Available online at: http://publikasi.mercubuana.ac.id/index.php/ijiem

IJIEM (Indonesian Journal of Industrial Engineering & Management)

ISSN (Print) : 2614-7327 ISSN (Online) : 2745-9063

Improving Veterinary Service Efficiency: Optimizing Home Visit Routes for Pet Clinics Using Particle Swarm Optimization Algorithm

Erico Sofyan Chrissandhi, Christa Dian Pratiwi*, Pringgo Widyo Laksono
Department of Industrial Engineering, Master's Degree Program, Universitas Sebelas Maret, Surakarta 57126 Indonesia

ARTICLE INFORMATION

Article history:

Received: 24 February 2024
Revised: 8 July 2024
Accepted: 11 September 2024

Category: Research paper

Keywords:
Home visit
Pet clinics
Travelling salesman problem
Particle sworn optimization
Google colab

DOI: 10.22441/ijiem.v5i3.25971

A B S T R A C T

High-stress levels can trigger other diseases if emotions are not channeled to reduce the feeling of stress. The stress-releasing activity that is currently trending is keeping animals, especially cats and dogs. Having a pet triggers awareness of the importance of pet care, especially in the context of home visiting services, highlighting the need for increased effectiveness of veterinary services. Determining a short route for veterinarians to visit their patients in a certain area is necessary in planning for pet clinics with home visit services. In the context of home visits by pet clinics, the Traveling Salesman Problem (TSP) is used to determine the most efficient route veterinarians can use when visiting many patients in a certain area by minimizing the total distance traveled to save time. This research uses the Particle Swarm Optimization (PSO) algorithm with 2-opt logic to solve the TSP problem. This TSP optimization was completed by utilizing Google Colab as a machine learning computing medium using Python. The results of optimizing the total distance for the best routes of home visits to pet clinics was 292.81 kilometers. This research can still be developed for more complex routes and have requirements for each route destination, such as visiting time for each patient and distance between destination points. The research is expected to impact the welfare of pets and meet community needs positively.

***Corresponding Author**

Christa Dian Pratiwi
E-mail: chrstdian@gmail.com

1. INTRODUCTION

High-stress levels can impact human life, especially as a trigger for other diseases. When dealing with stress, channeling emotions is necessary to reduce these feelings (Yaribeygi et al., 2017). In her writing, Brigita states that one of the activities for channeling emotions currently trending is keeping animals (Brigita, 2021). In the Rakuten Insight survey in 2018, Indonesia was ranked fourth in Asia as the country with the most pet owners, with a percentage of 67% of the Indonesian population (Rakuten Insight, 2021). Several types of pets included in the survey conducted by Rakuten Insight include cats (37%), birds (19.3%), goldfish (15.6%), dogs (15.5%), etc. Types of animals that have been popular for a long time, such as cats and dogs, are among the four most common pets the Indonesian population keeps. The popularity of this type of pet has also impacted the increasing population in Indonesia and even throughout the world, especially during the COVID-19 pandemic (Ho et al., 2021). This increasing pet population is directly proportional to meeting the increasing pet needs. As many as 70% of pet owners consider their beloved pets to be like children or family members who need special attention to ensure the welfare of their pets (Quinn, 2005). Pet owners need appropriate housing facilities to meet the needs of these pets, providing good food, vitamin supplements, snacks, regular vaccinations, and quality grooming care. These things are important to ensure your pet's health and happiness.

Pet health needs to be maintained to ensure that pets can survive longer. Prevention related to keeping pets healthy can be done by regularly checking them with a veterinarian. Routine pet examinations are also necessary because some pets have a habit of hiding the illness or disease that the pet is experiencing (American Association of Feline Practitioners, 2016). However, the increase in pet owners' awareness of their pets' health is not supported by an even distribution of available pet clinics. An example of an uneven distribution area is the Solo Raya area, which includes Surakarta, Kartasura, Boyolali, and Sukoharjo; only 9 pet clinics are centered in a few places, as depicted in Figure 1.

