IMPROVING THE QUALITY OF LIFE IN AUSTIN THROUGH THE REDUCTION OF TRAFFIC CONGESTION

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ABSTRACT

The assessment of traffic congestion in Austin, Texas prompted the development of a comprehensive solution aimed at addressing the issue. Commuters often face prolonged travel times and uncertainty surrounding bus or car arrival schedules, leading to passenger discomfort. In order to enhance the quality of public transportation services and tackle these challenges, this research proposes the implementation of an innovative design encompassing various key components, including customer and system requirements. Furthermore, this novel design incorporates the capability to monitor potential passenger and pedestrian patterns that could contribute to unexpected traffic congestion or accidents. The effectiveness of this model design was compared favorably with the Austin Core Transportation (ACT) and Austin Strategic Mobility Plan (ASMP), both of which are slated for implementation in Texas. Additionally, a case study was presented to demonstrate a sample implementation of the proposed model, showcasing its accuracy and indicating its potential for high user ratings, thereby confirming its efficacy in improving the quality of public transportation services

1. INTRODUCTION

Poor transport infrastructures, rising road accidents, traffic congestions, and increased emissions are some of the problems facing the transportation sector in recent times [1, 2]. Ensuring a sustainable, efficient, and functional public transport system is crucial for mitigating congestion and pollution in urban areas worldwide. Transportation plays a pivotal role in the economy of the United States, significantly contributing to its overall productivity and growth. According to data from the U.S. Department of Transportation, the transportation sector accounted for 5.4 % of the country's Gross Domestic Product (GDP) in 2020, reaching a staggering $1.2 trillion [3]. This sector employs millions of Americans, supporting over 11.5 million jobs in various transportation-related industries. Efficient transportation networks facilitate the movement of goods, enabling businesses to reach domestic and international markets. Due to the importance of this sector, there is always the need for transportation modes to compete and complement each other.

The road transportation system in Texas largely needs improvement yet the purchase of cars is increasing [4]. This will ultimately lead to an increase in traffic congestion especially in the urban areas. Ensuring the sustainability of cities amidst ongoing urbanization is of utmost importance [5]. Several cities have seen the need to create more road networks and delineate more spaces for future road plans. Nonetheless, an increase in population and car demands often lead to more car trips and unintended consequences such as traffic congestion. Traffic congestion will not only lead to the decline of various economic and social functions but also lead to the continuous deterioration of the urban living environment, becoming a "stubborn urban disease" hindering the development of the city. The direct impacts of traffic congestion on social life include travel time, gas cost increase, and accidents which sometimes cause inestimable loss. In addition, heavy traffic also leads to an increase in accidents, which in turn worsens traffic congestion. The increased cost of travel not only affects work efficiency but also inhibits people's daily activities, reducing the vitality of the city and the quality of life of residents.

The influence of urban traffic on the natural environment includes automobile exhaust pollution, noise, and vibration. The urban transportation system has become a major source of air pollution, and in some cities, motor vehicles have even accounted for the entire pollution source. In addition, the impact of traffic noise and vibration on the living environment of residents and sensitive facilities such as hospitals and schools in the surrounding areas of the road has become a prominent social problem. Gas exhaustion from vehicles is the main pollution source of the urban atmosphere. The main harmful emissions from automobiles are carbon monoxide, hydrocarbons and nitrogen oxides, odors, particles, photochemical fumes, etc. According to the detection data of large and medium-sized cities in developed countries in Europe and America, all kinds of major pollutants in cities, such as carbon monoxide (CO), carbon dioxide, hydrocarbons, and motor vehicle exhaust accounts for about 40% to 90% of the total amount of formaldehyde, nitric oxide, nitrogen dioxide, sulfur dioxide, copper particulates, and suspended particulates. In addition, according to the survey of 11 urban areas in the United States, more than 67% of the CO in the atmosphere, and more than 92% of the hydrocarbons are vehicle emissions [6].

In recent years, there has been more news about self-driving cars which are predicted to be the future of transportation. While it won't be the dominant mode of road traffic for decades to come, the emergence of self-driving cars is becoming popular. Self-driving cars could significantly reduce the distance between the front and rear of the vehicle and avoid road accidents caused by human error. However, it will take time for autonomous vehicles to become the dominant mode of road traffic, and whether these advantages become a reality will depend on customer acceptance of this technology. We know that once autonomous vehicles are officially on the road, they will greatly influence the long-term investment decisions of major infrastructure (such as roads, toll roads, railways, large parking lots, and mass transit) and infrastructure investors.

