7 % ; (Cuernavaca) which records the state of Morelos five municipalities concentrated more than half of the total state population (53.1 %) , with a figure of 20.5 % , surpassed by the proportions of 20 municipalities in the state ; Cuernavaca be the first place where most of the population of Morelos is concentrated with a density of 365 168 inhabitants per km2 , according to INEGI 2010 [24]. Given this situation it is planned that the chain pharmacies have an assortment of medications at the right time, supplied by the warehouse located in Civac, Jiutepec, Morelos; for this distribution strategies for their respective delivery vehicles they are proposed; considering a deposit associated with 17 branches and a defined number of vehicles; which creates a problem of VRP type, with restricted ranges, since it leaves the store until it reaches the end customer. The vehicle is set based on expected travel times, customers and the demands that are emerging as the operating cycle progresses.

This problem involves the optimization of the total sum of the distances of each client, with restricted time windows.

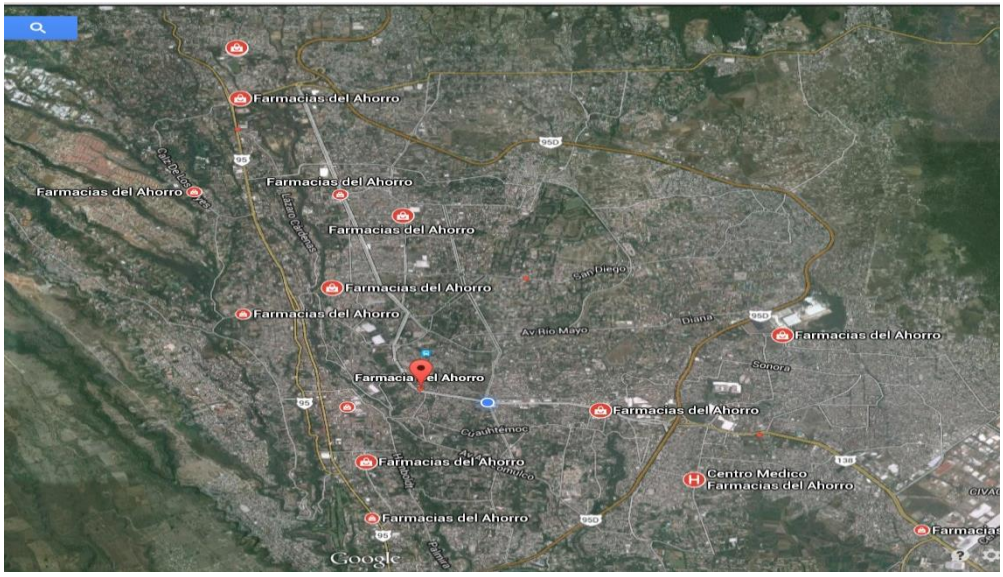

Figure 1: Map of Cuernavaca with the locations of pharmacies savings.
Source [27] Google maps.

For development of this problem VRPTW model, which is explained more in detail is used.

Operation VRPTW

The variant of the problem, in addition to capacity, each client$i \in V/\{0\}\}$ It has an associated time window $[e_i, l_i]$ It is establishing a permitted service time for a vehicle to reach it and a time delay of service s_i. If (i,j) It is an arc of the solution and t_i y t_j are arrival times to customers i y j, time windows mean that necessarily must be fulfilled $t_i \leq l_i$ y $t_j \leq l_j$. On the other hand, if $t_i < e_i$, The vehicle then you'll have to wait until the client "open" and necessarily $t_j = e_i + s_i + t_{ij}$. Using the nodes 0 y n + 1 to represent the tank and the whole K, to represent the vehicles. [5, 6, 9, 12,14, 19].

- Target function that minimizes the overall travel time and the number of vehicles.

$$min \sum_{k \in K} \sum_{(i,j) \in E} C_{ij}^k x_{ij}^k \quad (1)$$

$$s.a \sum_{k \in K} \sum_{i \in \Delta-(i)} x_{ij}^k = 1 \qquad \forall i \in V/\{0.n+1\} \quad (2)$$

$$\sum_{j \in \Delta+(0)} x_{0j}^k = 1 \qquad \forall i \in N \quad (3)$$

$$\sum_{j \in \Delta+(i)} x_{ij}^k - \sum_{j \in \Delta-(i)} x_{ij}^k = 0 \qquad \forall k \in K, i \in V/\{0, n+1\} \quad (4)$$

$$\sum_{i \in V/\{O,n+1\}+(i)} d_i - \sum_{j \in \Delta+(i)} x_{ij}^k \leq q^k \qquad \forall k \in N \quad (5)$$

$$\mathcal{Y}_j^k - \mathcal{Y}_j^k \geq s_i + t_{ij}^k - M(1 - t_{ij}^k) \qquad \forall i,j \in V/\{0,n+1\}, k \in K \quad (6)$$

