IFN712-1 Research in IT Practice

Assignment 3A: Research paper

Automating Traffic Congestion Analysis in Brisbane: A Comprehensive Study on Intersection Dynamics and Real-time Analytics

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Abstract

Brisbane grapples with intensifying traffic congestion due to urban growth. This research focuses on understanding the intricacies of this issue, offering solutions through data-driven analysis, automation, and tool development. Traffic congestion not only hinders daily life but also poses environmental and health challenges. The research primary aims to understand the traffic dynamics at intersections and to automate the process of fetching real-time data for analysis. The study's objectives encompass graphical representation, interactive visualization tool creation, real-time data authentication. The significance of this research in the potential benefits it can bring to transportation system. These include informed traffic planning, improve economic efficiency, reduce environment impact. The research is structed into phases encompassing traffic data collection, data interpretation and visualization, automation for real-time analytics. Ultimately, this research seeks to aims the solve the issue of traffic congestion in Brisbane be delivering practical tools and insights to enhance traffic management and overall quality of life for its residents.

Keywords

Traffic congestion, lane capacity, degree of saturation, Traffic volume, lane detectors, Traffic congestion performance

1. Introduction

Brisbane has experienced rapid population growth and urban expansion in recent years. As the thriving metropolis continues to evolve and attract more residents, it faces a growing challenge in traffic congestion. Due to rush in population and urbanization, it led to an increase in demand for transportation services. The resulting traffic congestion, especially at intersection, has emerged as a significant concern, affecting the city's transportation system and daily life for its residents [1]. Traffic congestion not only impact daily inconvenience but also has great consequences on both the community and the environment. This results in time and productivity losses but also has adverse environmental and health impacts. Increased air pollution due to vehicles and elevated stress levels among commuters are among the visible consequences. This research study aims to address these critical challenges by examining the complexities of traffic congestion in Brisbane and developing a tool to mitigate its impacts. The research problem tries to solve for understanding of the major factors contributing to traffic congestion at intersection in Brisbane [2]. Previous studies have touched upon traffic congestion in the city, but there is a need for more in-depth research that considers real-time data and automation to provide actionable insights and tools for efficient traffic management.

To address this problem, this research sets out to answer two critical research questions:

RQ1: How to develop traffic dynamics at the intersections level?

> **Obj1:** Develop a sensor-based representation that resembles the actual road traffic network, allowing for a more detailed and accurate understanding of traffic dynamics.
>
> **Obj2:** Utilize the extracted traffic information generated to develop an interactive visualization tool aimed to enhancing road operational traffic management, which can assist in decision-making and optimizing traffic flow.

RQ2: How can the above process be automated to fetch real-time data for generating traffic analytics?

> **Obj3:** Authenticate access to Brisbane City Council (BCC) open data sources and establish a mechanism for fetching real-time data at equal intervals to ensure data accuracy and relevance.
>
> **Obj4:** Scheduling the final visualization to continuously update with latest data.

The study aims to provide new insights and solutions to identify traffic congestion, which, in turn, can lead to several positive outcomes. By mitigating traffic congestion, we can contribute to a reduction in air pollution, a crucial step in making urban areas more environmentally sustainable. Reduced cost savings and increased productivity for businesses, positively impacting the city's economy. Lows the stress levels among commuters can lead to improve public health and well-being, as well as reduced healthcare costs. The research's insights can inform future traffic planning and infrastructure development in Brisbane, allowing for more efficient and sustainable urban growth. The research will be organized into several key phases:

- Data collection and Storage: The initial phase involves collecting and storing raw traffic data from BCC open data sources into a database, forming the foundation of the study.
- Data Interpretation and Visualization: The subsequent phase focuses on developing sensor-based representation of traffic dynamics at key intersections and creating interactive visualization tools to enhance road operational traffic management.
- Automation for Real-time Analytics: The research will explore mechanisms to authenticate access to real-time data sources and efficiently store this data in the database for analysis.
- Data Analysis and Insights: Advanced data analytics will be applied to extract valuable insights about traffic congestion and its patters.
- Tool Development: Based on the obtained insights, the research will lead to the development of tools and application to benefit both commuters and traffic management authorities in Brisbane.

