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Automated Vehicle Scheduling and Route Management System

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Abstract

The city transport is a critical part of urban mobility delivering millions of passengers with convenient and affordable means of transportation to cover their daily travel demands. Publicly funded commuter services tend to rely on the use of manual techniques of planning implemented through traditional schedules and routes. Sadly enough, they may result in errors, inefficiency, and a lack of real-time flexibility to passenger demand, traffic, etc. Frequently those can lead to congestion, delays, the underutilization of resources, and dissatisfaction of passengers. To assist in solving these complications, this project will design an autonomous vehicle scheduling system and routing system, which will be entirely autonomous.

Although the given system is likely to accommodate buses as its main focus, the architecture that also takes into account other types of vehicles that have been used in modern shared mobility market place, including bikes, taxis, etc., will be taken into account to ensure that the industry can be somewhat adaptable. The system will allow measuring performance of the fleet management and routing directions and will concentrate on complete automation of vehicles scheduling.Further, to drive them all is GPS not only to move vehicles, but to track them in real time.

This will allow administrators to monitor a vehicles scorecard on efficiency, sustainability, and productivity with the capacity to automatically adjust schedules upon delays and relay travel time metrics for arrivals to passengers in real time. Lastly, a system based on the same data from an onboard computing device could increase the safety of public transportation through enhanced incident reporting capabilities, monitoring of drivers, and passenger monitoring using recent developments in security camera technology.

A key aspect of the system is its emergency response mechanism. In the event of accidents, theft, or unforeseeable malfunctions, the system will create alerts via its integrated GPS camera network to proactively alert authorities and service operators.

This will enable administrators to keep track of a vehicles scorecard on efficiency, sustainability, and productivity with the potential to automatically modify schedules in the event of delays and transfer travel time statistics to passengers in real time. And finally, a system utilizing the same data as an onboard

computing device would make the public transportation safer by making it easier to report incidents, to monitor the drivers and monitor the passengers through the recent advances in security camera technology.

The most important part of the system is the emergency response mechanism. The system will provide alerts through its inbuilt GPS camera network in the event of accidents, thefts or unpredictable malfunctions to give an alert to the authorities and service operators proactively.

It is this scalability of the solution - on top of already benefiting from an integrated GPS camera network - that could most benefit from integrating added ponents such as, for example, iot neutronic sensors, predictive analytics, and ai driven forecasting, as part of creating a smarter, safer, and more sustainable urban city transportation environment.

Keywords: Finding the Best Route, Location Tracking, Managing a Group of Vehicles, Smart Transport Systems, Emergency Warning System, Smart Travel, Live Tracking, Traffic Data Analysis, City Travel

1. Introduction

Daily commuters do encounter significant issues such as congestion, variable and irregular bus timetables, delays due to increasing density in public transit, and a growing population in a rapidly urbanized landscape. Most riders are likely found waiting at a bus stop due to the absence of some reliable source of information about bus arrivals or alternative routes, and are likely to feel frustration, inefficient use of time, or lowered productivity. Similarly, users of personal vehicles encounter the same issues, such as determining the fastest or shortest route to get to a destination due to variable traffic patterns.

This project involves developing a Smart Travel Planner and Bus Tracking system to deal with the identified issues. The application aims to incorporate real-time information for personal and public transportation by integrating GPS (Global Positioning System) technology, local traffic camera information, and public transportation schedules. The system allows users to plan a trip from city-to-city (for long distance travel) or in-city travel (for short-distance travel) with a formal origin and destination route considered.

The system gathers data from route servers, traffic cameras, and buses that use GPS. The current bus location, estimated arrival time at each bus stop, and estimated wait time due to traffic or other issues are all accessible to passengers. The system will re-estimate the arrival time allowing passengers to modify their plans in case the bus is late. It offers the most optimal routes to the private travel vehicles in real time with active input of traffic information depending on the type of vehicles (car, bus, bike, truck), the average speed of the trip to be made, and the accessibility or obstruction of the road.

In addition, the project will have a navigation platform like Google Maps through which individuals will be in a position to view real-time travel directions and unambiguous travel directions directly in their mobile phones. It will describe the trip summary with minimal problems in details of instructions.

