IOSR Journal Of Humanities And Social Science (IOSR-JHSS)
Volume 29, Issue 5, Series 3 (May, 2024) 57-61
e-ISSN: 2279-0837, p-ISSN: 2279-0845.
www.iosrjournals.org

Local Optimization And The Traveling Salesman Problem: A Modified Metaheuristic Algorithm For Delivery

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Abstract:
Background*: Mobility is a topic widely discussed in the literature, not only because of its notorious importance for movement in cities and urban environments, but also for development and the economy. In this context, customer service, at the right time, place and in the right quantity, needs to go beyond physical and material logic. This need can be attributed mainly to electronic and communication media, which increasingly promote a systemic integration between the user, the company and the order. Within this context, the Traveling Salesman Problem (TSP), being a classic combinatorial optimization problem, has been widely used in the literature as a benchmark for various applications and solutions.*
Materials and Methods*: The improvement measures verified in this work include different initialization approaches, cross-approaches and local optimization approaches. Different parameterizations and comparison criteria are used to evaluate the contribution of the proposed optimization model. The model in question is solved using the LINGO solver. It is worth noting that the route distance, capacity and vehicle speed data were collected on site from the company that served as the research unit.*
Results*: The results revealed that the greater the number of points in terms of geographical positioning and/or number of customers to be served, the model's performance will be enhanced. The solution implemented can be replicated for scenarios and situations involving different vehicles, different orders and different locations, regardless of the number of customers to be served.*
Conclusion: *In this work, we proposed the traveling salesman problem with an optimization solution to compose shorter critical paths to make deliveries for a pizzeria that serves exclusively in the delivery mode, with the aim of covering several customers in the solution through one delivery person. Thus, according to the analyses and comparisons, the proposed optimization model generated better performances in terms of the quality and robustness of the solution. Later on, we plan to continue and advance the research and, with this, present new approaches and ways of solving discrete optimization problems, such as the use of Artificial Intelligence, online use of the solution, parameterization of elements, among others.*
Keyword*: Routing planning. Decision support. Real-time systems. Computer modeling. Reinforcement learning.*

Date of Submission: 01-05-2024 Date of Acceptance: 10-05-2024

I. Introduction

The pandemic caused by Covid-19 has directly contributed to the growth of e-commerce. Within this context, the Brazilian Association of Electronic Commerce highlights a significant growth in the sector's turnover in the first eight months of 2020, with an increase of 56.8% compared to the same period in 2019 and an increase of 65.7% in the number of orders, which led to an increase in distribution demand (Abcomm, 2020).

In parallel with this phenomenon, Mitieka et al. (2023) and Yuan et al. (2023) point out that urban mobility has been highly compromised, whether by urban overcrowding, or other various social, political and economic factors that directly interfere in the daily life of cities. Corroborating these authors, Alessandretti et al. (2023) and Tori, Te Boveldt and Keseru (2023) point out that urban commercial relations have been highly impacted by the lack of mobility in cities, requiring computer solutions that can be effective in a world increasingly connected to technologies.

As such, companies operating in the delivery segment need to constantly improve their delivery processes, given the growing demand in this segment in recent years (Cheikhrouhou & Khoufi, 2021).

Consequently, they need to constantly redesign their routes in urban areas. This need is justified by the current obligation to reduce costs, sales prices and delivery times, which can become a competitive differentiator for companies in the delivery segment (Huerta et al., 2022).

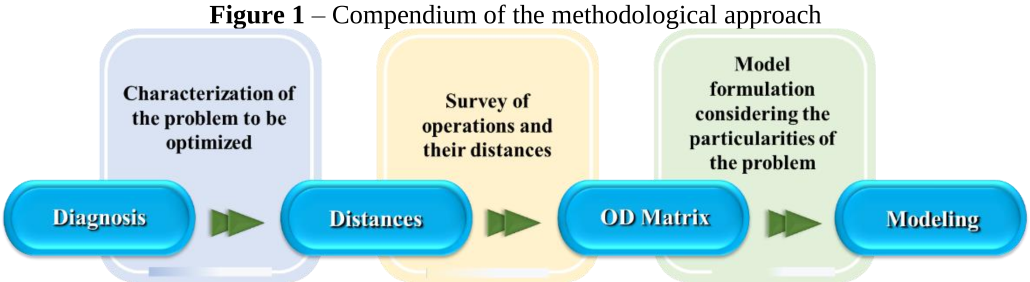
According to Kumar and Memoria (2020), Di Placido et al. (2023) and Liu et al. (2023), in view of the various transportation logistics studies in the literature, the Traveling Salesman Problem (TSP), due to its versatility in adapting to various cases and also in using technologies to find shorter routes considering the lowest cost and total distance, presents itself as a modern solution suitable for today's business models.

