

Review of Vehicle Routing Problems Solving Software

Revisión de Software de Resolución de Problemas de Ruteo de Vehículos

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Resumen

Introducción— En un contexto de competencia global y avances tecnológicos, la logística se ha vuelto muy relevante para el correcto funcionamiento de las empresas, ya que esta puede representar hasta el 25% del costo de los bienes. En este sentido, los software de resolución de Problemas de Ruteo de Vehículos (VRP) constituyen una oportunidad de mejorar el desempeño de las pequeñas y medianas empresas (pymes) argentinas. En los últimos años, la oferta de estos aumentó significativamente, aunque presentan variantes que son —a priori— difíciles de discernir.

Objetivo— Identificar, caracterizar y comparar programas informáticos de resolución de VRP, reconociendo entre ellos los más recomendables en términos de herramientas de trabajo y factibles de aplicar en pymes, en pos de generar un aporte para el fortalecimiento de los sistemas de distribución de las mismas.

Metodología— Se plantea el interrogante: ¿Cuál o cuáles de los software de ruteo estudiados y analizados son más convenientes y recomendables para las pequeñas y medianas empresas? ¿Por qué? Para la búsqueda de información se consultaron las plataformas Scopus, ResearchGate, Google Académico y Google. Con base en una definición de criterios previa, se compararon los software seleccionados y se respondió el interrogante.

Resultados— De los resultados obtenidos en la búsqueda bibliográfica, se utilizaron una serie de criterios para seleccionar, luego caracterizar los programas informáticos, compararlos y analizarlos. Los seis software seleccionados fueron: SimpliRoute, RouteXL, RoutificMain, OptimoRoute, VRP SpreadsheetSolver y ArcGIS Online.

Conclusiones— Los programas informáticos considerados más adecuados son VRP Spreadsheet Solver, SimpliRoute y OptimoRoute debido a su fácil acceso y la capacidad para abarcar numerosas variables de decisión. Sin embargo, SimpliRoute y OptimoRoute tienen la desventaja de no ser gratuitos.

Palabras clave— Logística; sistema de distribución; problemas de ruteo de vehículos; programas de ruteo; VRP; pymes

Abstract

Introduction— In a context of global competition and technological advances, logistics has become very relevant for the proper functioning of companies, as this can represent up to 25% of the cost of goods. In this sense, vehicle Routing Problem Solving (VRP) software is an opportunity to improve the performance of small and medium-sized enterprises (SMEs) in Argentina. In recent years, the supply of VRPs has increased significantly, although they present variants that are —a priori— difficult to discern.

Objective— To identify, characterise and compare VRP resolution software, recognising among them the most recommendable in terms of work tools and feasible to apply in SMEs, with the aim of generating a contribution to the strengthening of their distribution systems.

Methodology— The following question is defined: Which of the routing software studied and analysed are the most convenient and recommendable for small and medium-sized enterprises? Why? For the information search, the platforms Scopus, ResearchGate, GoogleAcademic, and Google were consulted. Based on a prior criteria definition, the selected software are compared and the question is answered.

Results— From the results obtained in the literature search, a number of criteria were used to select and characterise, compare and analyse the software. The six selected software were SimpliRoute, RouteXL, RoutificMain, OptimoRoute, VRP Spreadsheet Solver and ArcGIS Online.

Conclusions— The software considered most suitable are VRP Spreadsheet Solver, SimpliRoute and OptimoRoute due to their easy accessibility and ability to cover numerous decision variables. However, SimpliRoute and OptimoRoute have the disadvantage of not being free.

Keywords— Logistics; distribution system; vehicle routing problems; routing program; VRP; SMEs



I. INTRODUCTION

Small and medium-sized Argentinean companies play a fundamental role in the industrial sector, not only for job creation but also for their contribution to the continuous renewal of different productive sectors and their potential to become a relevant complement for large companies [1].

The main functions of this kind of companies are manufacturing and distribution of goods and services to society, but due to real global competence environment, technological development & innovation [2], companies are forced to study and execute continuous improvement of processes, which generate continuous investment in technological advances and research and development, so production no longer represents an important difficulty.

Nevertheless, the problem growing in small and medium companies, due to the actual dynamic environment already mentioned, is that of needed logistic for an appropriate distribution of produced goods [3].

In detailing how the difficulties in distribution or route problems have huge importance due to its high impact on the client because it's a process with close contact to them [4], and besides, they represent high logistics costs for companies, which affects very often their financial earnings.

