Safetrip: Suggested Itineraries to Reduce Accident Risk Factors

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Abstract. *Every hour, five people are fatal victims of traffic accidents in Brazil. Between 2008 and 2016, more than 350 thousand people died from accidents on the roads and streets from the country. In this direction, this work proposes a prototype for suggesting safe routes, based on open data, in order to reduce the probability of the user being involved in an accident on a federal highway. For this, the application offers a* web *platform for viewing information on a suggested safe route, as well as the fastest route.*

Resumo. *A cada uma hora cinco pessoas são vítimas fatais de acidentes de trânsito no Brasil. Entre os anos de 2008 e 2016, mais de 350 mil pessoas morreram vítimas de acidentes nas estradas e ruas no país. Nesta direção este artigo propõe um protótipo para sugerir itinerários seguros, baseado em dados abertos, com a finalidade de reduzir a probabilidade do usuário se envolver em um acidente em uma rodovia federal. Para isso, a aplicação utiliza uma plataforma web paravisualizar informações sobre rotas seguras e rotas mais rápidas.*

1. Introduction

The 2018 General Report by the Urban Mobility Information System [Associação Nacional de Transportes Públicos 2018] shows that in Brazilian cities with more than 60,000 inhabitants, 67.0 billion trips were made in 2018. This corresponds to around 183 million trips per day. Walking and cycling were the majority (28.0 billion), followed by individual motorized transport – cars and motorcycles (20.3 billion) and collective transport (18.8 billion). When analyzing these trips, according to the same report, 605,239 people were victims of traffic accidents, of which 21,887 died, with an estimated cost of traffic accidents for the year of 2018 of 115.1 billion reais.

According to the World Health Organization (WHO), approximately 1.3 million people die worldwide each year from road accidents[1]. The situation is even worse in low and middle-income countries. WHO estimates that 90% of deaths occur in developing countries — including Brazil — even though this group owns only 48% of the planet's vehicles. With this in mind, the UN 2030 Agenda for Sustainable Development has set a target of halving the number of road traffic deaths and injuries by 2030.

[1]https://www.tecmundo.com.br/apps/107940-nova-funcao-waze-evita-areas-maior-risco-crime-rio.htm

Since the second half of the 20th century, safety items such as seat belts and airbags began to be gradually incorporated into vehicles [Andrade and Antunes 2019]. After the invention of microprocessors, the digitization of safety components has also contributed to reducing accident and mortality rates in traffic. One can cite the use, for example, of electronic radars and collision avoidance systems, which provide crucial seconds for an accident to be avoided [He and Qin 2017].

Apart from technology focused on road safety, many routing solutions for vehicles are emerging and being widely used. The success of this use is largely due not only to the power of current computer systems, but also to the development of mathematical models aimed at solving routing problems [Toth and Vigo 2014]. These applications usually adopt the optimal route based on distance, travel time, or even cost as a solution, when, for example, there are tolls along the way [Johnson et al. 2017]. Finding the optimal path, based on road safety, has never been properly explored by commercial solutions.

In parallel with contemporary challenges, cities that use technology to efficiently provide urban services, improve the quality of life of citizens and transform the relationship between local entities are classified as smart cities [Cunha 2016]. To achieve good public management and promote greater transparency, smart cities use open data that are available on public portals accessible by all [Cunha 2016].

In this direction, the objective of this work is to present a prototype with a web application which provides the safest and the fastest route to travel a certain route within the state of Paraná. This itinerary is based on open data from accident from the Brazilian Federal Police, containing location, day of the week and time of accidents on federal highways. The rest of this paper is organized as follows: Section 2 presents the related work. Section 3 describes the prototype. And finally, section 4 contains the conclusions of the study.

2. Related Work

In order to achieve good public management and promote greater transparency, smart cities use open data, which are available on public portals accessible to all [Cunha 2016].

In this direction, the Brazilian Federal Police has published open data referring to accidents on highways [2]. Some of these data are: the number of victims and severity, type of accident, main cause, location configuration, weather conditions, time of day, geographic coordinates of the accident, etc. From this database, it is possible to verify, for example, that the highest number of accidents in Paraná are related to 7AM and 6PM (Figure 1). Figure 2 shows the number of deaths for each federal highway in Paraná. Note that the distribution of deaths on the different highways is irregular, and sectors of highways with few kilometers can have a big number of deaths.

