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Heuristic of the Nearest Neighbor in the delivery of supports within the State of Veracruz

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Abstract. The supply of products of first necessity is one of the most important problems inside to the humanitarian logistics for, this activity must have attributes such as a) quantity; b) propitious derived from the physical and social aspects of the area; c) speed, and d) reliability. This document addresses this problem during the emergency phase of the disaster; two methods of solution are put to evaluation and comparison, with their different characteristics, attributes, advantages, and disadvantages, but with the same objective, to find the routes of delivery of products that allow the worthy survival of the victims. These methods are tested in the municipality of La Perla, Veracruz, Mex., houses 46 localities and it has been impacted by a natural phenomenon in repeated occasions. Through the heuristic technique of the nearest neighbor (NN), five delivery routes of products are obtained, and a locality is omitted. While the exact programming through the classic vehicle routing problem with capacity (CVRP) throws six paths.
Keywords: Hydrometeorological phenomenon; Logistics; Supports; Multiple Vehicle Routing;VMC Heuristics.

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1. Introduction

In recent years, the frequency of occurrence of destructive natural disasters in the world has caused serious damage to social construction and economic development, such as the Indonesian tsunami in 2004, the earthquake of 5.12 Richter scale in Wenchuan in 2008, the freezing rain disaster in southern China in 2008, the devastating 2011 earthquake in Japan, the flood disaster in India in 2013 and the hail disaster in Yancheng in 2016, Jiangsu. Especially in July 2016, heavy rains continue to hit northern China, with heavy flooding in southern China at the same time [1].

Natural disasters refer to the natural processes that occur in the eco-system, which can lead to the loss of the stability of the socio-economic system and to the serious imbalance between the supply and demand of social resources. Natural disasters can be divided into six categories: geological disasters, meteorological disasters, environmental pollution disasters, fires, marine disasters and biological disasters [2]. In Mexico, the National System of Civil Protection has adopted the classification based on the type of disturbing agent that produces them. The risks of geological, hydrometeorological, chemical, sanitary and socio-organizational origin are thus distinguished. With this approach, defines hydrometeorological phenomenon as the disturbing agent that is generated by the action of atmospheric agents, such as tropical cyclones, extreme rains, rain, river, coastal and lake floods, snowstorms, hail, dust and electricity, frost, droughts, warm and cold waves and tornadoes [3].

The National System for the Integral Development of the family of Mexico, determines three phases in which a situation of risk, emergency or disaster develops: *a)* preventive stage, occurs under conditions of normality, the actions foreseen are essentially, the organization and development of preparedness measures to be able to face an emergency situation or disaster if it occurs; *b)* stage of the emergency, when there is the presence of an emergency or disaster, and includes rescue measures, first aid and other relief mobilizations; and *c)* stage of rehabilitation, occurs when the emergency or disaster has been quantified and foresees the activities that seek to recover, alleviate and rebuild the damaged area, in order to allow the population to resume their daily life. In addition to the material recovery of the environment, you should consider including the psychological rehabilitation of the population due to an emergency situation or disaster that goes beyond your attention capacity [4].

Mexico, is a country of great contrasts and great climatic variability, this is derived from the fact that it is located in an intertropical region, which makes it subject to hurricane attacks that are generated both in the Pacific Ocean and in the Atlántico The effects of these phenomena, in terms of swells and winds, mainly reside in the coastal areas of the Pacific, the Gulf,and the Caribbean; The intense rain that these phenomena originate can cause floods and landslides not only on the coasts but also in the interior of the territory. Of the 25 cyclones that on average arrive each year to the nearby seas of the country, four or five usually penetrate the territory and cause severe damage [5].

Some regions of Chiapas, Tabasco, and Veracruz are extremely humid (> 2000 mm / year) due to their complex topography, their proximity to the Intertropical Convergence Zone, the influence of tropical systems of the Atlantic and the Pacific and the passage of fronts cold and northern winters that cross from the Gulf of Mexico to the Isthmus of Tehuantepec generate rain all year round. Tabasco and Veracruz are the states most prone to extreme rains in both winter and summer and those that declare more emergency and disasters annually [6-8].

