Big Data Course

Capstone Project   
Final Report

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| **Analizing reasons of crash traffic in American roadways** |

**DATE**  16/ 08/ 2024

**Team 3**

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## **1. Introduction**

### 1.1. Background Information

The United States has one of the most extensive and complex road networks in the world, facilitating the daily movement of millions of vehicles. However, with this extensive road infrastructure comes a significant challenge: traffic accidents. Every year, the United States records hundreds of thousands of traffic accidents, resulting in severe injuries, loss of life, and substantial economic costs. These incidents not only affect the individuals involved but also burden society as a whole.

**The Importance of Traffic Accident Analysis:** In recent years, the importance of analyzing traffic accident data has become increasingly apparent. By leveraging Big Data technologies, we can identify patterns and trends that are not immediately obvious. This deep understanding allows policymakers, urban planners, and traffic safety authorities to make informed decisions that can lead to improved road safety measures, targeted interventions, and ultimately, a reduction in the number of accidents and fatalities on American roadways.

**Project Overview:** This project aims to analyze the reasons behind traffic accidents on American roadways. By utilizing modern data processing and analysis tools such as AWS, Hadoop, MariaDB, and Power BI, the project seeks to uncover the most accident-prone roads and the primary causes of these accidents. The ultimate goal is to provide actionable insights to help formulate strategies to mitigate these accidents and enhance overall road safety.

### 1.2. Motivation and Objective

**Motivation:** Traffic accidents remain a persistent problem in the United States, leading to significant human and economic losses every year. The motivation behind this project stems from the urgent need to address this issue through data-driven insights. By understanding the underlying causes of traffic accidents, we can propose effective measures to prevent them, thereby saving lives and reducing the social and economic impact of these incidents.

**Objectives:**

* **Identify High-Risk Roadways:** The project aims to pinpoint the specific roads and highways in the United States where accidents occur most frequently. Understanding these high-risk areas will allow for targeted interventions.
* **Analyze Key Causes of Accidents:** By examining the data, the project will identify the primary factors contributing to traffic accidents, such as speeding, drunk driving, distracted driving, and poor road conditions.
* **Provide Recommendations:** Based on the findings, the project will propose practical solutions to reduce the incidence of traffic accidents. These may include road design improvements, enhanced enforcement of traffic laws, and public awareness campaigns.
* **Utilize Advanced Data Techniques:** The project will demonstrate the application of Big Data techniques in analyzing large datasets, showcasing the power of tools like AWS, Hadoop, and Power BI in generating meaningful insights from complex data.

### 1.3. Members and Role Assignments

The project team consists of four members, each with a specific role tailored to their strengths and expertise:

* **Phạm Minh Hiếu:** This member is the team leader, constructing the pipeline for the entire project. Building a data processing model and listing the apache needed. Divide work among members and completion time of each stage. Perform a test run of the project.
* **Vũ Đỗ Thành Đạt:** In charge of Data Analysis and Querying. This role involves writing SQL queries, exploring data, and extracting key insights from the processed data.
* **Phạm Hải Nhi:** Leads Data Visualization and Reporting. This member will use Power BI to create dashboards, visualizations, and reports that communicate the analysis findings effectively.
* **Nguyễn Chí Hoàng:** Responsible for Data Selection and Preparation. This role involves identifying suitable datasets, ensuring data quality, and preparing the data for ingestion into the analysis pipeline.

### 1.4. Schedule and Milestones

**Week 1: Data Collection and Planning**

* **Tasks:** Identify and acquire the relevant datasets from national traffic accident databases. Conduct an initial review of the data and set up the AWS environment. Develop a detailed project plan and assign tasks to team members.
* **Milestones:** Dataset selection was completed, the AWS environment was set up, and the project plan was finalized.

**Week 2: Data Ingestion and Transformation, Data Analysis, Visualization, and Reporting**

* **Tasks:** Begin the process of data ingestion by loading the data into Hadoop. Create databases in HIVE and start processing raw data. Ensure data is cleaned, transformed, and stored in a structured format ready for analysis. Perform detailed data analysis using SQL queries to identify trends and insights. Develop visualizations in Power BI to represent the findings clearly. Compile the final report and prepare for the presentation of the project results.
* **Milestones:** The data ingestion pipeline is operational, and the initial data cleaning and transformation are completed. Key insights were identified, visualizations and dashboards were created, and the final report and presentation were completed.