In the following sections of this paper, we will delve into the specific methodologies, data analyses, and findings that will contribute to achieving these objectives and addressing the research questions in greater detail.

2. Literature Review

2.1 Introduction

The issue of traffic congestion is a persistent challenge that has a far-reaching implication for transportation, and overall quality of well-being. The aim of this section is to provide an overview of the existing research related to traffic congestion, with a focus on the evolving landscape of traffic management, the impact of emerging technologies, and the gaps that this research intends to address.

2.2 Progress in Traffic Congestion

Travelling has become a major part of our lives, for work, food, place of employment, and to travel to new places. But as the population grows, so does the quantity of private and public cars in the road that has increased dramatically, which lead to increase in global warming. Most of the harmful chemical emissions happen at the signals, intersection [3]. According to a study, intersection traffic signals generate roughly 50% more emission than high traffic [4]. There is a direct correlation between travel time and fuel consumption. A method of dealing with the problem of cars idling at red lights was presented in the study [5], and it can result in better fuel efficiency. Improving the percentage of passing vehicles at crossings can lead to more effective traffic flow, which is crucial for lowering carbon emissions and idle fuel consumption. The steps involved in the proposed model was to capture images of real-time traffic installed at every lane, then detect vehicles using captured images and then analyze the traffic density. Using traffic density as a parameter the green signal time is calculated and scheduler signals all the lanes to update the lights in real time.

A variety of strategies have been developed to reduce traffic congestion. One method is to given transportation authorities aggregate traffic data (lane occupancy rates, velocity, and intensity of traffic volumes), which they then feed into sophisticated traffic management systems to enable them to take appropriate action [6]. Many of the early studies primarily focused on traffic volume, road design, and their influences on congestion. The classification approach offers a fresh and more effective means of determining traffic congestion. A paradigm for classifying visual processes modelled by spatial-temporal auto-regressive models with both spatial and temporal components was suggested by Anto B.Chan and Nuno Vasconecelos [7]. This method improves the congestion estimation performance under extreme environment conditions [8].

2.3 Real-time Traffic Management

Xiaoyu Zhang, Shiqiang Hu presented the approach of presenting a real-time solution for video-based traffic congestion identification [9]. The proposed technique included multiple vehicle tracking, vehicle detection, projective transformation, and traffic congestion identification. When there are several cars, they come and disappear, changing the total number of cars. The sensors typically do not pick up every car that is currently on the road. Clutter that did not come from the car potentially reach the sensors. An alternative to conventional association-based approaches for estimating the number of cars and their statuses from a series of noisy and cluttered observations is the random finite set approach [10]. Advance filtering can be used to track unknow and time-varying vehicles in the presence of uncertainties, noisy traffic data. These ellipsoidal gates and filters can be used to determine each vehicle's speed as well as to shape the trajectory of the vehicle. Average speed of the traffic is the most important parameter when it comes to identifying traffic congestion.

Wan Li and Jeff Ban [11] created the deep intersection spatial-temporal network (DISTN), which takes into account both spatial and temporal features by utilizing convolutional neural networks (CNN) and long short-term memory (LSTM), based on real-time traffic volume data that predicts congestion at signalized intersections. The proposed model was to evaluate using real-time and demonstrate traffic conditions using deep learning.

Significant progress has been made in understanding and addressing traffic congestion, certain limitations persist at the current moment. Many studies rely on historical or limited data sources, which can hinder that the real-time monitoring and prediction of traffic conditions. Existing research tends tend to focus on predictive modeling or data collection, rather than offering an integrated solution.

2.4 Conclusion

This research seeks to fill the identified gap by developing an integrated system that fetches real-time traffic data, automates traffic analysis, and presents live traffic congestion information through an interactive dashboard. By addressing the limitations and providing a panoramic solution, this research aims to contribute to the enhancement of urban mobility, the improvement of transportation systems, and a more effective approach to addressing traffic related issues.

In summary, the literature review highlights the progression of this research. It identifies the existing gap in research, which underscores the need for automated solution. This gap serves as the driving force behind the development of the interactive dashboard presented in this research, with the aim of providing an integrated system for addressing traffic congestion in real-time. This research builds a valuable insight of previous studies, using real-time data, automate and interactive dashboard to address the critical issue of traffic congestion.