Therefore, considering the need for companies in the delivery sector to review and replan their routes on a daily basis, the aim of this study was to use TSP to determine routes. To achieve this goal, a model was developed to optimize the delivery operations of a pizzeria.

II. Material And Methods

The methodological approach presented in this section establishes the scope of the research, distinguishing the practices adopted to identify the parameters needed to solve the TSP in 4 stages (Figure 1). According to Lin (1965), Johnson and McGeoch (1997), and Suim et al. (2023), the problem studied in the scope of this work is a single-collector routing problem, in which there are alternative routes to the delivery locations, and all of them must be visited.

Figure 1 – Compendium of the methodological approach



Source: Authors (2022).

In order to help with the operationalization and methodological development of this work, the research unit used was a micro-company that operates in the field of pizza sales (delivery) in the municipality of Itarana - Espírito Santo (Brazil). In this way, the investigations were carried out in order to understand and clarify the operationalization of this company's deliveries, following the precepts of Lin (1965), Johnson and McGeoch (1997), Applegate et al. (2006), Di Placido et al. (2023) and Liu et al. (2023) for mapping and structuring research data.

Following the precepts of Barrena et al. (2023), the problem of optimizing the delivery routes of this micro-enterprise was characterized through an on-site visit on July 9, 2022, when details of the operations were presented and clarified, and data was also collected (days and times of departure and arrival of the delivery person, as well as knowledge of the delivery routes). Based on notes from the company manager, five routes were selected for analysis (Kumar & Memoria, 2020, Liu et al., 2023). At the same time, the company's delivery man was interviewed to identify factors that could cause delays or seasonality in deliveries (Applegate et al., 2006, Di Placido et al., 2023), thus concluding the first stage.

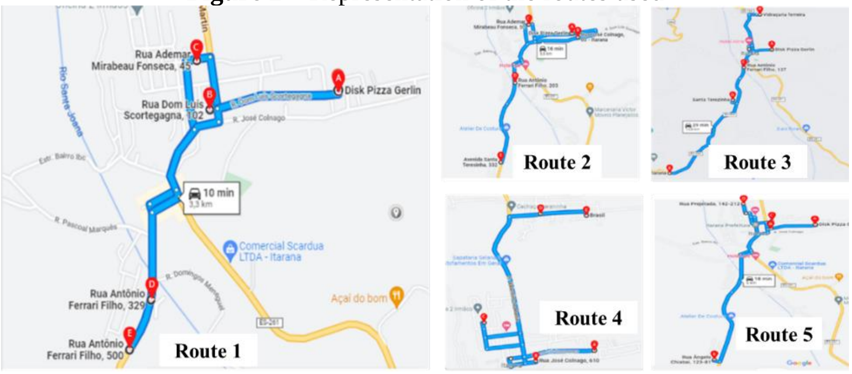
Thus, after acquiring the initial data and characterizing the problem, the distances between one stopping point and another were determined, in the second stage, using the Google Maps application (Google, 2022). Subsequently, an Origin-Destination (OD) matrix was designed to represent the distances between the component sections of the routes (Lin, 1965, Johnson & McGeoch, 1997, Huerta et al., 2022). Once the OD matrix had been obtained, the TSP was modeled using the LINGO 19.0® trial version solver, in accordance with Liu et al. (2023) and Suim et al. (2023), taking into account the particularities and specific conditions of the research unit.

III. Result

The research unit was chosen because it offers delivery services in an important municipality in the Central Serrana region of the state of Espírito Santo, which stands out for its agribusiness. For this reason, the established competition has sometimes demanded offers that need to go beyond the hygiene, pre-preparation and preparation process, in order to guarantee fast and efficient delivery, in other words, it is also necessary to think about the safety of this food.

In view of this, delivery data (distances traveled and stopping points for each route) was initially collected for the five main routes. To this end, a meeting was held with the company's manager and delivery man, and the respective delivery route locations were confirmed (Figure 2).

Figure 2 – Representation of the routes used



Source: Google Maps (2022, adapted).

According to Cheikhrouhou and Khoufi (2021), the locations visited by the courier are represented by dots in order to demarcate each route. The company is the initial origin (point A), and the deliveries are indicated in alphabetical order (B to E). Based on these indications, the distance between each point was obtained and an OD matrix was drawn up for each route - as shown in Table 1.