According to studies [5], these logistic costs could group in provisioning, represented by buying order costs; storage, represented by physical space, infrastructure, manipulation and possession of inventory; distribution, represented by transport and delivery costs; and associated information, represented by logistic management costs.

In Latin America, logistic costs represent between 18% and 35% of final product value, so, one of the main motives to measure the logistic performance is to reduce logistic costs [6]. Likewise, due to the geographical characteristics of our country, and physical infrastructure state, the mentioned logistic costs are approximately 25% of the goods final cost for Argentinean small and medium enterprises [7].

On the other hand, logistic services such as transport, distribution, and cross-dock represent 51.6% of outsourced logistic activities, and storage management a 35.3% [8]. The huge growth of direct sales, the explosion of e-commerce and their delivery to the owner, plus the traffic issue, impact on the client and affect transport efficacy [9].

Distribution schemes could effectively reduce distribution costs. According to this situation, having a routing system to manage resources efficiently to reduce these costs represents a research topic to be deepened, to obtain models similar to reality, or to search for algorithms to solve problems efficiently [4], [10], [11].

Several researches [12] is described the general characteristics that software should have to provide an effective solution according to customer goals, such as the use of different process' variables like vehicle quantity, speeds, and capabilities.

However, not all available routing software provides the same benefits, usage, and access requirements. At this point, it is considered opportune a research to find the right software to be used in small and medium-sized businesses.

Based on the positive impact that the use of these software could bring to the proper functioning of an organization, the objective of this work is focused on a comparison of different software, related to the work tool, the simplicity of use, and the access to the tools themselves, is the first condition to be free or free trial period.

II. METHODOLOGY

To carry out a study of the advantages and disadvantages of a certain number of routing computer programs, the following stages are developed:

1. Formulation of questions to be answered through research.
2. The search of diverse routing software.
3. Selection of informatics programs to be included in the comparison according to selection criteria.
4. Definition of criteria for analysis of advantages and disadvantages of each software.

5. Test of different computer programs and description of characterization and comparison among them.
6. Conclusions development based on the comparison of different software.

In the beginning, the following question is defined: which of the diverse routing software studied and analyzed are more suitable and recommended for small and medium companies? Why?

Referring to the search of diverse routing computer programs, it was used a historic register of different software generated into a classroom on an activity that connects this research topic with teaching practices and participation of a student's group, reaching an interactive process oriented to knowledge use. Together with this register, some search platforms such as Google, Google Scholar, Scopus, and Researchgate, were used to deepen the research, with keywords such as "Programas de ruteo", "Routing software", "Routing Optimizer", "Optimización de distribución de mercadería", among others.

In the next step, the programs that will be part of the analysis were selected based on the following selection criteria: availability to test the application with data and explore levels of benefits and tools, flexibility to add a large number of stops, and ability to include problem restrictions.

Table 1 shows the selected software for its analysis.

TABLE 1. SELECTED COMPUTER PROGRAMS.

Name	Download / use link
SimpliRoute	www.simpliroute.com
RouteXL	www.routexl.es
RoutificMain	www.app.routific.com
OptimoRoute	www.optimoroute.com
VRP Spreadsheet Solver	www.people.bath.ac.uk/ge277/index.php/vrp-spreadsheet-solver/
ArcGIS Online	www.esri.com/es-es/arcgis/products/arcgis-online/resources

Source: Authors.

The definition of comparison criteria is based on needed characteristics of these computer programs to provide an effective solution [12], such as, permit the entry of variables or problem's restrictions, for example, vehicle quantities, its speeds and capabilities, location, and client's demand. In this way, these criteria were defined considering the impact of both the form and ease of use of each software, as well as the fact that the solution's results are quite similar to the reality of each case and in the ability of each one to demonstrate different paths.

In this manner, the following comparison criteria were established: format of use, restrictions of use, vehicles, temporary windows, graphic resolution, analytic resolution, additional data, and suitability for small and medium companies.

The criteria "Format of use" explains if the software is downloaded to be installed or is used directly in the navigator. Also, it is identified the program access mode.

The criteria "Restrictions of use" identifies three options: free time-unlimited access to all tools of the computer program, free time-limited access to all tools of the software, or free and limited tool access of the software.

The criteria "Vehicles" refers to the opportunity that offers the software to operate with variables related to transport means, such as vehicle quantities, capabilities, speeds, associated costs to its use, among others.