3. Methods

3.1 Methodology

We will create an intelligence algorithm to recognize traffic congestion at crossings in this section. The methodology adopted for this research aims to address the issue of congestion using Brisbane traffic data with a focus on identifying the congestion. Creating a sensor-based depiction of the road traffic network is one of the main goals, utilize the extracted traffic information to create an interactive visualization tool, automate the process of fetching real-time data and built a relational model which can be used to draw conclusion about the traffic condition. To achieve these objectives, a quantitative approach is employed, combining data collection, analysis, and tool development. By using rapid application development (RAD)process, a high-quality automation system can be developed [12]. There are four phases: requirements planning, user design, construction or implementation phase, testing and turnover.

3.2 Research Design and Development

The research design follows a mixed approach that encompasses both quantitative and software development methodologies. The key components of the research design and development are as follows:

- **Data collection:** The data collection involves obtaining traffic information from Brisbane City Council (BCC) open data sources. This includes data from loop detectors and other pertinent traffic monitoring systems. The requirement for real-time traffic statistics is to effectively address the issue of congestion guides the choice of data source.
- **Software Development:** Another important component of this research is software development, which is done along with data collection. Data management systems, data visualization libraries, and programming languages (Python, JavaScript) are all used in the building an interactive visualization application. Data analysis and visualization are done with Python and its

libraries, such Matplotlib and Pandas.

- **System Development:** Two key elements of the system development are the automated real-time data fetching and developing the interactive visualization tool. This includes creating and implementing algorithms for data processing, retrieving data, designing the user interface. The particular goal of the research serves as a guide for the design and development of the program.

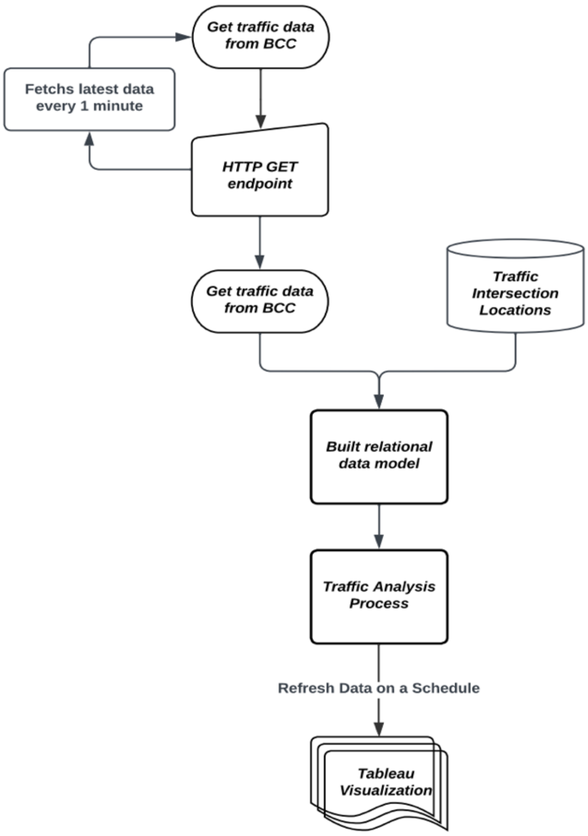

Figure 1. flow-chart of Research Design

3.3 Data collection methods

The data collection methods in this project involves two main components: data retrieval from open sources and real-time data acquisition as demonstrated by Jeong Seong and Yunsik Kim [13]. Since numerous researchers have shown that the API Layer technique is applicable for TC research, it was chosen to gather traffic data [14, 15]. Data is gathered from the BCC open data website to facilitate the development of the tool and to obtain historical traffic data. Information from the loop detectors is included in this data. Python scripts are used to authenticate, authorize, and retrieve the publicly available data, which in then used for data processing. It ensures the ability to collect data at predetermined intervals by authenticating access to the BCC open data volume to fetch real-time data. The interval is set to 1 minute as the portal updates with new data every minute.

3.4 Data Analysis

There are various realistic traffic conditions that contribute to clustering at intersections such as interfering traffic, switching to a different lane, and large group of cars that can limit feasibility. Extensive experiments have been done to intelligently control and improve the traffic efficiency at intersections [16]. To improve the likelihood of vehicles departing the signal fast, cut down on waiting times, and stop at red lights, the vehicles were first grouped and then multi-agent deep reinforcement learning was applied.

