Rome Safe Roads

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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, pedestrian and death accidents), the system provides valuable insights into the causes, consequences, and risk factors associated with these incidents. 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 includes the complexity of the data and a multitude of factors. Specifically, the complexity of road accident data, often from several sources and formats, presents a significant obstacle. 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
- Types of vehicles involved
- Geographic distribution of incidents

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.*

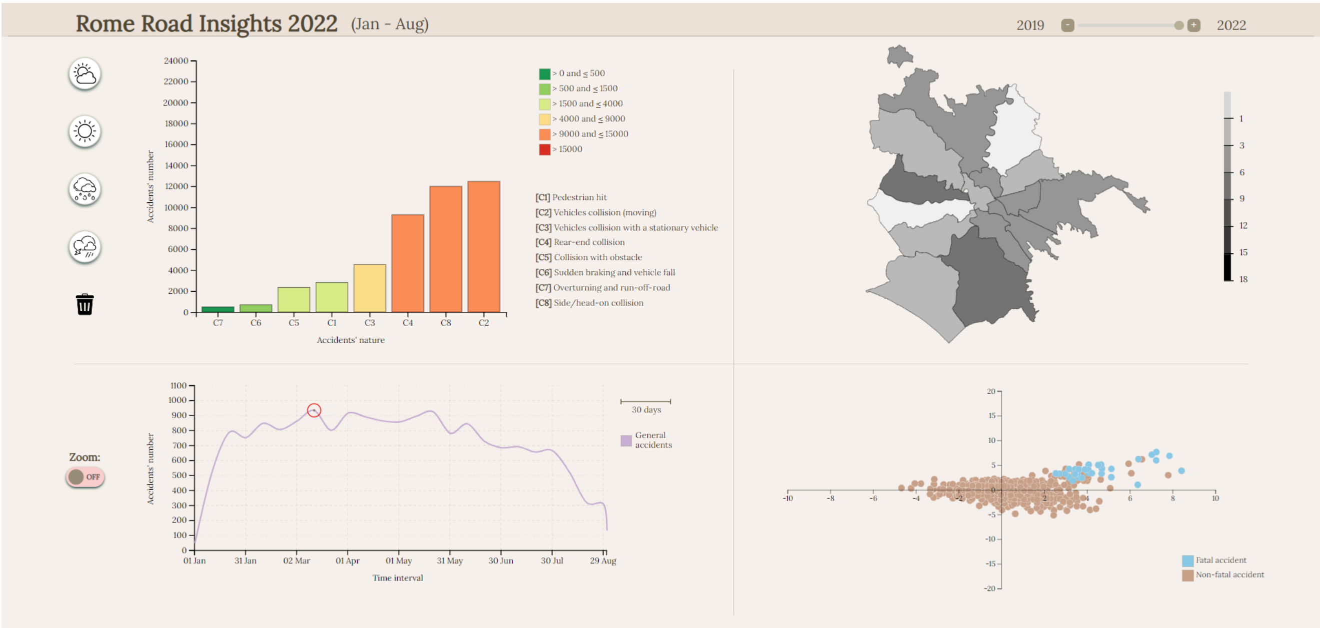

Figure 1

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 (Rome district), 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), geographical coordinates, 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, Pandas python library has been used for analyzing, cleaning, exploring, and manipulating data.

3. VISUALIZATIONS & INTERACTIONS

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 was started with the creation of a mockup as a visual blueprint. This mockup [Figure 2] highlights how the system's different graphs would look and function.