The criteria "Temporary Windows" explore the option of entering time data of different locations to visit and in the operation of the distribution system, such as attention schedules, compliance with specific schedules as customer service, start and end time of workday, loading and unloading times, as well as service time in each location, among others.

The criteria "Graphic Resolution" refers to the clarity that solution paths are shown considering colors use, routes with name identification, and direction of circulation.

The "Analytical Resolution" criterion seeks to assess the analytical format of representing the routes to be executed and the profile of relevant data on the routes to be traveled, such as

distance traveled, circulation times, vehicle stops, the average and the total load of each transport, compliance with time and capacity restrictions, among others.

The criteria “Additional Data” is used as an extra topic to describe positive and negative items of each software, which are not included in the previous criteria.

At last, the criteria “Suitability for SMEs” looks for identifying routing software which is designed suitable for small and medium business, considering the analysis of all previous criteria. This answers the question: the computer program analyzed has the necessary features to be used for SMEs?

In the previous criterion, the following detail must be considered to define which one is adequate. The decision is based on the need of SMEs to access the use of software with low investment. Likewise, the application could allow obtaining a real and representative solution considering capacities vehicle restrictions, delivery schedules, simplicity to locate demands and clear representation of results, at least analytically.

In order of relevance, it is considered that characteristics and tools that the software has, valuated on the criteria “restrictions of use”, “vehicles”, “temporary windows”, together with high specification solution resolved by the software, considered in “Analytic Resolution”, have higher relative weight that the easy graphical representation (“Graphical Resolution”), and some additional features used by the software, included in “Additional Data”. At the bottom is located the criterion “Format of use”.

Once the comparison criteria of the programs were defined, an analysis of benefits and responses was carried out, modifying the values of the significant variables of the informatic programs. For this, a problem and data from a real situation in the context of the city of Olavarría (Buenos Aires) were used.

This research process was enriched by the problem-based learning or active learning methods, where the research activities were connected to teaching activities focused on concrete and real situations of the community. The execution of this integrality of functions provides knowledge and learning simultaneously to actors involved, both professors and students [13].

Active problem-based learning arises when different actors combine their specific knowledge within an interactive process aimed at the expansion of culture and the socially valuable use of knowledge, connecting research activities to community problems and the sectors that know from direct experience, hence the potential of creation expands [14].

In this way, the levels of motivation of both professors and students are higher through the resolution of specific situations.

Finally, the software are characterized, analyzed, and compared to answer the research question asked.

III. RESULTS

A. Software characterization and analysis

From the execution of numerous tests, taking as an example a real problem mentioned in the methodology section, a description of each software was established, to then make a comparison between them.

On the results of such comparison, an analysis on the characterization was executed, defining the computer programs as more adequate and suitable for application on small and medium businesses.

1) *SimpliRoute*

This optimization software for vehicle routing problems called SimpliRoute, developed in Chile in 2015. Today, SimpliRoute is recognized throughout the American continent, reflected in a high number of users.

Some reasons to explain the selection of this software we could mention easy access, simple use and the possibility of using it, both from the computer and from a mobile device.

Various research [15] is detailed the 4 restrictions that this SimpliRoute optimization model has, which are:

- Vehicle capacities.
- Different start points for vehicles.
- Driver change.
- Temporary Windows for clients.

Its beginning is to access the official website of the program, where an account is created, and a Free Access of 14 days is obtained, then a specific amount must be paid. To create an account, you must specify the numerical range of vehicles to use.

The software is used in internet navigator and uses Google Maps as a tool to determine locations and routes.

The first step is to characterize the vehicles, through maximum capacity, start (warehouse) and end points, driver information, usage costs, schedules, maximum number of visits. It has a specific alternative called “Skills”, which allows you to categorize vehicles into different types and assign the correct means of transport for special visits.

A disadvantage of this program in the identification of vehicles is the inability to specify the speed of movement of each one.

In the characterization of vehicles you can see the sections “Routing Options” and “Account Settings”. In the first, the route optimization characteristics are selected, with the option of using one or more vehicles, defining whether the routes end at a delivery point or warehouse, assigning a route per car, among others. The second section provides the option of entering the recharging time of the vehicles in the warehouse and the maximum linear distance in which shipments are made.

Once the vehicle definition step has been completed, you go to the location of the visiting points, which can be carried out directly in the program using the “Example worksheet” or using a Microsoft Excel worksheet. With the option of naming and locating these visiting points by address or coordinates.