Traffic congestion takes a huge toll on the economy as a whole. First of all, there is a marked decline in the efficiency of people's daily business. The congestion wastes a lot of effective work and rest time, and the tension and depression caused by the congestion also reduce the work efficiency of the citizens. In terms of government investment, in order to alleviate congestion, the government has to increase investment in road maintenance and construction direction, widen the original road, and build microcirculation roads and parking facilities. The air pollution caused by traffic congestion also requires the government to invest heavily in environmental control and pollution treatment. And pay more medical insurance fees for the patients caused by air pollution, and increase the investment in hospitals and other medical facilities. Furthermore, the transportation industry drives consumer spending by connecting individuals to employment opportunities, education, healthcare, and recreational activities. Consequently, any improvements in transportation infrastructure and systems have the potential to enhance productivity, stimulate economic activity, and improve the overall well-being of the nation.

Due to the few public transportation stations, slow running speeds, incomplete coverage, and lack of comfort, a large number of people still choose to drive private cars, which worsens traffic congestion. As the economic situation improves, more families are buying private cars, which gradually reduces the number of people who ride bicycles and walk. The occurrence of unexpected weather also leads to the overuse of private cars. In the current policies on transportation, there are already fees for car purchase, parking, and fuel tax. If congestion charges are added, it may bring negative social impacts. The objective of this paper is to provide a suitable model to reduce traffic congestion in a busy city like Austin, Texas.

2. AUSTIN TRAFFIC SITUATION

According to a navigation provider [7], Austin is ranked among the cities having the worst traffic congestion problems in the world in 2019. After conducting a global index study measuring 2018 traffic in 403 cities across the globe, Austin is ranked No. 19 and 179 in the US and the world respectively, for most congested traffic. In the state of Texas, Austin is also ranked No.1 for having the worst traffic congestion. According to the index, drivers in Austin will have their travel time increase by an average of 25% due to traffic congestion. The worst time to be on the road is weekday evenings from 4 p.m. to 6 p.m., where travel times can be an average of 63% longer.

Fig. 1. shows the real-time traffic map in Austin at 4:30 PM. Roads near downtown Austin became busy (represented in yellow color) in working peak times such as morning and late afternoon. The red/yellow dots show the car accidents reported, which are common and frequently happen on these roads. **Table 1** shows the traffic report for Austin on May 5th. Among those eight reports, seven of them are related to crashes and traffic with many of them happening in regions near downtown Austin, the business concentrated areas.

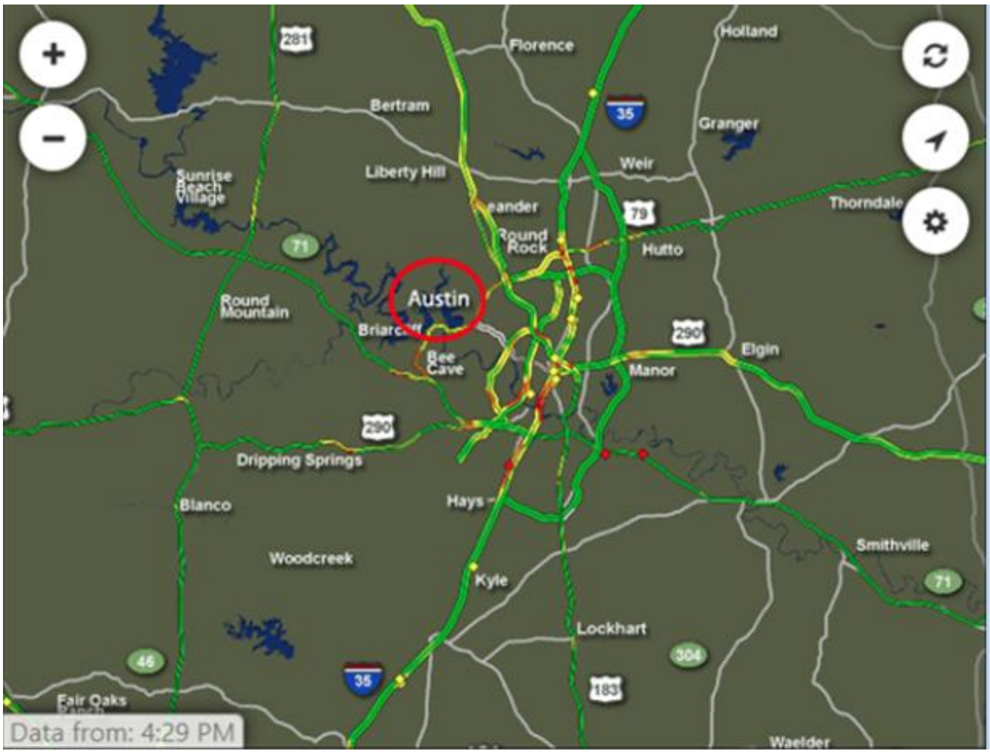

Fig. 1. Real-time traffic map [8]