Table 1 – Distance between points on Route 1 (meters)

Points	A	B	C	D	E
A	0	500	650	1,300	1,500
B	500	0	260	800	1,000
C	750	290	0	1,000	1,100
D	1,300	850	1,000	0	190
E	1,500	1,000	1,200	190	0

Source: Authors (2022).

Following the approach proposed in the methodology, the results obtained in Table 1 were inserted into the Delivery Operations Optimization Model (Figure 3) and route simulations were carried out with the solver, which then used the Branch and Bound algorithm to find optimal solutions (O'Neil & Hoffman, 2019).

Figure 3 – Model for optimizing delivery operations

```
sets:
points / A B C D E/:;
matrix(points,points) : dist, x, f;
endsets

data:
dist = 0    X12  X13  X14  X15
       X21  0    X23  X24  X25
       X31  X32  0    X34  X35
       X41  X42  X43  0    X45
       X51  X52  X53  X54  0;

enddata

! Minimizes total distance traveled;
[fo] min = @sum (matrix(i,j) : dist(i,j) * x(i,j));
! At each point j only one edge arrives;
@for (points(j) : @sum (points(i) : x(i,j)) = 1);
! From each point i only one edge comes out;
@for (points(i) : @sum (points(j) : x(i,j)) = 1);
! The flow that arrives at a point j, except the origin, minus what leaves is equal to one unit;
@for (points(j) | j #ne# 1 : @sum (points(i) : f(i,j)) - @sum (points(i) : f(j,i)) = 1);
! The maximum flow on each edge is (n-1), where n is the number of points;
@for (matrix(i,j) : f(i,j) <= (@size (points) - 1) * x(i,j));
! The variable x(i,j) must be binary;
@for (matrix(i,j) : @bin (x(i,j)));
```

Source: Authors (2022).

The solutions reached were organized in a binary matrix, where a given point in the matrix is assigned a value of one if it is selected as the solution to the problem and, if not, it is assigned a value of zero (Kumar & Memoria, 2020). Considering this logic, the model returned optimized solutions for each route (Table 2).

Table 2 – Overview of simulations

Routes	Initial distance traveled (m)	Final distance traveled (m)	Interactions	Suggested route
1	3,450	3,290	179	A → C → E → D → B → A
2	5,500	5,400	107	A → C → E → D → B → A
3	13,700	13,601	40	A → E → D → C → B → A
4	5,250	4,835	158	A → E → D → C → B → A
5	5,980	5,800	37	A → B → E → D → C → A

Source: Authors (2022).

The processing time for all routes was a maximum of 1 second. It is worth noting that route 4, with a reduction of 7.89%, showed the highest percentage, followed by route 1 with the second highest reduction (4.63%), then route 5 (3.01%), then route 2 (1.81%) and finally route 3 (0.72%), although these findings indicate a route as the best to be optimized, to implement improvements it will be necessary to review delivery scheduling practices (Cheikhrouhou & Khoufi, 2021).

Strictly speaking, although there is no exact time for each production process (O'Neil & Hoffman, 2019), the usual market estimate for delivery pizzas suggests that this time is around 40 minutes maximum. Another important point to be observed and practiced refers to the delimitation of the delivery area, and from this, to ensure that delivery times do not increase without planning and control of the various situations (Huerta et al., 2022). This tends to be possible in the case studied, since in different circumstances (routes) there are possibilities for improvement by shortening the route.

Another way of speeding up delivery procedures is by scheduling the fulfillment of grouped orders (Abcomm, 2020). However, this also means that the preparation of orders must be synchronized and grouped as much as possible, so that there is a single departure for the delivery person. According to the company manager, this is possible up to a 28% increase in current production capacity, i.e. a limit of 150 pizzas on peak days and times.

Therefore, in order to meet the estimated timeframe in the face of adversity and competition, the company needs to have a dynamic and integrated ordering system, as well as organized stocks, production standards (master plan), a defined team with the necessary profile for the projections and the definition of minimum processes to be carried out individually (O'Neil & Hoffman, 2019).

IV. Conclusion

In recent years, the field of Operations Research has been pushing the boundaries of learning. In general, researchers and professionals have provided the literature with better solutions than the traditional learning models used since the 1950s. However, it is important to note that although traditional solutions are still being studied, with the current technological development more advanced work and research will spontaneously increase in association with other varied tools, techniques and resources, such as hybrid use with Artificial Intelligence.

This paper presents a study on the use of TSP in a delivery company. It focuses mainly on the routing problem with the aim of reducing transportation time, which could potentially help the survival of companies in the delivery sector by improving their operational decisions in the face of the growing trend in e-commerce.

