Integration of data sources on traffic accidents

Salatiel Ribeiro dos Santos[1], **Clodoveu A. Davis Jr.**[1], **Rodrigo Smarzaro**[1]

[1]Depto. de Ciência da Computação – Universidade Federal de Minas Gerais (UFMG)
Av. Presidente Antônio Carlos, 6627 – 31270-901 – Belo Horizonte – MG – Brasil

{salatiel.ribeiro,clodoveu,smarzaro}@dcc.ufmg.br

Abstract. *General interest geographic information is routinely produced by several public agencies. In cities, the use of smartphones and other mobile devices generates an increasing amount of unofficial georeferenced data. Although official data have usually higher reliability, it takes longer to be updated and made available, while the opposite occurs with unofficial data. This work explores the potential for integrating data from both official and unofficial sources. We present a case study with two traffic accident datasets in the city of Belo Horizonte, Brazil. We compare official traffic accident data to unofficial data collected from the mobile app Waze. We found that 7% of accidents reported by official sources have also been reported by users of Waze. Accidents reported only by official sources are concentrated in the central region, while those recorded by Waze are mostly on some major roads all over the city.*

1. Introduction

Among their institutional responsibilities, several public organizations produce geographic data of general interest. However, due to operational or technological difficulties, part of these data does not become accessible to the public, or is published in formats that preclude their dynamic integration to other data sources, thereby making it harder to accomplish more elaborate analyses. In Brazil, in spite of the approval of the Law on Information Access in 2011, most governmental data producers still have no clear open data policy or practice, nor do they implement technological resources such as APIs and service-based spatial data infrastructures (SDI) to foster easy access to data that are relevant to the society at large.

On the other hand, the intensive use of smartphones and other mobile devices generates a significant volume of data, since wherever people go their trajectories can be recorded, and there are many ways for them to express themselves on the visited places [Zheng et al. 2009]. Simultaneously, the interest in geographic data and geographic applications grows, as they enable users to locate themselves and to find events and other people based on their location [Quercia and Capra 2009, Quercia et al. 2010]. In this scenario, users are routinely issuing comments and opinions through social networks (e.g., Twitter and Facebook), commenting on tourist attractions and commercial venues (Foursquare, Yelp), publishing personal videos and photos (Instagram, Snapchat, Flickr) or sharing real-time information on traffic (Waze[1]). With a large number of contributors, such applications become important, albeit unofficial, sources of information.

This work intends to explore the potential for integrating official and unofficial sources of data on urban events, in order to verify to which degree data generated by

[1]http://www.waze.com

the usual work processes in public organizations can be confirmed or enhanced by data generated by volunteers, in crowdsourcing or crowdsensing systems. The possibilities for adding, expanding or replacing official data sources with unofficial ones is analyzed, with the additional challenge of treating the intrinsic heterogeneity of such data sources. Therefore, the main objective of this work is to integrate multiple and heterogeneous geographic data sources to support analyses that can be used in decision-making related to improvements in urban services. It includes a case study that uses official data and data obtained from Waze on traffic accidents in the city of Belo Horizonte, Brazil. Both sources contain geographic information on the location of accidents, but other descriptive attributes are quite distinct.

This paper is structured as follows. Section 2 describes related work. Section 3 presents a comparison between official and unofficial sources of traffic accident data. Section 4 describes our integration methodology. Results are presented and discussed in Section 5. Finally, Section 6 concludes the paper and presents ideas for future work.

2. Related Work

A study by the World Health Organization (WHO) [WHO 2015] indicates a serious worldwide traffic problem. According to that study, in 2013 alone 1.25 million deaths occurred due to road accidents in 180 countries, especially in those with low income. Another alarming information is that traffic accidents represent the main cause of death among people aged between 15 and 29 years. Also, Brazil is ranked in position 56 among the countries with the highest number of deaths caused by traffic accidents.