$$e_i \leq \mathcal{Y}_j^k \leq l_i \qquad \forall i \in V/\{0,n+1\}, k \in K \quad (7)$$

$$x_{ij}^k \epsilon \{0,1\} \qquad \forall (i,j) \in E, k \in K \quad (8)$$

$$\mathcal{Y}_j^k \geq 0 \qquad \forall i,j \in V/\{0,n+1\}, k \in K \quad (9)$$

The variables x_{ij}^k Indicate if the arc (i,j) It is traversed by the vehicle$K$. The variables$\mathcal{Y}^k{}_i$ Indicates the time of arrival to the customer$i$ when it is visited by the vehicle$K$ (If the customer is not visited by that vehicle the value of the variable does not make sense).

The aim of the function (1) is the total cost of the routes. The restriction (2) indicates that all clients must be visited. Restrictions, (4) y (5) determine what each of the companies$k \in K$ Moves a way of 0 $a\ n+1$. The capacity of each vehicle is imposed on (6). Where M is a large enough constant, the restriction ensures that if a vehicle (7) K travels of i at j, j You cannot come before $y_i + s_i + t_{ij}^k$, and also act as restrictions eliminated by sub -tours. Finally, the restriction (8) it is understood by limits of the time window. [20]

Algorithm a close neighbor.

This algorithm was used because it looks for a solution supported by the closeness of two nodes or immediate customers; the heuristics of the nearest neighbor, uses a measurement which makes a weighted balance between the geographical proximity of the customers and the travel time respective from one node to another. One of its advantages is that searches for an approximation, i.e. a client that is near, but does not imply feasibility in terms of time, and this is the reason that the cost of the path to the insert a client makes a balance between these two parameters, and assigns the customers to the path by giving priority to those whose "balance" is less than [9, 14].

If you have a path (0,… u_i,0), the cost of inserting the defined customer then u_i of the path as:

$C_{ij}=\delta_1 d_{ij}+ \delta_2 T_{ij}+\delta_3 V_{ij}, \delta_1 + \delta_2 + \delta_3 =0$

$T_{ij} = W_j - (w_i + \delta_i)$

$V_{ij} = b_j - (w_i + \delta_i + t_{ij})$

Where the parameters $\delta_1 + \delta_2 + \delta_3$ are non-negative and added 1

d_{ij} Represents the distance that exists between two nodes and measured its geographic proximity. The value of T_{ij} It shows the difference between the time of commencement of service j and the end of service i, measuring the proximity of customers; thus minimizing the shortest travel time and delay between two clients. In change V_{ij}calculates the difference between the arrival time j (not including the wait) and last time that you could get to that client. This prioritizes customers

to insert considering the difference of time later to serve the customer j. Values δ_1 , δ_2 and δ_3 , they give different results, according wing perspective you want to give to the model. If you look insert customers on routes minimizing its proximity, less value is given to δ_1. If customers are prioritized because of its proximity, lower values δ_2, heuristics form allows routes with lower values of time and distance. When there are clients with service time later, its location, the coefficient δ_3, should be less for the service to ensure no other clients clientes.When to insert into the current path, it creates a new one until all clients are visited. [14]

Instances

The instances are associated with characteristics of the problem and the approach used in specific run or a modelo.En The following table details the first 17 branches Pharmacy Savings shown; X, Y are the geographical coordinates of franchises; "d" It is the demands associated with each customer; ai with the beginning and end of the time windows, "bi" It represents the window width; "Si" service time.

Table 1: Input data according to branches.

	X	Y	d	ai	bi	si	
1	91	65	0	0	1236	0	
2	45	68	10	912	967	90	
3	55	89	30	825	870	90	
4	42	33	10	65	146	90	
5	42	45	10	727	782	90	
6	38	32	10	15	67	90	
7	34	14	20	621	702	90	
8	38	19	20	170	225	90	
9	48	54	20	255	324	90	
10	58	58	10	534	605	90	
11	35	28	10	357	410	90	
12	58	97	10	448	505	90	
13	59	65	20	652	721	90	
14	50	23	30	30	92	90	
15	49	36	10	567	620	90	
16	55	30	40	384	429	90	
17	55	84	40	475	528	90	

Source: Modified data.

Programming in Matlab.

It was taken as reference the below psecodigo Close Neighbor to walk the Matlab program, which the software reads it and gives results through execution according wing programming. [2, 14,21]

Pseucódigo.

Generating the first solution (x)
Make
X'= Structured neighborhood (σ)
$If(f(X') < f(X)$ then
$X' =$ Best solution found
$X' = X$
End = Yes
While end stop criterion

To carry out this program, we immediately gives an interface where you can destinguir optimizing routes and total distances incurred according to the total branch that has the franchise of Pharmacy savings in Cuernavaca, Morelos. So it is stocked by the store located in Civac, in the municipality of Jiutepec, Morelos state.