From the route calculation point of view, algorithms such as Dijkstra or A* can be used. Both algorithms allow the criterion for the weight of the edges to be the distance of the vertices plus a constant that would be calculated from the accident data (in order to determine a risk linked to that highway sector). The categorization for geographic vehicle routing can be divided into positive, negative, topological and personal-

[2] http://vias-seguras.com/dados_da_prf/dados_abertos_de_acidentes_nas_rodovias_federais_ate_2018

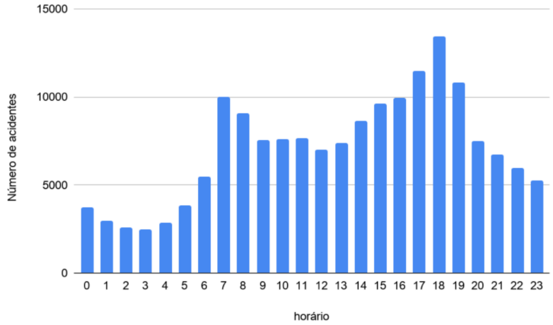

Figure 1. Accidents on federal highways in Paraná - 2007 to 2018.

BR	# mortos	# km	mortos/km
467	90	6,5	13,85
116	745	227,6	3,27
277	1701	748,8	2,27
376	1200	567,4	2,11
476	530	346,5	1,53
369	514	416,9	1,23
373	270	281,9	0,96
272	89	116,9	0,76
163	214	330	0,65
487	59	95	0,62
153	259	430,6	0,60
280	35	63	0,56
158	127	278,9	0,46
466	0	30	0,00
469	0	22,4	0,00
600	0	6	0,00

Figure 2. Number of deaths, number of kilometers and number of deaths per kilometer.

ized [Johnson et al. 2017]. The first two are related to the impact of aspects related to the environment: the positive ones to incorporate areas of interest to the route (such as tourist spots and types of landscape), and the negative one to avoid predetermined areas (such as regions with extreme weather conditions). Routing by topological criteria takes into account aspects of the road itself, such as the number of curves, longest highway sectors and shortest path. Finally, the routing criteria uses individual preferences into account. For this prototype, the criteria to be used fall into the negative category.

In order to calculate the risk related to traveling on a road, it is quantified by different highway sectors[Nizam 2017]. To achieve this objective, the Urban KiwiRAP methodology is used in this work: it quantifies risk metrics based on the number of deaths and serious injuries associated with historical accident data, along with the risk of death or serious injury for each one[Kingsbury et al. 2015]. There are three types of factors that affect safety in traffic accidents: human factors (such as sleeping behind the wheel and drinking alcohol); road and environmental factors (such as time of day, lighting condition and asphalt conservation status); and vehicle factors[Treat 1980].

From a visualization point of view, the prototype takes advantage of concepts from Geographic Information Systems (GIS). GIS integrate a series of features to display, manipulate and analyze large data sets related to the geographic position on Earth

[Egenhofer 1993]. In this direction, the prototype uses *GraphHopper* - an open source routing library and server written in Java [Mrazovic and Matskin 2015]. It provides road network travel time estimation and routing problem solving for vehicles using Dijkstra, A*, their two-way versions, and other strategies to ensure fast routing [Samah et al.] .

3. The Prototype

Figure 3 shows the architecture of the prototype. The presentation layer is a web page having as input the origin and destination. The page is able to make an HTTP request to the server, sending the data informed by the user in order to obtain the calculated route. The server receives this information and performs the processing, which consists of calculating the safest route based on the accident data provided by the database, as well as the fastest route, (with respective distances and time). After this calculation, the server returns the response to the presentation layer, which in turn makes a call to a geolocation API to plot the route on the map.

