Canguinha: an Intelligent Recommendation System for Optimizing Shopping Routes

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Abstract. *This work introduces Canguinha Alagoas, an online platform designed to minimize the cost of the basic food basket, particularly for low-income consumers. Given a selected list of essential products and a search radius, the system identifies the most cost-effective stores within the specified area and generates an optimized route that reduces both travel time and overall purchase cost. The platform leverages real-time price data from the SEFAZ API (NFC-e), models the problem as a Traveling Purchaser Problem (TPP), and applies a metaheuristic algorithm to efficiently explore the solution space. Experimental results demonstrate that the platform achieves significant cost savings for consumers, contributing to economic efficiency and positively impacting community well-being.*

Resumo. *Este trabalho apresenta o Canguinha Alagoas, uma plataforma online desenvolvida para minimizar o custo da cesta básica, especialmente para consumidores de baixa renda. Dada uma seleção de produtos essenciais e um raio de busca, o sistema identifica os estabelecimentos mais vantajosos dentro da área especificada e gera uma rota otimizada que reduz tanto o tempo de deslocamento quanto o custo total da compra. A plataforma utiliza dados de preços em tempo real da API da SEFAZ (NFC-e), modela o problema como um Problema do Comprador Viajante (TPP) e aplica um algoritmo meta-heurístico para explorar eficientemente o espaço de soluções. Os resultados experimentais demonstram que a plataforma proporciona economia significativa aos consumidores, promovendo eficiência econômica e impactando positivamente o bem-estar da comunidade.*

1. Introduction

Family financial planning is a recurring challenge, especially in contexts of economic instability, where the prices of essential goods vary significantly. Although digital platforms for budget control are becoming more common, many still impose financial and technological barriers that limit access, particularly for low-income families. Moreover, such solutions often overlook transportation costs — including travel and fuel — which directly impact the final value of purchases.

To address these limitations, this study proposes the *Canguinha* platform, a free and innovative system designed to recommend the lowest-cost routes for purchasing essential goods: `https://www.canguinhaal.com.br`. The solution is grounded in the Traveling Purchaser Problem (TPP) [Golden et al., 1981], an extension of the classical

Traveling Salesman Problem (TSP) [Applegate, 2006], that simultaneously involves product selection, market choice, and the definition of an economically optimized shopping route.

The proposed platform takes into account both the prices practiced in local markets — obtained via Brazil's NFC-e system, through the API provided by the State Revenue Department of Alagoas [Secretaria da Fazenda de Alagoas, 2025] — and the transportation costs involved in traveling between locations. To achieve this, it leverages data from the OSMNx library to extract the local street network and estimate actual distances between markets. As illustrated in Figure 1, the user provides a product list and a maximum travel radius, and the platform constructs a mobility graph with accessible markets. Based on this graph, an algorithm based on the Adaptive Large Neighborhood Search (ALNS) [Pisinger and Ropke, 2018] metaheuristic is applied to solve the TPP and return the optimal combination of markets and route with the lowest total cost.