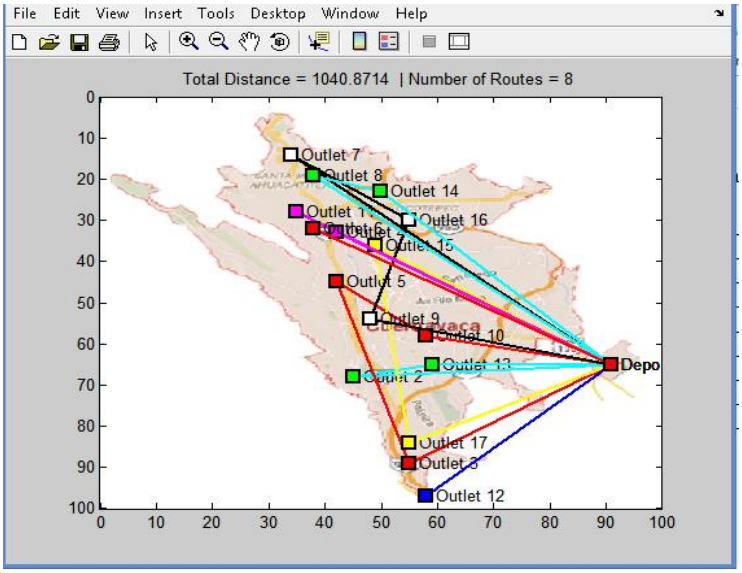

Figure 2: Image thrown in Matlab.
Source: Software Matlab.

Table 2: Analysis of the results of the number of routes.

Route.	Pharmacy						Total Demand
		Bi-ai		**Bi-ai**		**Bi-ai**	
1	14	62	8	55			50
2	9	69	16	45	7	69	80
3	15	53	17	53			50
4	4	81	11	53			20
5	6	55					10
6	10	52	5	55	3	45	50
7	13	69	2	55			30
8	12	57					10
Total distance	1040.8714						
Total number of vehicles	8						

Source: own preparation.

According to the program interface thrown 8 vehicles shown, which was determined according to the program, based wing capacity of the total demand for each route and volume weight a vehicle can be conditioned; Likewise the length of service can be distinguished by the difference of the time interval from start to end that is within the range of a service. This design is considered distribution agreement as long as each branch is acquiring in the duration of the discharge of pharmaceutical products with a certain margin service available

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Pseucódigo of ant colonies.

The problems of routes and optimization are perfectly suited to the use of algorithms based on ant colony. [23]

Procedure AS ( )
Initialize parameters
While condition do
Inicializar_New ant ( )
While state <> state_end
For each_arc_possible_ motion
Calculate probalididad_election
end_for
Next_position = politics_decision
Lista_Positions =+ Next_position
End_While

Realize_ Evaporation Tank _ Pheromone (list_ position)
End_While
End_ procedure

Design of Experiments

The aim of making the design of experiment is to find the values of beta, rho and the percentage of ants. It took the instance of 17 data, i.e. the branches that must be managed as evidence in 10 races.

Table 3: Experiments 10 runs.

Table 3.1
17 Branches
60 % ants
Beta = 1
Rho = 0.9

Race number	Iteration	Result
1	204	296.758
2	68	308.815
3	408	300.105
4	136	304.44
5	119	293.054
6	68	296.758
7	102	313.829
8	595	297.636
9	255	294.61
10	102	299.577

Table 3.2
17 Branches
60 % ants
Beta = 1
Rho = 0.95

Race number	Iteration	Result
1	102	301.78
2	51	297.561
3	170	296.758
4	799	294
5	119	301.956
6	68	304.44
7	204	301.78
8	255	300.105
9	85	296.758
10	153	308.815

Tabla 3.3
17 Branches
60% Ants
Beta=5
Rho=0.9

Race number	Iteration	Result
1	170	298.461
2	136	300.105
3	85	294.61
4	153	306.747
5	238	290.912
6	51	308.419
7	374	290.311
8	51	301.78
9	85	305.133
10	102	300.105

Tabla 3.4
17 Branches
60%Ants
Beta=5
Rho=0.95

Race number	Iteration	Result
1	289	299.021
2	561	300.105
3	85	305.794
4	1122	296.758
5	119	293.13
6	629	290.311
7	187	290.311
8	102	310.846
9	85	301.78
10	34	294.818

Table 3.5
17 Branches
80% Ants
Beta=1
Rho=0.9

Race number	Iteration	Result
1	102	290.311
2	867	300.105
3	119	304.163
4	119	296.758
5	204	304.612
6	527	299.021
7	85	300.105
8	119	294.61
9	68	296.758
10	51	304.936