Overcoming this problem requires improvements in infrastructure and educational campaigns, thus the responsibility of changes is shared among politicians, managers, road designers, vehicle manufacturers and citizens that use the road system. Professional and amateur drivers have access to several technologies for routing in streets, roads and highways, including real-time information on accidents and traffic events. On the other hand, as citizens we perceive the lack of objective and useful information that allows drivers to take instantaneous notice of problems and adopt measures against accidents in critical points along urban streets and highways.

Data produced by governmental organizations, or data contributed voluntarily or unconsciously by common citizens, help in understanding city dynamics and user preferences in moving through urban space. Such information are instrumental in decision-making for improving infrastructure and can contribute to improvements in life quality [Corsar et al. 2015, Wolf and Fry 2013]. In the current context, in which solving traffic and transportation problems in large urban centers becomes even more urgent, it is important to promote the use of alternative transit so that the number of vehicles in the streets can be reduced. However, it is necessary to provide minimal security conditions for people that opt for the alternative transportation methods. Machado et al. (2015) identify points in which traffic accidents are concentrated for the city of São Paulo (Brazil) and Rome (Italy). The focus of the study are accidents involving individuals traveling by non-motorized means (on foot or by bicycle). From the results of the study, users of alternative transportation can be extra careful or avoid completely such dangerous regions. The article invokes the discussion on traffic accidents in Brazil.

Even though there are public data on accidents in Brazil, the absence of a nationally integrated database is remarkable. Bezerra et al. (2015) present a number of difficulties inherent to Brazilian sources that have an impact on the establishment of such an integrated database. Among these difficulties, authors highlight the way federative agents are structured and the distribution of responsibilities among them. Brazil has a mixture of federal highways, state highways and urban thoroughfares in charge of local governments. In the first case, accidents are recorded and followed up by many organizations, in particular the national highways department (DNIT - Departamento Nacional de Infraestrutura de Transportes), the Ministry of Transportation, the Ministry of Cities and the Ministry of Health, along with the Federal highway police. In each state, there is a transit department, a state highway police, an military police, and administrative organizations in charge of transit and transportation. As to municipalities, while the largest ones maintain transit and transportation engineering companies, the less populous ones usually have no means to record and analyze accidents.

The diversity of transit-related organizations would not be an important obstacle if there was a unified process for recording traffic events. Bezerra et al. (2015) highlight that there is not even a standardized police report form. Nevertheless, event reports are the largest source of information currently available. Undernotification of traffic accidents is also expected, since involved parties seek official reporting of the event mostly in case there are victims or the need to sustain insurance claims. Authors also indicate difficulties for data analysis in accident reports, due to incompleteness, coding errors, discontinuity and lack of elements with which to locate the accident.

In other countries, accident data are treated in a much different manner, leading to well-grounded analysis works. Morris et al. (2008) present the creation of a database on fatal traffic accidents in Europe. Many works use United States governmental sources to diagnose problems such as lack of attention while driving, hitting pedestrians, light vehicle crashes [Najm et al. 2003] and effects of driver population aging [Stamatiadis and Deacon 1995]. Such analyses are strongly hindered in Brazil due to the lack of a nation-wide system for recording traffic accidents.

Using Twitter data, Ribeiro et al. (2012) geolocate traffic-related events based on the content of posts. From that, traffic accidents, congestions and interruptions can be identified and mapped. Also using unofficial data, Silva et al. (2013) detect traffic conditions in urban roads using Waze data. They also discuss limitations related to the source, including its coverage.

Integrating the various sources of official data and combining them with unofficial sources is an important problem for initiatives related to Brazilian traffic problems. Such integration may help solving problems such as undernotification, and promoting unified access to official reports. A major goal is to obtain an integrated dataset that can be used in diagnosing and analyzing events such as those reported in the works listed in this section. The next section describes two datasets from the city of Belo Horizonte that are used in a case study for the integration of official and unofficial data. Following that, a methodology for integration is discussed.

3. Datasets

3.1. Official Data

Accidents are usually reported to the authorities in charge of traffic or public security, who, in turn, record the event in police reports, incident reports or similar documents. Such information are kept in databases by the authorities at the federal, state or local levels. In Brazil, accidents in urban thoroughfares are recorded by municipal authorities. Accidents in state or municipal highways are recorded by the respective administrative levels. Accidents in federal highways can be recorded by authorities at any level, depending on existing administrative agreements. Accidents on segments of federal highways that cross urban areas are typically recorded by the state's military police.