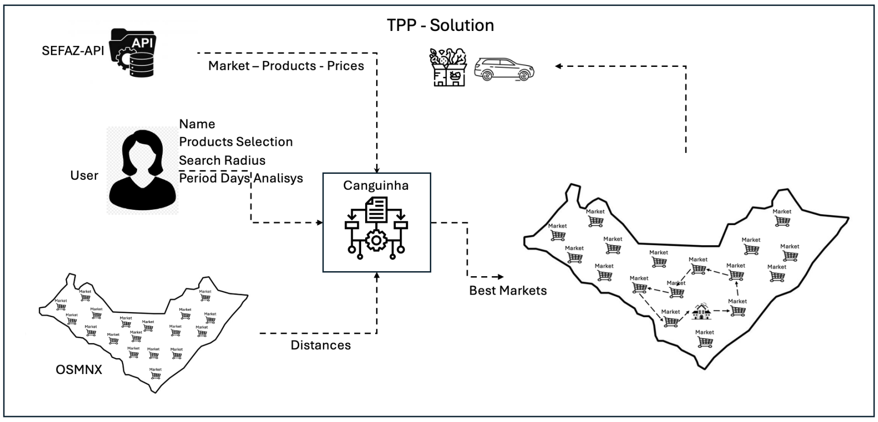

Figure 1. *Canguinha* Shopping Route

Beyond its technical and economic contributions, *Canguinha* was developed with a strong focus on social impact and user autonomy. Targeted at consumers with limited budgets, the system promotes financial inclusion by presenting a ranked list of markets where the selected items are available, without relying on commercial partnerships or charging service fees. Although it does not offer delivery services, the platform enhances the in-person shopping experience by generating optimized routes based on geolocation, product availability, and cost minimization. This enables users to plan their purchases more efficiently, gaining greater control, convenience, and savings in their daily routines. The feasibility and efficiency of the proposed solution are demonstrated in Section 6, which presents cost analyses under different scenarios, confirming the economic advantage of *Canguinha* compared to other approaches.

2. Related Work

Several academic studies have explored optimization methods to solve the TPP and its variants, focusing on the different constraints addressed in each proposal. Riera-Ledesma and Salazar-González [2005] present heuristics focused on reducing processing time and computational complexity, through strategies based on local search. Angelelli et al. [2009] address the dynamic TPP, incorporating aspects such as frequent price volatility and variable product availability, balancing travel and acquisition costs. Xiao et al. [2022], in turn, propose predictive models that dynamically adjust shopping routes according to anticipated price changes.

With the growth of service apps, the *Canguinha* platform emerges as a strategic alternative compared to large consolidated players and emerging regional solutions. Among the best-known platforms, *iFood*[1] dominates the delivery sector, with a primary focus on food delivery, but incorporates fees and commissions that increase the final cost to the consumer. Similarly, *Rappi*[2] also offers delivery services with additional charges. Regional apps, such as *ClickSuper*[3], offer a similar proposal to large platforms, providing delivery based on commercial partnerships and charging fees. *Economiza na Lista*[4], on the other hand, focuses on promotion listings and individual price consultation, without offering a route optimization system or total cost analysis.

The *Canguinha* platform stands out by adopting an approach focused on optimizing the acquisition of basic goods, using real data obtained through the SEFAZ-AL API, updated periodically. This differential ensures greater pricing accuracy by considering both product costs and the estimated travel cost based on fuel consumption, delivering a realistic estimate of the total purchase cost.

3. Methodology

This section describes the methodology of the *Canguinha* platform for data collection, which is essential for the optimization model. We detail the acquisition of local market prices, the precise calculation of routes and distances, and the conversion of this information into logistical costs, aiming at effective and assertive solutions.

3.1. Price Acquisition

The *Canguinha* platform performs automated and integrated acquisition of product prices, routes, and distances, focusing on cost optimization for the consumer. This information feeds the optimization algorithm based on the ALNS metaheuristic.

Product prices are extracted from the public API *Economiza Alagoas*, provided by SEFAZ-AL [Secretaria da Fazenda de Alagoas, 2025]. This API is integrated with the electronic fiscal documents platform (NF-e and NFC-e), reflecting the actual prices practiced by commercial establishments in the state. The SEFAZ module performs `HTTP POST` requests to the API using *multithreading* to parallelize requests. The parameters sent include:

- Product barcode and description;
- User geolocation;
- Maximum search radius (in km);
- Reference period;
- List of products to be compared.

[1] `https://www.ifood.com.br`
[2] `https://www.rappi.com.br`
[3] `https://clicksuper.com.br`
[4] `https://economizanalista.com.br/home`

3.2. Travel Cost

After the price retrieval stage, the process of calculating travel costs begins, which is essential to feed the ALNS optimization algorithm. In this phase, a dictionary is built containing relevant logistical information for each market, based on product prices retrieved from the SEFAZ API, market geolocation, and the average regional fuel price.