Much research in the late 1980s focused on operations research applied to disaster management. The general and relatively complete reviews of the literature in the field of logistics applied to emergencies and disasters can be found in Altay and Green[9], Caunhye et al.[10], Galindo and Batta [11], Manopiniwes and Irohara [12], Faturechi and Miller-Hooks [13], Hoyos et al.[14], Özdamar and Ertem [15] and Zheng et al. [16].

Regardless of the type of disaster, the severity, the losses, and the quantity demanded, the identification of critical routes can be considered as a separate investigation. Therefore, the separation between the determination of critical routes and the problem of distribution (that is, mainly includes problems of the evacuation of victims and distribution of aid and aid) can be effective in practice. Some distribution problems can be found in Haghani and Oh [17], Viswanath and Peeta [18], Özdamar et al. [19].

Few works focus on the design of the emergency transport network as Viswanath and Peeta [18] and Shariat Mohaymany and Pirnazar [20]. Viswanath and Peeta [18] they focus on the identification of critical routes under disaster conditions, they also developed a network design problem with maximum coverage of multiple products to plan critical routes for response to earthquakes with two objectives: minimize total travel time and maximize the total population that can be covered with these resources.

Problem Statement.

To the state of Veracruz of Ignacio de la Llave, Figure 1, it is made up of 212 municipalities; it is located at the coordinates latitude 19. 39296º 28'17º9'N, longitude -96. 41856º 36'98º39'W. With an extension of 71,824 Km2, it represents 3% of the national territory. Until 2010, it has a record of 7,643,194 inhabitants, showing an annual growth rate of 1% [21].

During the last twenty-two years, hydrometeorological phenomena have severely hit the aforementioned State, the disasters caused by the remnants of Hurricane Roxanne (October 1995); the combination of cold front No. 5 and tropical depressure No. 11 (October 1999); hurricane Keith (2000); the impact of four tropical storms: Bret, Gert, José and hurricane Stan (2005); hurricanes Dean, Felix (2007); tropical storm Marco (2008); hurricane Karl and tropical storm Matthew (2010); the tropical storm Arlenne, the tropical wave 8 (2011); the tropical tormentor Ernesto y hailstorms (2012); tropical storms Barry, Fernand and Manuel, hurricane Ingrid (2013); Heavy rains and river and pluvial floods (2014, 2015); heavy rains (2016), and hurricanes Franklin and Katia (2017), are clear examples, not counting the damages caused by increasingly frequent mesoscale convective systems that generate intense rains, storms [22].

Figure. 1 Municipalities of the State of Veracruz of Ignacio de la Llave, Mexico.

- La Perla is located in the center and highest area of the state of Veracruz, with an area of 137.5 km^2, represents 0.19% of the state territory, is made up of forty-six locations, one urban and forty and five of rural type, has an indicator of very high degree of municipal marginalization and high social lag. Each year, the town hall is significantly impacted by natural phenomena, leaving. As a result, a large number of victims, examples of which are: *a)* Severe rainfall, 7095 affected in 2016; *b)* Heavy rains and snowfall, 7095 victims in 2015, and *c)* Hillside movement and severe rain, 8280 affected in 2015.

The present work addresses the problem of multiple routing in the emergence stage of the disaster in the State of Veracruz. With the purpose of segmenting the subject state of study and establishing the delivery routes of consumables to people affected by the presence of a hydrometeorological type phenomenon. For this, the closest neighbor algorithm is used, which is a technique widely used in pattern recognition problems. In order to evaluate the feasible result obtained and derived to the required hardware needs and the consumption time for the search of an optimal solution, a comparative scenario is developed between the result of feasible routes through the VMC against the result of optimum routes, through the application of a vehicular routing problem with capacity (CVRP), to the municipality of La Perla.

2. Literary Review

Logistics is a part of the supply chain process that plans, carries out and controls the efficient and effective flow and storage of goods and services, as well as related information, from the point of origin to the point of consumption in order to meet the requirements of customers (Council of the Logistics Directorate, CLM) in [23]. In emergency operations, logistics is required to support the organization and implementation of response actions so that they are not only fast, but also agile and effective. The mobilization of personnel, equipment, the material necessary for the work of the organizations that provide assistance and even the activities related to the evacuation of the wounded or the relocation of populations affected by the disaster, require a logistic system to be carried out efficiently [24]. In this area and in order to meet the objective of the humanistic logistics system, different algorithms have been applied that can be used both to obtain optimal solutions and feasible solutions. The heuristic method is the procedure that tries to discover a very good feasible solution but not necessarily an optimal solution, for the specific problem under consideration, whereas a metaheuristic is a general solution method that provides both the structure general as strategic criteria to develop a specific heuristic method that fits a particular type of problem [25].