Table 1. Traffic report on May 5th by 01:39 PM (AustinTexas, 2021) [9]

DATE	TIME	DESCRIPTION	ADDRESS	CROSS STREET
May 05, 2021	12:16 PM	LOOSE LIVESTOCK	14510 Wells School Rd	MANDA CARLSON RD/WELLS LN
May 05, 2021	12:17 PM	Crash Urgent	Palo Blanco Ln / E Stassney Ln	
May 05, 2021	12:20 PM	Crash Urgent	3600-3605 Todd Ln	E BEN WHITE BLVD SVRD WB/E BEN WHITE BLVD SVRD EB
May 05, 2021	12:46 PM	Crash Service	4201-4237 W Balcones Center Dr	No CrossStreet Found/W BRAKER LN
May 05, 2021	12:49 PM	Traffic Hazard	14000 N IH 35 SB	KORMAN TO IH 35 SB RAMP/N IH 35 SB TO KORMAN RAMP
May 05, 2021	01:01 PM	Crash Urgent	8300 N FM 620 RD	ROCK HARBOUR DR/CONCORDIA UNIVERSITY DR
May 05, 2021	01:16 PM	Traffic Hazard	10000 E Us 290 Hwy Wb	N 130 TO E 290 WB RAMP/E US 290 WB RAMP
May 05, 2021	01:27 PM	Crash Urgent	S Pleasant Valley Rd / Turnstone Dr	

Furthermore, **Fig. 2.** below shows the history of accidents happening in Austin from 2014 to 2018. The number of accidents increased from around 16,500 in 2014 to above 17,000 in 2016 and thereafter decreased to about 16,500 in 2017 and 2018. Compared to 2014, they markedly increased in later years. Traffic congestion formed may due to several reasons such as unreasonable city planning to meet the rising population, poor public transportation, and an increasing number of private cars.

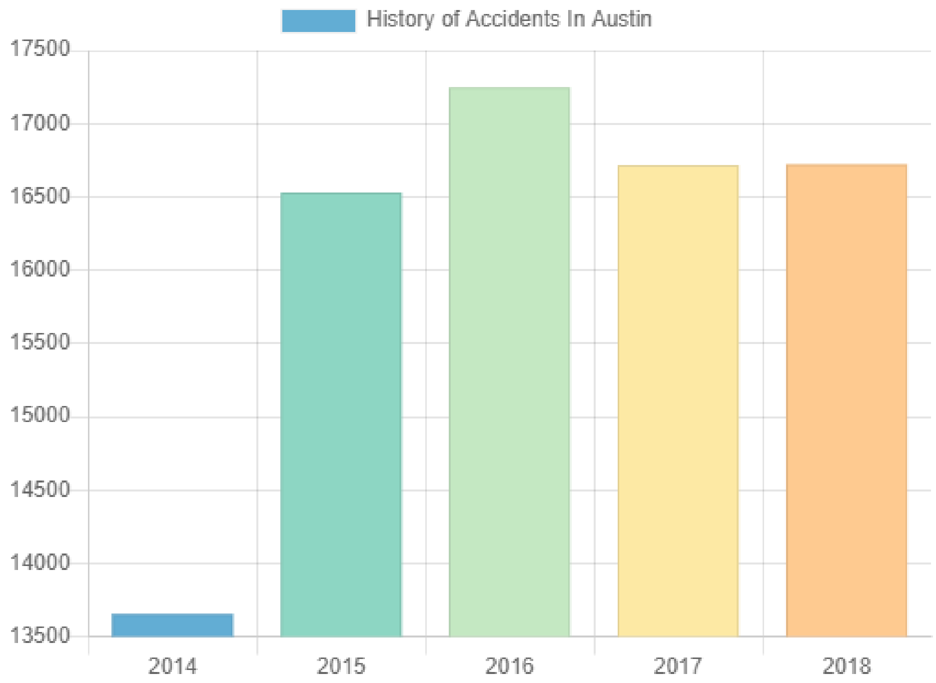

Fig. 2. Car accidents in Austin [10]

Workplace separation is the biggest cause of congestion. Austin is a city with many people living outside the city and working inside. During the morning and evening traffic peak hours, hundreds of cars ply the roads as a result of workers commuting to and from work. The poor public transportation and the increasing number of private cars are making the situation more difficult. Those cars take over half of the transportation resources but only send out less than 5% of people since the majority of the cars on the roads are private cars, with only one person (the driver). Furthermore, if the drivers have poor traffic morality, there is a higher chance to form congestion due to any unexpected accidents on the roads. Due to the rapid growth in population in Austin, it is important to have measures in place that could help reduce the burden Austinites go through on congested roads.