Then the demanding load of each destination is specified, allowing to attach information regarding service hours, service times, data of the person to contact at that point, among others.

The software solves both simple and highly complex routing problems. A list is obtained with the different destinations to visit for each vehicle along with the times, loads, and average distances per route.

The different roads are shown on the map, taking into account the direction of the streets without identifying the route of each vehicle by color, which makes it difficult to see the graphic resolution.

2) *RouteXL*

The RouteXL software was developed in the Netherlands in 2009 and is today highly recognized and used worldwide. It is an extremely comprehensive software with multiple applications [16], it uses various options of information sources to obtain live traffic data and avoid delays.

Once the software web page is accessed, a background map and a window are displayed where it gives the options to register (Log in) or only have the map display (Continue). To register, you only have to create a user with a corresponding e-mail, a username, and a password, it also presents a plan option between free and paid.

It should be noted that, when using RouteXL on a computer, it is not downloaded, and installed, but is used through its website.

When you log in as a user, it shows the map where you can click on the different destinations. The “Import” option allows you to insert up to 12 locations, “Directions”, shows the list of loaded points, “Routes”, records the calculated routes and “Options”, chooses the map to use and the service times are configured in the points, departure time, vehicle type and departure address.

Once the different variables have been configured and the different destination points have been loaded, “Find Route” is executed.

RouteXL also presents the option of downloading the application on mobile devices with iOS, Android, and Windows operating systems, to export the routes.

To access the variables of capacity and speed of vehicles, costs of use, and other benefits, a monetary sum must be paid. The free version allows loading the departure location together with the different destination points and calculates the best route in terms of time and distance traveled. Thus these results in a considerable disadvantage as the constraints of the problem cannot be taken into account and you get the same options as a regular GPS device. As a secondary disadvantage, it is worth mentioning the inability to import the destination point data through an Excel spreadsheet or other program.

3) *RoutificMain*

The Routific company, founded in Canada in 2012 under the idea of helping different business areas not only reduce their distribution times and costs, but also minimize harmful emissions to the environment, designed the RoutificMain software, which optimizes product distribution routes [17], can help its users save time and fuel with 40% shorter routes.

To access it, you start with the creation of an account, for which you need the name, an email address and a password, using it from the web browser.

When accessing the program, you must specify the number of vehicles to be used, the type of product to be transported and the type of destinations (businesses, homes, etc.). Once the fields are completed, the map and the options “Drivers” and “Stops” are displayed.

It begins with the “Drivers” section, where three options are provided to load the different vehicles to be used. The first is called “Add Drivers (Basic)”, where you must specify the amount to be used and the starting point. The second option is called “Add Drivers (Advanced)”, in which one vehicle is added at a time and is more complete than the previous one, being able to enter:

- Driver’s name.
- Tour start and end points.
- Working hours.
- Driver’s telephone number.
- Vehicle capacity.
- Type of vehicle.
- Speed (Slow, Normal or Fast).
- Rest interval.

As a last option, “Upload a List of Drivers” is presented, where the data of the vehicles and drivers are imported through a Microsoft Excel file.

Once the means of transport to be used have been loaded, the stops are entered, where the same three previous options are presented, “Add Stops (Basic)”, “Add Stops (Advanced)” and “Upload a List of Stops”. In the first mentioned, the locations are loaded one by one and the name and address or coordinates of the same are requested. In the second alternative, the stops must also be entered one by one, but it allows loading related data such as:

- Name.
- Direction or coordinates of the point.
- Stop opening hours (it must be attended within those hours).
- Service duration.
- Charge demanded.
- Phone number.
- Email.
- Type of stop.
- Notes to keep in mind about the stop.

The last alternative allows entering the data through a Microsoft Excel spreadsheet. The program offers the option of downloading a sample sheet for both vehicles and stops.

Once this point is reached, “OptimizeRoute” is executed and the software shows the optimal routes of the problem both graphically and analytically.

Regarding the analytical resolution, an exemplary list is displayed like the one shown in [Table 2](#):

TABLE 2. LIST OF ROUTIFICMAIN.

Driver	Capacity	Time	08:00	09:00	10:00
Driver1	50%	80%	Departure	Stop1	Stop2

Source: Authors.

[Table 2](#) specifies the name of the assigned driver in the “Driver” field, in “Capacity” and “Time” the percentages of total capacity and available time used respectively, are shown and in the columns where the hours are, it is detailed in which moment the stops are made, in this case an exit sign would appear at 08:00 am and all the stops organized chronologically as they should be made until 10:00 am.