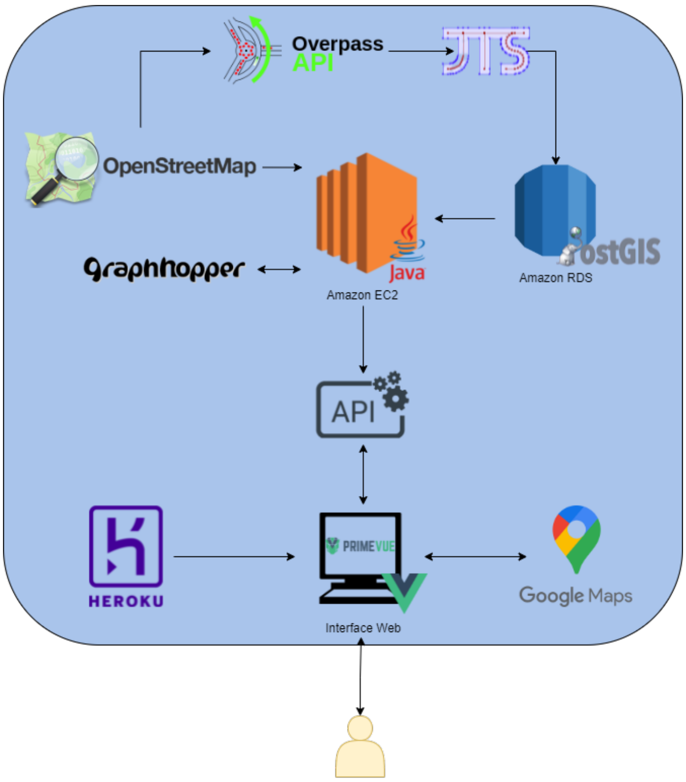

Figure 3. Architecture from the Prototype

The prototype used the following technologies:

- PostgreSQL[3] (version 13-3.0);
- PostGIS[4] (version 2.4): used to store GIS data related to accidents and highways;
- Vue.js[5] (version 2.3): *framework* Javascript[6] was used for the user interface;

[3]https://www.postgresql.org/
[4]https://postgis.net/
[5]https://vuejs.org/
[6]https://www.javascript.com/

- PrimeVue[7] (version 2.5.1): was used to renderize graphic components for the aplication;
- Google Places *API*[8] (version 2.0): was used for mapping origin and destination;
- Google Maps Javascript *API*[9] (version 3.46): was used for mapping origin-destination;
- Overpass *API*[10] (version 0.7.57): was used for extracting highways data;
- JSTS[11] (version 2.5.0): *port* from library JTS[12] was used for showing the highway geometries;
- *Elastic Compute Cloud* (EC2)[13]: was used for storing the processing layer;
- *Amazon Relational Database Service* (RDS)[14]: used to store the database;
- Java (versão 8)[15]: used for implementing the processing layer.

The diagram representing the data/tables is presented in Figure 4. The accident table contains information regarding accidents by the Brazilian Federal Police, between 2007 and 2018. It stores information such as day of the week, time, year, highway, fatalities, injuries, number of vehicles involved and latitude. The highway sectors which have the highest concentration of accidents is also stored, along with the number of accidents with deaths or serious injuries.

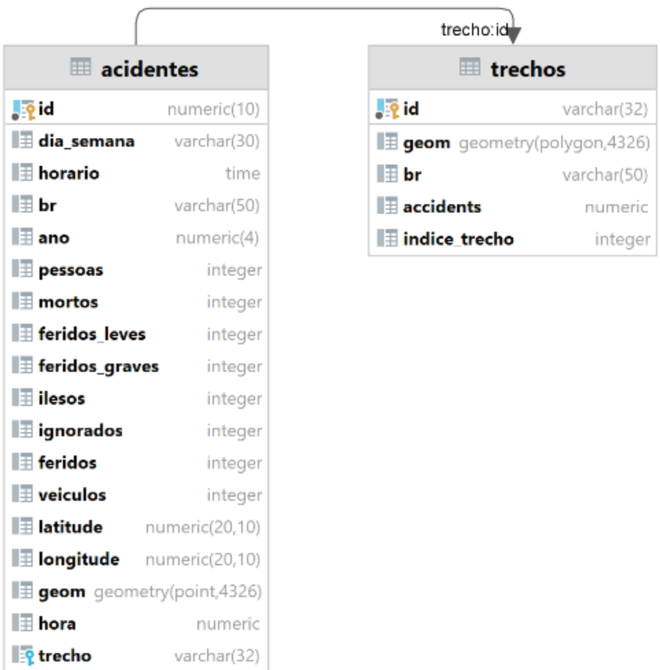

Figure 4. Diagram from the tables.

[7]https://www.primefaces.org/primevue/showcase-v2/
[8]https://developers.google.com/maps/documentation/places/web-service/overview
[9]https://developers.google.com/maps/documentation/javascript/overview
[10]http://overpass-api.de/
[11]https://github.com/bjornharrtell/jsts
[12]https://github.com/locationtech/jts
[13]https://aws.amazon.com/pt/ec2/
[14]https://aws.amazon.com/pt/rds/
[15]https://www.java.com/pt-BR/

The user interface can be seen in Figure 5, with a form (left side) and a map (right side), with an image from Paraná. The form has three fields, two of which the user can enter the origin and destination, and one where the user can enter the time and day of the trip through a calendar component. Finally, there is a button to submit information.