Affordable central housing is one of the safest and best methods for improving traffic congestion in Austin. A lot of traffic could be reduced if people could work close to where they live. But they cannot afford it. The biggest problem is low-wage workers who have to drive in and out of Austin from outlying towns, such as Round Rock, Georgetown, Salado, and Pflugerville. On the other hand, there are highly paid high-tech people who live in the central part of the city but drive far North or Southwest to work.

Another solution can be building the subway in downtown Austin. Interstate 35 is a major Interstate Highway in the central United States that crosses Austin and connects surrounding towns. However, with the rapid growth of the economy in Austin, more and more people work downtown, which causes lots of traffic congestion on I-35. The main reasons for traffic congestion on I-35 include unable to perform real-time traffic management, vehicle and road operating optimization, and unpunctual emergency response. Considering the cost and operation efficiency, if there is a subway system in downtown Austin that connects near surrounding areas such as Round Rock and Kyle, which will be more convenient for people who need to spend 30 minutes driving rather than an hour in traffic jams. This will help to reduce the traffic congestion downtown and improve road safety.

Another possible solution to improving the traffic congestion in Austin is through a combination of driving up bus ridership through free fares, more express buses, and carpool vans. This could significantly improve congestion. Buses and van carpools, although not as favorable as light rail, can have a big impact on roads by taking cars with lone commuters off the highway during peak rush hours. Better (and more intricate and far more frequent) bus routes from outlying areas to the city. For instance, It is no problem for someone from Round Rock to get to Austin proper; it's getting them to their actual workplaces that are highly problematic. The only thing that the City seems focused on is the downtown area and building public transportation for them.

3. DESIGN REQUIREMENTS

3.1 Customer Requirements

Considerations about the customer's requirements can be mainly divided into five aspects:

3.1.1 Affordability: the new system shall be affordable for all users. Low costs will entice users to utilize the system. The cost of taking the system should be lower than taking private cars else, everyone will choose to drive their car instead of trying another option. All cities within Austin will also need to be able to sustain and maintain the system hence, affordability is essential in making the new system a success.

3.1.2 Safety: the safety of customers and users is the utmost priority. Users need to feel safe when utilizing the new system. Privacy, physical, and personal safety needs to be guaranteed. Although the security system of the subway/railway may be inconvenient, this system allows for it to be an option on the list.

3.1.3 Reliability: It shall be reliable in terms of software, privacy, and being able to accommodate large users online without glitches or downtime. The consistency should be the same which means constant customer requirements lead to the directed answer/solutions.

3.1.4. Accessibility: Accessibility is crucial in the sense that the majority of people must hop onto the new system. It should be very easy to navigate and move around. The more customers, the more successful the new system shall be. Accessibility is also related to affordability, the high cost of the new system will not increase affordability, and in other words, accessibility.

3.1.5. User friendly: user-friendliness makes users and customers navigate through the new system without having difficulties. There should be explicit instructions on how to use it. Furthermore, the user-friendly interface must incorporate accessibility options for disabled users.

3.2 System Requirements

3.2.1 Input/output Requirements

- The system will allow the users to provide basic information such as name, current address, and phone number among others.
- It will assist passengers and drivers to either choose to interact and connect or not.
- Users will be allowed to have the option of opening and closing the system.
- The system will use the latest GPS by importing either from Google or Apple map and location tracker to locate both drivers and passengers.
- It will be able to access the latest traffic information in and around the city.

3.2.2 Technology Requirements

In our new system, our application will have the following technical requirements.

- The new system will be able to work perfectly on Android, IOS, and Windows devices.
- It will track the number of trips for drivers.
- It will track the number of trips for passengers.
- The system will require basic information such as name, age, gender, and contact information, among others.
- It will provide options to calculate and collect miles and earn free trips in the future.
- The new system will have a user-friendly interface with additional assistance for disabled personnel.

It is important to note that, in order for the new system to work efficiently, we would like to incorporate other factors and implement the following measures into the system.