Regarding the graphic resolution, the routes to be carried out by each vehicle are shown with different colors, taking into account the direction of the streets.

As for the disadvantages that the RoutificMain software presents, the following can be mentioned:

- Low specification of vehicle speed, select 3 categories, slow, normal and fast.
- If a vehicle exceeds its total capacity, it does not return to the warehouse and go out again, but rather a percentage higher than 100% appears in the “Capacity” field of [Table 2](#).
- A portion of the entire software tools can be accessed free of charge for a period of 7 days.

4) *OptimoRoute*

OptimoRoute is a routing optimization software, created in 2012 in the United States, used by multiple companies from different business sectors around the world.

OptimoRoute is defined as a commercial service on the web [18], where the different orders are assigned to the vehicles based on the route that each must do. It also involves variables such as drivers’ working times and maximum vehicle capacities.

Like the previous programs characterized so far, it is used through the web browser and requires the creation of an account, for which a user name, email address and password are required.

Its start corresponds to the location of the warehouse, the type of business (fast food, garbage collection, etc.) and the number of vehicles, along with work and rest times.

Then the map is displayed with the location of the departure point and the sections to insert the visiting points, managing the vehicles to be used.

The destination points, called “Orders”, can be loaded from the program or through the import of a Microsoft Excel file, and are carried out with the following specifications:

- Name of the point.
- Date of visit to the point.
- Type of order (Delivery or Collection).
- Assign a particular driver to carry out the order (optional).
- Location through address or coordinates.
- Duration of the visit (optional).
- Priority (High, Medium or Low).
- Cargo demanded, in terms of weight or volume.
- Temporary window, that is, the time within which the visit should take place (optional).
- Contact email and telephone number (optional).
- Notes to keep in mind about the visit (optional).

The “Plan Routes” button allows defining conditions of variables related to how many vehicles to use, their maximum capacities in kilograms or liters, enabling drivers to return to the warehouse upon reaching the maximum capacity and exit again, and the duration of that stop at the warehouse in minutes.

Also, “Plan Routes” gives the option of balancing the work of the drivers, balancing time and quantity of orders. Once this point is reached, the calculation of the optimal routes is executed.

In graphic terms, the program shows the routes made by the vehicles on the map taking into account the direction of the streets and differentiates the route of each driver by color.

Regarding the analytical solution, there are three results related to destinations, routes and schedules:

- “*Orders*”: Where the list of destination points is reorganized according to chronological order, the time in which each point is visited is also illustrated and the stops of the first driver are shown first, then the second and so on, identifying the color with which each one is represented on the map.
- “*Routes*”: Here you can see a list of the vehicles used, with the identification color, name, distance traveled, working time and number of stops made by each one.
- “*Timeline*”: The stops made by each driver are specified chronologically through a matrix where each row represents each vehicle and the columns represent work hours.

Among the advantages of this software we can highlight its high ease of use, the clarity with which solutions are shown, both graphically and analytically, through the use of colors and the sense of the streets, and the high amount of data from the different routes illustrated in the solutions.

As regards the disadvantages, the following can be mentioned:

- It has access to a free 30-day trial.
- No matter how many colors are used, if the destination points are very close to each other, the graphical interpretation becomes confusing.
- The option to specify vehicle speeds is not given and once the number of drivers to be used has been entered, it cannot take higher values.

5) *VRP SpreadsheetSolver*

VRP SpreadsheetSolver is an open-source tool that is added to Microsoft Excel. Unlike the various computer programs specified above, this one must be downloaded and installed on the computer. Upon entering the software, a Microsoft Excel file opens containing the “VRP Spreadsheet Solver” tool.

It is worth clarifying that, to obtain data on distances and driving times, VRP Spreadsheet Solver gives the option of using the Bing Maps platform, for which a free license must be obtained.

Fig. 1 illustrated which shows the relationship between each Microsoft Excel worksheet of the program and the instructions for its use are detailed [19], which begins with a sheet called “VRP SolverConsole”, where the following data of the problem to be solved:

- Number of warehouses to use.
- Number of points to visit.
- Method of computing distances and times, where, if you have a Bing Maps license, you can select to use both distances from the platform as well as driving times in real time according to car traffic. In case of not having a license, you can choose Euclidean or rectilinear distances and select the average speed of the vehicles.
- Number of vehicle types, that is, categorizes them in order to later be able to differentiate them.
- If vehicles must return to the warehouse at the end of the day or at multiple times during the day.
- Temporary windows.