As soon as the user submit the data, the processing layer is called, and the system displays the safest and the fastest route, differentiating them by color (Figure 6). Information about the duration and distance of the trip is also displayed, as well as graphs showing the historical amount of accidents on the highway by day and hour. In these graphs, the columns highlighted in orange represent the hour and day the user will be traveling, according to what was submitted by the user previously.

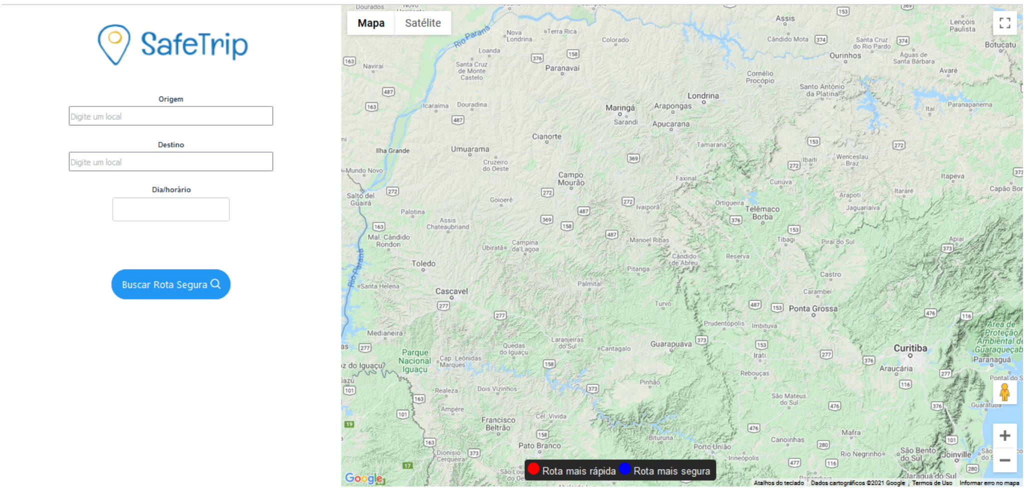

Figure 5. Initial Prototype Interface.

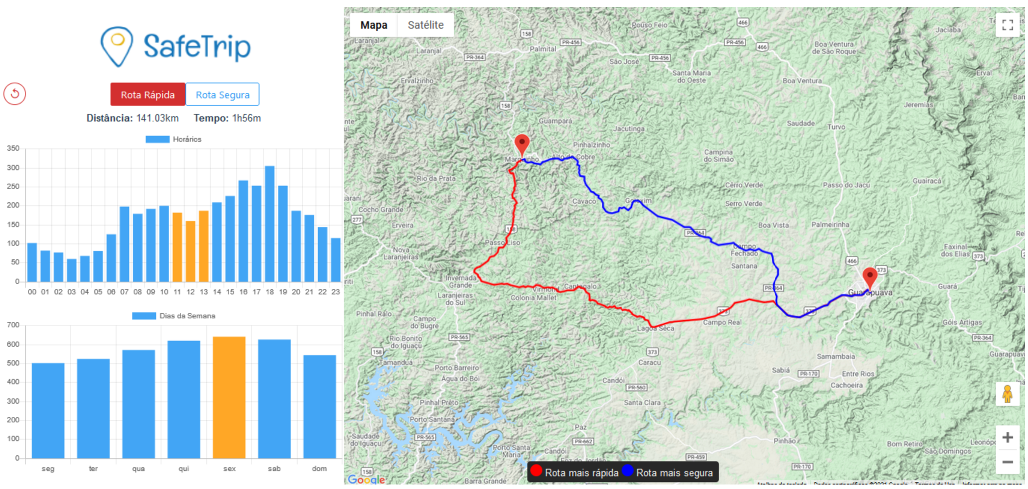

Figure 6. Interface with the fastest and safest route.