## **2. Project Execution**

### 2.1. Simulated Scenario Description

In this project, we aim to simulate a real-world scenario where we analyze traffic accidents across various American roadways. The simulation involves the processing of a large dataset containing records of traffic accidents, including information on accident locations, causes, time of occurrence, weather conditions, and the severity of the outcomes. The goal is to replicate the challenges faced by transportation authorities in understanding and mitigating traffic accidents.

The scenario involves a multi-step data processing and analysis pipeline that mirrors the data handling procedures used by large organizations. Our team will act as a data analysis unit tasked with cleaning, processing, and analyzing this data to generate actionable insights. The scenario is set in a context where the findings will be used to inform policy decisions, enhance road safety measures, and reduce the frequency and severity of traffic accidents.

### 2.2. Datasets Selection and Description

**Dataset Overview:** The primary dataset used in this project consists of traffic accident records across various American roadways over a defined period. This dataset is sourced from reputable national traffic safety databases and includes a comprehensive set of variables related to traffic accidents.

**Key Variables:**

* **Accident Location:** Latitude and longitude data pinpointing the exact location of each accident.
* **Date and Time:** The specific date and time of the accident, allowing analysis of temporal patterns.
* **Weather Conditions:** Information on the weather conditions at the time of the accident, such as rain, fog, or clear skies.
* **Road Conditions:** Details about the state of the roadway, including surface condition, lighting, and signage.
* **Accident Cause**: Categorized data on the primary causes of accidents, such as speeding, distracted driving, or driving under the influence.
* **Severity:** The severity of each accident, including the number of injuries or fatalities.

**Dataset Selection Criteria**: The selection of this dataset was guided by several criteria:

* **Relevance:** The data must directly relate to traffic accidents on American roadways.
* **Completeness:** The dataset should include all necessary variables contributing to a thorough traffic accident analysis.
* **Accuracy:** The data must be sourced from reliable databases to ensure the validity of the analysis.
* **Volume:** The dataset should be large enough to provide statistically significant results but manageable within the project’s time constraints.

### 2.3. Project pipeline

A diagram of a block diagram

Description automatically generated

The data ingestion process is a critical phase of the project, where raw data is imported into the analysis environment and prepared for subsequent processing. Our pipeline is designed to ensure that data is handled efficiently and systematically, enabling accurate analysis.

**Step 1: Data Upload to AWS**

* The raw dataset is first uploaded to Amazon Web Services (AWS) S3 storage. AWS provides a scalable and secure environment for storing large datasets, ensuring easy access for all team members.

**Step 2: Data processing in hadoop**

* From AWS, the dataset is imported into the Hadoop ecosystem. Hadoop’s distributed processing capabilities allow us to handle large datasets effectively, distributing the workload across multiple nodes.
* Data from aws transferred to Hadoop is in the form of a .csv file that will be converted into a table in Hive. Here data is saved as a Database.
* The data is now in DataBase and will be ingested to DataLake according to the OLTP (Online Analytical Processing) model. At this time, the data in DataLake has been cleaned.
* Data from DataLake performs processing to DataWarehouse, which creates table data to directly visualize the data and is stored at DataWarehouse.

**Step 3: Visualization**

* The data tables in DataWarehouse are transferred to the aws folder in the form of a .csv file, which will be pushed into Power BI and performed data visualization.

### 2.4. Data Transformation Processing

Once the raw data is ingested and stored, the next phase involves transforming the data into a format suitable for analysis. This stage includes data cleaning, normalization, and transformation processes.

**Data Cleaning:**

* **Handling Missing Data:** We identify and address any missing data points within the dataset. Depending on the severity, missing data is either imputed using statistical methods or removed if deemed inconsequential.
* **Removing Outliers:** Outlier data points that could skew the analysis are detected and managed appropriately through transformation or removal.