Figure 1. Map of the distribution of Solo Raya pet clinics
Source: Google Search

The long distances pet owners must travel can reduce their willingness to conduct routine checks on their pets. This condition is also supported by habits that have changed slightly due to the COVID-19 pandemic, which means that all work is done at home and purchases of necessities are processed using digitally supported delivery orders (Sari et al., 2022). Potential problems can be overcome by having pet clinics implement a home visit system or making direct visits to the animal owner's home as a patient. Animal owners or patients who use pet clinic facilities with home visits will be charged an additional fee for the distance from the pet clinic to the patient's home. However, the advantage of this facility is that patients do not need to take their pets out of the house to go to the pet clinic. One pet clinic that applies this business model is Pawless Pet Care. Home visits carried out by Pawless Pet Care cover the areas of Surakarta, Sukoharjo, Boyolali, Kartasura, and Klaten. The implementation of this system by Pawless Pet Care means that patients need to make a reservation in advance when using this service. Several patients who use the home visit service from the Pawless Pet Care pet clinic use it for routine check-ups and to carry out several injections according to the patient's needs and requests. Routine home visits for Pawless Pet Care patients are carried out every month on the 20th with twelve patients. Twelve patients who routinely use Pawless Pet Care's home visit services have home addresses spread across different regions and far apart. That situation creates problems regarding patients' orders to be visited first.

Modeling the route that Pawless Pet Care must take during home visits is urgent in this research. The best route model for home visits for twelve patients in one day on the 20th of each month is expected to solve the problems at Pawless Pet Care.

Problems related to finding the best route to save travel time or increase effectiveness in general can be solved using the Traveling Salesman Problem (TSP) method. The TSP method is designed to effectively create the best route solution from one starting point to another destination point until it returns to the starting point. The algorithm used in the TSP method, in general, is Particle Swarm Optimization (PSO), which is used to carry out continuous iteration until the best coefficient value is obtained. Previous literature has documented many studies that address TSP by applying different optimization techniques, especially the PSO algorithm and its various adaptations and integrations with other algorithms. Previous studies by Kurniawan et al., related to completing the best route with TSP, were implemented to optimize distributor routes to supply logistics supplies by also comparing the algorithms used between the PSO or Brute Force (Kurniawan et al., 2021). The results of this research found that the shortest and best route was produced using the PSO algorithm with a competitive total distance. Other research related to TSP problems was carried out on the best routes for school transportation by Azhari et al (Azhari et al., 2018). In this research, the PSO algorithm was applied in the TSP method to optimize the determination of school transportation routes to overcome various obstacles, such as variations in student delivery, driver delays, and instability in operational funds. The results show that the implemented system can provide better route recommendations in most experiments, although it is not always optimal.

Another study by Zhan et al., examined home service problems (such as health care, equipment repair, and banking services) to find the best route for scheduling appointments by considering stochastic time (Zhan et al., 2021). However, this research does not use the PSO algorithm; instead, it uses the mixed-integer program (MIP) model and the L-shaped method. However, several other studies still use the PSO algorithm as the basis for solving TSP in combination with other methods. Research that combines the PSO algorithm with other algorithms or methods includes: Mostafa et al., who proposed a method that integrates PSO with Ant Colony Optimization and the 3-Opt heuristic method (Mahi et al., 2015); Kefi et al., who developed a hybrid Ant Supervised-PSO approach (Kefi et al., 2016); and Khan et al., who utilized a combination of PSO, Ant Colony Optimization, and K-Opt Algorithms (Khan et al., 2017). Referring to the existing literature regarding TSP completion using the PSO algorithm, there is still a research gap in its application in the veterinary field, especially for home visit services in Indonesia. This research aims to fill this research gap by developing a PSO-based TSP optimization model tailored to pet clinics' home visit scheduling needs, which specifically uses Pawless Pet Care as the research object. This research will utilize Google Colab for computational analysis, which in previous research has not been used as a tool for calculating TSP optimization with the PSO algorithm. In this research, 2-opt logic will also be used in the PSO algorithm because the simplicity of implementing the 2-opt algorithm allows for the development of efficient solutions with minimal errors, which is an important factor in the context of scheduling pet clinic home visits (Uddin et al., 2023). Table 1 summarizes the research gap identified in this study.

Optimizing the optimal route for home visits using the PSO-based TSP algorithm provides significant hope for increasing operational efficiency and maximizing profits for pet clinics. The results of identifying the most efficient home visit route are expected to be able to minimize travel distances, which will affect fuel costs. Ultimately, the proposed optimization model aims to design the most efficient home visit schedule for Pawless Pet Care, specifically on the 20th of each month, thus facilitating improved service delivery and customer satisfaction. This research effort represents a novel contribution to veterinary service optimization, offering a comprehensive solution to the complex logistical challenges associated with scheduling home visits.