Viera et al. [26], proposes an information system for decision-making at three levels: a) strategic, to define the quantity, location and capacity of the logistics centers, distribution points and shelters; b) tactical, inventory policies for disaster supplies, transportation strategies, vehicle replacement and maintenance policies, and c) operational, operational decisions in real time for vehicle dispatch and routing. In its third section, the document proposes possible models and methods (quantitative) applicable to the case, the proposed measures within section two, such as vehicle routing.

For its part Cornejo et al. [27], performs a numerical analysis through a mixed whole linear programming model, to obtain the location and optimal number of stores, when the attention capacity increases, ending with a trend analysis of the marginal benefit that is defined as the incremental number of people that they will receive the support when the storage capacity increases, which has the purpose of distributing humanitarian aid with attention to the victims in their totality after the occurrence of an earthquake. While the work of Argon et al. [28] the forecasting decisions that must be made in the face of the occurrence of an earthquake of magnitude greater than 8 degrees are addressed in a specific manner, obtaining. As a result, the optimal location of warehouses in the safe areas surrounding the most vulnerable districts. The researchers develop a two-stage model, using the first linear programming to establish a coverage model by the geographical affinity of the districts, through the Lingo Software 11. The second consists of a heuristic model, which enter the results provided by the software used in stage one, to obtain the number of stores per affinity zone, using the demand of families affected
In the publication of Vaira & Kurasova [29] a Genetic Algorithm based on insertion heuristics for the Vehicle Routing Problem (VRP) with restrictions is proposed, which provides a feasible solution through heuristic inserts, where the stochastic characteristic is preserved of the AG and solutions can be generated within the feasible space, checking that the restrictions defined in the insertion process are met. The proposed Genetic Algorithm model consists of two new operators called, "Extract and Reinsert," the extracted parts are reinserted again using a previously defined insertion. In this Genetic Algorithm, no additional local search methods are involved to improve the solution, so it does not depend on local search limitations and can be easily extended with additional restraints.

Tunjongsirigul & Chiadamrong [30] which develops, a comparison between two methods for the problem of vehicular routing (VRP, for its acronym in English) in a pastry company. This comparison was carried out for both the simple VRP and the VRPTW variant; in both cases, the problem consisted of minimizing the distance and the total cost of transport, for this, the authors made use of the Genetic Algorithm (AG) with the reproduction, crossing and mutation operators, in order to optimize the total costs of transport and compare them with their current system where the operators use their own distribution experience similar to the heuristic of the nearest neighbor.

On the other hand, Liu et al. [31] present a variant of the Vehicle Routing Problem (VRP), in which the vehicles leave different warehouses and do not necessarily return to it, this variable is the Problem of Vehicle Routing with Multi-warehouse Open (MDOVRP, for its acronym in English). The authors solve the problem with a hybrid genetic algorithm, in which it is intended to find the minimum cost of travel of vehicles in different instances. For which they made use of solver CPLEX. The computational results indicated that the hybrid genetic algorithm was tested in a range of instances better than in the CPLEX and that it can solve the problem of vehicle routing with open multi-warehouse giving in 2.78% the best result for the total cost.

3. Description of the Models

– Heuristic.

The software package created by Sas Wahid Hamza in 2012, composed by three files (NIAlgVRP: Nearest Insertion Algorithm for Serving Vehicle Routing Problems, ConstEvalVRP: Constraint Evaluation of VRP, Problem25: consist of n nodes, demands, and x and y coordinates positions) is used [32, 33]. The algorithm is:

```
1. Begin
2. Begin with [1 1], 1 is Depot.
3. Examine all outlet that not yet served; there will be feasible
   outlets and infeasible outlet.
4. For feasible outlets, choose the best outlet.
5. Decision: There is a more feasible outlet.
     a. Yes, return step 3.
     b. No, go to step 6.
6. Create new Route [1 1]
7. Decision:  Are outlets served:
     a. Yes, go to step 7.
     b. No. return to step 2.
8. End.
```

– Optimization

Routing planning is proposed in two senses: *1.* It seeks to minimize the total cost of transport, distance, travel time, waiting time or transhipment at the terminals; and *2.* It seeks to maximize the benefits through the intensive use of the units, the level of customer service and balance the resources of the company, that is, to create productivity. Etrasa (2007) points out that in planning routes, two important aspects must be taken into account: *a)* the level of supply in each source and the amount of demand in each destination, and *b)* the unit transport cost of the merchandise. -each to each destination.