- Potential Passengers tracking
  This is essential because most people only think about vehicles and buses when thinking about traffic congestion. The ability to track potential passengers will lead to addressing pedestrian traffic which in turn could lead to traffic congestion.

- Patterns tracking
  This is essential in the sense that the movement of pedestrians, passengers, and vehicles will help future planning much easier. Pattern tracking enables the new system to track and zone out where there is significant traffic, the time of traffic, the alternate route, and among others.

- Adaptive traffic signals
  Adaptive traffic signals allow us to gain better insight and understanding of traffic. This enables us to control the flow and the length of time vehicles become idle at the traffic lights. This then, can be used to modify the timing of traffic signals to coincide with the patterns of traffic during the day.

- Real-time traffic feedback
  Real-time traffic feedback helps to choose the very best route with real-time feedback. Potential passengers, buses, and other vehicles will be able to avoid congested areas and rather choose the best possible route. This will maximize the use of vehicles because potential passengers will know exactly where buses are.

3.2.3 Performance Requirements

- The new system will be able to cater to a large number of customers hopping on the system at the same time.
- The new system will find the best possible route for every ride.
- Subsequently, the new system will reduce the time of travel for both drivers and passengers.
- The new System will give users the options to either share or match rides with other users on the same route.
- The system will track real-time traffic information in order to select the best route.
- The system will provide a quick response to riders.

3.2.4 Cost Requirements

- The new system will cost about $250,000 to construct and set up.
- The new system will have monthly maintenance and updates for $30,000.
- Initial advertisement and marketing for the first 3 months will cost under $65,000.
- Subsequent advertisement and marketing will reduce to $10,000 per month.
- Users and customers with membership will have a monthly fee of $20.
- One-time users with no membership will have a fee of $$9.99 per ride.
- Cities acquiring the new system will have their citizens pay a monthly fee of $14.99.

3.2.5 Trade-off Requirements

- Users with no membership will be offered a good one-time deal.
- A family can have a good deal with family being able to pay less and being able to share each other's membership.
- The new system will give users the option to use high occupancy vehicles in exchange for picking up other riders.
- The system shall calculate a degree of burden for passengers and drivers based on extra distance from the route they must go.

3.2.6 System Test Requirements

- The system shall undergo performance testing to measure how it will behave if there is an increasing workload of users demand during specific times.
- The system shall undergo user interface and usability testing.
- The system will go through server testing to build powerful, reliable and stable applications.
- The system will make sure that the vehicle used to transfer riders is in good and reliable condition by asking for license plates or VIN numbers.

3.3. System Validation

Customer needs include:

- The system shall operate autonomously
- The system shall be able to plan the best/most suitable route as the customer's needs
- System shall assist customers
- The system shall be able to track potential customers and future patterns
- The system shall have adaptive settings that can modify as the real-time condition changes

Requirements that satisfy the customer needs:

I. **The system shall operate autonomously**: The systems should be designed in a way that is able to operate autonomously with the provided information. The subsystems function together and should be able to identify what commands the customer required. And based on the provided information, data analysis, and decision-making processes, the next movements are made.

II. **The system shall be able to plan the best/suitable route as customer needs:** It is important to design a system that can identify emergencies like car accidents on the roads. And data analysis combined with other subsystems like GPS can find another way or solutions to meet customers' requirements.

III. **The system shall assist customers:** The system should be designed to provide additional information or assistance for the customers. It can assist passengers and drivers with multiple options. Also, it can provide assistance for disabled personnel.

IV. **The system shall be able to track potential customers and future patterns:** The system can be designed with machine learning techniques and combined with big data to predict potential passengers and future patterns. Because not only do vehicles and buses play important roles in traffic congestion, but also the pedestrians are influencing traffic conditions. The system should enable pattern tracking so it will know where there is significant traffic, the time of traffic, the alternate route, and among others.

V. **The system shall have adaptive settings that can modify as the real-time condition changes:** The system should be designed to have adaptive settings for real-time conditions which allows customers to gain better insight and understanding. Also, it should provide real-time traffic feedback to enhance customer experiences.