Table 1. Research gap in this study

No.	Research	Algorithm/ Method	Application	Findings	Research Gap
1	Kurniawan et al. [8]	PSO, Brute Force	Distributor route optimization	PSO produced the shortest and best route with a competitive total distance.	Comparison between PSO and Brute Force; focus on logistics supply chain. No application in veterinary field.
2	Azhari et al. [9]	PSO	School transportation route optimization	PSO algorithm provided better route recommendations despite some experiments not being optimal.	Focus on school transportation; did not address veterinary field or home visit services.
3	Zhan et al. [10]	MIP model, L-shaped method	Home service scheduling (healthcare, etc.)	MIP model used to find best route considering stochastic time.	Did not use PSO; different field of application (home services rather than veterinary).
4	Mostafa et al. [11]	PSO, Ant Colony Optimization, 3-Opt	General TSP problems	Proposed a method integrating PSO with Ant Colony Optimization and 3-Opt heuristic method.	Combination approach; no specific application to veterinary home visits.
5	Kefi et al. [12]	Hybrid Ant Supervised-PSO	General TSP problems	Developed a hybrid Ant Supervised-PSO approach.	Hybrid approach; no specific application to veterinary home visits.
6	Khan et al. [13]	PSO, Ant Colony Optimization, K-Opt	General TSP problems	Utilized a combination of PSO, Ant Colony Optimization, and K-Opt algorithms.	Combination approach; no specific application to veterinary home visits.
7	Proposed Study	PSO, 2-opt	Veterinary home visit scheduling	Aims to develop a PSO-based TSP optimization model for pet clinics' home visit scheduling.	Specific focus on veterinary home visit services in Indonesia; using Google Colab for computational analysis, which hasn't been utilized in prior studies.

2. THEORETICAL FRAMEWORK

Kennedy and Eberhart developed Particle Swarm Optimization (PSO) due to their inspiration from stochastic populations (Kennedy & Eberhart, 1995). This algorithm is inspired by the behavior of intelligent flocks of birds to choose the search direction and speed (Shao et al., 2012). The social behavior of a flock of birds can be translated into a computational procedure to solve optimization problems, as in PSO, where each particle represents a possible solution. Swarms of particles explore space in specified dimensions and select the best answer to the current problem (Shami et al., 2022). PSO has several advantages over other optimization techniques, but the most significant advantages are its ease of implementation and limited number of parameter adjustments. The basic concept of PSO is that it will always look for the best position for the herd or swarm. This basic concept will be utilized to complete the best route using TSP. The following are the factors that make up the PSO algorithm (G. Goldbarg et al., 2008)(Rizki & Nurlaili, 2021) :

1. **Swarm**, is the number of particles contained in a population. The size of the problem complex will affect the size of the swarm.
2. **Particles**, are individuals who have their position and speed within a swarm and present solutions to solve problems.
3. **Personal best (pBest)**, is the best position of the particle based on the results of comparing the fitness value of the previous particle position with the current position.
4. **Global best (gBest)**, is the best position of the particle compared to the best fitness value from pBest with all the particles in the swarm.
5. **Velocity (v)**, is a vector that regulates the displacement of the position of each particle at each iteration.
6. **Inertia Weight (w)**, functions as a controller for changes in particle velocity.

7. **Acceleration coefficient,** is a factor that controls how far a particle moves in one iteration. The values of the acceleration coefficients C1 and C2 are generally the same, namely between 0 and 4. However, each study can obtain these values independently in

different ways. The PSO mathematical model that displays the state update mechanism of particles formulated by Kennedy and Eberhart is as follows (Kennedy & Eberhart, 1995). Equation 1, update particle velocity:

$$V_i(t) = V_i(t-1) + c_1 r_1 \left(X_i^L - X_i(t-1) \right) + c_2 r_2 (X^G - X_i(t-1)) \quad (1)$$

Equation 2, update the particle position:

$$X_i(t) = V_i(t) + X_i(t-1) \quad (2)$$

Description:

X_i^L = Local Best

X^g = Global Best

c_1, c_2 = Learning Factor (0,)

r_1, r_2 = Random numbers [0,1]

