Using Business Intelligence to Analyze Road Traffic Accidents

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ABSTRACT

Road Traffic Accidents constitute a significant concern around the world. Understanding the primary and contributing factors may combat traffic accidents and mitigate their impact. Based on an actual traffic accidents dataset of the United Arab Emirates (UAE) between 2012-2019, we investigate the importance of data science and Business Intelligence (BI) in visualizing traffic accidents in a descriptive format. The proposed BI solution provides visual data exploration for authorities to analyze and make informed decisions. This paper provides an example of how open data can save lives and resources. The design and implementation of the BI solution and its features are also presented in this paper.

CCS CONCEPTS

• **Computing methodologies** → Modeling and simulation; Simulation types and techniques; Visual analytics; • **Information systems** → Information systems applications; Decision support systems; Data analytics.

KEYWORDS

Business intelligence, Data analytics, Road traffic accidents, Traffic management, E-government, Descriptive analysis

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1 INTRODUCTION

Road Traffic Accidents (RTAs) comprise a significant concern in our societies. Every year, about 1.3 million people lose their lives due to traffic accidents worldwide [1]. Road traffic accidents are considered the tenth leading cause of death in developed countries [2]. Furthermore, around 50 million people suffer non-fatal injuries, with many incurring a disability as a result of their injury. In the UAE, as stated by the World Health Organization (WHO), road accidents are the second leading cause of mortality in the UAE [3]. According to the UAE's Ministry of Interior (MOI), an average of two persons died daily in crashes on the roads over the past five years [4].

Furthermore, accidents have serious economic, social, and environmental consequences. For example, the WHO estimates that crashes cost 3% of the gross domestic product (GDP) for most countries [1].

It is often challenging to determine the root cause of traffic accidents due to the complex combination of behavioral and external factors such as the driver's mental state, road conditions, weather conditions, characteristics of vehicles, and traffic rule violations. Additionally, and for the same reason, it is difficult to predict the severity of injuries of those affected by accidents. Thus, local law enforcement faces challenges in addressing the causes and severity of traffic accidents.

Using a historic traffic accident dataset, it is possible to explore the data and provide deep insights to conclude accidents patterns. Therefore, we can identify risk factors for automobile collisions, injuries, and fatalities and take preventative measures to save lives.

A decision support system can visualize the dataset to help the authorities better understand traffic accidents nature and suggest mechanisms to mitigate them. For example, A Business Intelligence (BI) application can highlight issues such as a high number of accidents on a specific road due to road conditions, high speed, poor lighting, or jaywalking. Based on the cause of the accident, the authorities may add speed bumps, radar cameras, streetlights, or pedestrian bridges. Additionally, the BI application may provide accidents details based on the date and time of the accidents. Based on that, the authorities may arrange some preventative measures in some anticipated locations during a given date and time.

A BI dashboard is a graphical interface that presents data in a visual format making it more intuitive to extract valuable information and make informed decisions. Technically, BI solutions handle the collection, transformation, storage, and analytics of data [5–8].

This paper aims to investigate the role of data science and Business Intelligence (BI) in analyzing traffic accidents in a descriptive format, which will allow authorities to easily extract insight from a massive amount of data and make informed decisions. Our work is based on an actual and real traffic accidents dataset of the UAE between 2012-2019.

The paper is structured as follows: The following section presents a literature review. Section 3 presents the proposed BI system architecture. Section 4 describes the utilized dataset. Section 5 presents the descriptive approach, and Section 6 concludes the paper.

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2 RELATED WORK

In the area of road safety, many studies presented techniques to determine the significant factors that may lead to traffic accidents and predict the severity of these accidents.

Assi et al. [9] used a crash dataset from Great Britain, UK, between 2011 and 2016 to predict crash injury severity using 15 crash-related parameters. They investigated the effect of C-means clustering on the performance of Feed-forward Neural Networks (FNN) and Support Vector Machine (SVM) in predicting crash injury severity. Assi et al. compared between their models based on injury severity prediction accuracy, sensitivity, precision, and harmonic mean of sensitivity and precision (i.e., F1 score). Their results showed that the SVM-FCM model outperformed the other developed models in predicting the injury severity level with 74% accuracy.

Chong et al. [10] utilized the National Automotive Sampling Systems Data (NASS) and General Estimates Systems Data (GES) between 1995 and 2000. Their study aimed to classify accidents injuries into five levels of severity (i.e., no injury, possible injury, non-incapacitating injury, incapacitating injury, and fatal injury). Chong et al. used four machine learning approaches to classify the injuries: Artificial Neural Network (ANN), Decision Trees (DT), SVM, and a hybrid approach combining DT with ANN (DTANN). Their results revealed that the DTANN approach outperformed the individual approaches.

Singh et al. [11] utilized four machine learning techniques to classify Punjab's road accidents. These techniques were Naïve Bayes, k-Nearest Neighbors (k-NN), Decision Trees (DT), and Support Vector Machine (SVM). Their outcome showed that the Decision Trees had the best performance with 86.25%.