To estimate travel costs in the *Canguinha* scenario, a standard vehicle fuel consumption of 9.5 kilometers per liter is assumed. Using the average regional fuel price—obtained from the SEFAZ API—the cost per kilometer driven (in BRL/km) is calculated as:

$$\text{Cost per kilometer} = \frac{\text{Average regional fuel price}}{9.5} \tag{1}$$

To enable this integration between travel costs and product price data, the algorithm first organizes the input information by defining the set of products, the available markets, the availability of each item per market, and their respective prices. Based on this structured dataset, a graph is constructed in which each node represents a market, positioned according to its geographic coordinates (latitude and longitude). Since the user's origin and destination points coincide, they are represented as a single node in the graph. This spatial representation allows for accurate distance calculations which, when combined with the cost per kilometer, enable detailed estimation of travel costs—an essential factor for evaluating and optimizing the shopping route within the ALNS.

After mapping the graph's edges (i.e., the segments connecting markets) and vertices (i.e., the markets themselves), the construction of the distance matrix $(n + 1) \times (n + 1)$ is carried out. In this context, n represents the number of market nodes in the graph, and the additional row and column correspond to the user's origin and destination, which coincide and are thus represented as a single additional node. During this process, fuel costs are incorporated into the total cost of each segment by multiplying the distance between markets by the average cost per kilometer. For graph construction and distance calculation, the *OSMnx* library was used [Boeing, 2017]. At the end of this process, a data dictionary is generated with the following parameters:

- Set of markets;
- Set of products;
- Products available per market;
- Product prices in each market;
- Distance matrix $(n + 1) \times (n + 1)$ among the selected markets and users starting/finish location;
- Average fuel consumption per segment (edges).

The data dictionary follows a standardized format widely used in the literature for solving the TPP. These parameters are used as input for the ALNS algorithm, as presented in Subsection 4.1 [Kucukoglu, 2022].

3.3. Traveling Purchaser Problem (TPP)

The TPP aims to minimize the total cost associated with a specific route. This cost, as described in Manerba et al. [2017], consists of two main components: the travel costs between markets and the acquisition costs of the required products in each visited market.

Formally, the TPP receives as input a complete graph $G = (V, A)$, where $V = \{0, 1, ..., n\}$ represents the nodes — with node 0 being the origin/destination point and $1..n$ the markets — and $A = \{(i, j) : i, j \in V, i \neq j\}$ represents the arcs, each with a travel cost t_{ij}. Each arc $(i, j) \in A$ has a travel cost t_{ij}, which represents the cost of traveling from market i to market j.

In the TPP, each market $i \in V \setminus \{0\}$ offers a set of products $P_i \subseteq P$, where P is the set of all desired products. Moreover, each product $k \in P$ has a cost c_{ki} at market i. The consumer demand for each product k is d_k. However, in this article, we consider a subcase of the TPP, where the demand for each product is $d_k = 1$ for all $k \in P$. It is also assumed that all markets offer the full set of desired products.

The problem addressed in this work consists of finding:

1. A subset of arcs $A' \subseteq A$ that defines a closed route starting and ending at node 0;
2. A purchasing allocation ϕ, where $\phi(i)$ is the market where product i was purchased, for $i = 1, \ldots, |P|$.

Such that the total cost of transportation and product acquisition is minimized, i.e.,

$$\min \sum_{ij \in A'} t_{ij} + \sum_{i=1}^{|P|} c_{i,\phi(i)}.$$

Ensuring that if product i was purchased at market $\phi(i)$, then market $\phi(i)$ is visited in the route A'.

4. Proposed Solution

This section presents the proposed solutions and design choices of the *Canguinha* Platform. First, a detailed explanation of the adopted ALNS heuristic is provided. Then, the platform's frontend is described, highlighting the configuration of parameters used to generate shopping routes. Finally, the backend architecture developed to support the platform's operations is outlined.