In order to calculate different weights for the edges of the graph that describes the Paraná highways, Algorithm 1 was used. This algorithm calculates the priority - a variable that represents the calculation of edge weights for *GraphHopper*. The edges whose vertices are not contained in any section receive priority 1. Later, these edge weights are

Algorithm 1 Priority Calculation for each Highway sector

```
Ensure: geometeria dos trechos geoms
totalAcidentes = 0
step = 0
nTrechos = 0
trechoMaxAcidentes = 0
for all geometria ∈ geoms do
    nAcidentes = getCountAcidentesMortosFeridos(geometria)
    totalAcidentes = totalAcidentes + nAcidentes
    nTrechos = nTrechos + 1
    if nAcidentes > trechoMaxAcidentes then
        trechoMaxAcidentes = nAcidentes
    end if
end for
mediaAcidentes = totalAcidentes/nTrechos
step = (trechoMaxAcidentes − mediaAcidentes)/50
for all geometria ∈ geoms do
    nAcidentes = getCountAcidentesMortosFeridos(geometria)
    prio[trecho] = 1 − (((nAcidentes − mediaAcidentes)/step) ∗ 0.01)
end for
return prio
```

used with the *landmarks* algorithm, allowing *GraphHopper* to process the customizable routing.

Within the prototype initial tests, in most cases, the fastest route is also the safest route. This conclusion was already expected, since, the faster routes are also commonly the routes with the shortest distance, which implies passing through fewer sections and thus having a lower weight in the path taken in the graph.

However, on some routes within the state of Paraná, the safest route suggestion is different from the fastest route suggestion. In some of these suggestions, it was recommended to avoid sections that pass through state highways and secondary roads, and to drive along highway sectors, despite the increase in travel time. For other suggestions, it was recommended to avoid federal highways and drive along state highways or secondary roads. For these cases, the fastest trip, using a federal highway, covered a longer path, but, due to the maximum speed allowed, had a shortest total travel time. The safest trip using state highways or minor roads typically traveled considerably less distance than the trip through sections of federal highways.

In most cases, the fastest route coincides with the safest route. Table 1 shows the distance, in kilometers, and the duration, in hours, of some routes where the fastest route is different from the safest route.

Figure 7 shows a highway sector from BR-376, where it is recommended, for the safest route, not to go through the city of Marinalva . The safest route is represented by the blue route on the map, while the fastest route is represented by the red route on the map. The different highway sector has, from 2007 to 2018, 20 accidents with deaths or

Table 1. Distances (km) e time (h) for the fastest and safest route

Origin	Destination	Fastest Distance	Fastest Time	Safest Distancea	Safest time
Curitiba	Ponta Grossa	114.39	1.33	114.39	1.33
Arapongas	Maringá	61.24	0.76	59.79	0.80
C. do Oeste	Douradina	74.74	1.19	61.84	1.29
Marquinho	Guarapuava	141.03	1.94	116.64	2.55
Cianorte	Campo Mourão	66.83	1.08	66.83	1.08
Cascavel	Pato Branco	232.80	3.14	323.80	3.15
Sertanópolis	Mauá da Serra	73.78	1.04	73.78	1.04

serious injuries, 53.8% higher than the average of all highway sectors.

Figure 7. Route from Arapongas to Maringá.

In Figure 8, the duration of the safest route is 47 minutes and has a distance of 59.79 kilometers. For the fastest route, the duration is 45 minutes and the distance is 61.21 kilometers. The graphs on the left represent the number of accidents (per hour and day of the week for the fastest route), and the graphs on the right represent the safest route. With Google Maps, the same route as the fastest route is suggested, with a distance of 61 kilometers and a duration of 51 minutes. If the route is changed to match the safest route, the duration is 57 minutes and the distance is 59.6 kilometers. The prototype code is available online [16].

4. Conclusion

Many routing solutions for vehicles are emerging and being used worldwide, along with the technology focused on road safety. These applications usually adopt the optimal route based on distance, travel time, or even cost as a solution.

This work presented a prototype for calculating a route between two cities in Paraná, in order to obtain the safest and the fastest route. In addition to this calcula-

[16] https://github.com/github

Figure 8. Historical data from Arapongas to Maringá.

tion, the tool also provides data so that the user can do their own analysis between the safest route and the fastest route. The prototype can be used to understand the traffic routing aimed at road safety.

In order to improve the performance of the prototype, it is proposed, as a future work, to optimize the processing time for the calculation of routes and retrieval of historical data. One possibility to achieve this objective is the creation of indexes to speed up data retrieval, along with additional data. Considering the user interface, the interaction with the user could be improved by further tests, along with the adaptation to accessibility standards.

5. Acknowledgements

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