Krishnaveni and Hemalatha [12] utilized Hong Kong's Transportation Department accidents dataset of 2008 with 34,575 cases. Their work investigated the application of Naive Bayes, AdaBoostM1, PART, J48, and Random Forest algorithms to predict injury severity. They compared the performance of the classifiers based on the accuracy metric. Krishnaveni and Hemalatha concluded that the Random Forest outperformed the other four algorithms.

Cuenca et al. [13] presented a case study of traffic accidents classification and severity prediction in Spain based on a Spanish traffic agency dataset from 2011 to 2015. They compared three different machine learning classification techniques: gradient boosting trees, deep learning, and Naive Bayes. Their prediction accuracy results revealed that the deep learning model outperformed the others.

Alkheder et al. [14] developed a classification model to predict four levels of traffic accidents injury severity (i.e., minor, moderate, severe, and deadly) using Artificial Neural Network (ANN). They used a dataset of 5,973 traffic accident records from 2008 to 2016 in Abu Dhabi, UAE. Their model's accuracy has reached 74.6%. In another study, Alkheder et al. [15] applied a Random Forest (RF) classifier on the same dataset to predict a crash's injury severity. The use of RF resulted in a higher accuracy of 78.5%.

Labib et al. [16] utilized a dataset from the Accident Research Institute of Bangladesh University of Engineering and Technology that consists of a total of 43,089 traffic accidents record between 2001 and 2015 in Bangladesh. They applied Decision Tree, K-Nearest Neighbors (KNN), Naïve Bayes, and AdaBoost to classify accidents intensity into four categories (Fatal, Grievous, Simple Injury, and Motor Collision). Among the four techniques, AdaBoost achieved the best performance with an accuracy of 80%.

On the other hand, few studies utilized Business Intelligence (BI) approach to present a descriptive view of road traffic accidents. For example, Sunkpho and Wipulanusat [17] explored the potential of using BI in accident analysis. Using the Tableau data visualization tool, they created a dashboard of traffic accidents during the new year holidays in Thailand from 2008 to 2015. Another work by Ulker and Coskun [18] analyzed traffic accidents in Turkey using a BI dashboard. Also, a study by Nikam [19] examined accidents in the United States using data gathered between 2016 and 2019 from 50 states using Tableau as a BI tool.

The majority of the reviewed studies addressed the predictive side of RTAs using different machine learning technologies, while others merely analyzed the descriptive view using BI tools. This work provides a comprehensive analysis of RTAs in a descriptive form providing an interactive dashboard using the Power BI platform.

3 ROAD TRAFFIC ACCIDENTS ANALYSIS SYSTEM

The architecture of our proposed road traffic accidents analysis system is displayed in Figure 1. The figure illustrates the data pipeline phases, starting with remote data extraction. This dataset is extracted from a governmental open data repository (Bayanat) in excel format. Then, we cleaned the data and tested its quality in the transformation phase. After that, the cleaned dataset was loaded into a data warehouse to be visualized via a BI dashboard.

The descriptive analysis allows us to visualize the UAE's road traffic accidents data between 2012 and 2019. Three main steps were applied to build the interactive dashboard using Microsoft Power BI tools. Firstly, Power BI Desktop was used to import the dataset from OneDrive and create the dashboard. Secondly, the created dashboard was published at the Power BI Service. Finally, end-users gain access to the shared interactive dashboard via the Power BI Service.

The upcoming sections provide more details on the system stages.

4 ROAD TRAFFIC ACCIDENTS DATASET

This section describes the utilized dataset and the preparation steps for that dataset.

4.1 Dataset Description

As mentioned earlier, this study relies on the crashes data obtained from the UAE's open data portal, Bayanat.ae [20]. The dataset comprises the details of 39,916 accidents from the MOI reports (2012-2019) in the UAE (except Dubai). Data were recorded in Arabic and contained accidents details. The dataset contained information about the time, location, and environment for each accident. Additionally, the injured person's information was provided. Table 1 illustrates the metadata of the dataset.