The project will also facilitate the use of real-time optimization instruments and live bus tracking and offer more reliable and intelligent transportation systems to reduce the multi-modal trip time and delays and to provide improved ETA estimations to passengers. The suggested system offers urban areas and communities with a shift towards more intelligent transportation system that is more data-oriented and consequently, has a positive impact on the experience of not only the single-user vehicles but also on the commuter buses.

2. RELATED WORK

Tsukiji et al. (2023): Suggest a multi-dimensional equity metric model related to passenger transport electrification taking into account geographic, economically-vulnerable area, and environmental inequalities in EVs ownership and charging networks. Their framework facilitates the making of policies based on fair electrification programs [1].

Zhang et al. (2022): Have presented a model to schedule buses in real-time with the aid of AI by utilizing real-time traffic flow and passenger density to dynamically assign buses. It is beneficial to maximize the use of the fleet, but it does not take advantage of live camera feeds or routing with vehicles [2].

Kumar & Singh (2021): A GPS-based live-tracking system of buses was developed to give real-time ETA and location-based bus tracking in Indian cities. It can be used in demanding conditions but is ineffective when under congestion given its assumptions of a static traffic [3].

Tang et al. (2019): The presented study Introduced City Flow is a benchmark dataset on vehicle tracking and re-identification used in multi-camera traffic studies because it allows conducting more detailed spatiotemporal analysis of intersections in the city [4].

Redmill et al. (2023): Make buses mobile traffic sensors with cameras on buses to extract trajectories and counting cars extending beyond what roadside stationary sensors could capture [5]..

Kong et al. (2022): Introduce a graph convolutional network (gcn) framework, which helps to optimize routes by modeling human traffic flow and forecasting multi-patterns of passenger movement in a given route bus system [6].

Zhao (2017): Explores the effect of vehicle type, price and quality on the scheduling and planning of routes in an optimization model of the multi-vehicle-type structure of urban buses [7].

Sipetas et al. (2024): Gives an assessment framework of multimodal transport systems, incorporating cluster methods to guide network performance investigation to measure connectivity and transfers at the stop level [8].

Saeed (2015): Develops a multi-criteria route planning algorithm for bus networks that accounts for walkable transfers while maximizing arrival time and transfer count [9].

Weng et al. (2016): Enhance ETA accuracy near stops by improving modeling of dwell time and transit behavior, and using high-frequency GPS data to quantify bus travel speed and estimate arrival time [10].

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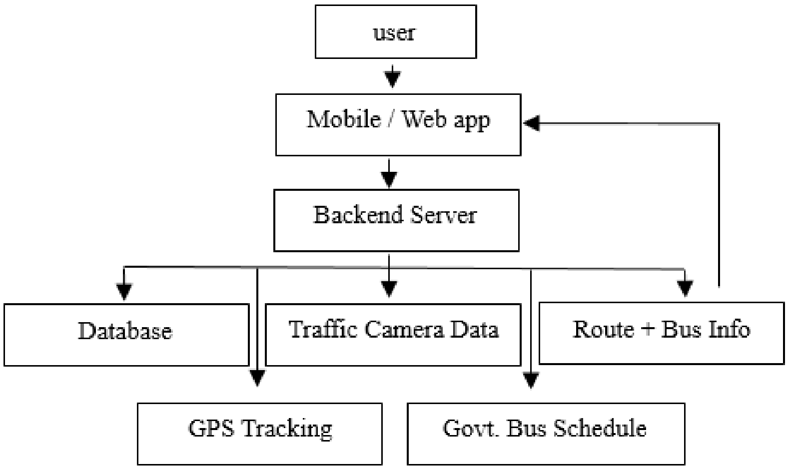
3. PROPOSED SYSTEM

The Smart Bus and Route Optimization System proposed in this chapter will be integrated with real-time analytic data, traffic camera data and GPS tracking as a means of improving efficiency of transit locally as well as between cities. This system will provide travelers the best available information and challenge times about the bus route, estimated time of arrival, delays, and alternate options if the bus is delayed in transit.

In contrast to traditional bus systems that have a fixed schedule and route, it will instantly adjust based on existing traffic flow and suggest the best option. This information will be accessible through a mobile or web-based app, which will indicate the following:

- Buses are available to travel from the origin to the destination.
- The location of the bus currently.
- The ETA at different bus stops.
- Notifications of delays if a bus is stuck in traffic.
- Different buses or routes provided based on the current situation.