The problem of vehicular routing with capacities (VRP or CVRP) is a variant of the Problem of the Traveling Agent (TSP), in which each client has a demand associated, and the fleet is homogeneous, that is, each vehicle has a capacity. In this case, the total demand of the customers visited by the vehicle cannot exceed its capacity.

The mathematical definition for the CVRP is:

$$\min \sum_{i\in V}\sum_{j\in V} c_{ij}x_{ij}$$

Subject to:

$$\sum_{i\in V} x_{ij} = 1 \qquad \forall\ j \in V \setminus \{0\}$$

$$\sum_{j\in V} x_{ij} = 1 \qquad \forall\, i \in V \setminus \{0\}$$

$$\sum_{i\in V} x_{i0} = K,$$

$$\sum_{j\in V} x_{0j} = K,$$

$$\sum_{i \in S} \sum_{j \in S} x_{ij} \geq r(S), \qquad \forall\, S \subset V \setminus \{0\}, \quad S \neq \emptyset$$

$$x_{ij} \in \{0,1\} \quad \forall\, i,j \in V.$$

Where: $V = \{v_0, v_1, \ldots, v_n\}$is a set of vertices of the graph, where $v_0$corresponds to the warehouse;C is the matrix of distances or costs c_{ij}between customers v_i and v_j;K is the number of vehicles of capacity *C*, necessary to load all the demand;S is the subset of the vertices of the graph where $S \subset V \setminus \{0\}$;$r(S)$is the minimum number of vehicles needed to serve all customers in S[34].

4. Methodology

To solve the problems described in this document, actions are carried out such as *1.* Choice of programming software; *2.* Application heuristics; *3.* Optimization problem; *4.* Data extraction, and *5.* Identification of variables, Figure 2. All the above to make way for the Results section.

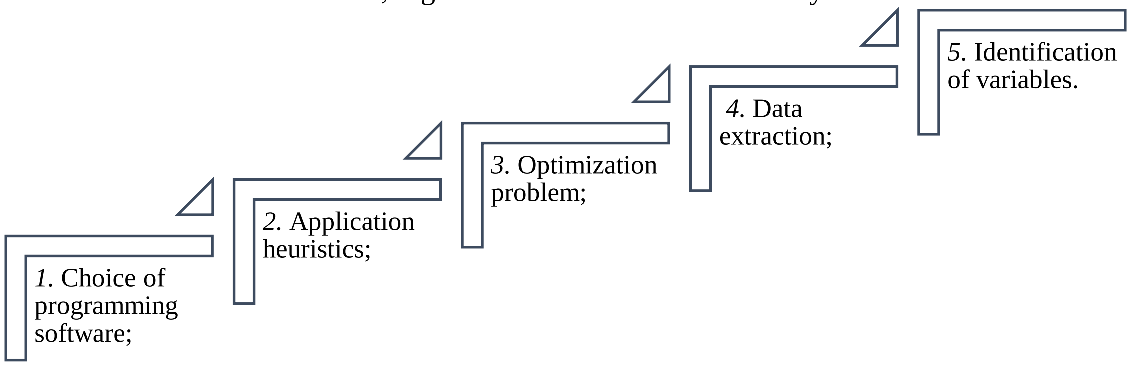

Figure 2. Methodology.

1. Programming software.

Octave version 4.0. GNU Octave is a high-level language, primarily intended for numerical computations. It provides a convenient command line interface for solving linear and nonlinear problems numerically, and for performing other numerical experiments using a language that is mostly compatible with Matlab. It may also be used as a batch-oriented language [35].