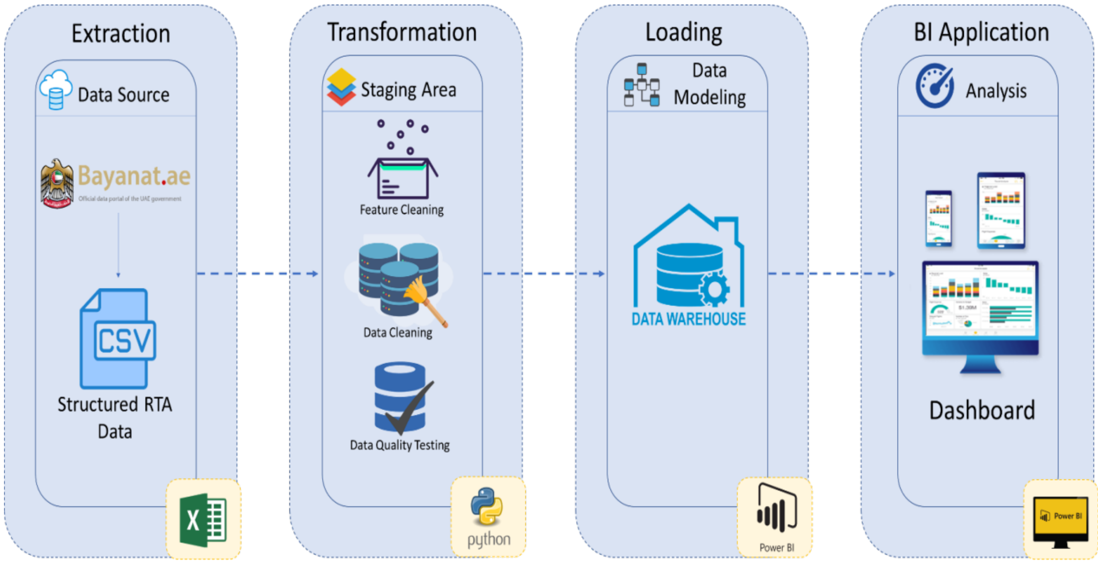

Figure 1: The proposed road traffic accident analysis system architecture.

4.2 Data Preparation

Data preparation (also referred to as data transformation) is the process of cleaning and transforming raw data to be readily and accurately analyzed. This is crucial to ensure data quality and readiness for later exploration and analysis. Thus, after extracting the dataset from the data source as an excel sheet, we used three main data cleaning steps as illustrated in Figure 1 and explained below. Note that data transformation is done in an intermediate storage area between the data source and the target data.

- Feature cleaning step: The dataset contains some unnecessary features, such as the accident ID, lighting, and accident record. The accident ID feature encloses a sequential number set upon the initiation of any accident record, which does not provide any relevant information. The lighting feature refers to the road's lighting situation at the time of an accident. After feature value analysis, we found contradicting and redundant data with the time feature. The accident record column contains the number of charges against each person. It has only one value, '1', which does not correlate with the other features.
- Data cleaning step: All duplicate records that may affect our system quality have been identified (348 duplicated rows) and removed from the dataset.
- Data quality testing step: Some features contained inaccurate values in the dataset. For example, the age feature, for some records, included unrealistic numbers that must have been typos. Also, a few records had "others" or missing values. In total, we have excluded 3,724 records from the whole dataset (around 9%).

By the end of the transformation phase, the dataset consisted of 24 features and 36,191 records.

5 DESCRIPTIVE ANALYSIS

This section presents the BI system specifications (functional and non-functional requirements), design, implementation, and utilized tools. A description of the system's capabilities and some of the use cases have been discussed in subsection 5.3.

5.1 Functional Requirements

Our proposed Road Traffic Accidents dashboard offers the user the following functionalities:

- The dashboard displays pertinent high-level information for traffic accident analysis based on various features such as locations, injury type, date, environment conditions, and particular events
- The dashboard provides an easier way to explore data through an interactive interface functionality
- The dashboard contains rich charts and graphs that are easy to understand and interpret, including bar, column, line, and pie charts. In addition to a map to display accident locations
- Several slicers and filters to view data related to customizable queries
  - ◯ For simplicity, we will refer to both as filters in this paper
- The dashboard retains the user's query across multiple pages
- Clear option to reset the display to the default state
- The ability to export the data in PDF, Excel, and PowerPoint format

5.2 Non- Functional Requirements

Our proposed Road Traffic Accidents dashboard accomplishes several non-functional requirements in the following categories:

- Operating: The dashboard supports multiple users at the same time
- Performance: The dashboard page load times are within reasonable time limits

Table 1: Features of the accident dataset

Feature	Data Type	No. of Categories	Details
Accident ID	Numeric	39916	A unique number assigned to each accident record
Year	Numeric	8	The year the accident occurred (from 2012 to 2019)
Emirate	Nominal	6	The emirate where the accident occurred (i.e., Abu Dhabi, Sharjah, . . .)
Month	Nominal	12	The month when the accident occurred (i.e., January, . . ., December)
Day	Nominal	7	The day of the accident (i.e., Sunday, . . ., Saturday)
Time	Nominal	4	The accident's time of the day (morning/noon/afternoon/evening)
Week	Nominal	5	The week of the month when the accident occurred (i.e., 1st week, . . ., 5th week)
Type of accident	Nominal	18	The type of the accident (i.e., rear-end collision, head-on collision, rollover, . . .)
Causes	Nominal	54	The cause that led to the accident (i.e., speeding, red light crossing, sudden deviation, . . .)
Road	Nominal	1059	Name of the street where the accident occurred
Place	Nominal	21	This variable indicates where the accident occurred (i.e., public area, government office, college, . . .)
Region	Nominal	688	The name of the area where the accident occurred (within the emirate)
Location	Nominal	14	The location on the road where the accident happened (i.e., intersection, roundabout, subway/bridge, . . .)
Lighting	Nominal	4	The road's lighting situation at the time of the accident (i.e., weak light, no light, . . .)
Road condition	Nominal	8	Road condition at the time of the accident (i.e., excavation, Salik road, . . .)
Weather condition	Nominal	8	Weather condition at the time of the accident (i.e., clear, rainy, fog, . . .)
Road surface	Nominal	10	Road surface at the time of the accident (i.e., dry, wet, muddy, . . .)
Injured posture	Nominal	3	The role of the injured (driver/passenger/pedestrian)
Injured seat	Nominal	5	The seat of the injured person in the vehicle (passenger in the back/passenger in front/driver seat / no passenger/ cycle driver)
Severity of injury	Nominal	4	Degree of injury (death/significant/moderate/minor)
Injured age	Numeric	80	Age of the injured person
Sex	Nominal	2	Gender of the injured person (male/ female)
Road speed	Numeric	90	Speed limit allowed on the road
Number of tracks	Numeric	9	Number of lanes on the road
Pedestrian behavior	Nominal	10	Pedestrian behavior on the road (i.e., crosses no crossings, crosses on cross-crossing lines, crosses without attention, . . .)
Intersections	Nominal	10	Type of road intersections (i.e., roundabout, no intersection, . . .)
Accident record	Numeric	1	The number of charges against each person