2.1 Particle Swarm Optimization

The optimization problem known as the Traveling Salesman Problem (TSP) is declared NP-hard, indicating that it cannot be solved in polynomial time and has a large search space (Stohy et al., 2021). In computer science today, this is one of the most important problems. TSP uses include microchip production, GSM packet routing, and vehicle routing. TSP aims to find the shortest journey, where each city can only be visited once and returned to the starting city (Wei et al., 2021). The TSP formulation is shown below, where the symbol n indicates the number of all points; and the symbol k is the number of points traversed.

$$p_n^k = \frac{n!}{(n-k)!} \quad (3)$$

2.3 Google Colaboratory (Colab)

Google Colab is the result of a Google Research product, which is a product intended to disseminate education and research that utilizes machine learning. The Google Colab service is Jupyter technology, which can be used without installation and can be accessed for free by computing resources, including GPUs-infrastructure from Google Colab, using hosting on the Google Cloud platform. Google Colab also has artificial intelligence libraries such as Tensor Flow, Matplotlib, and Keras (Carneiro et al., 2018)(Soen et al., 2022). Penggunaan Goole Colab akan membantu proses penelitian untuk mengeksekusi perintah yang digunakan untuk mendapatkan rute terbaik menggunakan TSP dengan algoritma PSO.

3. RESEARCH METHOD

The primary and secondary research data used is from literature studies. The primary data used is patient visit locations obtained directly from the owner of Pawless Pet Care. The patient visit data is used in patients who routinely carry out home visit check-ups on the same day. The location data is in the form of coordinate data from Google Maps, converted into latitude and longitude coordinates. Secondary data was obtained from many published journal sources, such as Google Scholar, websites, and GitHub. The data obtained will be used to solve TSP problems during home visits at Pawless Pet Care. The research process flow is described as follows:

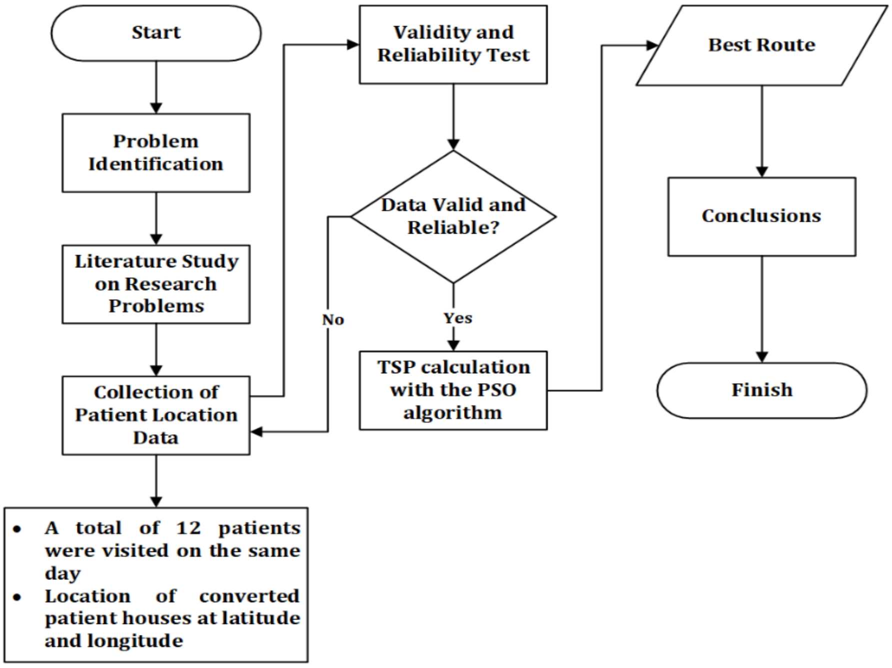

Figure 2. Research flowchart

This study begins by identifying the issues faced by Pawless Pet Care, namely the travel problem for monthly visits to patients' homes. The identified issues were successfully addressed by utilizing the Traveling Salesman Problem (TSP) method, sourced from various literature. The use of TSP is considered an effective method in solving these problems. The utilization of Google Colab as a tool for implementing the TSP method also brings significant novelty to the current research. The subsequent step in the research involves gathering location data from 12 monthly check-up patients to be visited for pet examinations. The locations obtained from Google Maps are converted into latitude and longitude coordinates for input into Google Colab. The gathered data will undergo validity and reliability testing to ensure that the data used is valid and consistent.

Following the validation and reliability testing, the data will be processed using TSP with the assistance of Google Colab. The calculated results will yield the best route, serving as a solution to the initial problem addressed in this study. The obtained best route will display the sequence of routes that can be taken from start to finish, along with the total distance traveled to the 12 monthly visit patients of Pawless Pet Care.