**Data Normalization:**

* **Standardizing Data Formats:** We ensure that all data is in a consistent format. For example, date and time fields are standardized to a uniform format, and categorical variables (such as accident causes) are encoded for compatibility with analysis tools.
* **Scaling Numerical Data:** Numerical variables are scaled to ensure that differences in magnitude do not disproportionately affect the analysis. This is particularly important for machine learning models that may be applied later.

**Data Transformation:**

* **Feature Engineering:** We create new features from the existing data that could provide additional insights. For instance, combining date and time data to create new features like “rush hour” or “seasonal effect” might reveal patterns not immediately apparent in the raw data.
* **Aggregation:** Data is aggregated to identify broader trends. For example, accident data might be aggregated by day of the week or by specific roadway to understand when and where accidents are most likely to occur.

### 2.5. Data Query and Insight

With the transformed data ready, the project moves into the querying phase, where we extract key insights from the dataset.

**SQL Querying:**

* We write and execute complex SQL queries against the Hive database to explore the data. These queries are designed to uncover patterns related to accident locations, times, and causes. For instance, queries might reveal which roads have the highest accident rates or which times of day see the most accidents.

**Exploratory Data Analysis (EDA):**

* Using statistical tools, we conduct an exploratory data analysis to identify correlations and trends within the data. EDA techniques such as correlation matrices, pivot tables, and visualizations (like histograms and scatter plots) help us gain a deeper understanding of the dataset.

**Insight Extraction:**

* The final step in this phase is synthesizing the findings into actionable insights. We identify the most accident-prone roads and the primary causes of accidents, providing a clear picture of the traffic safety landscape on American roadways. These insights form the foundation for the recommendations and solutions proposed in later sections of the report.

## **3. Results**

### 3.1. Data Ingestion Scripts and Code

A diagram of a data processing process

Description automatically generated

The data ingestion process is crucial for bringing the raw data into the analytical environment, ensuring that it is properly stored and accessible for subsequent processing and analysis. In this section, we detail the scripts and code used to ingest the data, highlighting the specific tools and methods employed.

**AWS S3 Data Upload Script:**

* The initial step involved uploading the raw dataset to AWS S3, a scalable cloud storage service.

A screen shot of a computer

Description automatically generated

* This script ensures that the data is securely stored in the cloud, making it accessible for the Hadoop processing pipeline.

### 3.2. Data Transformation Scripts and Code

* Data transformation is a key phase where raw data is cleaned, normalized, and converted into formats suitable for analysis. This section outlines the scripts and code used for these transformations.

**Hadoop Database Ingestion Code:**

* When loading data in aws, the file is in .csv format, you need to convert this file into a table and save it to Hive, this is where the data is stored (Database).

A screen shot of a computer code

Description automatically generated



**Database Ingest DataLake:**

* Retrieve data from the Database and perform queries to get the data needed for the project. A new data table is created and saved to DataLake.

A screen shot of a computer error

Description automatically generated

A white background with black and white clouds

Description automatically generated with medium confidence

DataLake process Datawarehouse

* Retrieve raw data from DataLake, conduct queries to create sub-tables containing data to create reports. These data tables are saved to Datawarehouse.



A screenshot of a computer program

Description automatically generated

A white background with text

Description automatically generated

A screenshot of a computer program

Description automatically generated

**Datawarehouse to AWS:**

* Data are tables saved in DataLake that are transferred and stored in AWS as .csv files. Data saved in aws will be convenient for visualization and data management.

A computer code with text

Description automatically generated with medium confidence

### 3.3. Description and Sample of Transformed Datasets

The transformed datasets are integral to the analysis, as they represent the cleaned, structured, and feature-engineered data ready for insights extraction. Here, we provide a detailed description of these datasets along with samples of the data.

Database ingest DataLake:

A screenshot of a computer

Description automatically generated

DataLake process Datawarehouse:

+ **Accident Frequency by Location**

A screenshot of a computer

Description automatically generated

+ **Statistics on causes of accidents**

A screenshot of a computer

Description automatically generated

+ **Weather Impact on Accidents**

A screenshot of a data

Description automatically generated

+ **Time-of-Day Analysis**

A screenshot of a calendar

Description automatically generated

### 3.4. Data Visualization of Query Results

Data visualization is a powerful tool for communicating insights from the data. This section describes the visualizations created from the query results and their significance.