- Reliability: The dashboard restarts with minimal overhead during any system failure (i.e., power fail, connection error, etc.)
- Security: Data accessed only by authorized users
- Scalability: The dashboard has the flexibility to involve new components and the ability to handle increasing data size
- Integrity: Data is exported and integrated from validated sources with high accuracy
- Availability and consistency: The system is accessible over its entire lifecycle, with minimum maintenance impact
- Usability: The dashboard has an intuitive user-friendly interface

5.3 Road Traffic Accidents Dashboard Design

In order to address our functional requirements, we designed a multi-page dashboard. It contains six pages; each page displays a report with different charts and graphs based on a criterion. On each page, several filters (i.e., emirates, year, day, time, special events, injured posture, and injury severity) are placed at the top to enable the users to easily filter out the data and view only the desired information. Also, the clear filter button at the top right of each page allows the user to clear all filters in one click. The content of the dashboard pages (reports) is described below.

5.3.1 Main overview report. This page presents an overview of the numbers of traffic accidents during the period 2012- 2019 based on different features (i.e., the severity of the injury, weekdays and

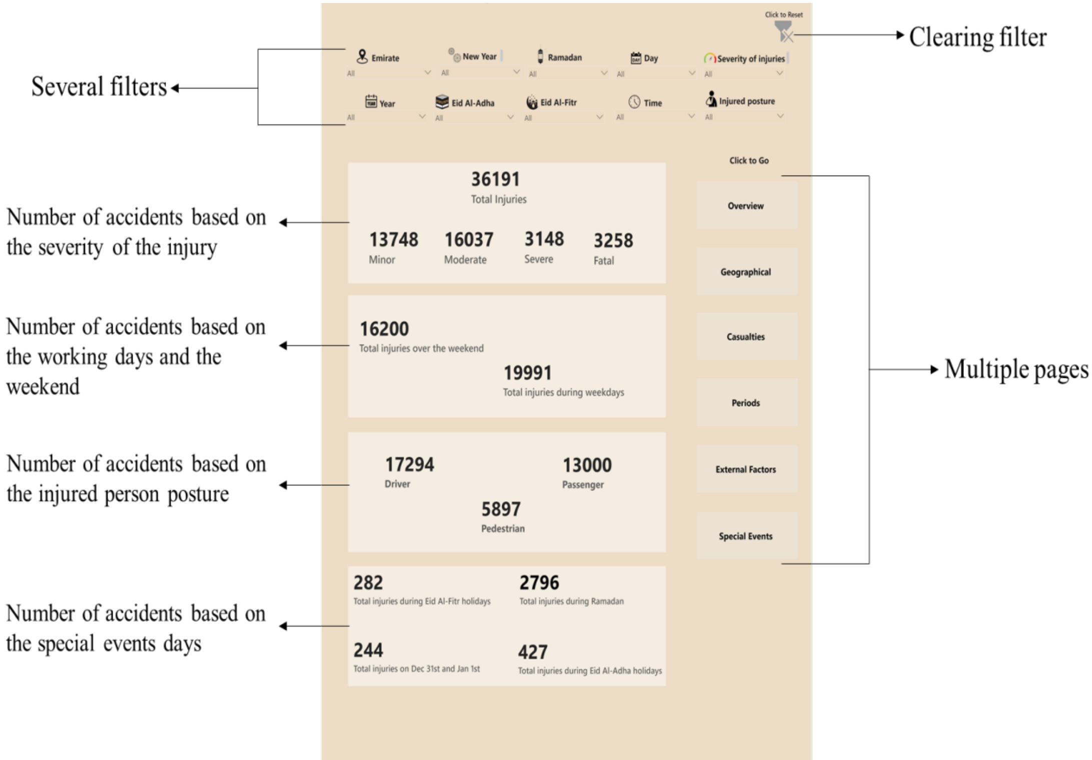

Figure 2: Main overview page structure.

weekends, injured person posture, and during holidays). Figure 2 illustrates the structure of the main overview report.