For this reason, we propose a routing model that uses Mixed Integer Linear Programming in its formulation, which is built mathematically to model the TSP based on the delivery scenario described in the previous section to solve the solution optimally, thus achieving the proposed objective.

Future research could integrate other constraints, such as time windows, weather, variation in operations. Finally, uncertainty can be considered in order to explore aspects that are as close as possible to real-life configurations, and from this assist decision-makers in their activities - for example, with the use of multi-criteria methods such as the Analytic Hierarchy Process (AHP).

Acknowledgements

We thank the Operations Research Laboratory, Logistics and Transport of the Federal University of Espírito Santo/ University Center North of the Espírito Santo by the academic and technical support in the design and development of this work.

References

[1]. Abcomm. (2020). Faturamento Do E-Commerce Cresce 56,8% Neste Ano E Chega A R$ 41,92 Bilhões. Https://Abcomm.Org/Noticias/Faturamento-Do-E-Commerce-Cresce-568-Neste-Ano-E-Chega-A-R-4192-Bilhoes/.
[2]. Mitieka, D., Luke, R., Twinomurinzi, H., & Mageto, J. (2023). Smart Mobility In Urban Areas: A Bibliometric Review And Research Agenda. Sustainability, 15(8), 6754.
[3]. Yuan, Y., Masud, M., Chan, H., Chan, W., & Brubacher, J. R. (2023). Intersectionality And Urban Mobility: A Systematic Review On Gender Differences In Active Transport Uptake. Journal Of Transport & Health, 29, 101572.
[4]. Alessandretti, L., Natera Orozco, L. G., Saberi, M., Szell, M., & Battiston, F. (2023). Multimodal Urban Mobility And Multilayer Transport Networks. Environment And Planning B: Urban Analytics And City Science, 50(8), 2038-2070.
[5]. Tori, S., Te Boveldt, G., & Keseru, I. (2023). Building Scenarios For Urban Mobility In 2030: The Combination Of Cross-Impact Balance Analysis With Participatory Stakeholder Workshops. Futures, 150, 103160.
[6]. Cheikhrouhou, O., & Khoufi, I. (2021). A Comprehensive Survey On The Multiple Traveling Salesman Problem: Applications, Approaches And Taxonomy. Computer Science Review, 40, 100369.
[7]. Huerta, I. I., Neira, D. A., Ortega, D. A., Varas, V., Godoy, J., & Asin-Acha, R. (2022). Improving The State-Of-The-Art In The Traveling Salesman Problem: An Anytime Automatic Algorithm Selection. Expert Systems With Applications, 187, 115948.
[8]. Kumar, R., & Memoria, M. (2020). A Review Of Memetic Algorithm And Its Application In Traveling Salesman Problem. International Journal On Emerging Technologies, 11(2), 1110-1115.
[9]. Liu, S., Zhang, Y., Tang, K., & Yao, X. (2023). How Good Is Neural Combinatorial Optimization? A Systematic Evaluation On The Traveling Salesman Problem. Ieee Computational Intelligence Magazine, 18(3), 14-28.

[10]. Di Placido, A., Archetti, C., Cerrone, C., & Golden, B. (2023). The Generalized Close Enough Traveling Salesman Problem. European Journal Of Operational Research, 310(3), 974-991.
[11]. Lin, S. (1965). Computer Solutions Of The Traveling Salesman Problem. Bell System Technical Journal, 44(10), 2245-2269.
[12]. Johnson, D. S., & Mcgeoch, L. A. (1997). The Traveling Salesman Problem: A Case Study. Local Search In Combinatorial Optimization, 215-310.
[13]. Suim, B. N., Dos Santos Scarpati, N., Do Rozario Clarindo, J., & Gonçalves, W. (2023). Modelagem Do Traveling Salesman Problem Com Dependência Dos Tempos De Viagem: O Caso De Uma Central De Ambulâncias. Revista Brasileira De Iniciação Científica, E023030.
[14]. Applegate, D. L., Bixby, R. E., Chvátal, V., & Cook, W. J. (2006). The Traveling Salesman Problem: A Computational Study (V. 17). Princeton University Press.
[15]. Barrena, E., Canca, D., Coelho, L. C., & Laporte, G. (2023). Analysis Of The Selective Traveling Salesman Problem With Time-Dependent Profits. Top, 31(1), 165-193.
[16]. Google. Google Maps. (2022). Https://Www.Google.Com.Br/Mapsz.
[17]. O'neil, R. J., & Hoffman, K. (2019). Decision Diagrams For Solving Traveling Salesman Problems With Pickup And Delivery In Real Time. Operations Research Letters, 47(3), 197-201.