Lingo version 16.0**.** LINGO is a comprehensive tool designed to make building and to solve Linear, Nonlinear (convex & nonconvex/Global), Quadratic, Quadratically Constrained, Second Order Cone, Semi-Definite, Stochastic, and Integer optimization models faster, easier and more efficient [36].

2. Application heuristics.

To establish the routes within the state of Veracruz, the heuristics of the nearest neighbor developed by Sas Wahid Hamzah in 2012 was used and adapted through the publication VRP and Nearest Neighbor Algorithm.

3. Optimization problem.

Likewise, in order to evaluate and compare the resulting paths, an optimization run is carried out, in which the problem of vehicle routing with capacity is applied.

4. Data Extraction.

The data about the location of the municipalities of the state of Veracruz, Ignacio de la Llave, are extracted through the Google Earth portal.

5. Identification of variables

Table 1 describes the variables used to solve the problem.

Table 1. List of variables.

Variables	Description
Cedistemporal	Stores the municipalities that can be part of the route.
Number_of_Zones	It accommodates the number of segments that are formed.
Municipality Number of Routes Total distance	Municipality to be assigned to a route. A number of final routes. Total distance traveled.
Route	The route to which municipalities are added.

5. Results

Table 2 shows a summary of the data fed and the results obtained in each of the scenarios, according to the proposed resolution method, Table 3 shows a comparison between the routes of the applied methods in La Perla municipality.

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With a database of 212 municipalities, the results obtained show a segmentation of six zones, that is to say, 6 different routes with a different number of municipalities, additionally, derived from the characteristics of the method used, there is a bias of 25 municipalities, which gives the basis for future work (Table 4).

Likewise, when applying the said algorithm to a single municipality of the entity subject to study, which houses 46 localities and with a supply capacity of 4,000 people, 5 different routes are obtained with a bias of 2.17%, that is, one locality was out of the route and 3939 unsatisfied victims (Table 5). In order to corroborate these routes, a vehicle routing problem with capacity in an optimization software is applied, where the results obtained were 6 routes (Table 6), however, the last route is an omission made by the VMC to the locality with a greater number of victims, and although the distance that reflects the application of the NN is less, not covering the total of the victims, one of the agents' objectives in the face of disaster is not met, maintaining a quality of life for people affected by a disturbing event, this case is a natural hydrometeorological event.

Table 2. Results.

Concept / Algorithm	NN	NN	CVRP
Geographical space.	*Veracruz state*	*La Perla Municipality*	*La Perla Municipality*
Number of elements (Municipalities and / or localities)	*212*	*46*	*46*
Estimated demand	*Dear*	*Total population*	*Total population*
Satisfied demand		*19,310*	*22,249*
Routes obtained	*6*	*5*	*6*
Distance traveled (m)		3.2214e+006	*407985*
Number of items omitted per system	*25*	*1 (La Perla)*	*0*
Unsatisfied demand		*3,939*	*0*
Example route		*Route 1*	*Route 5*

Table 3. Route 1 vs Route 5.

Feasible: La Cienega (1223) – **San Miguel Chinela (130) – San Miguel Pilancon (458)** – Cumbre del Español (629) – Potrero Nuevo (175) – La Paloma (22) – El Minero (72) – Rancho Nuevo (348) – **Rancho Viejo (68)** – **Galicia (45) – El Comal (203) – El Paso (577)** – Las Trincheras (50).
Optimum: Yerbabuena (146) – Barrio de San Miguel (1145) – San Lorenzo (389) – La Golondrina (463) – Tlamanixco Grande (66) – **Galicia (45) – San Miguel Pilancon (458) - San Miguel Chinela (130) – Rancho Viejo (68) – El Comal (203) – El Paso (577).**