4. RESULT AND DISCUSSION

4.1 Google Colaboratory (Colab)

Patient Data Processing: The data used is the patient's home location data, and the patient routinely uses home visit services from Pawless Pet Care on the 20th of each month. The number of patients on the 20th of each month who require a home visit is 12. Collecting data on the patient's home location utilizes the home location in Google Maps format, which the patient has sent to Pawless Pet Care. The patient's house location data on Google Maps is translated into latitude (latitude) and longitude (longitude) units. A summary of the patient's home location data is shown in Table 1.

Table 1. Patient location data for home visit pawless pet care

Location	Latitude	Longitude
Pawless Pet Care	-7,57313944659414	110,775180640476
Patient 1	-7,56220932540295	110,756934855179
Patient 2	-7,54920718978647	110,745463186323
Patient 3	-7,55154014779143	110,744206957240
Patient 4	-7,56198133832656	110,721238642119
Patient 5	-7,55147257380173	110,744672915327
Patient 6	-7,57314084217059	110,771884272986
Patient 7	-7,58172889800877	110,824201808430
Patient 8	-7,59216973681323	110,817899241345
Patient 9	-7,58186897608872	110,781647897624
Patient 10	-7,57792533924635	110,779549797573
Patient 11	-7,59719951331914	110,813404526398
Patient 12	-7,58613237277995	110,822582970747

4.2 Validity Test on Patient Location Data

Validity testing is used to determine the accuracy level of the data that will be processed in research. The function of this test is to validate the suitability of the research instrument (Sekaran & Bougie, 2016). This research uses the help of IBM SPSS Statistics software to calculate significant values. A significant value is required for the data to pass the validity test if the value is less than 0.05. The results of the validity test of the data used in this research are presented in Figure 3. In Figure 3, it is shown that the significant values for latitude and longitude are 0.00, whereas the result is worth less than 0.05. The data used in this test can be declared valid.

Reliability Test on Patient Location Data. Reliability testing is a test of the level of stability and consistency of the research data instruments used (Sekaran & Bougie, 2016). Data is to be reliable if the Cronbach Alpha value of the data is greater than 0.60. This research uses the help of IBM SPSS Statistics software to calculate the Cronbach Alpha value.

Correlations

		Latitude	Longitude
Latitude	Pearson Correlation	1	-.877**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	.003	-.006
	Covariance	.000	.000
	N	13	13
Longitude	Pearson Correlation	-.877**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	-.006	.014
	Covariance	.000	.001
	N	13	13

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 3. Data validity test results

The results of the reliability test of the data used in this study are shown in Figure 4. In Figure 4, it is shown that the Cronbach Alpha value from the home visit patient location data is 0.803, which is greater than 0.60, so those used in this test can be declared reliable.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.803	.935	2

Figure 4. Data reliability test results

4.3 PSO Algorithm Coding for Solving TSP

The TSP coding command in this study uses the PSO algorithm. The initial input to the coding command is to use the NumPy library for data processing for scientific calculations (Astiko & Achmad Khodar, 2020). Next, the input command is logical for calculating the ecluded distance because the data used uses latitude and longitude coordinates based on the earth's round shape. There is also logic for the 2-opt algorithm to calculate TSP. The command to repeat iterations to get the best route is also applied to the coding command for this research. The entire coding command steps in this research can be seen or downloaded from the *Google Drive* website. The following are the steps and algorithms used to determine the best route for a Pawless Pet Care home visit:

1. **Calculating Euclidean Distance.** Calculating the Euclidean distance is necessary because the data used is latitude and longitude where the point is at an angle to the earth's curvature, so it is necessary to calculate the euclidean distance using the coding command shown in Figure 5.

```
path_distance = lambda r,c:
np.sum([np.linalg.norm(c[r[p]]-c[r[p-1]])
for p in range(len(r))])

two_opt_swap = lambda r,i,k:
np.concatenate((r[0:i],r[k:-len(r)+i-1:-
1],r[k+1:len(r)]))
```