This work uses accident data for the city of Belo Horizonte, Brazil, in 2014, as supplied by the municipal transit company, BHTrans. These data are well structured and are reliable, since they originate in police reports, filed by the state's military police. However, these are the latest data available for analysis, since BHTrans is still unable to release the 2015 data at the time of this writing (September 2016).

3.2. Unofficial Data

We classify as unofficial those data that come from social networks, active or passive crowdsourcing or crowdsensing applications [Mateveli et al. 2015] or any other source that is not connected to governmental institutions. In this work, we use data from Waze, a GPS-based navigation application that is able to integrate data collected by users in order to guide others through traffic. Such collected data includes actively volunteered information on traffic congestion, police actions and accidents, as well as passively collected data on travel speeds.

The lack of an API for data collection is a serious shortcoming of Waze. Obtaining Waze data without an API requires monitoring the app's Web-based live map in small areas, and extracting relevant information from the underlying JSON files. As in the case of many crowdsourcing or volunteered geographic information (VGI) applications, Waze also suffers from lack of detail, questionable reliability of contributing users, and irregular spatial coverage. The validity of Waze information can partially be assessed by confirmation from other users. The main advantages of Waze are the timely access to accident data, which allows users to plan trips that avoid congested areas. This strongly contrasts with data publication policies by official transit authorities. Waze is also expected to record accidents that are not officially communicated to transit or police authorities, which is the case of less serious incidents or accidents involving uninsured vehicles.

4. Methods

The first step towards the implementation of this work is data acquisition. As mentioned, traffic accident reports for 2014 were provided by BHTrans. Besides geolocation, accident data includes date, time, type of accident and vehicles involved.

The unofficial data was obtained from Waze in 2014, as part of a data collection experiment in a project that intended to map frequently congested areas. Specifically, for this work we selected accident reports from the 2014 dataset. From each accident alert it is possible to obtain information that is similar to official BHTrans data, such as geolocation, date, time and type of accident.

Since Waze does not have an official API, data was collected through a GeoRSS file[1] generated by the Live Map at the application's Web site[2]. A JSON file is downloaded in regular intervals, containing real-time geographic features and locations of objects and, in this case, data on traffic congestion and alerts. Live Map can hide some alerts, depending on zoom settings. This is the main limitation on the data collection process, since it reduces data coverage. Furthermore, since JSON collection is re-executed frequently, the series of JSON files needs to be processed to eliminate duplicate incident reports.

The second step of the process is data processing: select data in the same time window (both between 2014-09-16 and 2014-11-06), group accidents reported more than once (by different users) on Waze and geocode records without geographical coordinates (some BHTrans records included the textual description of a location but not actual coordinates). In order to consolidate accidents reported more than once on Waze, the average position of the reports is calculated and the number of contributions that each of the accidents received is noted. The resulting datasets contain 1,434 and 1,543 accident reports, respectively in BHTrans ans Waze datasets.

Finally, the last step integrates data from the official and unofficial sources. In this step, data are checked for overlapping events. Furthermore, the characteristics of data coming specifically from either source are explored, thus verifying how complementary they might be. We established a set of matching criteria, by which two records, each one belonging to one of the data sources, refer to the same accident if they (1) were reported within 1 hour of each other and (2) occurred within 50 meters of each other or within 150 meters and on the same road. At the end of the process, a single integrated dataset on accidents is created, containing annotations about the origin of each data item.

The first matching criterion reflects that there might be a delay between the time the accident actually happened (informed by the involved parties in a police report) and the time the accident was reported on Waze. The second one was adopted because there might be situations in which the Waze user is passing by the accident location, but reports it to the app in a position that is away from where the accident actually happened.

We evaluated the accidents reported in both datasets, the notifications contained only in the official data and the accidents contained only in the unofficial data. Next section presents and discusses the results of the matching process.