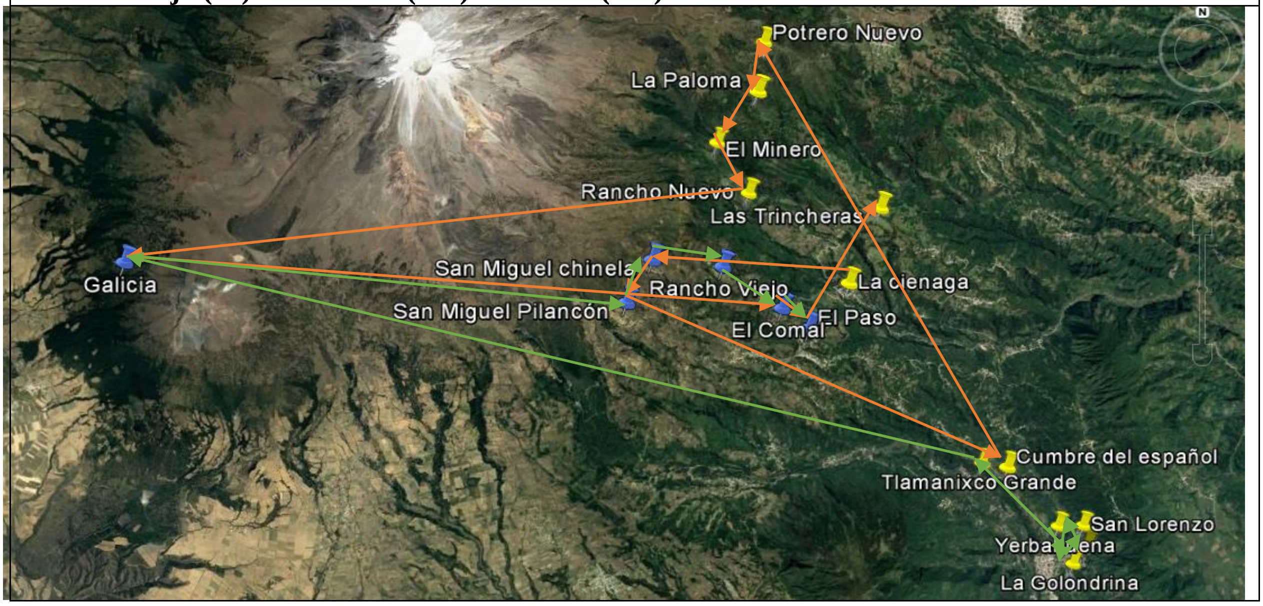

Table 4.VMC applied to the State of Veracruz (212 municipalities)

Route1
1-140-187-23-91-47-183-193-117-202-49-203-170-56-188-168-194-150-71-79-22-100-162-99-201-133-10-21-86-169
Acatlan - Rafel Lucio – Tlalnelhuayocan – Banderilla – Jilotepec – Cuacuatzintla – Tlacolulan – Tonayan – Naolinco – Xalapa – Cuatepec – Xico – Teocelo - Cosautlan de Carbajal – Tlaltetela - Tenampa –Totutla – Sochiapa – Huatusco - Ixhuacan de los Reyes – Ayahualulco - Las Vigas de Ramirez – Tatatila - Las Minas - Villa Aldama – Perote – Altotonga - Atzalan-Jalancingo – Tenochtitlan.
Route2
111-2-97-39-172-9-4-87-15-185-54-109-171-82-57-26-8-192-43-65-68-20-96-106-80-124-85-139-174
Miahutlan – Acatlan - Landero y Coss – Chiconquiaco – Tepetlan - Alto lucero de Gutiérrez Barrios – Actopan – Jalcomulco – Apasapan - Tlacotepec de Mejia – Comapa – Zentla – Tepatlaxco -Ixhuatlan de Café – Coscomatepec – Calcahualco – Alpatlahuac – Tomatlan – Chocaman - El Higo –Fortin – Atzacan - La Perla - Mariano Escobedo – Ixhuatlncillo – Orizaba – Ixtaczoquitlan - Rafael Delgado – Tequila.
Route3
206-113-53-94-199-120-146-107-189-66-212-60-45-108-67-61-48-51-129-69-164-136-33-180-31-163-166-35-173-81-181-207-175
Yecuatla – Misantla – Colipa - Juchique de Ferrer - Vega de Alatorre – Nautla - San Rafael - Martínez de la Torre – Tlapacoyan – Espinal - Zozocolco de Hidalgo – Coxquihui – Chumatlán –Mecatlan - Filomeno Mata – Coyutla – Coahuitlan – Coatzintla – Papantla – Gutiérrez – Zamora -Tecolutla - Poza Rica de Hidalgo – Cazones – Tihuatlan - Castillo de Teayo – Tuxpan – Temapache -Cerro Azul – Tepetzintla - Ixhuatlan de Madero – Tlachichilco – Zacoalpan – Texcatepec.
Route4
138-197-95-105-153-27-131-19-34-13-118-52-62-205-63-123-103-191-141-74-121-28-143-152-104-16-6-18-102-210-176-114-190-165
Puente Nacional - Úrsulo Galván - La Antigua - Manlio Fabio Altamirano - Soledad de Doblado - Camarón de Tejeda - Paso del Macho – Atoyac – Córdoba - Amatlán de los Reyes - Naranjal- Coetzala – Cuichapa – Yanga – Cuitlahuac – Omealca – Magdalena – Tlilapan - Rio Blanco – Huiloapan – Nogales

