Rome Safe Roads

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ARTICLE INFO

Keywords:
Accident
Rome
Vehicle
Traffic
Analysis
Road Safety
Collisions

ABSTRACT - The following paper focuses on *Rome Safe Roads*, a system developed to examine and analyze traffic accidents that occurred in Rome, the capital of Italy, from 2019 to 2022. By using several data sources (general and death accidents), the system provides valuable insights about the features, consequences, and risk factors associated with these accidents. This information is crucial for the development of effective road safety strategies. The Rome Safe Roads system has the potential to support the Municipality of Rome, in particular the *Polizia Locale di Roma*. The aim of the project is to identify traffic issues, enabling authorities to investigate them. Thus, the *Polizia Locale di Roma* can easily identify road conditions, high-risk pedestrian areas, and other relevant transportation factors, facilitating the adoption of various preventive measures to enhance road safety.

1. INTRODUCTION

Road accidents are a significant contributor to global mortality and injuries. In a bustling metropolis like Rome, an average of 79 accidents occur daily, resulting in 0.3 fatalities and 100 injuries. These statistics highlight the urgent need for a thorough understanding and effective strategies to address the complex challenges posed by road safety within the city.

The analysis of road accidents is conducted by dealing with the complexity of the data and a multitude of factors. A significant obstacle has to do with the complexity of road accident data, which often comes from several sources and has different formats. Moreover, road accidents are subject to a myriad of variables, like weather conditions, road infrastructure and user behaviors that amplify the complexity of analysis. Available data on accidents may be incomplete or inconsistently recorded, resulting in the imprecision of analytical outcomes.

Acknowledging the challenges and considering them stimulating, the following paper proposes a system called Rome Safe Roads [Figure 1]. The project aims to analyze road accidents in Rome from 2019 to 2022, and to identify and classify them according to some criteria useful for guiding the countermeasure implementation. This aims to develop an analysis and/or a forecasting tool that can be used both at the planning level to define appropriate measures for reducing accidents, and at the operational level, to promptly intervene in areas prone to accidents.

The tool will cover:

- General accidents, involving different natures
- Mortality rates
- Temporal analysis based on months and days
- Accidents' severity
- Geographic distribution of accidents

The visualization system presents a graphical overview of these factors, enabling users to quickly understand the accidents landscape. All the color scales and bands have been chosen using the colorbrewer [2] web utility.

Through simple and intuitive interactions with the graphs, users can explore and choose analysis to lead.

2. DATA & PREPROCESSING

The proposed visual environment deals with data collected from the official website of the Municipality of Rome[1]. This authority collects the datasets coming from the following units of Rome: *Ufficio Stampa; Corpo di Polizia Locale Roma Capitale; Ufficio del Responsabile della Protezione dei Dati (RPD); Ufficio di Scopo UEFA Euro 2020; Ufficio di Scopo Innovazione per le Politiche Comportamentali.*

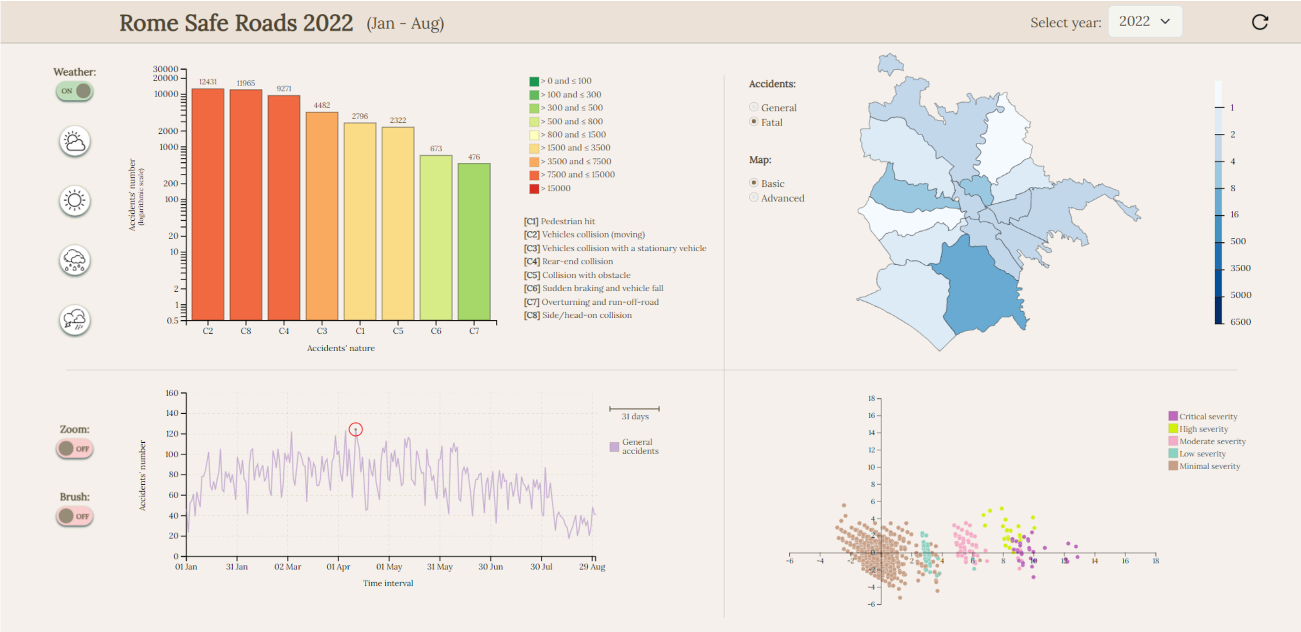

Figure 1

The website contains data available in several formats (xml, json, csv) and grouped by month for each year. For the conducted analyses in the project only .csv files have been considered. The dataset contains all road accidents in which any group of the Polizia Locale di Roma was involved. Therefore, incidents in which the parties have reached an agreement autonomously are keeped out.