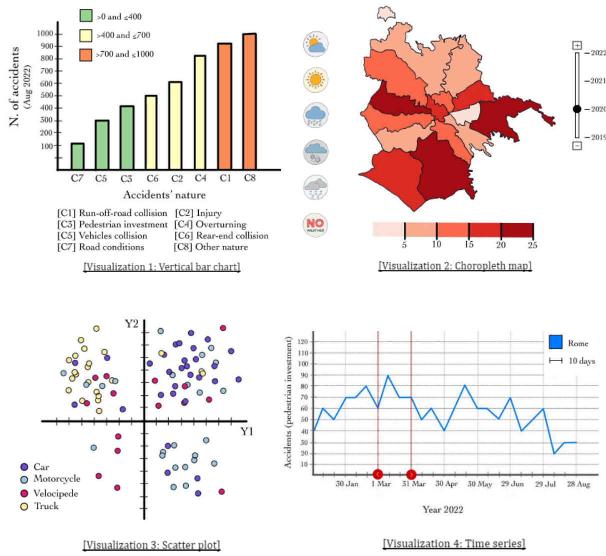

Figure 2

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 fatal accidents that occurred.
- [Time series] It analyzes the accident trend over time.
- [Scatter plot] It identifies clusters based on fatal and non-fatal accidents, where each point on the plot represents an accident.

The first global implemented interaction is a slider that holds significant importance. By incorporating the slider, users can focus analysis on the year of interest within the range of 2019 to 2022.
The detailed explanation of the visualization/interaction concept for all four graphs is provided in the following subsections.

3.1 Vertical Bar Chart

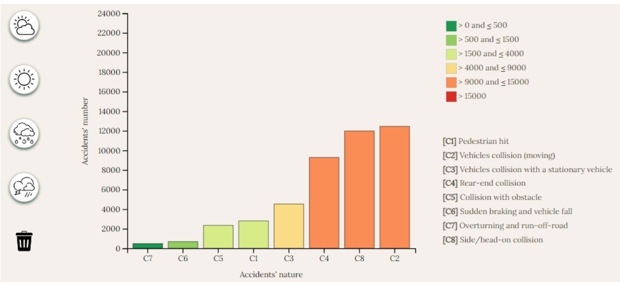

Figure 3

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, ...).

3.1.2 Interaction

Weather Condition Filters
Five buttons have been implemented to enable the filtering of accidents based on weather conditions (Cloudy, Sunny, Rainy, Severe or None). 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.

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.

Identification of Fatal Accidents for each nature
By clicking any bar in the vertical bar chart, the choropleth map dynamically responds by showing, in the involved Rome districts (Municipio I, Municipio II ...), the number of fatal accidents associated with the selected nature. Each number is displayed on the choropleth map for five seconds, after which the map is automatically restored.

Comparison of Time Series Trends
The last interaction, as the previous, is activated by clicking any bar in the vertical bar chart. In particular, a corresponding line is drawn on the time series graph, representing the accidents trend of the selected nature for the specified year. 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.

3.2 Choropleth Map

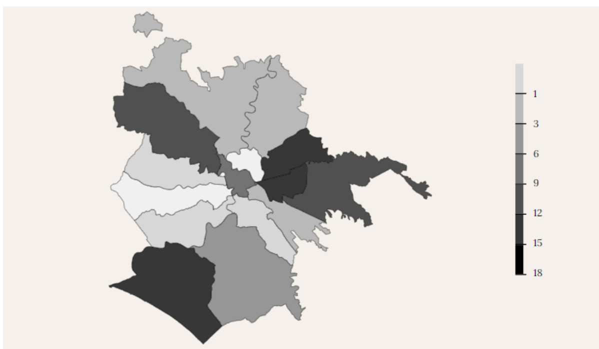

Figure 4

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 fatal accidents that occurred within its geographic boundaries. The map implementation was possible using a repository [3] that contains geo-referenced limits for all municipalities in Italy in the geojson format. The intensity of the color is determined by a grayscale legend starting from a lighter gradient for fewer accidents to a darker shade for higher fatality counts.
The 15 districts facilitate a localized analysis, displaying into which areas occurred more severe consequences in terms of fatal 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 deaths occurred in that district. This interaction offers an overview of fatal incidents within that specific geographic area.

District Click
By clicking on any district within the Choropleth Map, a dynamic response is triggered. The system updates the Vertical Bar Chart, showing all fatal accidents 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.