A screenshot of a graph

Description automatically generated

**Visualization 1: Accident Frequency by Location**

* **Description:** A bar chart displaying the frequency of accidents across different locations, highlighting the most dangerous roads.
* **Significance:** This visualization helps quickly identify which locations require the most attention for traffic safety improvements.

A graph of a number of blue bars

Description automatically generated with medium confidence

**Visualization 2: Statistics on causes of accidents**

* **Description:** A pie chart showing the distribution of accidents by severity level, providing an overview of how severe most accidents tend to be.
* **Significance:** Understanding the severity distribution helps in prioritizing response strategies, particularly for high-severity areas.

A pie chart with text and numbers

Description automatically generated

**Visualization 3: Weather Impact on Accidents**

* **Description:** A line graph plotting the number of accidents against different weather conditions, illustrating the correlation between weather and accident frequency.
* **Significance:** This visualization underscores the need for weather-specific safety measures, such as advisories or road closures during hazardous conditions.

A graph with text on it

Description automatically generated

**Visualization 4: Time-of-Day Analysis**

* **Description:** A heat map showing accident occurrences at different times of the day, with emphasis on rush hours.
* **Significance:** The heat map reveals the times of day when accidents are most frequent, guiding the implementation of targeted interventions such as increased patrols or traffic calming measures during high-risk periods.

A graph of a graph

Description automatically generated

### 3.5 AI and ML (Machine Learning)

**3.5.1: AI**

Raw data from DataLake can be the data input to create a model for AI to use. Here the team builds an AI model from input data such as weather, lighting conditions, road surface conditions and travel speed to make predictions about the type of accident that may occur and the cause of the accident. problem. From there, advice is given to users to help ensure safety when traveling.

**Declare the library to use:**

A white background with black text

Description automatically generated

Get input data:

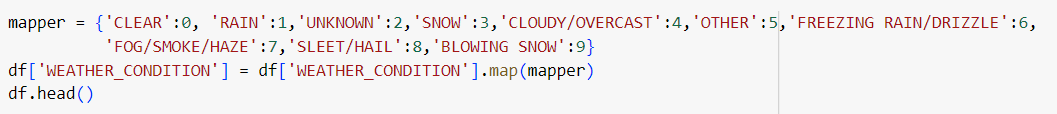
A close-up of a computer code

Description automatically generated

**Get data to create model:**



**Converts string data to numbers**



A close-up of a white background

Description automatically generated

A close-up of a computer screen

Description automatically generated

**Convert data to a two-dimensional array as input to the KMeans algorithm:**

A screenshot of a computer code

Description automatically generated

**Use the elbow algorithm to find the clustering number:**

A screenshot of a computer program

Description automatically generated

A graph with a blue line

Description automatically generated

**Use two functions: silhouette\_score and calinski\_harabasz\_score to evaluate the algorithm score:**

A screenshot of a computer

Description automatically generated

**Draw a chart after using the algorithm: the chart shows the number of clusters, distinguishing between clusters by color. The center point of the cluster is the star shape.**

A screenshot of a computer program

Description automatically generated

**Create two tables from DataLake data: one table is the input of the model, one table is the desired output of the model:**

A close-up of a sign

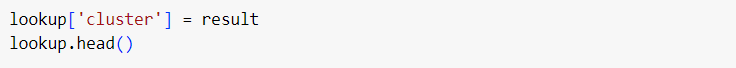
Description automatically generated



**Combine two tables and assign clusters:**

A black and red text

Description automatically generated



**Write the functions of the AI ​​model and conduct testing:**

A screenshot of a computer code

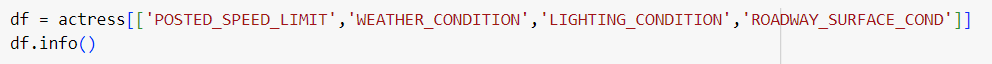
Description automatically generated

**The output gives us information about the suggestion to the user**

A screenshot of a computer

Description automatically generated

**3.5.2: Machine Learning**



A screenshot of a computer

Description automatically generated

For machine learning models, to increase the accuracy of the model, the AI ​​model needs to go through the machine learning process, here not simply by getting data from DataLake but after we have input data for the input model. It is necessary to create more test data by labeling the data lines, the model will absorb the machine learning data accurately. From there, when the user uses the AI ​​model to respond correctly to the given request. .