5. Results and Discussion

5.1. Matched accidents

In order to verify which portion of Waze data corresponds to the data provided by BHTrans (that is, the number of accidents reported both officially and by Waze users), we apply comparisons following the criteria described on Section 4 (date/time frame and distance between reported positions). We found that only 7% of BHTrans reports matched accidents reported on Waze. Figure 1 shows the location of accidents reported on both official and unofficial datasets. Spatial distribution is sparse, with a few clusters of accidents in major thoroughfares.

[1]http://www.georss.org/
[2]https://www.waze.com/pt-BR/livemap

Since Waze allows a single event to be reported more than once, we consider only one of the multiple reports. Indeed, the consolidation step in the preparation of the Waze dataset shows that 38% of the accidents on Waze were reported by two or more users. A positive aspect on this repetition is that it makes the data more reliable, since many events are based on reports from more than one user. Notice, however, that Waze users that have already seen in their smartphone an accident report in their path, will probably select another route or consciously avoid reporting that same accident again.

Official data on traffic accidents are usually recorded in police reports, which are mandatory only in cases where the parts involved aim some kind of material compensation for damages, directly from the responsible for the accident or through an insurance claim. Considering that, it's possible that part of the accidents with lower severity are not officially reported. We therefore expect that a share of the events recorded in Waze are not officially reported, and thus the datasets are expected to be complementary. Likewise, a share of the accidents reported officially may not be recorded by Waze users, especially if they take place in locations where the impact on traffic is small, or at times and places where the presence of Waze users is low. Notice that Waze usage naturally tends to be concentrated around rush hours, in which knowing about traffic problems along one's path is of greater concern. We now proceed to analyze accidents that have not been matched at either dataset.

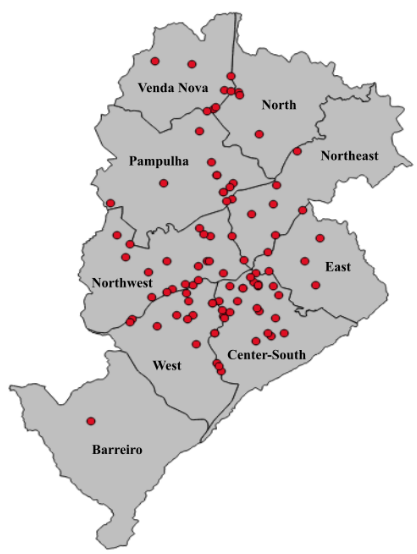
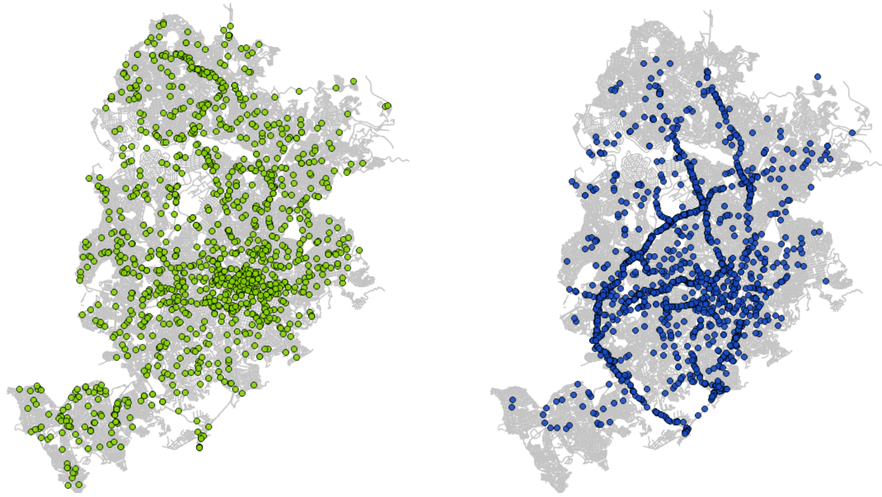


Figure 1. Matched accidents

5.2. Unmatched accidents

Analyzing the reports that appear exclusively on either Waze or BHTrans datasets, we can see a different distribution from the one seen on Figure 1.