In order to classify the traffic, we have used a threshold approach. This threshold is generated using traffic parameters such as speed, capacity of the lane, number of vehicles passing through the lane detector [17]. A score of 100% indicates that demand and capacity are equal and that more traffic cannot pass through that lane or junction[18]. The degree of saturation (%) is a ratio of demand to capacity on each approach to the function. The maximum rate at which cars can pass through a specific location in an hour at a saturation flow rate and the ratio of the time that cars can enter the intersection determine the capacity:

$$c = s\left(\frac{g}{C}\right)$$

where c is the capacity, s is the saturation flow, g is the effective green time for the lane in seconds and C is the cycle length in seconds.

The volume to capacity ratio or the degree of congestion is calculated for each lane by using:

$$v/c = \frac{v}{s\left(\frac{g}{C}\right)} = \frac{vC}{sg},$$

where v is the demand volume of the lane in vehicles per hour. The v/c ratio represents the proportion of the area defining capacity that is occupied by volume.

3.6 Validation and limitations of the methodology

Several actions have been done to guarantee the findings validity and dependability. The authenticity of data is guaranteed by open available sources from Brisbane City Council. To guarantee proper depiction of traffic conditions, testing and validation are also applied to the produce application.

Nevertheless, this system has certain limitations. The study depends on publicly open available and accurate data source, which may have restrictions on the scope and calibre of the data. Furthermore, even while the dashboard provides insightful information on traffic congestion, it ignores issues like urban planning and road design, which require a more thorough and interdisciplinary approach.

In summary, the research technique integrates data gathering, software engineering, and system architecture to tackle the problem. This project seeks to offer a novel approach to the problem of traffic congestion in the city.

4. Results and Discussion

4.1 Results

The traffic can be grouped into three classes—high, moderate, and low congestion—using the congestion metric described in the section above. It is possible to classify lanes as undersaturated if their v/c ratio degree of saturation is less than 0.85. These lanes usually have adequate capacity and reliable operations. When lane groups have a v/c ratio of 0.85 to 0.95, it means the intersection is almost at capacity. While longer wait times might be anticipated, steadily growing lines shouldn't happen. Cycle-to-cycle changes in traffic flow make lane groups with a v/c ratio of 0.85 to 1 less stable in terms of traffic flow. This indicates that a natural variation in traffic flow is more likely to occur when traffic load is closer to capacity. We use these thresholds to define which lane groups have high, moderate, low congestion, which focuses on the objective 1 of this research.

The objective 2 of the project is to build the final data visualization that displays the above measures for each lane in the city and displays the list of regions for each congestion class as shown in Figure 2. The dashboard represents congestion groups that are divided into three different colors to easily identify by the viewers. Along with degree of congestion, the measured flow for a lane, or the number of vehicles for that lane's cycle, and the reconstituted flow for a lane, or the anticipated number of vehicles for that lane's cycle, are also shown on the dashboard.