- Display map to use.
- Time limit for searching for the optimal solution.

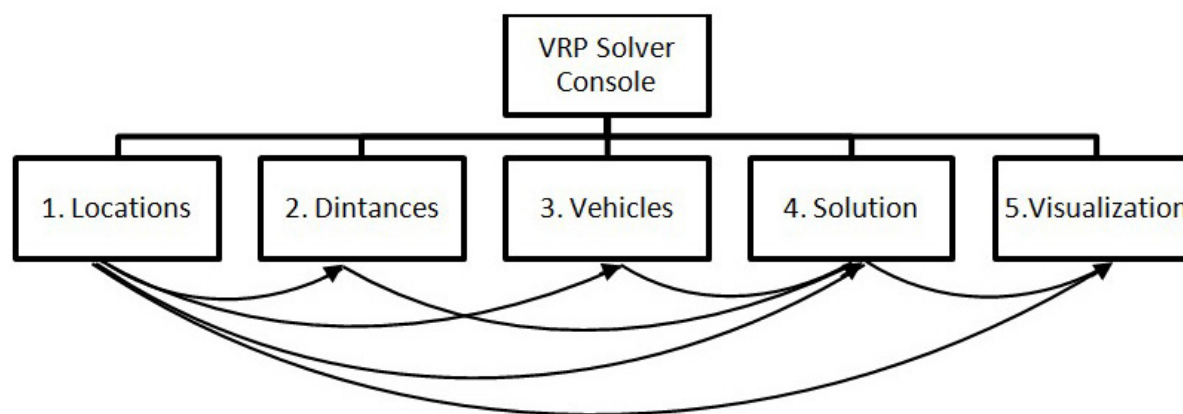


Fig. 1. Relationship between the VRP Spreadsheet Solver worksheets.
Source: [19].

Then the data referring to the warehouse and the points to visit are loaded:

- Name of the point.
- Location, using addresses or geographic coordinates.
- Hours in which the point should be visited.
- Whether it should be visited or not.
- Service time.
- Charge demanded.

Once the locations are loaded, the button “2.Distances” is clicked and the program calculates the distances between each point previously loaded with the others, including the warehouse. It also calculates the driving times required to travel those distances.

Next, the button “3.Vehicle” is pressed and the different means of transport to be used are loaded, through the following data:

- Starting point.
- Type of vehicle.
- Maximum capacity.
- Maximum distance to travel.
- Costs per trip or unit of distance traveled.
- Working hours.
- Maximum working time.
- Final destination point.
- Number of vehicles to be used that will have these characteristics.

Now with the data of the different geographical points and of the vehicles to be used in the problem, the button “4.Solution” is pressed and the program builds the problem solution tables, there will be a table per vehicle used and they will show the points visited, distance traveled, arrival times, service and departure from each point, vehicle operating cost and a follow-up of the load that it carries at all times.

Having the solution tables built, the button “5.Visualization” is clicked and the map is generated with the warehouse and the points to visit marked, also together with the line color that will represent each vehicle.

Finally, the button “6.Solver” is executed, with which the software is put into operation, the solution tables are filled with the data and the routes that each vehicle will take are marked on the map, but they will be illustrated through straight lines, without taking into account the direction of the streets.

Among the main advantages of the VRP Spreadsheet Solver can be highlighted:

- Access to all the software's work tools completely free of charge.
- Alternative to use a geographic information system that gives distances and driving times in real-time such as Bing Maps.
- Ability to load multiple data related to the problem so that the solution obtained is consistent with reality.
- It is used through a worldwide known program as Microsoft Excel.
- High analytical resolution, with the provision of multiple important data.

Regarding disadvantages, the main one has to do with the low graphic resolution, although the distances that appear in the solution tables are those calculated as specified (Euclidean, rectilinear or those of Bing Maps), on the map they have illustrated the routes through straights, without taking into account the direction of the streets. Also, if you have multiple vehicles and points close to each other, the graphical interpretation becomes confusing.

6) *ArcGIS Online*

With more than a million users worldwide and facilities in over five thousand universities, Environmental Systems Research Institute, Inc. (ESRI), founded in 1969, is a leading company in the design and development of software for Geographic Information Systems (GIS) [20].