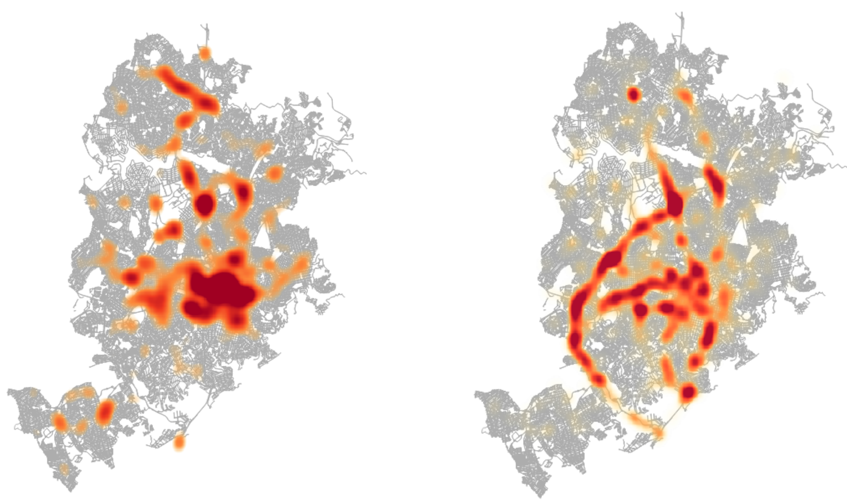
Accidents that appear only in the BHTrans dataset (Figure 2a) are found mostly in the central regions of the city, which is understandable since this area has a more intense traffic flow with a high concentration of economic activities. Secondary commercial areas in a northern and in a southwestern regions of the city also concentrate many accidents.



a) BHTrans b) Waze

Figure 2. Unmatched accidents

Events reported exclusively by Waze (Figure 2b), on the other hand, show a distinct pattern. Accidents are concentrated along some large city thoroughfares and urban segments of highways. Figure 3 shows heatmaps based on the concentration of unmatched accidents from either source.



a) BHTrans b) Waze

Figure 3. Heat map of unmatched accidents

5.3. Severity and types of Accidents

Official records include the types of traffic accidents. Most frequent types include side collisions, collisions involving pedestrians, rollovers, rear-end colisions, and even accidents where people are thrown out of the vehicle. The existence of victims (injuries, fatalities) is also indicated. However, the records do not consistently inform on the severity of each accident. For example, a collision can either cause light injuries or more serious ones, requiring hospital treatment, or even leading to death. However, such details are absent from official records.

Waze records include less details than official ones. Data about an accident are informed by users when they are nearby, often driving, and it can be difficult for them to obtain details. Waze uses two severity classifications for accidents: major and minor. A minor accident is described as “fender benders with minor or no injuries, also no fatalities” while major represents “major damages to vehicle, major injuries and possible fatalities” [Waze 2016].

The most frequent types of accident found in official dataset are “side collision with victims” (39%), followed by “rear-end collision with victims” (18%). In the Waze dataset, 56.1% of the accidents are classified as minor, and 21% as major. The severity of the remaining 23% is not reported. Figure 4 shows the six most frequent types from official data and Figure 5 shows the distribution of severity classification from Waze data.