As the information included in the dataset, the most important ones are: accident timestamp (accident time and data), location (latitude and longitude), nature (e.g., frontal/lateral collision), road characteristics (such as type, surface conditions), weather conditions (e.g., sunny, cloudy), and traffic details. Furthermore, the dataset logs the number of individuals affected (injured, reserved, deceased and uninjured) and info about the type of involved vehicles. These key components allowed insights into the dynamics of road accidents and their contributing factors.

The entire data source used for the system has the following dimensions:

- 2019 contains 79 283 tuples
- 2020 contains 54 222 tuples
- 2021 contains 73 100 tuples
- 2022 contains 47 060 tuples

Therefore, the total number of tuples given by summing all the four years is 253 665, while 37 are the attributes.

The AS (AngeliniSantucci) Index of the dataset defined as:

$$AS = \#tuples \times \#dimensions$$

is equal to the following value:

$$AS = 253\,665 \times 37 = 9\,385\,605$$

Given the large amount of available data source, by using a mechanism of pre-processing, it was possible to obtain some subsets of the dataset needed for each visualization. In this regard, python Pandas library[6] has been used for analyzing, cleaning, exploring, and manipulating data.

Particularly, a lot of dataset fields contained wrong information. For instance, some data were entered under the wrong columns, some had null values, while others were characterized by typing errors, making it challenging to identify fields based on their correct content. To solve these issues, extensive data cleaning was employed to rectify inaccuracies and ensure the reliability of subsequent analysis. In this way the dataset has been refined enhancing its usability. Furthermore, an exploration and manipulation of data has been applied to filter and grouped accidents based on their nature, weather conditions, fatality and other factors.

To identify the geographic distribution of accidents, geopandas library[7] has been used. More in particular, the town hall of each accident has been derived exploiting latitude and longitude included in the dataset.

3. VISUALIZATIONS & INTERACTIONS

The Rome Safe Roads system [Figure 1] is composed of four different visualizations, with which the user can interact.

The development of the Rome Safe Roads system started with the creation of a mockup as a visual blueprint. This mockup [Figure 2] highlights how the system's different charts would look like and function.

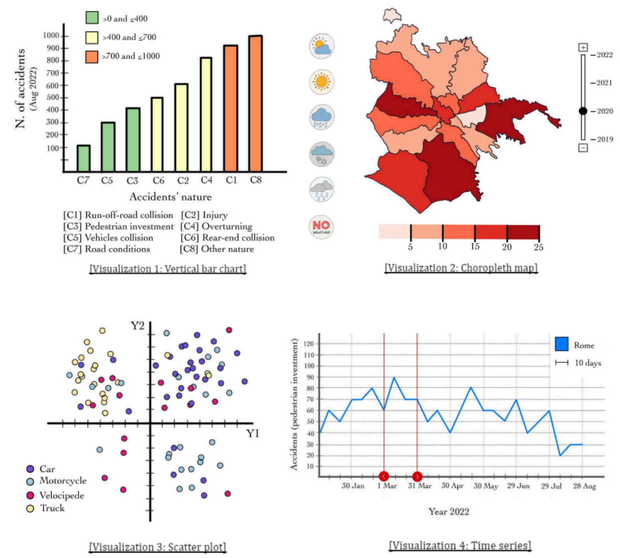

Figure 2

More in particular, the overall ecosystem includes:

- [Vertical bar chart] It illustrates the number of accidents for each cause.
- [Choropleth map] The map of Rome is depicted with different districts coloured according to the number of general or fatal accidents that occurred.
- [Time series] It analyzes the accident trend over time.
- [Scatter plot] It identifies clusters based on accidents' severity, where each point on the plot represents an accident.

The first global implemented interaction is a dropdown menu [Figure 1] (on the top-right of the page) which holds significant importance. Thanks to the menu, users can focus analysis on the year of interest within the range of 2019 to 2022.

The second global implemented interaction is the reset button [Figure 1] (on the top-right of the page), its goal is to reset all filters applied in the dashboard.

The detailed explanation of the visualization/interaction concept for all four graphs is provided in the following subsections.

3.1 Vertical Bar Chart

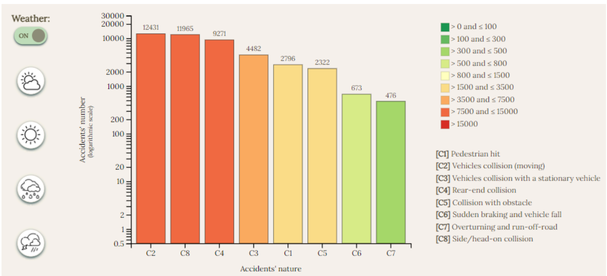

Figure 3

3.1.1 Visualization

The Vertical Bar Chart [Figure 3] plays an important role in visually representing the number of different accident natures on roadways.