3.3 Time Series

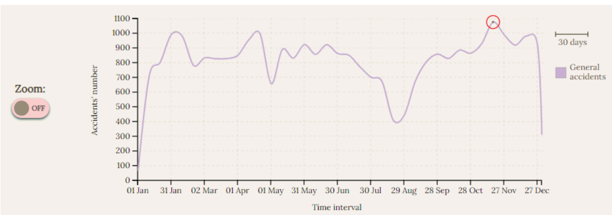

Figure 5

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 30 days.
- The color of each drawn curve.

The Time Series highlights the highest point on the curve with a distinctive red circle.
The latest element inserted within the Time Series visualization is the switch. It allows users to choose between two interactions: zoom mode or dual curve comparison mode.
The combination of a grid, legend, red circle and switch facilitates analysis in the yearly trend.

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 specific point in which the mouse cursor is in. The popup shows the date and the number of accidents occurred on that specific day. Doing This allows users to continuously monitor the counting of accidents throughout the timeline.

Zoom Mode
Through the switch element the zoom mode can be enabled. New dots are inserted on the Time Series curve at ten-day intervals. By mouse hovering over these dots, the exact number of accidents occurred is revealed.
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.
- On the y-axis more accurate accident counts appear.

Dual Curve Comparison Mode
When zoom mode is off, a comparative mode is always activated. In this case, two curves can be displayed simultaneously, allowing users to compare the general yearly accidents trend to the trend associated with a specific accident nature. As described in subsection 3.1.2 (*Comparison of Time Series Trends*), this feature is triggered by clicking on any bar in the Vertical Bar Chart. The goal is to facilitate a side-by-side comparison between two curves.

3.4 Scatter Plot

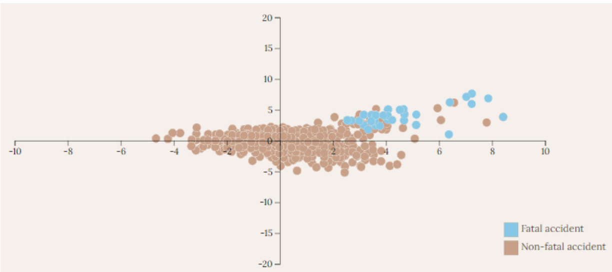

Figure 6

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 fatal and non-fatal accidents 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, ...).

Brushing Technique
Another type of interaction is the "brushing" technique. Users can select a subset of points by brushing over them with the mouse. At the same time, all accidents within the brushed selection dynamically appear on the Choropleth Map. This allows to visually identify geographic locations of chosen clusters, outliers, or specific areas of interest with all occurred accidents.

4. ANALYTICS

The analytical process of the project is focused on applying Principal Component Analysis (PCA) as a technique for dimensionality reduction. This was possible by using the python library scikit-learn [4], that allows to enhance the precision and scalability of the PCA application inside the context of road accidents in Rome.
The PCA algorithm is an important step in improving the visualization and understanding of complex relationships within the dataset.
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.
By reducing the dimensionality of the input data to a bidimensional space, PCA enables a more accessible representation of patterns and associations among various variables related to road accidents in Rome. The selection of the number of principal components was guided by ensuring a good representation of the dataset's variability, identifying key variables that contribute most to the observed variance.
By using the PCA, the project aims to reveal significant features contributing to the occurrence of road accidents. 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.

5.1 Vertical bar chart

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.
Weather was so excluded as one of the relevant causes of accidents in Rome, due to the limited influence.

Critical accidents nature
A second aspect emerging from the analysis of the Vertical Bar Chart is about 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.

5.2 Time Series

Peaks comparison
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.

Curve dip in summer season
A second 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 most 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 escalated, lockdown measures were implemented in various regions, including Rome. These restrictions brought to limitation of vehicle movement, smart working and a drastic reduction in overall mobility.