Figure 5. Euclidean distance calculation coding command

2. **2-opt Algorithm.** The 2-opt algorithm is widely used to solve problems, especially TSP problems. The use of the 2-opt algorithm is because this algorithm functions to create a solution to the problem by moving 2 sides of the path and then connecting the 2 paths again with optimal results (Englert et al., 2014). With the function of the 2-opt algorithm, the application of the 2-opt algorithm in this research is presented in Figure 6.

```
def two_opt(cities,improvement_threshold):
    route = np.arange(cities.shape[0])
    improvement_factor = 1
    best_distance =
path_distance(route,cities)
```

Figure 6. 2-opt algorithm coding command

3. **PSO Algorithm.** The PSO algorithm in this research is used to iterate until the best route option is found. The use of the PSO algorithm refers to the function of PSO itself, where the particles in PSO will explore space in the dimensions that each particle will carry out to obtain the g-best of the problem (Shami et al., 2022). The application of the PSO algorithm in this research is shown in Figure 7.

```
# Command repetitions to get the best route
    while improvement_factor > improvement_threshold:
        distance_to_beat = best_distance

        # Command to move patient sequences according to the best route
        for swap_first in range(1,len(route)-2):
            for swap_last in range(swap_first+1,len(route)):
                new_route = two_opt_swap(route,swap_first,swap_last)
                new_distance = path_distance(new_route,cities)

                # Command to stop repetition when the best route has been found
                if new_distance < best_distance:
                    route = new_route
                    best_distance = new_distance
        improvement_factor = 1 - best_distance/distance_to_beat
    return route
```

Figure 7. PSO algorithm coding commands

4. **Best Route.** When searching for the best route for a home visit, Pawless Pet Care uses the MinMaxScaler command, which can function to normalize and process data using vector type. The coding command for finding the best route in this study is presented in Figure 8.

```
df = cities.copy()

from sklearn.preprocessing import MinMaxScaler
scaler = MinMaxScaler(feature_range=(0, 100),
copy=True)
scaled_df = scaler.fit_transform(df)
scaled_df = pd.DataFrame(scaled_df, columns=['x1',
'x2'])

cities = np.asarray(cities)

scaled = np.asarray(scaled_df)

route = two_opt(scaled,0)
route
```

Figure 8. Best route finder coding commands

Best Route Results for Pawless Pet Care. The best route for Pawless Pet Care to conduct home visits to patients' homes has been obtained with the help of Google Colab. Google Colab is a platform developed by Google to process data using machine learning or deep learning techniques by adapting from Jupyrter Notebook (Sengkey et al., 2020)(Bisong, 2019). With the help of Google Colab, shown in Table 2, the data processing results show the best route for Pawless Pet Care to carry out home visits on the 20th of every month. The best route starts from Pawless Pet Care as the starting point, continues to each patient (P), and ends back to Pawless Pet Care as the ending point. The order of the routes is as follows: Pawlesss Pet Care, P12, P7, P8, P11, P9, P10, P4, P2, P3, P5, P1, P6, Pawless Pet Care. The best route for Pawless Pet Care to conduct home visits on the 20th of every month is shown in Figure 9. The route in Figure 9 is also equipped with each patient's house's latitude and longitude coordinates. The total distance traveled in one day when Pawless Pet Care conducted a home visit was 292.81 kilometers.

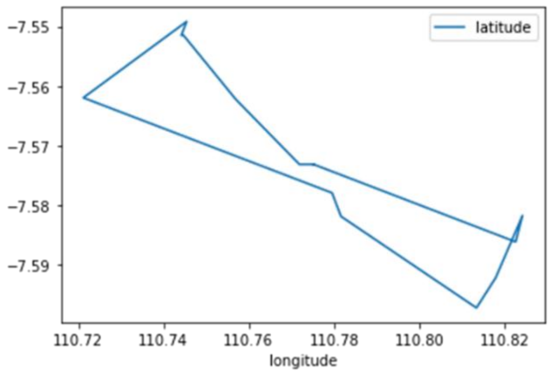

Figure 9. Plot pawless pet care's best route with coordinates

5. CONCLUSION

The conclusions section show the answer or clarification of the research questions and opportunities for future research. The results of the research have effectively applied the Particle Swarm Optimization (PSO) algorithm to overcome the Traveling Salesman Problem (TSP) in a home visit scenario carried out by a pet clinic (Pawless Pet Care). Research findings show that using the PSO algorithm in Google Colab can produce the best (optimal) route to reduce travel time and minimize travel distance, thereby increasing the efficiency of veterinary services. The best route obtained can save the time needed to carry out a home visit because the route obtained is the shortest. Based on the results obtained from Google Colab, the distance that must be covered in one day when Pawless Pet Care carries out a home visit on the 20th of each month is 292.81 kilometers. The resulting best route for a home visit is as follows: Pawlesss Pet Care – Patient 12 – Patient 7 – Patient 8 – Patient 11 – Patient 9 – Patient 10 – Patient 4 – Patient 2 – Patient 3 – Patient 5 – Patient 1 – Patient 6 – Pawless Pet Care.