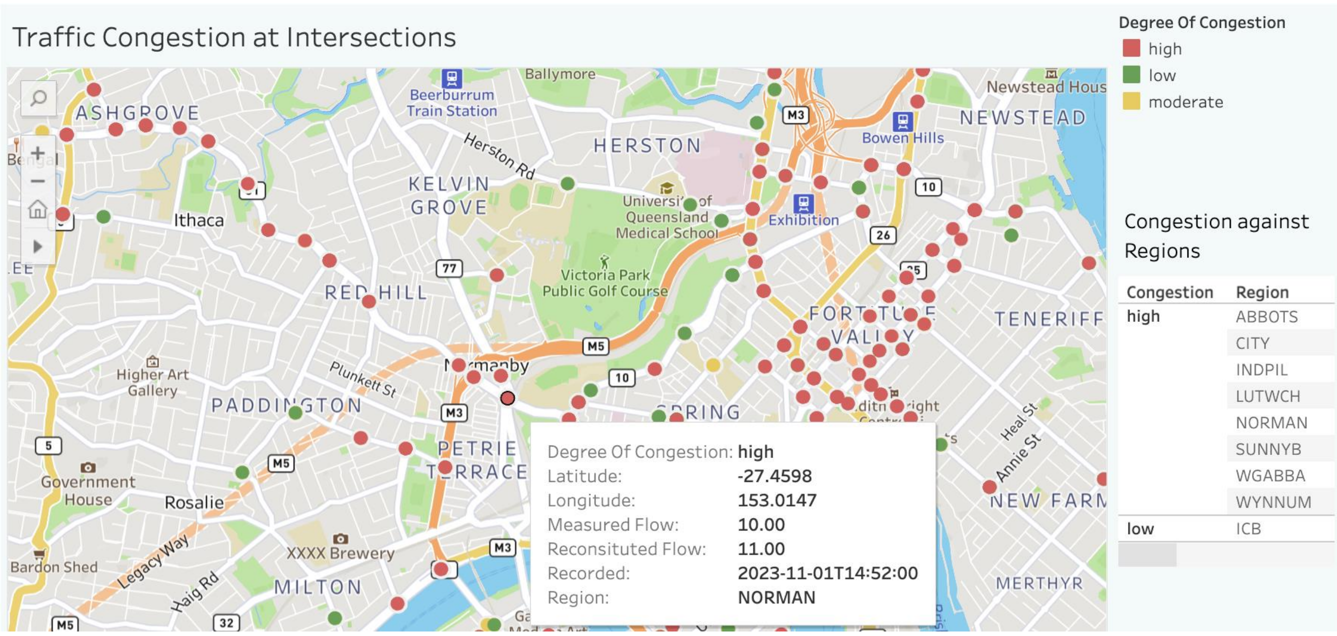

Figure 2. Dashboard view of Traffic Congestion

The dashboard offers a comprehensive tool for filtering and understanding traffic congestion data within different regions of the city as shown Figure 3. It enables users to pinpoint congestion patterns, aiding in strategic route planning and decision-making for more efficient citywide travel [19].

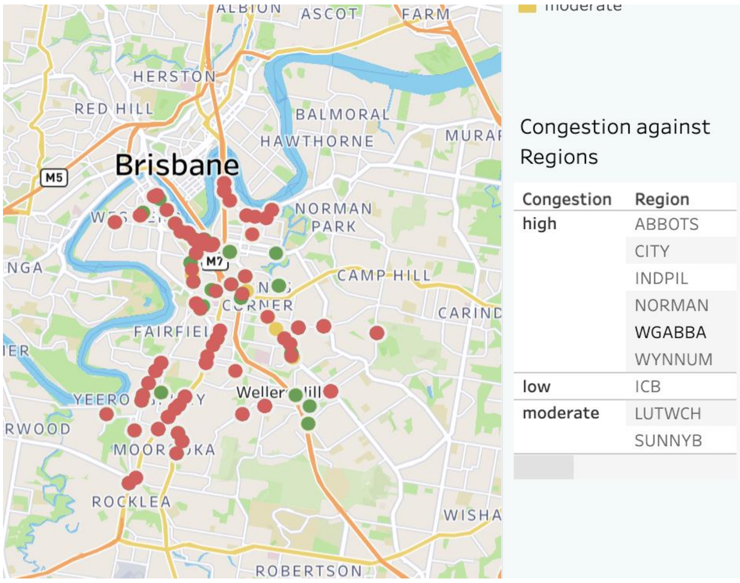

Figure 3. Congestion view for one region

The dashboard embeds real-time data from the BCC portal. The data is updated every one minute since the portal add new data approximately after one minute. The dashboard can be viewed at an endpoint (localhost:5050) which is scheduled to refresh data source every 45 seconds to fetch latest data. The process of data collection and analysis can take time which can introduce latency between the current time and recorded time of the data. There is a latency of 4-5 seconds. this focuses on the objective 4 of this research. To continuously fetch data from the data resource, a corn job is created using Python to authenticate the user from the BCC portal and get the traffic management – intersection volumes data. This step answers the objective 3 of the research.