4.1. Proposed Algorithm: ALNS

The pseudocode in Algorithm 1 summarizes the main logic of the ALNS method, which iteratively explores and improves a feasible solution through the combination of destruction and repair operations. The process begins with the generation of an initial solution x (line 1), which is also stored as the best-known solution x^b. The selection weights ρ^- and ρ^+ — associated with the destruction and repair operators — are initialized with equal values, ensuring uniform selection at the start of the process (line 2).

Each iteration selects a pair of operators $d \in \Omega^-$ and $r \in \Omega^+$ based on their past performance (line 4). The weight vectors ρ^- and ρ^+ guide this selection using a roulette wheel mechanism to choose the destroy and repair methods. The destruction operator d removes part of the current solution, and the repair operator reconstructs a new solution x' using heuristics focused on cost minimization (line 5).

In line 6, the new solution x' is accepted if it has a lower cost than the current one. Otherwise, it may still be accepted with a decreasing probability, governed by an implicit cooling function — similar to Simulated Annealing [Delahaye et al., 2019] — that considers the iteration progress. If accepted, x' replaces x (line 7) and, if it is also the best solution found so far, x^b is updated (lines 9–10). In line 12, the operator weights are periodically adjusted based on their accumulated performance, giving higher priority to those that contribute most to solution improvements. The weight vectors are updated by increasing the scores of operators that recently produced good solutions while gradually decreasing the influence of older performance data, ensuring adaptability over time.

Algorithm 1 ALNS for the TPP

1: Randomly generate an initial feasible solution x
2: $x^b \leftarrow x$; $\rho^- = (1, \ldots, 1), \rho^+ = (1, \ldots, 1)$ ▷ Initalize weights
3: **repeat**
4: select $d \in \Omega^-$ and $r \in \Omega^+$ based on ρ^-, ρ^+ ▷ Select destroy and repair methods
5: $x' \leftarrow r(d(x))$
6: **if** `accept`(x', x) **then**
7: $x = x'$
8: **end if**
9: **if** $c(x') < c(x^b)$ **then**
10: $x^b \leftarrow x'$
11: **end if**
12: update weights ρ^-, ρ^+
13: **until** stopping criterion is met
14: **return** x^b

Finally, the main loop of the algorithm continues running while the following three conditions hold simultaneously (line 13): (i) the number of iterations is below the maximum limit; (ii) the number of consecutive iterations without improvement does not exceed a predefined threshold; and (iii) the number of consecutive infeasible solutions remains within an acceptable limit. In line 14, the algorithm returns the best solution x^b found during the search.

The ALNS relies on well-defined components that balance diversification and intensification throughout the search process. The destruction operators (Ω^-) used in this implementation include: (i) `Random Removal`, which randomly excludes markets; and (ii) `Worst Removal`, which eliminates markets with the highest impact on the total cost. For the repair phase (Ω^+), two insertion operators are employed: (i) `Random Insertion`, which reintroduces products into randomly selected markets; and (ii) `Greedy Insertion`, which prioritizes the most cost-efficient combinations. This adaptive interaction between destruction and repair — guided by performance-based selection and acceptance criteria — allows the algorithm to efficiently navigate the solution space.

4.2. Canguinha Platform

The *Canguinha* Alagoas platform aims to reduce the cost of basic goods for low-income consumers by integrating price data made available by the Department of Finance (SEFAZ) and route optimization algorithm. As illustrated in Figure 2, the user can configure both the search radius (up to 15 km) and the time range (in days) for the price search of the product list, ensuring flexible analysis of available offers.

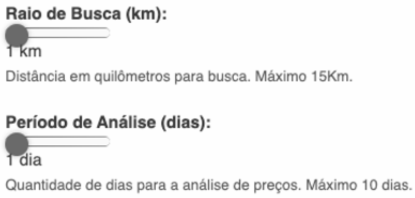

Figure 2. Search radius and number of days used to locate products. (In Portuguese)

To define the starting and ending point of the itinerary, the system allows the user to manually enter an address or use their current location, as illustrated in Figure 3. This feature is particularly useful for those who wish to plan their purchases from a fixed location, such as their residence or another point of reference.