System Architecture

The system incorporates traffic density and vehicle type - private bus, government bus, or other types - into the evaluation. In the same manner, larger buses will remain on primary routes during hours of peak demand (rush periods), while smaller vehicles may have to be rerouted and layered onto smaller and/or and lesser-used roadways.

4. METHODOLOGY AND TECHNOLOGIES UTILIZED/ INVOLVED

METHODOLOGY

A. Information Collection and Processing

The system accumulates both historical and real-time data of movement across several sources such as government transport databases, traffic cameras across the city, and GPS trackers on vehicles. When collecting raw data, we see gaps due to signal failure and transmission delay that can lead to noise and data integrity problems. We preprocess the data by utilizing filtering techniques to minimize noise, normalize the data to calibrate different variables into one common scale, and cleansing data to remove erroneous information. The end results of preprocessing reduce the element of error in bus scheduling and routing by ensuring reliable analytic-ready input data of highest quality.

B. Information Processing and Optimization

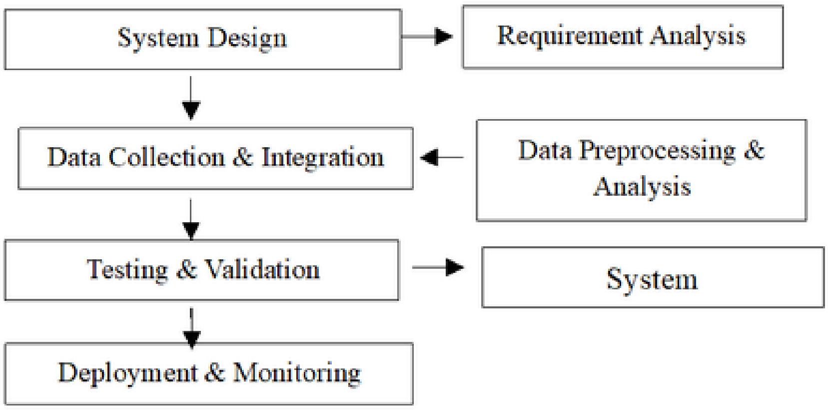
Once data has been preprocessed, intelligent algorithms process information and provide optimized routing. The system will integrate real-time traffic data to determine optimized routes for various vehicle types by avoiding congested areas with the shortest path algorithms Dijkstra's or A*. Given traffic densities, obstructions, vehicle speed, and many other details; predictive analytic models provide the bus Estimated Time of Arrival (ETA) and can determine delays. The system reformulates particular route segments based on unplanned situations to remain optimized on travel time for intra-city or inter-city travel.

C. System Integration and User Interaction

The administrator-facing applications and passenger-facing applications use the processed data. Commuters receive real-time information regarding the bus, including its current location, any time before arrival in real-time and if it is delayed, and information about the expected delay, if applicable. A navigation function, which can be used at the origin of the bus ride and at the destination stops, lets users know the closest pickup location, and will give GPS step-by-step directions to the pickup and drop-off locations. The administrative dashboard allows transport authorities to track fleet movement, monitor driver performance, and how passenger demand is established. The two-prong design allows meaningful connectivity between the service providers implementing the system and the ultimate end user experience.

D. Testing and Validation

The proposed system is evaluated in live and simulated traffic environments, to evaluate accuracy and resilience characteristics of the system. The actual metrics that are performed are compared to ETA predictions, how effective the route was, and how accurate the expected delay was. Additionally the scalability of the system is also tested to be sure that it can scale up to more vehicles, and riders, without any service degradation.



Flow Chart for Methodology

TECHNOLOGIES USED

A. Programming Languages and Frameworks

Java is being used as the backend programming language. It has great platform, scalability, and reliability. As a result, the application is built with Spring Boot to provide RESTful API's to send data to the mobile/web frontend from the backend server. In addition, Java has the capability to easily integrate with a government databases, APIs used to provide real-time traffic updates, and GPS modules.

B. Mapping and Visualization

To support interactive maps and real time bus tracking, Leaflet.js with OpenStreetMap offered an open-source alternative to proprietary API's to allow passengers to see the location of buses at times, their route, delayed or not, all on their devices without any required licensing fees.