- Camerino Z Mendoza - San Andrés Tenejapan - Soledad Atzompa – Maltrata – Aquila - Acultzingo – Atlahuilco - Los Reyes – Zongolica – Texhuacan - Mixtla de Altamirano –Tlaquilpa – Tehuipango.
Route5
30-59-88-110-200-25-186-75-11-184-5-84-55-29-12-36-196-179-178-204-17-195-125-92-142-101
Carrillo Puerto – Cotaxtla – Jamapa – Medellín – Veracruz - Boca del Rio – Tlalixcoyan -Ignacio de la Llave – Alvarado – Tlacotalpan – Acula – Ixmatlahuacan - Cosamaloapan de Carpio -Carlos A. Carrillo – Amatitlán – Chacaltianguis – Tuxtilla - Tierra Blanca – Tezonopa – Xoxocotla –Astacinga - Tres Valles – Otatitlan - José Azueta - Salta Barranca - Lerdo de Tejada.
Route 6
156-119-42-158-155-159-46-44-78-40-24-211-76-72-37-182-134-38-160-167-127-157-137-132-64-14-148-144-32-73-77-93-135-154-208.
Tamiahua – Naranjos – Amatlán - Chinampa de Gorostiza – Tancoco – Tamalin – Tantima – Citlaltepec – Chontla –Ixcatepec – Chicotepec - Benito Juárez - Zontecomatlan de López y Fuentes –Ilamatlan – Huayacocotla – Chalma – Tlacojalpan - Platón Sánchez – Chiconamel – Tantoyuca -Tempoal- Ozuluama de Mascareñas - Tampico Alto - Pueblo Viejo – Panuco - El Higo - Ángel R Cabada - Sochiapa - San Andrés Tuxtla – Catemaco - Hueyapan de Ocampo – Isla - Juan Rodríguez Clara - Playa Vicente – Soteapan – Zaragoza.

Table 5. Nearest neighbor applied to the Municipality of La Perla (46 locations)

Routes	Localities	Results
Route 1 = 1 2 34 35 3 29 45 12 30 31 42 11 13 46 1	La Cienega (1223) – San Miguel Chinela (130) – San Miguel Pilancon (458) – Cumbre del Español (629) – Potrero Nuevo (175) – La Paloma (22) – El Minero (72) – Rancho Nuevo (348) – Rancho Viejo (68) – Galicia (45) – El Comal (203) – El Paso (577) – Las Trincheras (50).	Victims = 4,000. Locations = 13.
Route 2 = 1 4 28 25 6 15 20 7 16 41 19 37 43 1	Agua Escondida (832) – Papalotla (681) – Magueyes (58) – Cruz de Chocaman (846) – La Coyotera (116) - La Mata (129) – El Cebadal (832) – La Cuchilla (188) – Cuesta Chica (12) – La Malvilla (164) – Tlamanixco Grande (66) – La Barranca (56).	Victims = 3,980. Locations = 12.
Route 3 = 1 8 39 5 18 10 33 44 1	El Lindero (632) – Villa Hermosa (585) – Chilapa (1282) – La Lagunilla (846) - Chilapilla (46) – San Martín (181) – La Curva (26).	Victims = 3,598. Locations = 7.
Route 4 = 1 38 36 14 26 22 1	Tuzantla (875) – Tejocote (481) – El Zapote (821) – Metlac Hernández (1082) – Los Fresnos (675).	Victims = 3,934. Locations = 5.
Route 5 = 1 40 32 9 17 23 24 27 1	Yerbabuena (146) – San Lorenzo (389) – Barrio de San Miguel (1145) – La Golondrina (463) – Macuilcatl Chico (358) – Macuilcatl Grande (626) – Metlac Solano (671).	Victims = 3798. Locations = 7.
Out of route location: a) La Perla 3939 Victims.		
Number of Routes = 5. **Total distance =** 3.2214e+006 m.		