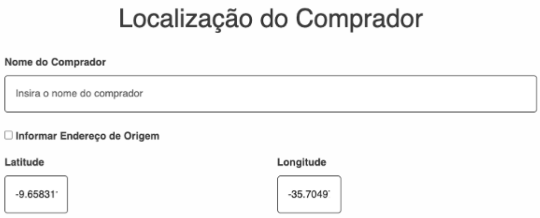

Figure 3. Start and end location configuration section. (In Portuguese)

Once the search parameters are defined, the user can select the items that will compose their shopping list. At this stage, the products were selected based on the criteria established for the composition of the basic food basket, according to the official list provided by Procon[5]. In order to optimize the interaction with the SEFAZ API, 15 representative items were defined, each associated with five different barcodes previously identified as the most popular and with the lowest average prices. Brand names were not considered as a selection criterion, thereby prioritizing items with higher consumption frequency, ensuring greater representativeness and comparability. This strategy aims to mitigate price discrepancies among equivalent products. As illustrated as show in Figure 4, only the generic names of the products and their respective units of measurement were considered, excluding any reference to specific brands.

Based on the collected information, the platform user receives a detailed list of items to be purchased and an optimized shopping route displayed on an interactive map (Figure 5). This approach provides a comprehensive view, allowing the user to visualize both the estimated cost of each product and the most economical route, minimizing travel and fuel expenses. In this way, *Canguinha* simplifies the purchasing process and presents savings estimates.

4.3. System Architecture

The architecture of *Canguinha* is composed of modular and well-defined components Figure 6, designed to ensure scalability, maintainability, and high performance across all

[5]Consumer Protection and Defense Program (PROCON), consists of state and municipal agencies responsible for consumer protection and defense, governed by the Consumer Protection Code in Brazil.

Figure 4. Items that compose the basic foods basket. (In Portuguese)

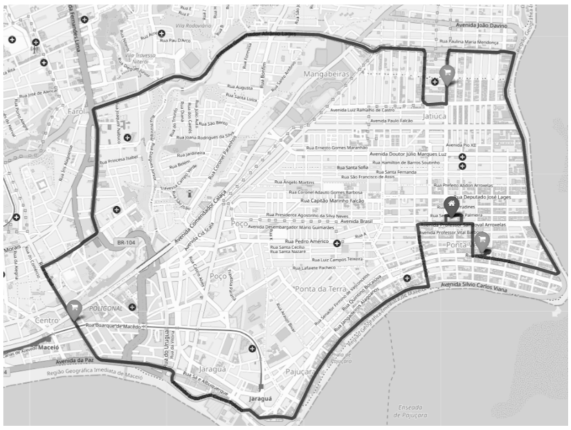

Figure 5. Visualization of the generated shopping route.

system layers.

1. **Architecture Model View Template (MVT):** Design pattern used by Django to separate application logic. The *Model* handles data and business rules, the *View* processes user requests and prepares the response, and the *Template* defines how the data is presented in the interface.
2. **Backend (Data Collection):** Implemented in Python/Django, it requests and organizes price information from the SEFAZ API. The data is cached to minimize latency and avoid redundant calls.
3. **Backend (Route Optimization):** Uses the ALNS heuristic to solve the TPP. The algorithm minimizes the total cost by combining item prices with travel costs.
4. **Frontend (Interface):** Built with Django Templates and JavaScript. The user selects products, defines the search radius, enters a starting address (or uses geolocation), and receives an optimized route displayed on an interactive map.
5. **Multithread:** The code uses *multithreading* through a `ThreadPoolExecutor` to perform up to 30 simultaneous requests to the SEFAZ API. The `request_produto_sefaz` function is executed concurrently for each GTIN. The `as_completed` loop waits for the completion of the requests and retrieves the results. Errors that occur during the requests are captured and handled within a `try-except` block.