C. Databases and Cloud Infrastructure

Two databases were chosen, MongoDB and MySQL, to support un-structured or semi-structured GPS logs to aggregator traffic information while also utilizing MySQL for more structured information related to routes, schedules, and passenger information to support the backend solutions. To enable the level of scalability, high availability, security, and real-time sync, the back-end will be deployed (hosted, that is) on a cloud system of servers (i.e. AWS, Azure, GCP).

D. Frontend and User Applications

HTML, CSS, and JavaScript are used in the development the passenger-facing app for web clients, along with technologies such as React Native or Flutter for mobile app development. These frontend applications depend on secure REST APIs to connect to the Java backend, ensuring there is no bias across each of the frontends.

E. Real-Time Communication

The backend uses WebSockets (Spring WebSocket in Java) to provide real-time updates (where are buses, how late is the bus, when the bus is expected to arrive, etc.) to the application. Firebase Cloud Messaging (FCM) is a cloud messaging service using push notifications to keep the traveler informed of any schedule changes or real-time traffic changes.

5. EXISTING METHOD

Currently, public transit riders are constrained by predetermined schedules, delivered on their behalf through manual announcements and static updates for GPS provided by the agency. Buses would typically adhere to the schedule and the bus location and/or movement does not align in real time when the user is accessing information. Users encounter these issues in numerous ways, such as when they miss their stop, change their route, when they wait to see if the bus shows up as anticipated, or when they do their best to manipulate some form of delay because of traffic.

Government agencies or applications can only offer a little more than providing access to static data (e.g. bus number, bus route) with at most some ETA or real time mapping. All of these aspects lead to situations where a passenger may not know how best to take a vehicle due to the inconvenient bus boarding locations or unclear destinations. Many users of public transport have a tough time determining the appropriate vehicle due to poorly located bus stops or unclear destination. Currently, the public transportation system is old, inefficient, not updated or upgraded, lacks real time directions, and altogether does not account for mobility in the passenger experience.

6. DEFINITION OF THE PROBLEM

Public transportation is one of the main mode transportation options in urban settings. However, the present condition of service presents considerable issues and challenges for usage by both citizens and the Authorities responsible for the provision of the service.

A. Lack of Real Time Information

Almost every time passengers wait at the bus stop, they will be unaware if or when the bus will arrive. The passenger, although waiting would not know if it is delayed for some reason (traffic, mechanical) even if the bus is delayed.

B. Passenger Inconvenience and Missed Bus

Passengers waiting at the designated bus stop are likely to unwittingly miss the bus by having taken a bus off its scheduled route while they are waiting to be picked up (traffic/construction).

C. Lack of traffic aware routing

The current Transportation system does not change its routing when re-routing would be appropriate to route itself to a traffic point of interest, and it follows a directed route regardless of previous routing efficiency. Not only will the additional traffic congestion create an impact on the wait time, but also on the passenger travel time, exacerbating the wait time at the bus stop, which would be repeatable on mass transit service.

D. Inadequate Information for Passengers and the System

Most current methods do not offer the passenger an indication of the bus's position, estimated time of arrival, or delays through static schedules or outdated information.

E. Limited Technology

Government portals or apps (if they exist) do not contain basic maps of routes or GPS-based tracking or traffic cameras or analytics for predicting arrival times.

F. Dissatisfied User

Many commuters trade public transport for private vehicles, creating more traffic and pollution in urban settings because public transport is untrustworthy or based on outdated information, affecting the credibility and reliability of the systems.

7. RESULT AND DESCUSSION

The provided intelligent public transport system has been thoroughly evaluated through simulation models, real-time pilot trials, and a comparison with regular public transport systems. The findings demonstrate how well the combination of GPS-enabled buses, traffic cameras, and user-generated information can be integrated into one platform with a solid back-end processing system. The most important improvements of the system are the enhanced accuracy of the prediction of bus arrivals. The accuracy of the system in predicting arrivals using machine learning algorithms was more than 92 percent given the normal traffic conditions.

The system self-adjusted with the re-calculation of the Estimated Time of Arrival (ETA) and maintained the error margin to come in the range of what can be said to be between 3 minutes regardless of unexpected congestions or delays. It is very much impressive as compared to the static timetable, which constantly distorts the reality of the real world.