4. CASE STUDY AND CONCEPT EXPLORATION

4.1. Case study

we looked at how different users interact with the system to properly deal with our concerns. As such, we described the goals of the users, the interactions between the users and the system, and the required behavior of the system in satisfying our goals. **Fig. 3.** describes the realization of the new design, and served as an abstraction of the implementation model. This is essential in the design model as it points out the input to activities in implementation and test. It represents all the events and attributes that will be associated with each of the actors or actions are shown by their respective type of arrow between them

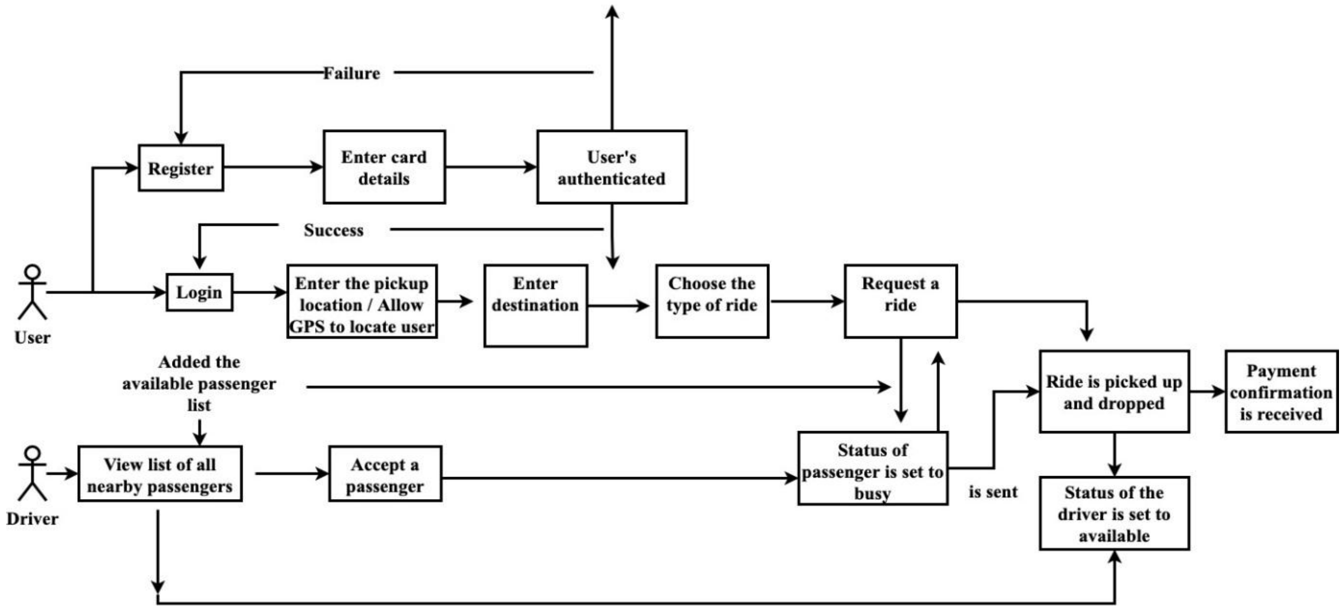

Fig. 3. Use case diagram

The Class diagrams (see **Fig. 4.**) allow the visualization of all event-driven actions with their domains and all domains that will be inherited by other actors with their attributes.