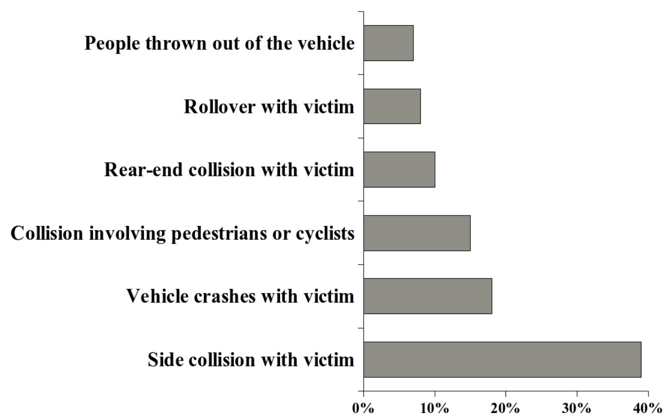


Figure 4. Main types of accidents from official sources

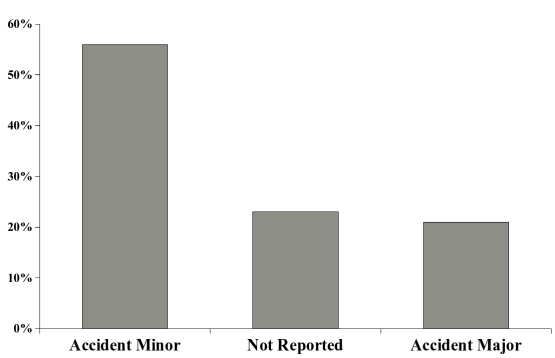


Figure 5. Severity of accidents from Waze

Comparing results from both datasets, most officially reported accidents can be understood as high severity (since they are classified as accidents with victims), while most accidents recorded by Waze are classified as minor severity. This discrepancy raises, at least, two hypotheses. First, it is difficult for Waze users to know detailed information about the accidents they report. If they witness the accident, they can overestimate its severity, while if they drive by the accident's location after some time their assessment can be underestimated. Second, Waze users may not be able to pay much attention on the correct severity classification when informing an accident.

Among matched accidents, Waze users only tend to classify as major severity accidents those officially classified as collisions involving pedestrians and rear-end collisions with victims (Table 1). In other cases, most accidents are deemed minor by Waze users. This indicates a semantic discrepancy between regular citizens (Waze users) and police or transit officials, which has to be investigated further. Also, for accidents reported by several different Waze users, the discrepancy among them must be assessed. However, as in any crowdsourcing process, accident classification by Waze users should be less reliable than official reports, since, as passers-by, Waze users do not have full access to the accident site.

Table 1. Classification of severity by Waze users for each type of accident from BHTrans (all numeric values are percentages)

Accident Types (BHTrans)	Severity (Waze - values are %)		
	Major	Minor	Not Informed
Side collision with victims	21.6	56.8	21.6
Vehicle collision with victims	31.1	46.6	22.3
Collision involving pedestrians without fatality	54.1	37.5	8.3
Vehicle crashes with victims	47.3	42.1	10.5
Rollover with victims	28.6	42.8	28.6
People thrown out of the vehicle	37.5	50.0	12.5

Regarding the distribution of accidents along the day, Waze reports concentrate on rush hours, either in the morning or in the afternoon (Figure 6). This is expected, since at those hours the impact of accidents on traffic is the greatest. On the other hand, official data, while also recording a high number of accidents at rush hours, contain reports of accidents that took place all through the day, including times at which circulation is lower.

5.4. Integrated dataset

After matching the two sources, an integrated dataset on accidents in Belo Horizonte was built. Table 1 shows its structure, indicating the attributes that were obtained from each individual source, plus an attribute that records the source of the original information. In the integrated dataset, there are 1,333 accidents that were reported exclusively to BH-Trans, 1,442 gathered exclusively from Waze, and 101 that have been matched from both sources. Since the number of matching records is small, integrating Waze data to the official dataset represents a 100.5% increase in the overall number of accident reports.

6. Conclusions

The growing use of mobile apps and social networks generates a considerable amount of data, which can be used for several purposes. Information from these sources can be