Figure 2 shows the statistics with the filters in their default option (display all). In other words, these are the numbers for all accidents between 2012 and 2019 in all emirates (cities). The figure provides several insights for the chosen option. For example, the number of accidents indicator shows that out of the 36,191 crashes, 3,258 were fatal. Also, we can see that around 45% of the accidents happened over the weekends. The page also shows that drivers were the most injured party and that about 16% of those injured were pedestrians. The last box on this report provides a breakdown of crashes occurrences during the month of Ramadan and other holidays.

The overview report facilitates an informative glance at the data on hand. As mentioned earlier, we can customize the dashboard to display statistics related to a specific city, date, injury type, etc.

5.3.2 Geographical report. The dataset contains geographical information about the accidents that could be displayed visually. For example, the location of the accident is based on the emirate, region, and road. We used bar charts to visualize the number of accidents based on the emirates and roads. Alternatively, a map is more suitable to visualize the number of accidents in a given region. Moreover, we used a pie chart to display the percentage of the accidents based on the accident location on the road. Additionally, a bar chart has been utilized to visualize the severity of injuries based on the aea type. Figure 3 illustrates the structure of this page. Similar to Figure 2, Figure 3 shows all accidents between 2012 and 2019 in all emirates. For consistency, all reports captured below display visuals for the entire dataset. The dashboard shows that the highest number of injuries (2,272) happened on the road between Abu Dhabi and Al Ain. Such information indicates that this road requires some investigation. Possible solutions to mitigate the number of accidents may include reducing the speed limit, installing radar cameras, and introducing an additional lane.

5.3.3 Casualties report. This page contains injured individuals' information such as gender, posture, and age group. We used a tornado chart to display the number of injuries based on their gender and posture. Also, the dataset contains a feature regarding the seat position of the injured person in the vehicle. Thus, we used this input with ages ranging from 4 to 17 to display the number of children casualties. Additionally, we generated a line chart for the number of injures based on the age and the seat position of the wounded and another line chart for the severity of injury based on the age. Furthermore, this page contains a bar chart for the accident causes and a pie chart for the pedestrian behavior on the road. Figure 4 shows the structure of the casualties' page.

The statistics from Figure 4 highlighted that sudden lane change and tailgating are the two leading accidents causes. Also, despite the low number, the line chart indicates that children were sitting in the front seat in some accidents. Over the past few years, the UAE has taken some actions to reduce the number of casualties on the road. In January 2020, Abu Dhabi installed smart radars to detect and fine both vehicles involved [21]. Also, in March 2022, Abu Dhabi's police announced the installation of new radars and

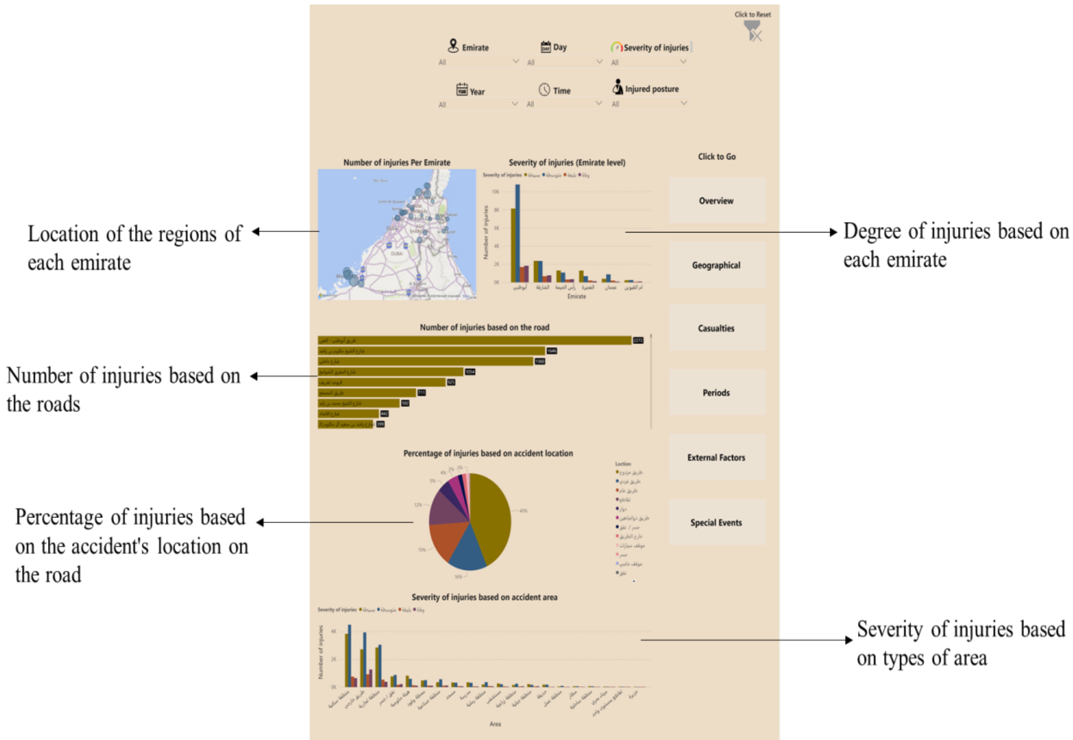

Figure 3: Geographical page structure.

smart cameras capable of identifying sudden lane changes [22]. These cameras are part of a new road safety campaign that aims to enhance compliance with safety laws. The fee for these fines is 400 AED (approx. 109 USD). Furthermore, the 2017 UAE traffic law amendment stated that front seat passengers must not be younger than ten years old [23].