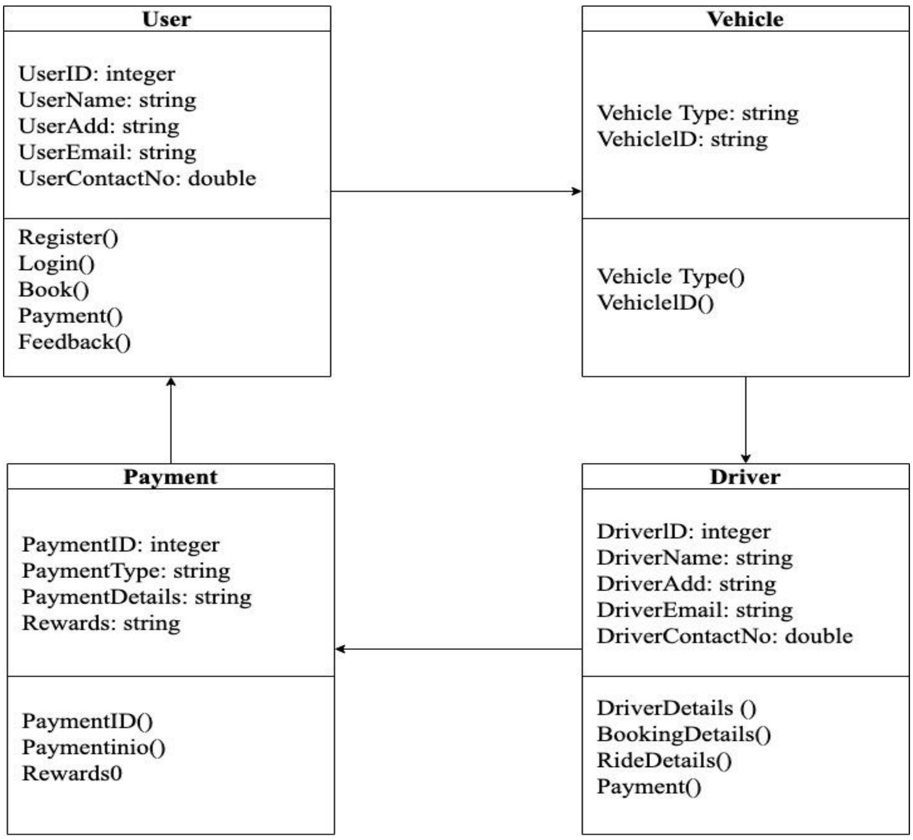

Fig. 4.: Class Diagram

Also, **Fig. 5.** shows the sequence diagrams that allowed us to represent use cases in a timeline with all possible scenarios included such as verification based on condition statements to start interacting with the system. The State machine diagram (see **Fig. 6.**) aids to illustrate the transitions of the behavior of the system as well as all feedback loops between behavior states.