This research can significantly contribute to optimizing animal health services, especially in the context of home visit services by pet clinics. These findings can provide a basis for improving the operational efficiency of pet clinics and meeting public demand for high-quality veterinary services. Although this study concentrates on a city scale with relatively simple pathways, there is still potential for further progress. The study could be expanded to cover a wider area by including additional criteria such as time spent with each patient during the visit and distance between different locations. These recommendations can increase the relevance and practicality of research findings in real application scenarios.

REFERENCES

American Association of Feline Practitioners. (2016). *5 Benefts of Routine Vet Visits for Your Cat*. American Association of Feline Practitioners.

Astiko, F., & Achmad Khodar. (2020). The Sentiment Analysis Reviewing Indosat Services from Twitter Using the Naive Bayes Classifier. *Journal of Applied*

Computer Science and Technology, *1*(2), 61–66. https://doi.org/10.52158/jacost.v1i2.79

Azhari, M. K., Cholissodin, I., & Bachtiar, F. A. (2018). Optimasi Travelling Salesman Problem Pada Angkutan Sekolah Dengan Algoritme Particle Swarm Optimization. *Jurnal Pengembangan Teknologi Informasi Dan Ilmu Komputer (J-PTIIK) Universitas Brawijaya*, *2*(11), 5691–5699. https://j-ptiik.ub.ac.id/index.php/j-ptiik/article/view/3403

Bisong, E. (2019). Building Machine Learning and Deep Learning Models on Google Cloud Platform : A Comprehensive Guide for Beginners. *Apress Media* (1st ed.). Apress Media. https://doi.org/10.1007/978-1-4842-4470-8_29

Brigita, R. (2021). *Usulan Peningkatan Kualitas Pelayanan Jasa di Pet Colony*. Universitas Atma Jaya Yogyakarta.

Carneiro, T., Da Nobrega, R. V. M., Nepomuceno, T., Bian, G. Bin, De Albuquerque, V. H. C., & Filho, P. P. R. (2018). Performance Analysis of Google Colaboratory as a Tool for Accelerating Deep Learning Applications. *IEEE Access*, *6*, 61677–61685. https://doi.org/10.1109/ACCESS.2018.2874767

Englert, M., Röglin, H., & Vöcking, B. (2014). Worst case and probabilistic analysis of the 2-opt algorithm for the TSP. *Algorithmica*, *68*(1), 190–264. https://doi.org/10.1007/s00453-013-9801-4

G. Goldbarg, E. F., C., M., & de Souz, G. R. (2008). Particle Swarm Optimization Algorithm for the Traveling Salesman Problem. F. Greco (Ed.), *Traveling Salesman Problem*, 75–96. https://doi.org/10.5772/5580

Ho, J., Hussain, S., & Sparagano, O. (2021). Did the COVID-19 Pandemic Spark a Public Interest in Pet Adoption? *Frontiers in Veterinary Science*, *8*(May), 1–5. https://doi.org/10.3389/fvets.2021.647308

Kefi, S., Rokbani, N., Krömer, P., & Alimi, A. M. (2016). A new ant supervised-PSO variant applied to traveling salesman problem. *Advances in Intelligent Systems and Computing*, *420*, 87–101. https://doi.org/10.1007/978-3-319-27221-4_8

Kennedy, J., & Eberhart, R. (1995). Particle Swarm Optimization. *Proceedings of the IEEE International Conference on Neural Networks*, 1942–1948. https://doi.org/10.1007/978-3-031-17922-8_4

Khan, I., Maiti, M. K., & Maiti, M. (2017). Coordinating particle swarm optimization, ant colony optimization and k-opt algorithm for traveling salesman problem. *Communications in Computer and Information Science*, *655*, 103–119. https://doi.org/10.1007/978-981-10-4642-1_10

Kurniawan, M., Farida, & Agustini, S. (2021). Rute Terpendek Algoritma Particle Swarm Optimization Dan Brute Force Untuk Optimasi Travelling Salesman Problem. *Jurnal Teknik Informatika*, *14*(2), 191–200.