5.3.4 Periods report. This page contains bar and line charts for the years, months, weeks, days, and times where accidents occurred. This page enables users to view accidents on a specific date or time easily. Figure 5 shows the structure of the periods page. The page indicates that the highest number of accidents happen on Thursdays (the last working day of the week). Possible mitigation would be increasing police patrols in areas where severe casualties have been noticed in the past.

Also, this page allows decision-makers to compare different years or months easily. For example, this can be useful to assess the effectiveness of previously taken actions and determine whether they enhanced safety on the road.

5.3.5 External factors report. The dataset contains information on external factors that may lead to an accident. The page has several charts. For example, a line chart is used to illustrate the degree of injuries based on the roads' speed limits. Also, we used a bar chart to show the correlation between the number of lanes on the road and the injuries' severity. In addition, two pie charts are used to show the road surface and conditions' effect on injuries.

Moreover, we utilized a clustered bar chart to display injuries severity and numbers for each accident type. The structure of this page is presented in Figure 6. This page provides several insights. For example, the highest number of injuries, including severe ones, happen on roads with a moderate speed limit (60 KMH). Thus, the addition of speed bumps and radars will mitigate over speeding. Also, pedestrian bridges or additional crosswalks on these roads will minimize the number of accidents.

5.3.6 Special events report. In Ramadan, Eid, and other holidays such as New Year's Eve, accidents rise due to several factors such as traffic jams. In 2021, more than 1,400 minor accidents were recorded during the first week of Ramadan [24]. Thus, it is helpful to depict the number of crashes, the severity of injuries, and their whereabouts during these events. However, the dataset does not have any information about these events, and many rely on the lunar calendar. Therefore, we matched the provided data (year, week, day, and time of accidents) with the dates of the mentioned events. For example, for Ramadan, we figured out the weeks of the month for each year (from 2012 to 2019) and manually added them to the dataset. Also, for Eid Al Fitr and Eid Al Adha, we matched all the Eid days with the accidents in each day. After that, we visualized the collected data on a separate page. For Ramadan, we used bar charts to present the degree of injuries over the eight years. Also, another bar chart was created to illustrate the degree of injuries in each week of the holy month.

Additionally, a clustered bar chart is used for the number of injuries based on the weeks and the time of the accident during Ramadan. On the other hand, Eid days injuries over the eight years are represented using a tornado chart, and the number of injuries

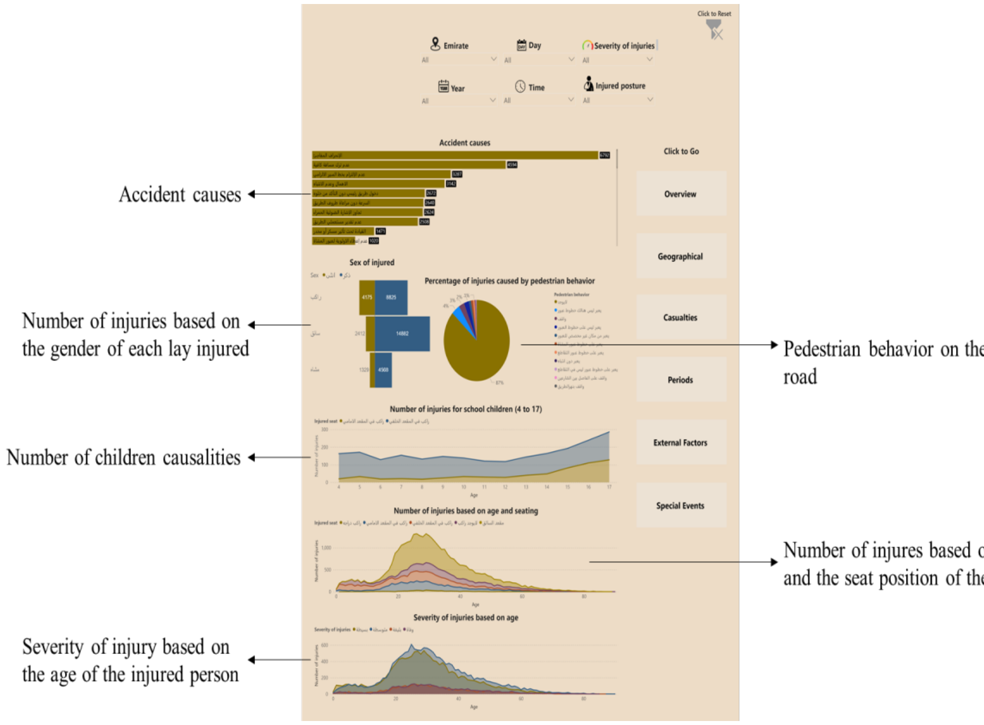

Figure 4: Casualties page structure.