The results emphasized several significant elements of Brisbane's traffic. The peak traffic hours in Brisbane occur during the morning and evening rush hours. During these periods, there was a substantial increase in the number of vehicles passing across key intersection close to the CBD. There is a usual pattern discovered, in which individuals are either heading to work or making their way back, leading to increased traffic. During the weekdays, the traffic was noticeably more congested, which is in line with the effects of everyday commuting. Weekend traffic move more smoothly since movement has less of an impact. Another pattern observed was the traffic volumes at crossing close to core business districts were continuously high, although patterns at residential neighborhoods varied significantly throughout the day.

4.2 Discussions

The result of this research provides a valuable insight into traffic congestion specifically at key intersections. Addressing research question 1, the analysis of traffic volume data revealed crucial findings related to peak traffic hours, intersection-specific patterns. The development of a visualization tool and the successfully implementation of real-time data fetching that align with the research objectives defined at the beginning of this research. The most important conclusions concern the patterns of traffic at important crossings. Everyday traffic congestion is highlighted by the identification of peak traffic time and regions where the traffic is high. In order to create plans to lessen traffic during these peak hours, traffic management authorities can take a note of this findings. The findings found strongly align with the research objectives. By analyzing traffic volume data (Obj1) we were able to construct a geographical representation of the traffic. Developing an interface for displaying real-time traffic conditions, was the emphasis of Obj 2. Fetching and accessing authorization to BCC open data sources were the two efficiently carried out components of Obj 3. The feasibility of the dashboard to refresh for latest data was the focus of Obj4 and it was also successfully completed. The resultant dashboard is consistent with a several well-established traffic studies that have noted comparable trends regarding congestion. Although the particular outcomes are peculiar to Brisbane, the general patterns align with the traffic dynamics found in many cities. One such research was done by Maxwell G Lay [20]. This research was on estimating and calculating the cost of traffic congestion.

There are few restrictions that must be noted. The dashboard offers insightful information on traffic, it ignores important factors like road design that contribute to traffic congestion. The notion that traffics volume pattern analysis by itself is a sufficient means of resolving traffic congestion concerns is one potential weakness in the interpretation of the results. A complete approach would be to take road design, traffic signal timings and traffic density is required for a better solution to congestion.
It can be challenging to define a metric for congestion. One such metric is the volume-to-capacity (V/C) ratio, which is the number of cars passing a certain location on a road divided by its capacity [21]. Congestion is not, however, quantified by the number of passing cars. For instance, in a severe traffic jam, very few cars would pass in front of a traffic counter in a given amount of time. Even if the same number of cars might pass by the same counter in the same amount of time during the day, the same road will be nearly deserted at night. This indicates that traffic density, not volume, is the measure of congestion [22].

In summary, the findings complement the goals of the research, it offers a workable way to deal with traffic, and correspond with traffic patterns seen in the city. To fully address the cause of congestion, it is imperative to recognize the limitations and the necessity of a multidisciplinary approach. Further research might build on these discoveries and ways to improve the scalability and accuracy of traffic data analysis in Brisbane and other cities.
GitHub repo for this project https://github.com/priyagunda1501/Traffic-Congestion

5. Conclusions

- This research is dedicated to understanding and alleviating traffic congestion using intersection volume data, has provided significant insights and practical solutions.
- The development of a real-time traffic congestion dashboard, which fetches and updates at fixed intervals, stands as a noteworthy accomplishment. It displays live traffic congestion information which can be used to make informed decisions.
- This dashboard offers vital, up-to-minute traffic congestion information, empowering decision-makers with the data they need to make informed choices. Additionally, the introduction of an automated traffic analysis system represents a giant stride forward in comprehending the intricate dynamics of traffic patterns and congestion.
- The ability of access real-time traffic data and automate traffic analysis can revolutionize the way we manage congestion and urban growth, not only in Brisbane but also in other cities worldwide.
- The horizon of possibilities extends beyond the scope of this research. Scaling up the analysis to encompass the entire city of Brisbane represents a logical progression. However, such an expansion necessitates a focus on optimizing computational resources to manage large datasets efficiently.
- Extracting travel information for the entire city can be computational time taking and expensive job, to overcome that new methods can be introduced to improve the performance.
- Only loop detector data is used in the current project, additional resources can be included to find extra information on the traffic.
- Authentication as a Service (AaaS) provides a cloud-based solution to authenticate client or user to the services over the internet. Authentication process can be built as a middleware service, which serves as an intermediary layer between the traffic data sources and the research team.

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