Mahi, M., Baykan, Ö. K., & Kodaz, H. (2015). A new hybrid method based on Particle Swarm Optimization, Ant Colony Optimization and 3-Opt algorithms for Traveling Salesman Problem. *Applied Soft Computing Journal*, *30*, 484–490. https://doi.org/10.1016/j.asoc.2015.01.068

Quinn, A. C. (2005). *An examination of the relations between human attachment, pet attachment, depression, and anxiety* [Ames, Iowa : Iowa State University]. https://doi.org/10.31274/rtd-180813-16451

Rakuten Insight. (2021). *Pet Ownership in Asia*.

Rizki, A. M., & Nurlaili, A. L. (2021). Algoritme Particle Swarm Optimization (PSO) untuk Optimasi Perencanaan Produksi Agregat Multi-Site pada Industri Tekstil Rumahan. *Journal of Computer, Electronic, and Telecommunication*, *1*(2), 1–9. https://doi.org/10.52435/complete.v1i2.73

Sari, D. R., Feryani, A. T., & Amelia, N. (2022). How the pandemic COVID-19 influenced the consumer behavior: A case in Indonesia. *Proceedings of the 5th International Research Conference on Economics and Business (IRCEB 2021)*, 1–9. https://doi.org/10.1201/9781003303336-1

Sekaran, U., & Bougie, R. (2016). *Research Methods For Business: A Skill Building Approach* (7th ed.). Wiley & Sons.

Sengkey, D. F., Kambey, F. D., Lengkong, S. P., Joshua, S. R., & Kainde, H. V. F. (2020). Pemanfaatan Platform Pemrograman Daring dalam Pembelajaran Probabilitas dan Statistika di Masa Pandemi CoVID-19. *Jurnal Informatika*, *15*(4), 217–224.

Shami, T. M., El-Saleh, A. A., Alswaitti, M., Al-Tashi, Q., Summakieh, M. A., & Mirjalili, S. (2022). Particle Swarm Optimization: A Comprehensive Survey. *IEEE Access*, *10*(January), 10031–10061. https://doi.org/10.1109/ACCESS.2022.3142859

Shao, L., Bai, Y., Qiu, Y., & Du, Z. (2012). Particle Swarm Optimization Algorithm Based on Semantic Relations and Its Engineering Applications. *Systems Engineering Procedia*, *5*, 222–227. https://doi.org/10.1016/j.sepro.2012.04.035

Soen, G. I. E., Marlina, & Renny. (2022). Implementasi Cloud Computing dengan Google Colaboratory Pada Aplikasi Pengolah Data Zoom Participants. *Journal Informatic Technology And Communication*, *6*(1), 24–30. https://doi.org/10.36596/jitu.v6i1.781

Stohy, A., Abdelhakam, H. T., Ali, S., Elhenawy, M., Hassan, A. A., Masoud, M., Glaser, S., & Rakotonirainy, A. (2021). Hybrid pointer networks for traveling salesman problems optimization. *PLoS ONE*, *16*(12), 1–17. https://doi.org/10.1371/journal.pone.0260995

Uddin, F., Riaz, N., Manan, A., Mahmood, I., Song, O. Y., Malik, A. J., & Abbasi, A. A. (2023). An Improvement to the 2-Opt Heuristic Algorithm for Approximation of Optimal TSP Tour. *MDPI : Applied Sciences*, *13*(12), 1–24. https://doi.org/10.3390/app13127339

Wei, B., Xing, Y., Xia, X., & Gui, L. (2021). A Novel Particle Swarm Optimization With Genetic Operator and Its Application to TSP. *International Journal of Cognitive Informatics and Natural Intelligence*, *15*(4), 1–17. https://doi.org/10.4018/IJCINI.20211001.oa31

Yaribeygi, H., Panahi, Y., Sahraei, H., Johnston, T. P., & Sahebkar, A. (2017). The impact of stress on body function: A review. *EXCLI Journal*, *16*, 1057–1072. https://doi.org/10.17179/excli2017-480

Zhan, Y., Wang, Z., & Wan, G. (2021). Home service routing and appointment scheduling with stochastic service times. *European Journal of Operational Research*, *288*(1), 98–110. https://doi.org/10.1016/j.ejor.2020.05.037