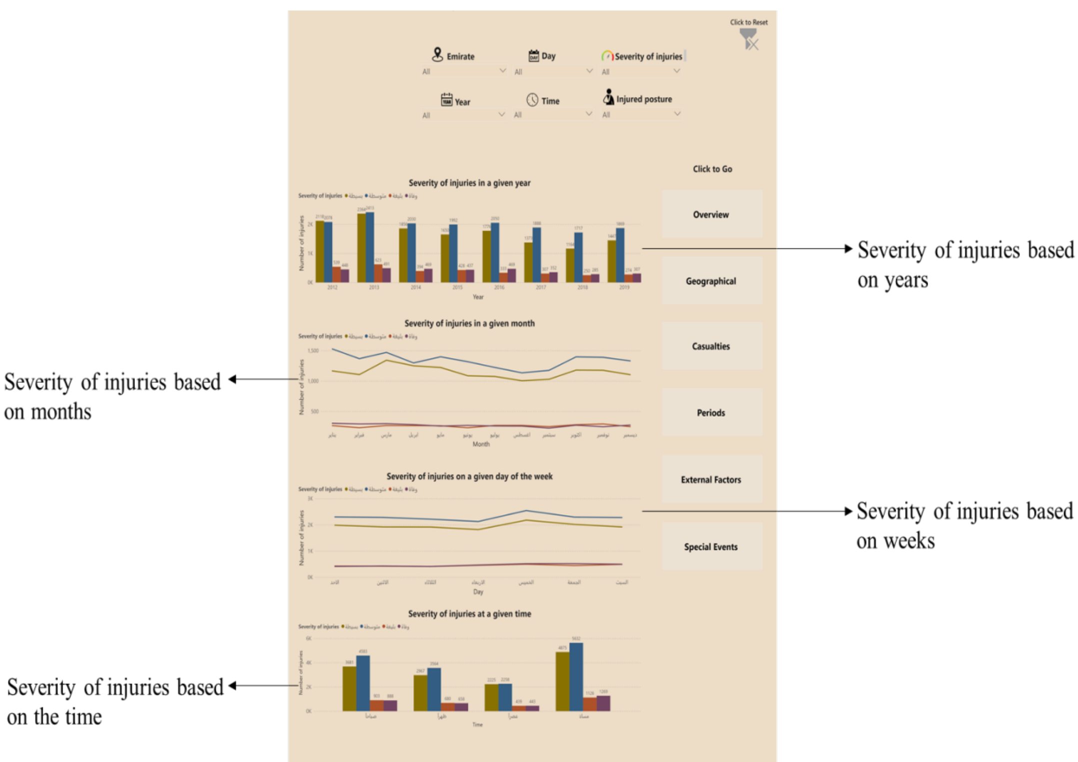

Figure 5: Periods page structure.

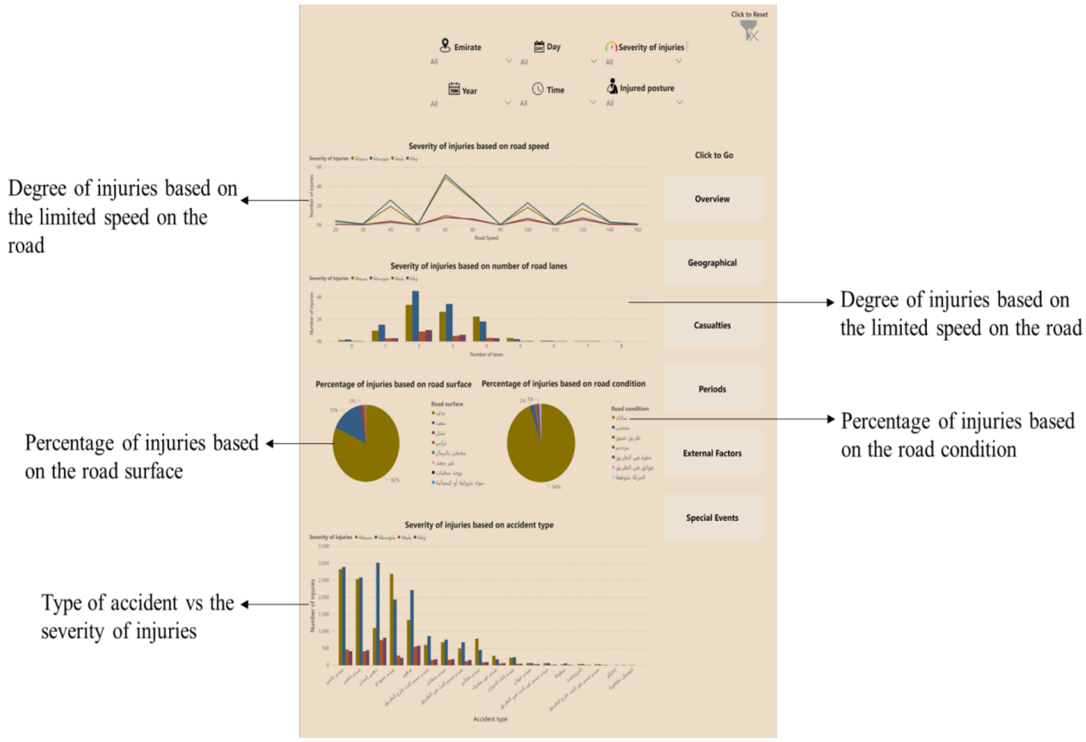

Figure 6: External factors page structure.