5. Usability Evaluation

The usability evaluation of the *Canguinha* platform was conducted with a group of 30 randomly selected participants, of which 23 completed a structured questionnaire. The

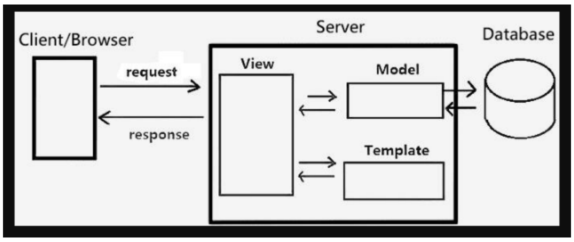

Figure 6. Simplified *Canguinha* architecture scheme Model View Template (MVT).

evaluation protocol involved accessing the platform, performing the initial setup — obtaining the average fuel price, selecting products — and then filling out a form with questions focused on user experience (Table 1).

Table 1. Usability evaluation questions for the *Canguinha* platform

No.	Questionnaire Items
1	On a scale of 0 to 10, how would you rate the ease of use of the system?
2	On a scale of 0 to 10, were the buttons and features clearly identified and easy to use?
3	How likely are you to recommend Canguinha to someone else?
4	On a scale of 0 to 10, what is your overall impression of the system, and how do you think it could be improved?
5	On a scale of 0 to 10, what did you like most and least about the application?
6	On a scale of 0 to 10, what is your level of satisfaction with the search result?
7	On a scale of 0 to 10, did the response clearly present the best prices?
8	Was the system useful in identifying the most economical establishments?
9	Did you experience any difficulty locating the entered address?
10	Is there anything you would suggest or improve on the platform?

The results reveal a broadly positive perception of the *Canguinha* platform, especially regarding ease of use, interface clarity, and efficiency in displaying results. Table 2 presents the average scores for the main evaluated indicators. Among the highlights, the clarity of buttons and features received the highest average score (**9.43**), followed by ease of use (**9.04**), satisfaction with search results (**9.00**), and the clarity with which the best prices were presented (**9.26**). The perceived usefulness of the results scored **8.48**, and overall satisfaction reached **8.78**, indicating a high level of user approval and reinforcing the platform's usability and functional value.

In addition to the quantitative responses, open comments highlighted strengths such as the agility of the search process, the intuitive layout, and the cost savings enabled by price comparison. Suggestions for improvement included expanding the range of products and supermarkets, enhancing geolocation accuracy, and refining the interface layout to improve readability and information organization. Despite the overall favorable evaluation, a small portion of participants reported the need for additional guidance when using the system, which reinforces the importance of ongoing improvements in accessibility and onboarding. The results suggest that *Canguinha* offers a solid foundation in terms of

Table 2. Average ratings on usability and interaction with *Canguinha*

Question	Average
Question 1 (0–10)	9.04
Question 2 (0–10)	9.43
Question 4 (0–10)	8.48
Question 5 (0–10)	8.78
Question 6 (0–10)	9.00
Question 7 (0–10)	9.26

usability and interaction, with great potential to evolve based on continuous user feedback.

6. Cost Analysis

To assess the economic feasibility of the *Canguinha* platform, we conducted a case study comparing the prices obtained through the platform with those from three distinct alternatives: (i) **Procon/AL** (Instituto de Proteção e Defesa do Consumidor de Alagoas), (ii) **iFood**, a nationally recognized food delivery platform, and (iii) the **Carrefour** supermarket's official shopping app. It is important to note that **Procon/AL** data served as a benchmark rather than a direct alternative, as it is maintained by the government with the purpose of manually aggregating the lowest prices recorded across eight selected retail establishments, thereby providing a reference for optimal cost scenarios.

The case study was based on data collected between January 22 and 24, 2025, and focused on a user located at latitude -9.65808 and longitude -35.70447. This location corresponds to a point in *Maceió*, Alagoas, Brazil. Moreover, we considered a search radius of 4 km and a one-day price lookup window. The product list in the study consisted of one unit of 15 different products from a typical basic food basket.