5.3 Choropleth Map

Safer Districts
The Choropleth Map analysis highlights interesting patterns in the distribution of fatal road accidents across Rome districts. Specifically, Municipio III and Municipio XII represent the least affected areas. Indeed, they have a lower accident rate compared to other regions within the city.
The spatial distribution 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.

Critical accident natures
A second aspect highlighted from the Choropleth Map analysis is the prevalence of specific natures involved in fatal accidents, which 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.

Star-shaped of accidents concentration
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 spreading. 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.

5.4 Scatter Plot

Cluster patterns in fatal accidents
The insights derived from the Scatter Plot in the Rome Safe Roads system highlight an important revelation regarding the spatial distribution of fatal accidents.
An immediate observation is the clustering of fatal accidents, which consistently tends to take place in the first quadrant of the Cartesian plane. This clustering phenomenon indicates an upward trend in both Principal Component 1 (PC1) and Principal Component 2 (PC2), specifically concerning fatal accidents.
In the context of mortality, this hints at a unique combination of factors that contribute to higher values of PC1 and PC2. A deeper analysis about the specific attributes correlated with elevated principal components could reveal critical insights into the dynamics of accidents. This is possible thanks to the presence of a well defined and localized cluster which indicates a limited range of factors that affect mortality. For instance, it may suggest a convergence of factors such as high traffic intensity, road quality, or other variables that amplify the risk of fatal accidents.

Non-Fatal accidents distribution
A second insight emerging from the Scatter Plot in the Rome Safe Roads system is about the distribution pattern of non-fatal accidents.
Quite the opposite from what was mentioned for fatal accidents, non-fatal ones are distributed across PC1, ranging from values -4 to 4, and PC2, ranging from values -5 to 5. This non-fatal accidents concentration remains constant through the different years. Although the cluster is well localized, it involves all the quadrants of the Cartesian plane. This indicates a wide range of factors which can affect non-fatal accidents that result in difficulties in taking preventive safety actions.

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 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 season traffic management

Scenario:
As the winter season approaches, an Officer of *Polizia Locale di Roma* predicts an increase in traffic flow and potential road safety issues. Exploiting the Rome Safe Roads system, the officer accesses historical data from recent years and identifies patterns of increased accidents

during previous winters. By using this foresight, he collaborates with traffic management authorities to better implement adaptive strategies. These may include the improvement of traffic signals, the increasing of patrolling during peak hours, and the launching of awareness campaigns to address seasonal driving behaviors.

Outcome:
The proactive seasonal traffic management strategies result in a more consistent flow of traffic, a reduction in accident rates, and an overall improvement in road safety during the critical winter season.
Analyzing the insights derived from Rome Safe Roads system, it is evident that the implemented measures contribute to a significant decrease in accidents, particularly the ones associated with the winter season. This success points out the value of using historical data and strategic collaborations to proactively address and mitigate potential road safety challenges.

2) Safety initiative impact assessment

Scenario:
The *Polizia Locale di Roma* has the goal to enhance road security. Hence, it decides to implement a specific safety plan throughout the city during the month of June. The initiative includes pedestrian safety improvement, speed limits adjustments, and strict enforcement of traffic regulations. The *Polizia Locale di Roma* chief uses the Rome Safe Roads system to monitor the impact of this safety plan. The different steps are the following:

- The *Polizia Locale di Roma* chief makes the access to the Rome Safe Roads system at the beginning of June.
- Using the system features, the chief identifies the historical trend of accidents in the Time Series chart, focusing on June.
- The safety plan is implemented, and all the *Polizia Locale di Roma* officers are strategically deployed based on insights derived from the system.
- During the month of June, the chief regularly checks the system to monitor any changes in the accident trend.

Outcome:
Analyzing the Times Series and focusing on the month of June, the chart reveals a notable deviation from the historical accident trend. This means that the actual plan is giving a strong impact on the safety road.
Throughout the month, it is clearly visible that there is an overall decrease in the number of accidents, particularly fatal ones. The insights 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. 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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