Table 6. CVRP applied to the Municipality of La Perla (46 Locations)

Routes	Localities	Results
Route 1 = 1 4 28 25 38 8 6 1.	Agua Escondida (832) – Papalotla (681) – Magueyes (58) – Tuzantla (875) – Lindero (632) – Cruz de Chocaman (846).	Victims = 3,924. Locations = 6. Kilometers traveled =
Route 2 = 1 14 24 33 23 44 43 22 3 36 1.	El Zapote (821) – Macuilcatl Grande (626) – San Martín (181) – Macuilctl Chico (358) – La Curva (26) – La Barranca (56) – Los Fresnos (675) – Cumbre del Español (629) – Tecojote (481).	Victims = 3,853. Locations = 9.
Route 3 = 1 21 1.	La Perla (3939).	Victims = 3939. Locations = 1.
Route 4 = 1 26 27 7 5 1.	Metlac Hernández (1082) – Metlac Solano (671) – El Cebadal (832) – Chilapa (1282)	Victims = 3,867. Locations = 4.
Route 5 = 1 40 9 32 17 37 42 35 34 31 11 13 1.	Yerbabuena (146) – Barrio de San Miguel (1145) – San Lorenzo (389) – La Golondrina (463) – Tlamanixco Grande (66) – Galicia (45) – San Miguel Pilancon (458) - San Miguel Chinela (130) – Rancho Viejo (68) – El Comal (203) – El Paso (577).	Victims = 3,690. Locations = 11.
Route 6 = 1 41 2 12 30 15 16 46 29 45 20 18 10 19 39 1.	Cuesta Chica (12) – La Cienega (1223) – El Minero (72) – Rancho Nuevo (348) – La Coyotera (116) – La Cuchilla (188) – Las Trincheras (50) – Potrero Nuevo (175) – La Paloma (22) – La Mata (129) – La Lagunilla (846) – Chilapilla (46) - La Marvilla (164) – Villa Hermosa (585).	Victims = 3,976. Locations = 14.
Starting point: Xometla. **Out of route location: 0.**		
Number of Routes = 6 **Total distance = 407,985 m.**		

Conclusions

This document shows the application of the algorithm of the closest neighbor to the segmentation and routing for the delivery of humanitarian support kits in the presence of a disaster caused by a hydrometeorological phenomenon in the State of Veracruz. With a database of 212 municipalities, the results obtained show a segmentation of six zones, that is to say, six different routes with a different number of municipalities, additionally, derived from the characteristics of the method used, there is a bias of 25 municipalities, which gives the basis for future work.

Likewise, when applying the said algorithm to a single municipality of the entity subject to study, which houses 46 localities and with a supply capacity of 4,000 people, five different routes are obtained with a bias of 2.17%, that is, one locality was out of the route. In order to corroborate these routes, a vehicle routing problem with capacity in an optimization software is applied, where the results obtained were six routes, however, the last route is an omission made by the VMC to the locality. With a greater number of victims.

Although it is a feasible solution, in emergencies its derivative application is recommended at the time of the program's shift, which does not have a great amplitude compared to an optimization method. Making us see that time is one of the main variables so that the actors in the disaster can maintain the quality of those affected by the natural event.

Future works

The nearest neighbor method assumes that the closest neighbors give us the best classification and this is done using all the attributes; The problem with this hypothesis is that it is possible that many irrelevant attributes dominate the classification: two relevant attributes would lose specific weight among other irrelevant ones. To correct the possible bias, a weight can be assigned to the distances of each attribute, giving greater importance to the most relevant attributes. Another possibility is to try to determine or adjust the weights with known examples of training. Finally, before assigning specific weights, it is advisable to identify and eliminate attributes that are considered irrelevant [37]. The latter is proposed as future work.

Likewise, a complete routing of the State of Veracruz is proposed, with the purpose of establishing pre-positioned warehouses and delivery routes to municipalities whose localities are affected by natural phenomena.

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