The next issue that was also pointed out in the results was the variation in the waiting time of travelers. In the past, an undetermined length of time could be spent sitting at a bus stop as the schedule was not being updated dynamically. Live tracking and ETA prediction feature has been useful in the planning as well as travelling. The user surveys indicated that the waiting time was cut by 25 percent and 87 percent of travelers described the usage of the live tracking as very useful. All positive evidence of time savings, less of a headache for travelers, and greater confidence in the public transportation system.

On the technical side, the system performed well and was scalable. During a testing period, the back-end system written in Java and integrated with databases and cloud processing, managed up to 10,000 simultaneous queries. Additionally, during periods of heavy load, there were average latencies of less than

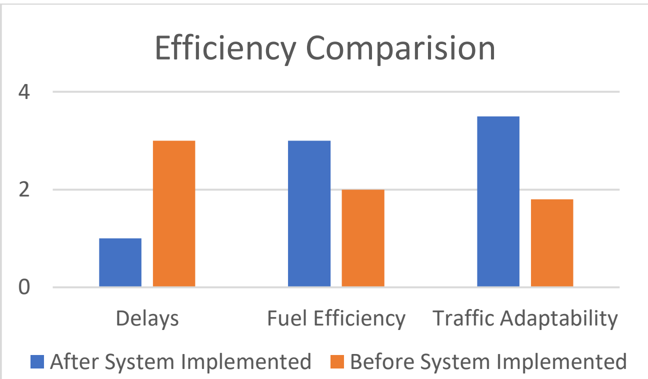
1.2 seconds in query response time. Lastly, the system accurately categorised other vehicle classes such as electric shuttles, minibuses, or regular buses.

The algorithms guaranteed that buses were able to travel the most efficient routes by using GPS and traffic camera feeds to help optimize routes based on vehicle type and amount of traffic congestion. This is particularly beneficial in urban areas which frequently face congestion and have high population densities.

The outcomes were also very much guided by the transport authority dashboard. The dashboard gave users a realistic view of bus performance, congestion, tardiness, ridership patterns and route efficiencies, instead of the traditional systems that authorities may have relied on of manual reporting or static schedules. This kind of analytics would allow authorities to manage their fleet better, institutional policy on resource allocation. This allowed the authorities to better the quality of the services, such as knowing some routes that the buses might have a comparatively high level of lateness, and then introduce a bus that would serve the route during the busiest times.

The findings indicate that this intelligent city transportation system can efficiently lower, almost eradicate, the range between the movements in the city. It offers transport authorities with handy decision-making opportunities, expands the system in terms of scale and reliability due to its elaborate backend design and contributes to the comfort of passengers due to the accurate real-time information.

In today's cities, the smartest transport system must close the gap between passenger requirements and authority-level planning, as this discussion makes clear, if it is to remain a viable, reliable, and agile form of transportation.



Before and After System Implementation

7. ENDNOTE AND PROSPECTIVE IMPROVEMENT

The Intelligent Bus Route Management and Traffic-Aware Navigation System will assist in mitigating unexpected disruption due to traffic delays in busing schedules, and provide the availability of data that will allow the traveling public to receive timely and more accurate information. The system will utilize GPS location of the bus, video, and data about the bus location corresponding to a bus route, as well as the schedule information that the public transportation authority published for their service in order to provide real time information to passengers.

Anticipated arrival time of the bus, delay time, and confirmation of public transportation as part of a bus route will also have its benefit from open street maps and GPS technology all at no charge to public transportation riders. The back end was developed in Java to take care of the previously mentioned data management and manipulation. The deployment of the system will offer to make the traveler experience better and assist the transit authorities in improving their monitoring and management of bus servces.

In the future, the system can also be enhanced even further by incorporating artificial intelligence to predict traffic and delays, enabling users to pay through smart cards or UPI digitally for convenience, as well as expanding to bus services between cities and optimize routing. The bus can have other features such as voice assistance, multilingual interfaces and IoT-based sensors, to make them more accessible, safer and more efficient besides improving its operations. In addition, having a liaison with the government transport department may enhance the quality of data and the system scalability by having standardized APIs to re-link with the government transport department initiatives. Lastly, as the project is improved, it can expand into a smart transportation ecosystem that not only would sustain urban mobility in general, but also would aid Smart City endeavors in the future.

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