By organizing accident natures along the x-axis and quantifying them on the y-axis, the vertical bar chart provides an overview of the number of the occurred accidents for each nature.

Two legends have been created in order to easily understand both the quantity and natures of road accidents:

- The quantity legend, consisting of the color bands from green (zero accidents) to red (more than 15.000 accidents), represents different intervals of accidents.
- The second legend denotes the nature of the accidents. The purpose is to help users in interpreting the abbreviations on the x-axis. Each abbreviation on the x-axis (C1, C2, C3, ...) corresponds to a specific accident nature (Pedestrian hit, Vehicles collision, ...).

On the top of each bar the number of accidents is displayed to easily compare how many accidents occurred for each nature.

3.1.2 Interaction

Weather Condition Filters

Four buttons have been implemented to enable the filtering of accidents based on weather conditions (Cloudy, Sunny, Rainy or Severe). This interactive feature provides a clear idea of how different weather conditions impact both the frequency and nature of road accidents. Thus, it aids in identifying potential correlations between weather and specific accident natures. Weather filters can be enabled or disabled using a switch button.

Hover-over Pop-up Information

Another type of interaction is represented by the creation of a popup when hovering over any bars in the vertical chart. This pop-up provides users with numerical information regarding the accident count related to the chosen bar. Simultaneously, the corresponding nature of the accident is underlined in the second legend. This allows a quick identification of accident natures starting from its abbreviation on x-axis.

Bar Click

By clicking any bar in the vertical bar chart, all other charts will be dynamically updated. This interaction will be explained more deeper in the next section (*3.5 Coordinated interaction*).

3.2 Choropleth Map

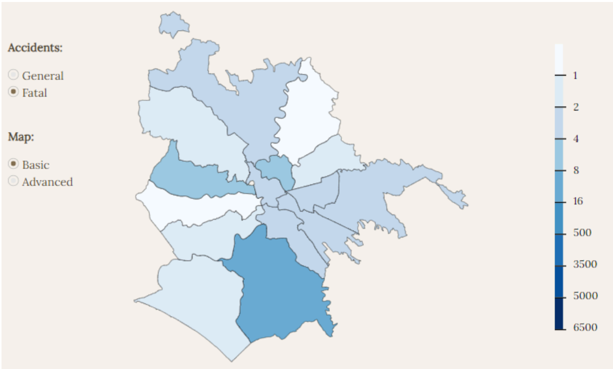

Figure 4

3.2.1 Visualization

The Choropleth Map [Figure 4] allows to show road safety dynamics in the city of Rome. This map offers a geographical perspective on the accidents within different districts. It consists of a map subdivided into 15 districts, each characterized by an associated color representing the number of general or fatal accidents that occurred within its geographic boundaries.
Two type of maps have been created:

- The basic map implementation was possible using a repository [3] that contains geo-referenced limits for all municipalities in Italy in the geojson format.
- The advanced map implementation was possible using a provider of custom online maps for websites and applications called MapBox [8].

The intensity of the color is determined by a bluescale legend starting from a lighter gradient for fewer accidents to a darker shade for higher counts.
The 15 districts facilitate a localized analysis, displaying which areas had the highest rate of accidents.

3.2.2 Interaction

Hover-over Pop-up Information
By mouse hovering over each district on the Choropleth Map, a pop-up provides essential information such as the district name (e.g., Municipio III) and the number of accidents occurred in that district. This interaction offers an overview of general or fatal accidents within that specific geographic area.

Fatal or general option
By using the appropriate radio buttons, data visualization on Choropleth Map can be changed. Particularly, by clicking on the fatal option, only fatal accidents are filtered and the relative map is depicted. While clicking on the general option, all accidents are taken into account and the associated map is depicted.

Basic or advanced option
By using the appropriate radio buttons, the type of map for visualization can be chosen. Particularly, by clicking the basic option a more static map is depicted. It is useful if the intended user wants to compare the rates of accidents in different town halls with a more simple visualization. While, by clicking on the advanced option a more detailed map is depicted. It is useful if the intended user wants to analyze the issues more closely exploiting the zoom on the map. This type of visualization, unlike the first one, allows the user to go deeper into the analysis displaying the situation of specific streets.

District click
By clicking on any district within the Choropleth Map, a dynamic response is triggered on all the other charts. This interaction will be explained more deeper in the next section (*3.5 Coordinated interaction*).

3.3 Time Series

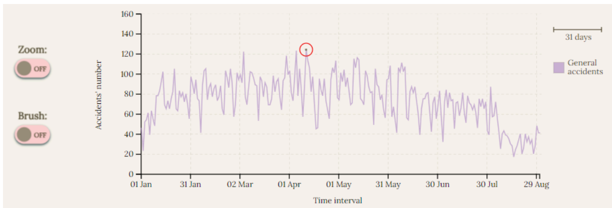

Figure 5

3.3.1 Visualization

The Time Series [Figure 5] displays the yearly trends of all road accidents within the city of Rome. This dynamic graph offers a temporal perspective. The time is represented on the x-axis while the y-axis quantifies the number of accidents, allowing users to visualize the continuous evolution of accidents throughout the year.
The graph contains a grid like a background. This grid aligns with the values along both x and y-axes, facilitating the interpretation of accident counts at specific points in time.
Another element of the time series is the legend which shows two characteristics:

- The unit of measurement, clarifying that each interval on the x-axis corresponds to a period of 31 days.
- The color of each drawn curve.