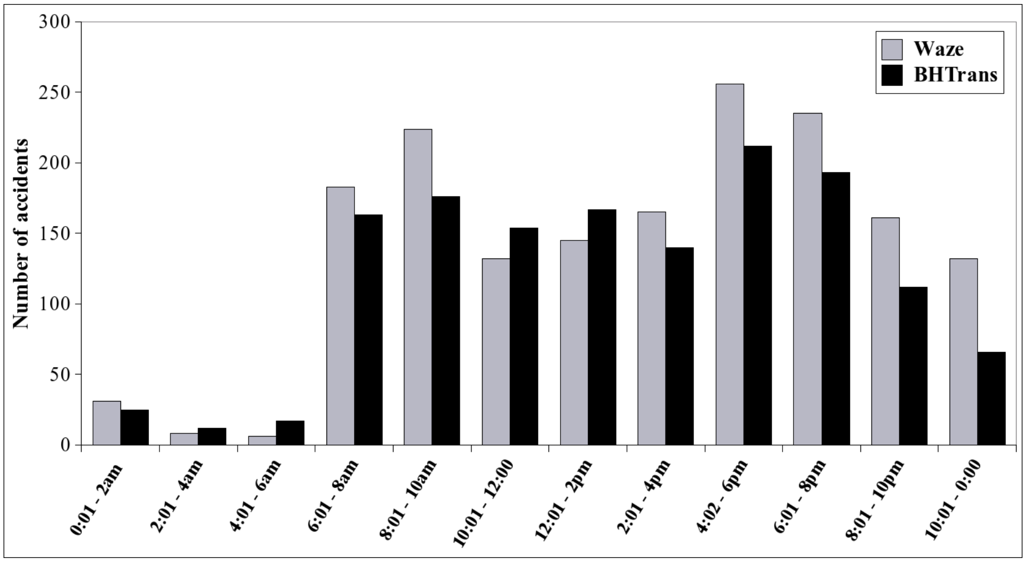


Figure 6. Distribution of accidents throughout the day (October 2014)

Table 2. Integrated accidents dataset

Integrated Attributes	Sources		Remarks
	BHTrans	Waze	
bhtrans id	police report id	—	—
waze id	—	alert id	—
date	date	date	—
street type	street type	—	—
street name	street name	street name	use BHTrans if available
number	number	—	—
neighborhood	neighborhood	—	—
region	region	—	—
city	—	city	—
country	—	country	—
geom	longitude, latitude	longitude, latitude	average position
type of accident	type of accident	—	—
severity	—	severity	—
number of victims	number of victims	—	—
number of deaths	number of deaths	—	—
vehicles involved	vehicles involved	—	number and type of vehicles
data source	—	—	BHTrans, Waze or both

used for identifying better routes, monitoring traffic conditions in real time and identifying areas with high car accident rates. Besides that, the data collected from this kind of source can complement the data extracted from official sources.

This work compared car accident records provided by BHTrans (official) and data collected from the mobile app Waze (unofficial). We found out that 7% of the car accidents officially reported were also reported through unofficial sources. Among these accidents, the main type was collision with victims, while most were classified as low severity according to Waze data. It's important to stress, however, that the classification used by Waze is not totally reliable, given that users usually do not have direct access to the accident site.

Accidents reported only by BHTrans were concentrated on the central region of Belo Horizonte, while the ones reported by Waze were mostly on highway segments, like Rodovia MG-10 and Anel Rodoviário. These patterns endorse the idea that the datasets are complementary, since coverages are quite distinct.

We verified that most of the accidents reported by Waze but not by BHTrans were classified as having lower severity. This happens possibly due to the fact that police reports are not mandatory, which probably implies that most of the lower severity accidents are not officially reported. Thus, Waze data can be used to fill the gap of undernotification in the case of traffic accidents, providing authorities with a broader view of the problem.

The official data has the advantage of being more reliable and detailed. However, it is harder to access due to government-imposed limitations and time constraints. On the other hand, the unofficial registers are easy to access, but poor in details. The data from these two sources can be integrated in order to obtain a dataset with broader coverage. This could compensate the deficiencies of each of the sources, taken individually. However, official data should be made available more readily, possibly using technologies such as spatial data infrastructures or APIs dedicated to the task of providing unrestricted access to traffic accident data.

The next step for this work is to collect data from a wider range of official sources regarding car accidents, expanding the analysis to other cities besides Belo Horizonte. Still regarding the official data, we aim to consider Brazilian federal highways accidents database, provided by the National Transportation Infrastructure Department (DNIT). We also intend to get data from other unofficial sources, such as Twitter. With multiple sources of heterogeneous data, integration methods need to evolve accordingly.

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