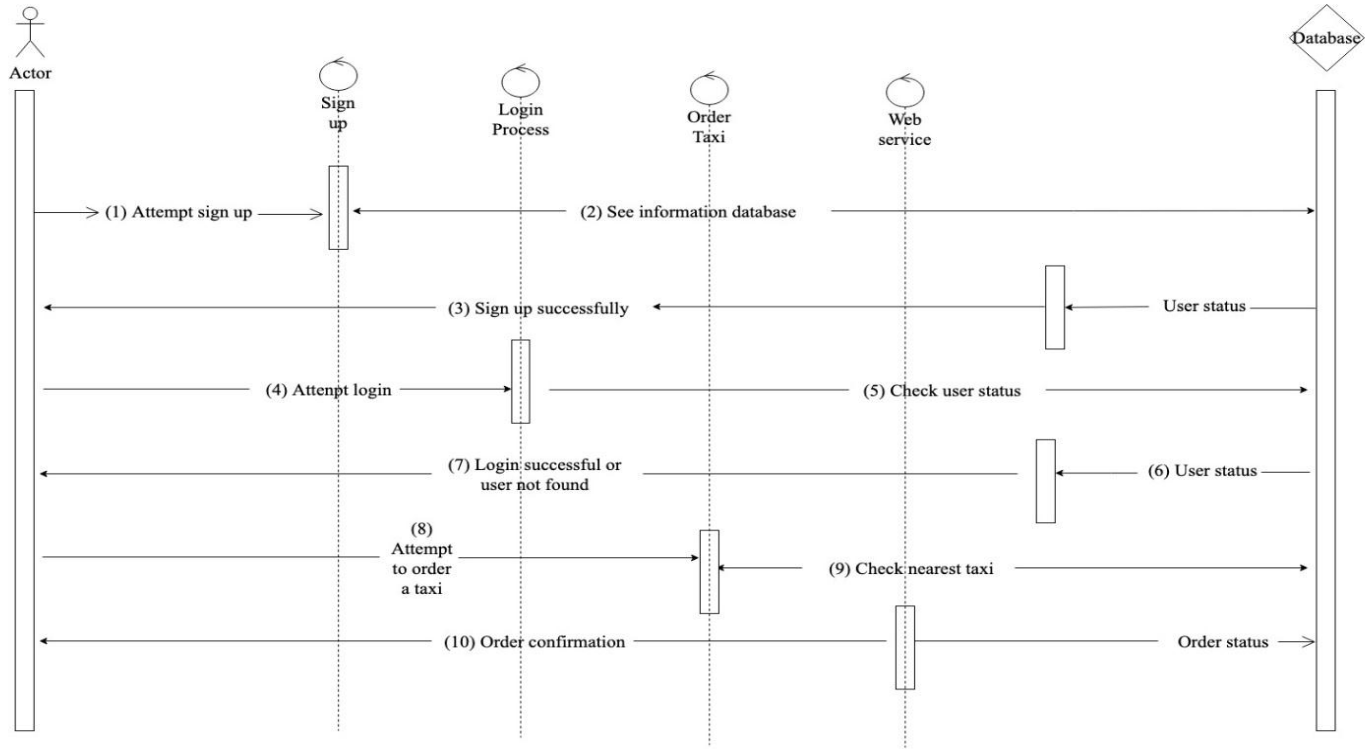

Fig. 5. Sequence diagram

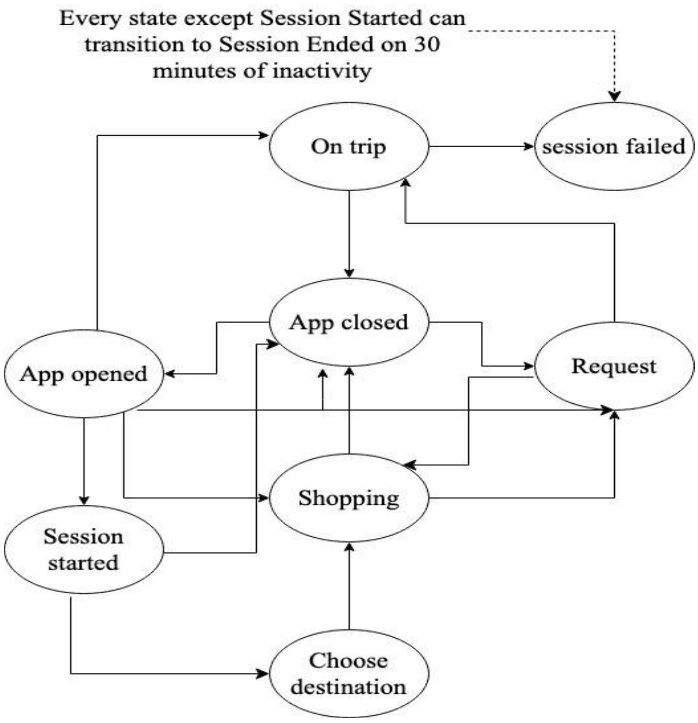

Fig. 6. State machine Diagram

4.2. Concept Exploration

4.2.1 Alternative design

This section investigated alternative system designs to study the system concepts. Currently, there were many applications such as Uber, Lyft, and so on. Those popular and convenient apps brought people new trip modes and business. Uber and its competitors have made structural changes to the old industry that operate much the same way they did decades ago. In the past, people who needed a taxi must get one in person or call a local car service two hours before picking up time to book the car. Electronic name-calling services like Uber or Lyft make it possible to secure a car or taxi from any location via a smartphone.

Several distinct advantages, instead of chasing a taxi down the street or calling and waiting for a half-hour car service, app users can order a car from any location and arrive at it within minutes. Because the passenger's credit card had been linked to an electronic name account, the payment will just be deducted from the account. For drivers, Uber and other electronic names enjoy greater freedom and flexibility. Drivers can log in and out of the system at any time and choose their own time. The downside, however, is that this disruptive technology reduces the market share of traditional taxi services and reduces drivers' overall profits. And most importantly, as there are more drivers, there are more private cars on the roads and more traffic congestion.

There were area-concentrated programs and projects like ASMP and ACT in Austin. For ASMP, it is a plan that combines policies, supporting actions, transportation networks such as public transportation, and bicycle systems, as well as the street network which was used to identify the right of way requirements. The purpose of this plan is to improve and sustain the life quality of all Austinites by providing a comprehensive multimodal transportation plan for the future of transportation networks. And to achieve mobility outcomes based on the continuous growth of Austin and the surrounding communities. However, the ASMP also has some challenges, which include how to promote public health while trying to lower the risk of travel-related injury. Or how to balance the accessibility to a growing region with a multimodal transportation network [11]. The ACT plan is another program that looks into the mobility of downtown Austin. Although this program is currently on hold, it will be resumed in the near future.

4.2.2 Trade-off study

The comparative study is given in **Table 2**. Compared with current existing programs, the designed system has several advantages than the others. While ASMP and ACT are more planning-related systems, our designed one combined the transportation networks, and build-in services which enable users to book tickets/trips directly through the system. Also, real-time traffic feedback can be provided by data analysis of machine learning techniques.

Besides that, the design system can track potential passenger and pedestrian patterns that may cause unexpected traffic congestion or accidents.

Table 2. Trade-off study of systems

	Mobility	System linked transportation services	Real-time traffic feedback
ASMP	+	-	-
ACT	+	-	-
Designed system	+	+	+

Conclusion

Traffic congestion arises as a consequence of inefficiencies and disruptions within urban transportation systems, leading to significant societal impacts due to increased traffic congestion. In this study, we have explored different technologies driving the Austin transportation systems, their development and examining their effects on passengers. A suitable design model for the case of Austin was introduced. Through the utilization of this model we have discovered its potential to significantly enhance the quality of public transport services, thereby attracting more passengers. Furthermore, this model has the capability to enhance the competitive edge of public transport when compared to private transportation alternatives

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