The Time Series highlights the highest point on the curve with a distinctive red circle.
The latest two elements inserted within the Time Series visualization are the switches. They allow users to choose between three interactions: zoom mode, brush mode or dual curve comparison mode.

3.3.2 Interaction

Guiding Line and Dot
By mouse hovering over the Time Series, a vertical guiding line and a dot dynamically follows the curve. In particular, the dot is placed exactly on the intersection between the guiding line and the trend curve, marking each specific point of interest. This dot moves with the guiding line and both follow the mouse cursor movement on the curve.

Hover-over Pop-up Information
By mouse hovering over the Time Series curve, in addition to the guiding line and dot, a pop-up appears and provides info about the date of the specific point in which the mouse cursor is on . Furthermore, the pop-up shows the number of accidents occurred every 30 days. This feature is triggered also when a user clicks on any bar in the Vertical Bar Chart (subsection 3.1.3 - *Bar Click*), aiming to provide a side-by-side comparison between two curves. This allows users to continuously monitor the counting of accidents throughout the timeline.

Zoom Mode
Through the first switch element the zoom mode can be enabled. By using the mouse wheel, users can zoom in on time frames of interest. Progressively, as the zoom increases, both the x and y axis scale are refined:

- On the x-axis more precise dates are added and visualized (up to daily precision).
- On the y-axis more accurate accident counts appear.

New dots are inserted on the Time Series curve at daily intervals. By mouse hovering over these dots, the exact number of accidents occurred is revealed.

Brush Mode
Through the second switch element the brush mode can be enabled. As a consequence, all the other charts will be updated. This interaction will be explained in the next section (*3.5 Coordinated interaction*).

3.4 Scatter Plot

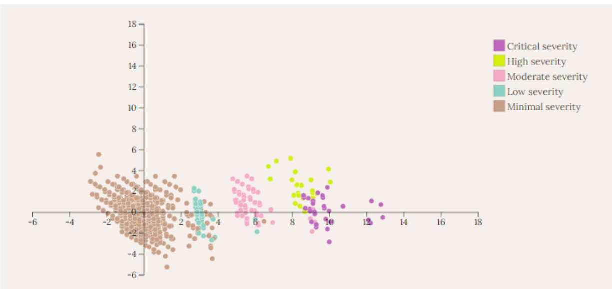

Figure 6

3.4.1 Visualization

The Scatter Plot [Figure 6] plots the result of the dimensionality reduction using the technique of Principal Component Analysis (PCA). This technique is used to reduce the number of input variables (such as traffic intensity, fatalities, injuries, uninjured individuals, seatbelt usage, etc…) creating a two-dimensional visualization, in which each point is associated with an accident.
On the Scatter Plot points are represented based on the two components that best differentiate them. In this way it is possible to see which accidents are similar and which are outliers. Thus, looking at the graph, clusters of accidents that share similar values for one or both the PCA variables can be identified. Cluster colors have been chosen to differentiate accidents based on their severity avoiding overlapping with respect to others visualizations. These colors are defined in a legend which clearly shows their meaning.

3.4.2 Interaction

Hover-over Pop-up Information
By mouse hovering over each point on the Scatter Plot, a pop-up appears. It displays the type of vehicle involved in that specific accident (e.g. Motorcycle, Car, Truck, …).

Brush
Another scatter plot interaction is the brush that dynamically involves the Choropleth Map. This interaction will be explained in the next section (*3.5 Coordinated interaction*).

3.5 Coordinated interaction

Bar Click
The interaction involves *Vertical Bar Chart, Choropleth Map*, *Time Series* and *Scatter Plot*. By clicking any bar in the Vertical Bar Chart, are updated consequently:

- The Choropleth Map that dynamically responds by showing, in the involved Rome districts (Municipio I, Municipio II, …), the number of general or fatal accidents associated with the selected nature.
- The Time Series (only when zoom and brush switch are off [Figure 5]), which promptly shows a corresponding curve, representing the accidents trend of the selected nature. This interactive feature enables users to visually compare the trend of accidents associated with the chosen nature against the trend of all incidents occurring in the selected year.
- The Scatter Plot that is updated showing the

result of the PCA algorithm applied to accidents caused only by the corresponding clicked nature. In this way it is possible to see which accidents based on their severity are similar and which are outliers for each nature.

District Click
The interaction involves *Choropleth Map* and *Vertical Bar Chart*. By clicking on any district within the Choropleth Map, a dynamic response is triggered. The system updates the Vertical Bar Chart, showing all general or fatal accidents (based on the selected radio button) within the selected district, categorized by their specific nature. This visual transformation offers users a comprehensive view of the correlation between fatal accidents distribution and their nature.

Brush Mode
The interaction involves *Time Series*, *Vertical Bar Chart*, *Choropleth Map* and *Scatter Plot*. By activating the second switch element of Time Series, the brush mode can be enabled. As a consequence, a dropdown menu is displayed on the right of the chart and the intended user can choose any nature curve he wants to analyze on the Time Series. Subsequently, users can select a period of interest by brushing over the chosen curve with the mouse. After the brush selection, dynamically Vertical Bar Chart, Choropleth Map and Scatter Plot are updated. In particular:

- In the Vertical Bar Chart, accidents occurred during the selected period grouped by nature and sorted in ascending order will be displayed. This mechanism is triggered only if no nature is selected from the dropdown menu, so the curve shown in the Time Series is about general accidents.
- In the Choropleth Map, colors of the 15 districts will be updated based on the number of general or fatal accidents that occurred during the selected period for the chosen nature.
- In the Scatter Plot, the accidents are filtered based on the selected period and the chosen nature. So, the chart will show the accidents which are similar or outliers in that period and of that nature and are always differentiated based on their severity.