Table 3.6
17 Branches
80% Ants
Beta=1
Rho=0.95

Race number	Iteration	Result
1	272	306.159
2	136	299.021
3	136	311.736
4	102	314.304
5	595	308.815
6	221	290.311
7	102	298.461
8	68	306.241
9	119	298.461
10	51	296.758

Table 3.7
17 Branches
80% Ants
Beta=5
Rho=0.9

Race number	Iteration	Result
1	85	301.78
2	221	294.818
3	153	290.311
4	408	294.818
5	136	299.021
6	170	296.758
7	51	308.815
8	68	293.498
9	255	301.84
10	731	310.219

Table 3.8
17 Branches
80% Ants
Beta=5
Rho=0.95

Race number	Iteration	Result
1	119	311.736
2	102	296.758
3	119	296.423
4	119	300.105
5	136	312.985
6	102	297.449
7	170	290.311
8	391	301.956
9	748	290.311
10	136	308.815

Table 3.9
17 Branches
100% Ants
Beta=1
Rho=0.9

Race number	Iteration	Result
1	102	307.035
2	187	296.758
3	102	299.021
4	119	308.815
5	187	300.105
6	1292	316.292
7	238	300.105
8	136	300.105
9	119	290.311
10	85	307.892

Table 3.10
17 Branches
100% Ants
Beta=1
Rho=0.95

Race number	Iteration	Result
1	170	306.159
2	289	299.021
3	136	300.105
4	255	300.105
5	170	290.311
6	544	297.449
7	153	301.956
8	272	296.758
9	102	311.39
10	170	308.419

Table 3.11
17 Branches
100% ants
Beta = 5
Rho = 0.9

Race number	iteration	Result
1	442	294.818
2	187	296.758
3	102	299.021
4	1275	294.818
5	374	293.13
6	799	294.818
7	255	299.021
8	34	294.818
9	527	294.818
10	680	294.818

Table 3.12
17 Branches
100% ants
Beta = 5
Rho = 0.95

Race number	iteration	Result
1	34	299.021
2	34	299.21
3	629	294.818
4	119	299.021
5	85	294.818
6	238	294.818
7	68	294.818
8	153	290.311
9	884	294.818
10	187	294.818

The rows that are highlighted in gray in each table represent the optimal values of time that a vehicle can travel to their respective distribution of pharmaceutical products in different locations is each branch of the city of Cuernavaca, Morelos. Then the results table summarized in this experiment of 120 samples with 17 pharmacies instance savings as shown

Table 4: Summary of experiment.

% Ant	Beta	Rho	Iteration	Results
60	1	0.9	119	293.054
60	1	0.95	799	294
60	5	0.9	153	290.311
60	5	0.95	374	290.311
80	1	0.9	102	290.311
80	1	0.95	221	290.311
80	5	0.9	153	290.311
80	5	0.95	170	290.311
100	1	0.9	119	290.311
100	1	0.95	170	290.311
100	5	0.9	34	294.818
100	5	0.95	153	290.311

Source: Own Preparation.

The first column shows the percentage of ants, the values used were:

60 % ant = 10.2
80 % ant = 13.6
100% = 17 ants

The results show marked up the best of all experiments performed. Based on these results it was found that the best values for beta, rho and the percentage of ants are:
Beta = 1
Rho = 0.9
Percentage ant = 100

This indicates that the result that was found in the iteration 290 311 119 is the most optimal for the distribution of orders to the different positions of the Pharmacy Savings time. This is not considered, gasoline or traffic.

Conclusions and future work.

When performing this article was achieved to obtain the optimization of routes, distance and time of the 17 franchises Pharmacy Savings, which is supplied by the distribution center Civac, Jiutepec, Morelos. Everything was achieved thanks to computer systems, and that the best results of the distances and time was obtained, using the codes with their respective programming in Matlab and C ++. With the use of nearest neighbor algorithms and the Ant Colony, yielded data that allowed approximate make a better decision when the distribution of pharmaceutical products.

An analysis of the interface Matlab program courage, according to 8 routes shown on the map of the city of Cuernavaca, Morelos was made. Where he was identified, that all depends on the algorithm that is being applied, so also the capacity, the distance of Pharmacy Savings suscursal another. Apart based on data and agree on the problem, there is a window of time when the vehicle reaches the customer and this begins to provide service in a time interval, as this depends on the amount of the order to supply and all customer.

Future work is appropriate to continue studying more problems relating to time window, since it will allow companies of any business twist and especially distributors to measure the travel time, the start time and end of the service, so same time planning service that is available to every customer.

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Amis fellow summer, that although not initially entediamos the goal, we work together, and with the support of everyone we could achieve each item regardless of the problems. Erik, Marlen, Fernando and Ricardo.

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