based on the time of the day was illustrated using a bar chart. For new year days, a pie chart is used to show the percentage of accidents, and a bar chart is used to demonstrate the injuries based on the time of the day. Figure 7 illustrates the structure of this page. The page shows a higher number of incidents during these events. For example, the number of crashes is higher in Ramadan around sunset. In addition to previously mentioned measures, educating drivers and asking them to take extra caution during these times can be very helpful.

5.4 Business Intelligence Tool

A Business Intelligence (BI) platform is a collection of processes, services, and technologies that transform unstructured data into meaningful insights [25]. It combines best data practices such as data analytics, data visualization, and data mining to support organizations make better data-driven decisions. BI platforms access and analyze datasets and display analytical findings in reports, summaries, dashboards, graphs, charts, and maps to offer users detailed insight into the business conditions [25].

Microsoft Power BI tool is a set of software services, apps, and connectors that work together to transform all types of raw data into coherent, easy-to-process, aesthetically engaging, and interactive insights [26]. In this study, as illustrated in Figure 1, The Power Bi Desktop app automates extracting data from a data source (OneDrive), transforming data in temporary memory (staging area), and loading data into a data warehouse, which can then be used as a source for Power BI visualizations. Furthermore, it is used to publish the designed dashboard to the Power BI service. Using the Power BI service, the end-users can easily access the dashboard.

6 CONCLUSION

This study investigated the role of data science and business intelligence in analyzing Road Traffic Accidents. This paper described the process used to design an interactive dashboard to provide authorities with meaningful insights from raw data.

As described earlier, the dashboard includes clear visuals to address any queries decision-makers may have with a few clicks. Such visuals will help authorities make informed decisions to enhance road safety. These decisions, informed by understanding the driving conditions, could reduce the number of collisions and fatalities. Indeed, understanding the existing traffic conditions, accident factors, and accident locations can aid authorities in taking preventative measures and ultimately saving lives. Some of the corrective actions that could be taken to reduce accidents include changes in speed limits and the addition of pedestrian bridges, speed radars, and speed bumps in flagged areas. Of course, the dashboard would also allow authorities to examine the impact and degree of success of such measures.

Future work could include the use of machine learning to design a predictive model to predict the severity of an injury based on various inputs (features). The proposed model would enable responsible parties, such as medics, to react swiftly and adequately to future accidents.

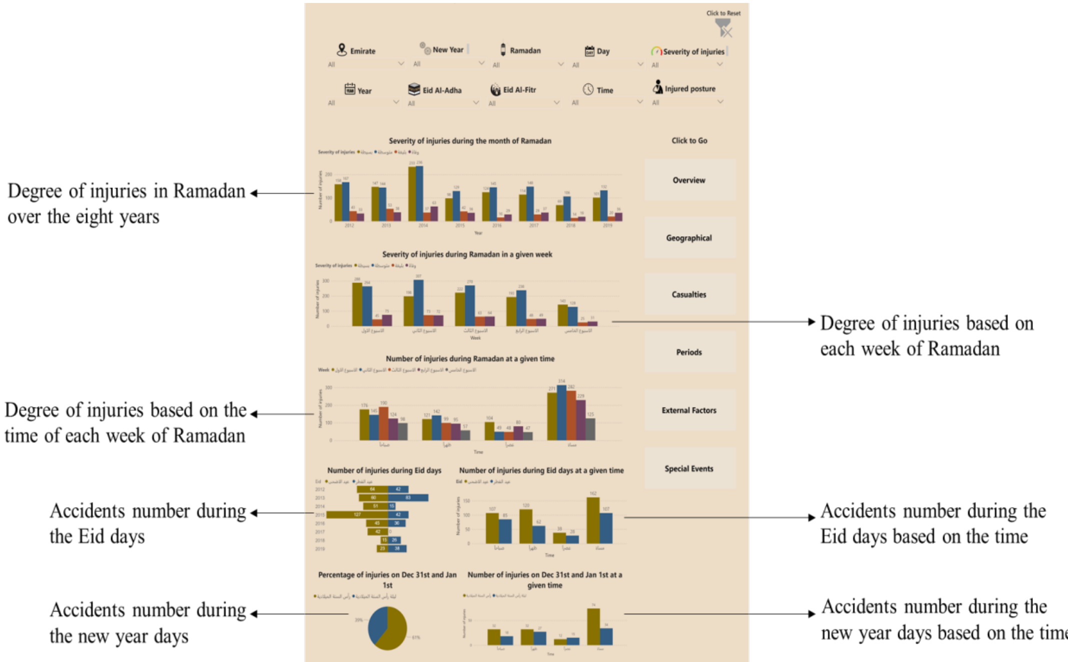

Figure 7: Special events page structure.

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