## **4. Projected Impact**

### 4.1. Accomplishments and Benefits

The analysis of traffic crash data on American roadways has yielded several significant accomplishments and benefits. These outcomes not only provide valuable insights into traffic safety but also offer practical solutions for reducing accident rates and improving road safety.

**Key Accomplishments:**

**1. Identification of High-Risk Areas:**

* Through detailed data analysis and visualization, we successfully identified the roadways with the highest frequency of accidents. This geographic insight is crucial for targeted interventions.
* **Benefit:** By pinpointing high-risk areas, transportation authorities can prioritize safety improvements and allocate resources more effectively.

**2.Understanding of Accident Causes**:

* The analysis revealed the primary causes of traffic accidents, including speeding, distracted driving, and adverse weather conditions. This comprehensive understanding helps in addressing the root causes of accidents.
* **Benefit:** Addressing these causes can lead to more effective prevention strategies, such as public awareness campaigns and stricter enforcement of traffic laws.

**3. Development of Predictive Models:**

* We developed predictive models to forecast accident-prone times and locations based on historical data. These models help anticipate potential traffic safety issues before they occur.
* **Benefit:** Predictive models enable proactive measures to be taken, potentially preventing accidents and improving overall road safety.

**4. Enhanced Data-Driven Decision Making:**

* The use of advanced data processing and visualization tools, such as Apache Spark and Power BI, allowed for an in-depth analysis of traffic crash data. This data-driven approach supports more informed decision-making.
* **Benefit:** Enhanced decision-making capabilities can lead to better policies and initiatives for improving road safety.

**Overall Benefits:**

**1. Improved Road Safety:**

By identifying accident-prone areas and understanding the causes, the project contributes to the development of targeted safety measures that can reduce the frequency and severity of traffic accidents.

**2. Informed Policy Recommendations:**

The insights gained from the analysis can inform policy recommendations for road safety improvements, such as better signage, road design modifications, and law enforcement strategies.

**3. Public Awareness:**

* The findings can be used to raise public awareness about traffic safety issues and encourage safer driving behaviors.

**4. Efficient Resource Allocation:**

* The identification of high-risk areas allows for more efficient allocation of resources and funding to areas where they are most needed.

### 4.2. Future Improvements

While the current project has achieved significant milestones, there are several areas for future improvement that can enhance the impact and effectiveness of traffic safety analyses.

Potential Future Improvements:

**1. Integration of Real-Time Data:**

* Integrating real-time traffic data into the analysis could provide more up-to-date insights and allow for dynamic adjustments to safety measures.
* **Benefit:** Real-time data integration can improve the accuracy of predictions and responsiveness to emerging traffic safety issues.

**2. Incorporation of Additional Data Sources:**

* Including additional data sources, such as vehicle telemetry and driver behavior data, could provide a more comprehensive view of factors influencing traffic accidents.
* **Benefit:** A broader data set can enhance the depth of analysis and lead to more effective safety interventions.

**3. Refinement of Predictive Models:**

* Further refinement of predictive models using machine learning techniques could improve their accuracy and reliability.
* **Benefit:** Enhanced predictive models can provide more precise forecasts and better support for preventive measures.

**4. Expansion to Other Regions:**

* Applying the analysis methods to other regions or countries could provide a comparative understanding of traffic safety issues and solutions.
* **Benefit:** Expanding the scope of the analysis can help identify universal trends and region-specific challenges, leading to more effective global and local traffic safety strategies.

**5. Enhanced Visualization Tools:**

* Developing more advanced visualization tools and dashboards could improve the accessibility and interpretability of the results for stakeholders.
* **Benefit:** Enhanced visualization tools can make it easier for decision-makers to understand and act on the data.

**In Summary:**

The projected impact of this project demonstrates the potential for significant improvements in road safety through data-driven insights and targeted interventions. Future enhancements and expansions will further strengthen the ability to address traffic safety challenges and contribute to safer roadways for all.