ArcGIS is the name of a set of software products developed by ESRI in 1999 in California, United States. These are downloadable and installable to the computer, except for the software called ArcGIS Online, which is used from the web browser.

To access the software, an account must be generated in ArcGIS, it grants a 21-day free program trial.

To create the account, the following data must be entered:

- Name and surname.
- Email address.
- Postal Code.
- Phone number.
- Company.

Upon entering the program, the map of the program is displayed and begins with the creation of your work map, for which the software provides a series of instructions to follow:

1. Move and enlarge the map to the required work area.
2. Select a base map (topographic, navigation, streets, etc.) and add layers to it.
3. Add map notes (optional).
4. Name and save the map.

It is recommended to solve vehicle routing problems by creating two layers, one for the warehouse(s) and another for the different destination points.

With the generated work map, the optimal routes of the problem are searched. This is where the program asks to load the conditions and pertinent data of the problem:

- Map layer containing stops.
- Type of means of transport to use.
- Starting point and final destination.
- Maximum number of vehicles to use.
- Maximum allowed quantity of stops by vehicles.
- Working time at each stop.

With the data entered, the software performs the analysis and displays the optimal routes on the map, discriminated by color, along with a list of the stops made in chronological order, distances traveled and working times for each vehicle.

The main disadvantage of using this software is that it is not developed to solve vehicle routing problems as its main function, but rather it is a program for creating work maps and optimizing travel routes. This can be seen in the fact that it is not requested to enter the data of the demanded load or the maximum capacity of the vehicles, nor is it involved temporary work windows of the different points nor is the working speed of the vehicles specified.

However, it is an extremely useful program in terms of route optimization related to times and distances.

B. Software comparison

Table 3 show comparison results of different routing computer programs, according previously criteria defined.

TABLE 3. COMPARISON OF VEHICLE ROUTING SOFTWARE.

	Use format	Use restrictions	Vehicles	Temporary windows	Graphic Resolution	Analytical resolution	Additional data	SMEs suitable
Simpli-Route.	Use in web navigator. Account creation.	Total free access during 14 days.	Sufficient, no speed specifications.	Sufficient.	Limited.	Adequate.	Download possibility in mobile devices.	Yes.
RouteXL.	Use in web navigator. Account creation.	Free access to a limited number of tools.	Insufficient.	Insufficient.	Limited.	Limited.	Download possibility in mobile devices.	No.
Routific-Main.	Use in web navigator. Account creation.	Free access to a limited number of tools and during 7 days.	Insufficient.	Sufficient, no work time in warehouse is specified.	Adequate.	Adequate.	No possibility to vehicle returns to warehouse when completed its capacity.	No.
Optimo-Route.	Use in web navigator. Account creation.	Total free access during 30 days.	Sufficient, no speed specifications.	Sufficient.	Adequate.	Adequate.	Vehicles number can not be modified.	Yes.
VRP Spread-sheet Solver.	It is downloaded and installed in computer. No account creation needed.	Free unlimited access.	Sufficient.	Sufficient.	Limited.	Adequate.	Real time data can be used through Bing Maps platform.	Yes.
ArcGIS Online.	Use in web navigator. Account creation.	Total free access during 21 days.	Insufficient.	Insufficient.	Adequate.	Adequate.	Loads and capacities not specified. Good to optimize in terms of time and distance.	No.

Source: Authors.

The criteria with the highest relative weight to decide on the decision “suitable for SMEs” are “Restrictions of use”, “Vehicles”, “Temporary windows” and “Analytical resolution”, as specified in the methodology.

The VRP Spreadsheet Solver software is the only one that does not require the creation of an account for its access and is downloaded and installed on the computer, it is not used from the web browser. Likewise, it is the only one that allows access to all of its work tools free of charge for an unlimited time.

On the contrary, RoutificMain is the one with the most restrictions of use, since a limited number of work tools are allowed during a defined time of free use.

The other programs have a temporary restriction, except for RouteXL that allows their use free of charge for an unlimited time but with access to a portion of its functions.

The RoutificMain and VRP Spreadsheet Solver programs can specify the vehicles to be used in an extremely comprehensive way, taking into account all relevant variables. However, RoutificMain has the disadvantage that the capacity of the vehicle is full and does not return to the warehouse to renew it and restart at zero.

In the case of SimpliRoute and OptimoRoute, it is not possible to specify the speed of the vehicles.