Brush
The interaction involves *Scatter Plot* and *Choropleth Map*. Users can select a subset of points by brushing over them with the mouse on the Scatter Plot. At the same time, all accidents within the brushed selection dynamically appear on the Choropleth Map. There will be two different situations:

- If the visualization chosen is the basic map, different points will appear on it. Each point represents an accident and is coloured according to its associated severity. In this way the user can visually identify geographic locations of chosen clusters or outliers and get a general idea of where accidents occurred.
- If the visualization chosen is the advanced map, different markers will appear on it. Each marker represents an accident and is coloured according to its associated severity. In this way the user can conduct his analysis more in detail zooming on town hall areas where there is a dense stain of accidents, until identifying the most involved streets and therefore dangerous.

4. ANALYTICS

The analytical process of the project is focused on applying Principal Component Analysis (PCA) as a technique for dimensionality reduction.
This process is performed real time on demand, exploiting a backend service deployed on a server which continuously listens for requests. The backend is developed using Python, with the support of Flask framework and scikit-learn library[4] for dimensionality reduction.
The PCA algorithm is an important step in improving the visualization and understanding of complex relationships within the dataset. The chosen algorithm results, after some attempts with other multidimensional techniques, the best approach for separating the data into clusters, which is the final scope of the analytics.
Before applying PCA, the dataset needs to be preprocessed, including the handling of missing data, feature normalization and outlier management. All these steps contribute to the efficacy of the algorithm in revealing meaningful patterns in the data.
After the application of the dimensionality reduction algorithm, follows the clustering step. Since different clusters are formed just coloring the accidents according to their level of severity, there was no need to apply a clustering algorithm.
The resulting visualization provides an insightful analysis of the data, offering a perspective on the interaction between different factors such as traffic intensity, fatalities, injuries and more.

5. INSIGHTS

In this section, the focus is on the insights derived from the analysis of the whole Rome Safe Roads system.

By exploring the complexity of data and by uncovering patterns and relationships among them, a deeper understanding is pointed out, shedding light on the dynamics of road accidents in Rome. The resulting insights not only contribute to a refined comprehension of the existing landscape but also pave the way for strategic decision-making and targeted interventions.

Weather conditions influence

The insights derived from the Vertical Bar Chart in the Rome Safe Roads system point out an important revelation about the impact of weather conditions on road accidents within the capital city.

One aspect that clearly comes out is the very limited influence of weather conditions on this city each year.

Generally, dry roads and sunny conditions offer better traction for vehicles and improve visibility. On the other hand, adverse weather conditions (fog, rain, snow, …) and wet roads can reduce visibility and increase the occurrence of accidents. Despite that, from the weather condition filters of the Vertical Bar Chart, it is pointed out that most of the accidents are associated with good weather conditions. Only a smaller percentage is associated with severe or rainy conditions.

This type of observation may be attributed to the predominant Mediterranean climate in the Lazio region.

To sum up, weather was so excluded as one of the relevant causes of accidents in Rome, due to the limited influence.

Critical accidents nature

Another aspect emerging from the analysis of the Vertical Bar Chart concerns the most involved accident natures. In particular, they are:

- Rear-end collision (C4)
- Side/head-on collision (C8)
- Vehicles collision (moving) (C2)

Each of these accident natures has their own set of characteristics and potential contributing factors.

For instance, the prevalence of C4 accidents may suggest potential issues related to driver attention, sudden braking or lack of safety distance. Instead, the prevalence of C8 accidents may be influenced by factors such as road design or visibility issues. Lastly, C2 highlights potential issues related to traffic flow or inaccurate intersection design.

This type of insights about critical accidents nature can facilitate the assessment of targeted interventions for enhancing security roads.

Curve dip in summer season

An insight emerging from the Time Series observation is the consistent dip in the curve during the July-August period of each year. This implies a significant reduction in the occurrence of road accidents during these summer months.

This finding suggests a deeper investigation into the factors that mostly affect this seasonal decrease. It may be useful a closer analysis of potential changes in traffic flow, behavioral patterns during summer holiday periods, or other external influences that may play a role in this observed trend.

Impact of Lockdown on Road Accidents in 2020

An additional detailed analysis of the Time Series chart reveals a significant decline in the number of accidents during the months of March and April through the year 2020.

This observed reduction in accident numbers can be directly attributed to the decreased activity on the road.

In March 2020, as the COVID-19 pandemic broke out, lockdown measures were implemented in various countries , including Italy and its capital, Rome. These restrictions concerned a drastic reduction in overall mobility, such as the limitation of vehicle movement, and the decrease in social interactions forcing people to work from home.

Peaks comparison

The insight originates from *Bar Click* interaction (section 3.5 - *Coordinated interactions*). Analyzing the Time Series in the Rome Safe Roads system, an important insight is pointed out about the yearly trend in road accidents within the capital city. Specifically, it can be observed that by making the side-by-side comparison between two curves, the peak of the trend associated with a specific accident nature does not always correspond to the peak of the overall yearly trend.