## **5. Team Member Review and Comment**

### 5.1 Comment

|  |  |
| --- | --- |
| NAME | REVIEW and COMMENT |
| Phạm Minh Hiếu | * As the team leader of the entire project, he developed and proposed the best plan for each process. Understand each member's strengths and help them maximize their strengths in each phase of the project * Role and Contributions: [Name] served as the Data Engineer for the project. They were responsible for designing and implementing the data ingestion pipeline and managing the AWS S3 storage. * Performance Review: [Name] demonstrated exceptional skills in handling data ingestion and cloud storage management. Their ability to integrate AWS services with Hadoop was crucial for the project's success.   - Challenges Faced: [Name] encountered challenges with  data synchronization between AWS and Hadoop was resolved  through careful troubleshooting and optimization.  - Comments and Feedback: [Name] appreciated the opportunity to  work on a real-world data engineering problem and gained  valuable experience in cloud-based data management. They  suggested exploring more automated data ingestion tools for  future projects. |
| Vũ Đỗ Thành Đạt | * Role and Contributions: [Name] acted as the Data Analyst, focusing on data transformation and processing using Apache Spark. They were instrumental in designing the data transformation scripts and preparing datasets for analysis. * Performance Review: [Name]'s work in data transformation was thorough and efficient. Their expertise in Apache Spark enabled effective processing and transformation of large datasets. * Challenges Faced: [Name] faced difficulties with performance optimization of Spark jobs, which were addressed through fine-tuning and resource allocation adjustments. * Comments and Feedback: [Name] valued the collaborative environment of the project and enhanced their skills in big data processing. They recommended further training in Spark for more complex transformations in future projects. |
| Phạm Hải Nhi | * Role and Contributions: [Name] was responsible for the Data Visualization and Reporting phase, utilizing Power BI to create interactive dashboards and visualize the analyzed data. * Performance Review: [Name] translated data insights into actionable visualizations. Their work significantly contributed to understanding the key findings and presenting them effectively. * Challenges Faced: [Name] encountered challenges integrating data with Power BI due to formatting issues, which were resolved by thoroughly preprocessing the data. * Comments and Feedback: [Name] found the project to be a great learning experience in data visualization and reporting. They suggested incorporating more advanced Power BI features and exploring additional visualization tools for future projects. |
| Nguyễn Chí Hoàng | * Role and Contributions: [Name] took on the role of Project Coordinator, overseeing the project timeline, coordinating tasks among team members, and ensuring that all milestones were met. * Performance Review: [Name] effectively managed the project’s timeline and facilitated communication among team members. Their organizational skills ensured the project stayed on track and deadlines were met. * Challenges Faced: [Name] faced challenges in balancing the workload and managing time effectively among team members, which were addressed through regular check-ins and adjustments to the project plan. * Comments and Feedback: [Name] valued the leadership experience gained through coordinating the project and appreciated the team's collaborative effort. They recommended using project management tools for better tracking and coordination in future projects. |

### 5.2. Summary of Team Performance

Overall, the team demonstrated strong collaboration and commitment throughout the project. Each member contributed their expertise effectively, resulting in successful project execution. The diverse skills and perspectives of the team members complemented each other, leading to a comprehensive analysis and impactful results.

**Strengths:**

* Effective teamwork and communication.
* Expertise in various areas such as data engineering, analysis, and visualization.
* Successful implementation of the data pipeline and visualization tools.

**Areas for Improvement:**

* Enhanced focus on optimizing performance in data processing and visualization.
* More structured project management and use of tracking tools.
* Exploration of additional advanced tools and techniques for future projects.

**Conclusion:**

The feedback and review process highlights the strengths and achievements of the team, as well as areas for future improvement. This comprehensive evaluation provides valuable insights for enhancing team performance and project outcomes in future endeavors.

## **6. Instructor Review and Comment**

|  |  |  |
| --- | --- | --- |
| CATEGORY | SCORE | REVIEW and COMMENT |
| IDEA | \_\_/10 |  |
| APPLICATION | \_\_/30 |  |
| RESULT | \_\_/30 |  |
| PROJECT MANAGEMENT | \_\_/10 |  |
| PRESENTATION & REPORT | \_\_/20 |  |
| TOTAL | \_\_/100 |  |