Figure 5 illustrates the route generated by the platform for this case study, which includes three distinct markets: Nobre, Unicompras Market, and Carrefour, where 4, 6, and 5 products were purchased, respectively. Table 3 provides a comparative analysis of prices between *Canguinha* and other reference methods.

The results in Table 3 show that the Carrefour platform recorded a total expense of R$115.88 — comprising R$113.19 in product costs and R$2.69 for delivery. Similarly, iFood presented a total of R$106.17 including R$103.87 for products and a R$2.30 service fee. Although these platforms occasionally offer promotional discounts, the associated fees contribute significantly to the final price.

Conversely, the *Canguinha* platform demonstrated the most cost-efficient alternative, with a total expenditure of R$92.50, consisting of R$88.81 for products and an estimated transportation cost of R$3.69. This estimation was based on an average vehicle fuel consumption of 9.5 km/l, a fuel price of R$5.70 per liter, and a total round-trip distance of 11.5 km.

These results show that *Canguinha* achieved savings of 15.25% and 20.19% compared to iFood and Carrefour, respectively. It is important to note that the savings could have been even larger if more than one unit of each item had been considered for purchase.

Table 3. Price comparison across platforms — January 22 to 24, 2025

Product	Procon (R$)	Carrefour (R$)	iFood (R$)	Canguinha (R$)
Beans	2,98	7.29	7.90	6.68
Rice	4,69	5.98	6.77	5.97
Pasta	2,19	3.35	4.48	3.28
Flour	2.69	5.78	5.00	7.19
Coffee	10.49	5.66	6.88	3.68
Biscuit	3.49	6.99	5.96	4.68
Cornmeal	0.99	3.23	3.52	1.98
Margarine	2.85	3.79	3.78	3.18
Butter	8.99	11.79	6.40	8.68
Powdered milk	6.15	8.79	8.79	7.68
Milk	4.49	5.98	4.20	6.68
Oil	7.89	9.89	7.50	7.58
Sugar	2,49	3.29	4.00	4.68
Eggs	12.90	24.79	22.35	11.28
Sardines	3.79	6.59	7.34	5.59
Subtotal	87.25	113.19	103,87	88.81
Fees/Delivery	–	2.69	2.30	3.69
Total	**87.25**	**115.88**	**106,17**	**92.50**

In comparison to the optimal prices, as obtained by Procon/AL, the results indicate that the prices obtained through our platform are 6% higher, whereas iFood and Carrefour are, respectively, 21.7% and 32.79% higher.

This case study underscores the economic advantage of the *Canguinha* approach, which enables users to purchase each item at the lowest available price across different retailers. By assuming responsibility for transportation, users benefit from significant savings, reaffirming the platform's potential as a viable and efficient solution for budget-conscious consumers.

The platform uses public data from SEFAZ/AL, in compliance with privacy and ethical standards. Geolocation collection requires user consent, and search parameters are not stored. API requests are secure, authenticated, and unlinked from personal data.

7. Conclusions and Future Work

The results of this study showed that integrating public price data provided by the Department of Finance (SEFAZ) with optimization heuristics (ALNS) leads to significant reductions in the cost of essential goods. The *Canguinha* platform achieved up to 20% savings on basic food basket purchases, which is especially relevant for communities with limited budgets. The proposed modular architecture also facilitates the expansion of features and the adaptation of the system to different regions or product groups, increasing the flexibility and scalability of shopping solutions. With such enhancements, *Canguinha* would become even more adaptable to diverse consumption scenarios. More than a shopping platform, it would serve as a strategic tool to handle complex market variations, reduce logistical costs, and promote more conscious and sustainable consumption. Future work will focus on integrating real-time traffic and weather data, expanding product coverage, and incorporating machine learning for price prediction. Prices originating from electronic fiscal receipts (NFC-e) reflect past transactions and, therefore, may vary. This temporal variability, not yet modeled by the system, may affect the accuracy of the recommendations. Future work will aim to mitigate this impact.

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