This implies that certain accident natures might follow different patterns or be influenced by factors different from that of the general trend. Thus, the divergence in peaks between specific accident natures and the overall yearly trend may suggest that targeted interventions could be more effective when customized to the unique characteristics of each incident type.

Safer Districts

The Choropleth Map analysis highlights interesting patterns in the distribution of general or fatal road accidents across Rome districts. Specifically, with regards to fatal accidents, Municipio III and Municipio XII represent the least affected areas in the last four years. While general accidents point out that the least affected areas are Municipio XII, Municipio XI and Municipio VIII. Indeed, they have a lower accident rate compared to other regions within the city.

The spatial distribution especially of fatal road accidents emphasizes the need for localized interventions. On the other hand, Municipio III and Municipio XII can be considered as areas of greater safety that adopt valid road preventions.

Star-shaped of accidents concentration
The insight originates from *Brush* interaction (section 3.5 - *Coordinated interactions*). By brushing over the Scatter Plot chart, all accidents are geolocated and visualized on the Choropleth Map. The resulting spatial distribution shows a large number of accidents forming a dense stain in the Rome central area Specifically, the pattern is characterized by an intriguing star-shaped structure.
The dense stain of accidents that appears in the central area of Rome, may be influenced by factors such as increased traffic, complex intersections and more.
The arising of a star-shaped structure may indicate multiple thoroughfares converging towards the central area, contributing to the formation of the observed dense stain.

Critical fatal accident natures
The insight originates from *District Click* interaction (section 3.5 - *Coordinated interactions*). By using the fatal choropleth map, clicking on each more critical district and analyzing the corresponding Vertical Bar Chart, the aspect which emerges is the prevalence of two specific natures involved in fatal accidents. They are:

- Pedestrian hit (C1)
- Vehicles collision (moving) (C2)

Hence, these two types of accidents stand out as prominent contributors to fatal road incidents.
More in particular, the prevalence of C1 accidents points out concerns related to pedestrian safety, emphasizing the need for interventions dealing with factors such as crosswalk visibility and pedestrian awareness. Instead, the prevalence of C2 accidents may be caused by issues associated with vehicle movement, suggesting the need for initiatives targeting traffic flow management and intersection design improvements.
So, this observation provides valuable insights for developing strategies focused on mitigating the impact of these specific accident natures.

6. APPLICATIONS & UTILITIES

This section focuses on the tangible impact of the Rome Safe Roads system, facing up its intended users and offering some specific use cases.

6.1 Intended user

The Rome Safe Roads system can be used as an invaluable asset for the dedicated members of the *Polizia Locale di Roma*. It offers a comprehensive and sophisticated tool for enhancing the operational efficiency and decision-making capabilities.
The system can be considered a force source, enabling the members of the *Polizia Locale di Roma* to strategically allocate resources where they are needed the most. By identifying critical areas and accident natures, the *Polizia Locale di Roma* can optimize their own utility and interventions, ensuring a customized and effective approach to enhancing road safety.
Through the employing of resources to high-risk areas or the implementation of adaptive strategies for seasonal variations, the platform allows the *Polizia Locale di Roma* to follow the evolving traffic dynamics.
Thus, the Rome Safe Roads system is an indispensable tool in the hands of *Polizia Locale di Roma*, contributing to the goal of creating safer streets.

6.2 Use Cases

In this subsection, two different use cases are going to be proposed.
The following two real-world scenarios not only prove the versatility of the Rome Safe Roads analytical system, but also highlight its practical applications in enhancing road safety and decision-making.

1) Preventive traffic management

Scenario:
As the new year approaches, an officer from the *Polizia Locale di Roma* decides to exploit the Rome Safe Roads system to better implement traffic management strategies for 2024. Given the high costs associated with road safety interventions across the entire territory of Rome, the system will be used to minimize these expenses while enhancing safety. Specifically, it will point out where and when targeted interventions are needed based on the most prevalent accident natures.
The officer accesses historical data of the most recent year with complete data that is 2021, to identify in the dashboard, different patterns about accident natures/areas/periods. Utilizing this insight, the officer collaborates with colleagues for managing traffic more effectively during the upcoming year.

The officer examines the *Vertical Bar Chart* to identify the most prevalent nature of accidents for 2021, which is identified as Vehicles collision (moving) denoted as C2. Seeking further insights into mitigating these issues, the officer investigates if weather conditions also contribute to the prevalence of C2 accidents.

By applying weather condition filters, it was confirmed that C2 accidents remain a significant concern regardless of weather conditions. This highlights the need to address the underlying causes of these accidents proactively. In this regard, for discovering when and where to take actions to mitigate nature C2 the officer clicks on the related bar.

To identify which are the most involved town halls taking into account all accidents that occurred in 2021, after clicking on the C2 bar the officer looks up to the *Choropleth Map* with general accidents selected radio button (both fatal and non-fatal). The map shows on each town hall the number of occurred accidents with nature C2. The most involved areas are: Municipio I and Municipio VII.