When it comes to Temporary Windows, SimpliRoute, OptimoRoute, and VRP SpreadSheet-Solver stand out from the rest because they provide the option to be specific in terms of work hours.

RoutificMain appears in the background, presenting the lack to specify the working time in the warehouse.

From the analysis it is derived that the most rudimentary software concerning Graphic Resolution are SimpliRoute, RouteXL, and VRP Spreadsheet Solver, because they do not use colors or take into account the direction of the streets, making interpretation difficult.

The other software analyzed present effective graphic resolutions, easy and good interpretation.

All the vehicle routing computer programs analyzed provide extremely complete and varied analytical resolutions, with the presentation of variables of great weight such as distances traveled, work times, stop chronology, etc. The exception in this section is RouteXL, which offers a small amount of solution data.

As additional relevant data that benefit or limit the programs, it is mentioned:

- SimpliRoute and RouteXL: can be downloaded on mobile devices.
- RoutificMain: when the vehicle's capacity is full, it does not return to the warehouse for renewal. The analytical resolution shows a percentage of utilization of the capacity of that vehicle greater than 100%.
- OptimoRoute: once the number of vehicles to be used has been entered, it can be varied by lower values.
- VRP SpreadsheetSolver: With a free license for Bing Maps, it have access to real distance data and driving time data in real time.
- ArcGIS Online: this is software for creating your own maps and optimizing routes. You do not have access to specific variables of vehicle routing problems such as capacity, loads, etc.

Finally, it is concluded that the most suitable vehicle routing problem solving software for SMEs are VRP SpreadsheetSolver, SimpliRoute and OptimoRoute, due to their ease of use and the high number of relevant variables that they take into account at the time to find the optimal solution. VRP Spreadsheet Solver has the particular advantage of being totally free, however, if favorable results are obtained when applying the SimpliRoute or OptimoRoute trial period, the SME can choose to adhere to the payment plans offered and have unlimited access to tested software.

IV. CONCLUSIONS

The work analyzes a set of vehicle routing problem-solving software, characterized and compared through eight criteria to determine the feasibility of use in SMEs.

Given that the selected programs are for commercial purposes, it is necessary to clarify that the analysis carried out is completely impartial and has no lucrative interest in promoting or rejecting the use of any of the computer programs analyzed.

Their selection was based on the level of accessibility, the flexibility to enter points of demand and the ability to incorporate problem restrictions.

The criteria used for the comparison of the selected programs are form of use, restrictions of use, vehicles, temporary windows, graphic resolution, analytical resolution, additional data and suitable for SMEs.

The SimpliRoute, OptimoRoute and VRP Spreadsheet Solver programs show to be the most suitable and recommended for use in SMEs mainly due to the large number of variables they have to manipulate. Its advantages are to be able to characterize both the vehicles to be driven and the points to visit in detail, with multiple variables such as speeds, schedules, load capacities, etc., a fact that allows obtaining more efficient solutions that are close to reality.

However, it should be noted that in this sense VRP Spreadsheet Solver stands out over the other two programs for being able to specify speeds.

The three programs mentioned above use geographic information platforms, such as Google Maps or Bing Maps, to define locations and use data in real time, an advantage that accompanies the choice of use for Argentinean SMEs.

As an advantage over the rest, OptimoRoute and SimpliRoute have the option of downloading on mobile devices. However, VRP Spreadsheet Solver has the benefit of being completely free.

On the contrary, the programs not recommended for use in SMEs are Route XL, ArcGis and RoutificMain. The first two due to the lack of specification of variables related to vehicles and temporary windows. Although RoutificMain improves performance in terms of these variables and returns adequate graphical and analytical solutions, it does not provide the possibility that the vehicle will return to the warehouse when it reaches its capacity.

The use of vehicle routing troubleshooting programs allows SMEs to obtain a defined distribution system, with projections of stops, times, loads and costs. In this sense, saving in logistics costs is addressed with the use of these computer programs, by minimizing the time and distance variables.

This research is useful in terms of its application, both in the SME industry and in the learning process of industrial engineering students.

The results obtained in this research advance are a first comparative step of VRP resolution software. However, to support the decision regarding the appropriate use for SMEs, the application of a multi-criteria technique could be used in the next stage of the study.

In future research, it is desirable to carry out tests of the recommended software, executing and analyzing their application in specific case studies, thus obtaining more knowledge about the factors that contribute and hinder their successful use to fine-tune the necessary characteristics for SMEs.

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