To identify optimal intervention periods for C2, the officer uses the *Time Series Chart*.
Particularly, after clicking the bar on the vertical bar chart, a new curve is added on the Time Series. So, two distinct curves are drawn in the chart: the overall accident yearly trend with a peak on November 26th and the C2 accidents nature specific yearly trend with a peak on September 28th. This implies that officers can focus on measures that should be implemented in September to address C2 accidents effectively.
Subsequently, he decides to refine Intervention Periods with Brush Mode. Enabling this modality, the officer can select C2 nature from the dropdown menu to focus on yearly trend of that nature. At this point he selects the period of interest by brushing with the mouse on the Time Series. Since the C2 peak is at the end of September and looking at the chart it is possible to see that at the end of the year the trend increases again, the officer decides to focus on a period that starts from the beginning of September and ends to the end of the year.

After using the brush mode on the Time Series chart, the officer visualizes the distribution of fatal and non-fatal C2 accidents on the *Choropleth Map* that occurred during the brushed period of time. This enables the officer to identify that from September to the end of the year the town halls with the highest accident rates are: Municipio I and Municipio VII (as pointed out at the beginning of the analysis) but also Municipio II, Municipio III, Municipio IV, Municipio V, Municipio VI, Municipio IX, Municipio XV (all the town halls positioning on the right of the map).

After the brushing mode on the Time Series, also the *Scatter Plot* is updated showing the clusters of C2 accidents occurred during the selected period coloured based on their severity (critical, high, moderate, low, minimal). At this point the officer uses the brush on the *Scatter Plot* brushing with the mouse over the clusters of the three highest severity to identify the specific zones where C2 accidents occurred most within the previously identified districts.

After the brush on the Scatter Plot, choosing the advanced visualization on the *Choropleth Map*, the officer zooms on the map to identify the most involved streets on accidents. In this way, he is able to know precisely where there is the need to allocate resources to mitigate accidents effectively, focusing efforts on high-density streets in the city center while leaving peripheral areas near the ring road less affected. Particularly, the officer notes that within the Municipio VII the most involved street is Via Tuscolana and the zone around San Giovanni. While for Municipio I the zones characterized by accidents with the highest severities are Lungotevere Aventino and Ponte Cavour. Lastly, for Municipio VI rhe most involved streets are: via Casilina, via Polense and via Prenestina.

Outcome:
At the end of the analysis, the officer realizes that urgent intervention is required for the C2 nature, especially during the winter period and in specific town halls. The officer makes decisions aimed at creating safer streets. Specifically, he decides to deploy more patrols during peak hours in the most affected areas to encourage heightened driver vigilance. Additionally, he decides to prioritize road maintenance, presence of road signs and more strict speed limits.
The proactive traffic management strategies result in a more consistent flow of traffic, a reduction in accident rates about vehicle collisions, and an overall improvement in road safety during 2024. This success points out the value of using historical data and strategic collaborations to proactively address and mitigate potential road safety challenges.

2) Pedestrian safety in urban environment

Scenario:
Nowadays, atmospheric pollution remains a pressing concern, emphasized also by the widespread use of private transportation methods. This reliance on cars not only contributes to air pollution but also leads to congested streets, higher accident risks, and a myriad of other urban challenges. To address these issues, there is a growing emphasis on promoting pedestrian-centric urban planning and infrastructure. Law enforcement agencies are increasingly prioritizing pedestrian safety, recognizing the importance of safeguarding those who choose to navigate city streets on foot. In this regard, the chief of

the *Polizia Locale di Roma* appoints some officers to conduct an analysis focusing on pedestrian infrastructure investments, seeking to identify areas of vulnerability and implement targeted measures to enhance safety and promote sustainable transportation methods. To do that, the officers decide to use the Rome Safe Roads system, accessing historical data of the most recent year that is 2022, to identify in the dashboard, different patterns about pedestrian accident areas and periods.

Looking at the *Vertical Bar Chart* of the last 4 years, the officers point out that the pedestrian hit (C1) is a quite common accident's nature. Focusing on the year 2022, they want to seek further insights into mitigating these issues. In this regard, for discovering when and where to take actions to mitigate nature C1 they click on the related bar and all the other charts update with respect to the selected nature.

The goal of officers is to reduce the rate of fatal pedestrian accidents within the urban city. So, after choosing the fatal accidents option from the radio button of the *Choropleth Map*, the officers use the tooltip generated by clicking on the bar to visualize where fatal C1 accidents have occurred most frequently. The most involved areas are: Municipio II, Municipio V and Municipio IX.

To identify optimal intervention periods for fatal C1 accidents the officers use the *Time Series Chart*.
Particularly, after clicking the bar on the vertical bar chart, a new curve is added on the Time Series. So, two distinct curves are drawn in the chart: the overall accident yearly trend with a peak on November 26th and the C1 accidents nature specific yearly trend with a peak on March 4th. Even though there is a peak for nature C1, in general the trend during the year remains constant without drastic changes, so the officers decide to focus on the entire year without the need to select a specific period brushing over the curve.

After clicking on the C1 bar in the Vertical Bar Chart, also the *Scatter Plot* is updated showing the clusters of C1 accidents occurred during the entire year coloured based on their severity (critical, high, moderate, low, minimal). At this point the officers use the brush on the *Scatter Plot* brushing with the mouse over the clusters of the most critical severity to identify the specific zones where C1 fatal accidents occurred most.

After the brush on the Scatter Plot, choosing the advanced visualization on the *Choropleth Map*, the officers zoom on the map and view the geolocation of C1 accidents that occurred throughout the year. This mechanism helps the officers to identify the most involved streets in pedestrian accidents, particularly the locations where fatal C1 accidents (marked in purple) have occurred and urgent interventions are needed. The officers also note that the fatal pedestrian accidents mainly occurred at intersections. Particularly, in Municipio II a fatal pedestrian accident occurred at the intersection between Via Claudio Monteverdi and Piazza Giuseppe Verdi, while in Municipio V occurred at the intersection between Strada dei Parchi and Via Dameta. Lastly, in Municipio IX a fatal C1 accident occurred at the intersection between Via di Vallerano and Via Pontina.

Outcome:
At the end of the analysis, the officers realize that urgent intervention is required for the fatal C1 nature during all the year. Only by making pedestrians feel constantly safe it is possible to encourage pedestrian-centric urban planning and infrastructure. Despite that, the officers point out that intersections are the most dangerous areas for pedestrians, so given the limited resources, they start to make decisions aimed at creating safer crossroads. Specifically, they decide to prioritize road maintenance, particularly at intersections, ensuring the proper functioning of traffic lights and the presence of adequate pedestrian signs. Additionally, they decide to pay more attention to review worn pedestrian crossings to ensure visibility and also consider installing speed bumps to enforce slower vehicle speeds.
Enhancing pedestrian safety is an ongoing concern, and allocating additional resources can facilitate interventions even in areas with minimal pedestrian accident severity. While addressing high-severity areas is crucial, extending interventions to encompass lower-risk zones is essential for comprehensive urban safety initiatives.
The continuous insights during the time derived from Rome Safe Roads allow the *Polizia Locale di Roma* chief to assess the effectiveness of the safety initiative and make data-driven decisions for future safety measures.

7. LITERATURE REVIEW

Road accidents have been increasing on a global scale becoming a crucial issue , causing a high number of fatalities and injuries each year. Beyond the human cost, these accidents also impose a heavy financial and economic toll on the society.
To mitigate the consequences of road accidents, existing literature has analyzed the most intrinsic and extrinsic factors associated with the highest risk of fatal road accidents. For instance, Rolison et al. (2018) focused on human factors and drivers characteristics (such as age, gender, adopted safety measures, risk-taking behavior) influencing crash severity outcomes. Findings revealed that young drivers have a higher risk with respect to the

older ones, because of a lack of adequate driving experience and more likelihood of driver distraction. Conversely, drug or alcohol impairment frequently leads to road accidents among middle-aged drivers with sufficient driving experience, while visual and cognitive impairment primarily causes crashes involving older drivers [10].

The type of driving at the time of collision also significantly contributes to accidents injury severity (Wali et al., 2020). Capturing driving variations such as fast acceleration, hard braking, and risky behavior toward other road users, were estimated crash severity and its correlation with driving type. Outcomes indicated a high correlation between injury severity and driving volatility within 30 seconds preceding the crash [11]. Similarly delineated the relationship of driver nationality, cultural background, and education with accident injury severity. Furthermore, several factors about the type of locality where the crash occurred such as residential/school zones or number of through lanes positively correlate with accident severity.

Existing literature has already addressed the problem of road safety in Rome. Particularly, the paper [9] pointed out that accident severity is influenced mainly by the type of vehicles involved. The paper asserts that the driver behavior and heavy vehicles cause the outcome results to be more severe than others.

Thus, while existing research primarily focuses on predicting future accidents based on the driver behavior and vehicle type, there is a lack of emphasis on addressing and preventing the intricate contributing road factors that influence these incidents. The Rome Safe Road system points out the need for a deeper understanding of the dynamics that characterizes road accidents to develop more effective preventative measures.

The current study aims to analyze and classify road accidents that occurred in the capital of Rome. It aims to develop a tool for both planning and operational interventions customized based on the specific involved causes to reduce accidents. Indeed, the system was developed for the Polizia Locale di Roma with the purpose of efficiently identifying and enhancing all factors relevant to improve road safety in the city.

8. CONCLUSION & FUTURE IMPROVEMENTS

The presented work is a demonstration about the efficacy of open data and an open environment processing approach. It successfully shows the possibility of evaluating the impact of various factors, such as weather conditions, traffic intensity, and road quality, to gain a comprehensive understanding of vehicular traffic in a metropolitan city like Rome.

Despite the complex scenario, the results generated by the proposed method are easily interpretable. In fact, they provide valuable insights for traffic management departments to make scientifically grounded decisions. The transparency and accessibility of the results contribute to the practical applicability of the system.

Looking ahead, the adaptability of the presented work promotes further exploration and improvements, ensuring its relevance and effectiveness in evolving urban traffic landscapes.

The continuous technological advances are an important opportunity for ongoing research and developments.

Particularly, the emerging technologies, such as IoT (Internet of Things) devices and advanced sensors, could contribute to a more comprehensive and real-time data collection process. This upgrade not only promises to enhance the investigation capabilities of the methodology, but also pave the way for more dynamic and responsive traffic management strategies.

Additionally, future efforts could focus on refining the project to handle additional variables or integrating advanced techniques for more accurate predictions. For instance, a collaboration with urban planning authorities and transport agencies could provide valuable insights for tailoring the methodology to specific city contexts. This would further improve the accuracy and timeliness of the insights generated by the system.

In conclusion, the presented work represents a solid foundation, but there is a wide opportunity for the future to enhance its capabilities developing intelligent urban traffic management systems.

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