INTELLIGENT COMPLEMENTARY RIDE SHARING SYSTEM

R.M.A.N.Gunathilake

(IT16033474)

BSc(Hons) in Information Technology
Specializing in Software Engineering

Department of Software Engineering

Sri Lanka Institute of Information Technology
Sri Lanka

August 2019

INTELLIGENT COMPLEMENTARY RIDE SHARING SYSTEM

R.M.A.N.Gunathilake

(IT16033474)

Dissertation submitted in partial fulfillment of the requirements for the Special Honours Degree of Bachelor of Science in Information Technology Specializing in Software Engineering

Department of Software Engineering

Sri Lanka Institute of Information Technology

Sri Lanka

August 2019

DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to Sri Lanka Institute of Information Technology the non- exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: _____ Date:_____

The above candidate has carried out research for the B.Sc Dissertation under my supervision.

Signature: _____ Date:_____

(Dr. Janaka Wijekoon)

ABSTRACT

Traffic congestion has aggravated by the attention of society as a major concern. Urban areas like Colombo has a huge problem with this traffic congestion. Increasing the number of vehicles that enter the city is a major concern for this congestion problem. In most instances, many vehicles are reaching the same destination where users are used to traveling their trip alone. As a result of the current study proposes a solution to minimize traffic congestion in urban areas by implementing a ride-sharing platform known as Plus Go. Plus Go platform is mainly focused on the office crowd in Sri Lanka. Because most of the offices are located in highly crowded areas. This +Go platform uses a crowdsourcing platform to increase the accuracy of the suggested routes. Dijkstra's algorithm and the Traveling Salesman Problem (TSP) algorithm were used to obtain the most accurate path. The basic determination of this report is to show the significant features and benefits of optimum path analysis and how this application will help to reduce the traffic congestion in urban areas and ensure the security of the users.

Keywords –Ride sharing, Machine Learning,Crowdsourcing

ACKNOWLEDGEMENT

I would like to extend my gratitude to Dr.Janaka Wijekoon for the constant guidance as the supervisor, Dr.Dharshana Kasthurirathna for giving feedback on our application, and everyone who provided their sensitive data to be used in the training and testing purposes of the application.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

API	**Application Programming Interface**
TSP	**Travelling Salesman Problem**
OPR	**Optimum Path Recognition**

1. INTRODUCTION

1.1 Background literature

With the technology evolution ,traffic congestion has become a vast problem in urban areas.According to the Department of motor vehicle ,in 2015 it has counted that more than 500000 vehicles entered to the Colombo city and among them over 1.8 million people arrived to the city in peak hours [1].443,586 number of privately owned vehicles are arrived to the city [1].As a result of that ,it will cause a traffic congestion in urban areas during rush hours.Since most of the people go to their work as a single owner ,it would be more helpful if they can share their ride with some other who travel to the same destination.Therefore it will minimize the traffic congestion and environment pollution which reduce the emission of carbon dioxide to the environment.

According to the survey conducted by CoMTrans study team,which was mainly concerned on Borella,Maradana,Dematagoda,Town Hall and Nugegoda areas have recognized that average travel speed is 17-18 $Kmph^{-1}$ in rush hours of both morning and evening time periods [2]. When the statics on number of trips the users have during the rush hours, based on western province statistics, CoMTrans incurred that 10.0 million trips were recorded in the year 2012. They predict that total trips in 2035 will be 17.8 million, whereas Sri Lanka expects 1.8 times high [3].Relevant to the survey results,there are various types of trips used by Sri Lankans.Some of them are home based trips and non home based trips.

To minimize this traffic congestion problem,we came up with implementing a ride sharing application.Moreover, we have done a survey to confirm our proposition. From the survey results, we identified that over 82% people up-voted for ridesharing as a good option for Sri Lanka, also over 72% of the people believe traffic will reduce from this proposed solution and over 61% of people stated that they like to collaborate in the car-pooling platform [4].

Ridesharing is considered as a possible solution to reduce traffic congestion [10]. Factors like cost of travelling, time, distance, ownership of vehicle, personal attitudes had an influence in choosing the individual transportation mode [6, 7]. Certain studies have focused on the factors like fuel price, demography and safety measures in selecting the transport mode [8, 9]. However, in Sri Lanka, over 443000 private vehicles enter the Colombo area in the rush hours. Out of them, 170000

vehicles are considered to be cars [1]. This is drastic increase of vehicles entering the city limits. The daily loss is calculated as Rs.500m due to the traffic congestion causes by the high number of vehicles [11].

Since the general objective of this research is to minimize traffic congestion in urban areas, the identification of the optimum path is very significant. Intelligent Complementary Ride Sharing System (ICRSS), the proposed solution;helps to find the optimum route which will lead to the traffic minimization.

Dijkstra algorithm is known as the shortest path algorithm. Dijkstra Algorithm is used to identify the shortest path of the tree by considering the root of the tree as the starting point and then expand the tree node-by-node [12]. According to the weighted directed graph, there is a shortest path node. For the matter of fact, that node is starting from the starting point and extend to the earliest smallest point. In here, point where entire nodes are adjacent to is known as the smallest point and the length of the arc is called as the chord length [14]. According to this weighted directed graph, vertices of the graph emphasize the cities while edges of the graph show the distances between two cities which adhere by a road. Therefore, Dijkstra's algorithm can be used to identify the closest path between a city and other entire cities [12, 13].

Similarly, Travelling Salesperson Problem (TSP) is another algorithm to identify the least weight tour, which cover all the nodes of the graph. According to the algorithm, it will identify a certain unique cycle in that graph and travel through each node of the graph for once with a minimal price [15]. Some algorithm have been developed some algorithm to solve TSP. Adewole (2011) have been proposed Genetic Algorithm for solving Traveling Salesman Problem [16]. From the study of Dweepna Garg and Saurabh Shah (2011), they used some other method to solve Travelling Salesperson Problem which is known as Ant Colony Optimization [17]. Tunon and Lopez (2005) proposed the algorithm of Branch and Bound to solve Travelling Salesman Problems [18]. Later on, Pragya, Dutta and Pratyush (2015) succeeded to identify another method to solve the Travelling Salesperson Problems, which is known as Dimensional Ant Colony Optimization (DACO) [19]. Another research used Dijkstra algorithm. It was performed by [20, 21].

1.2 Research gap

We have identified several ride sharing applications within the country during the initial stage.However most of the applications couldn't able to satisfy the users with their requirements.Since traffic congestion has become a huge concern in the society,we proposed a solution to minimize this problem by implementing a new ride sharing application.Here we have identified a research gap among some ride sharing applications by referring some literature surveys and other related findings.Therefore through our proposed solution we were able to satisfy the users needs by ensuring their reliability,security and some other essential factors.

Following table emphasize a comparison between the existing products and our proposed solution.

Table 2.1.1 - Comparison of Existing Products

Features	**Uber**	**UDIO**	**Carpooling.lk**	**Rideshare.lk**	**+GO**
Crowdsourcing to improve the optimum path by analyzing more than one algorithm.	✗	✗	✗	✗	✓
Allowing the registered users to enter the live updates by uploading images.	✗	✗	✗	✗	✓

1.3 Research Problem

In this country today, traffic control has become the most prevalent factor for the police force. There will be a substantial reduction in deploying many police officers when traffic congestion is reduced. According to the articles, surveys, and police reports, there is a gradual increase of vehicles that enter to the Colombo in the rush hours [5]. Moreover, with the increase in traffic congestion, the number of accidents too increases. From the surveys conducted by the Central Bank, they have identified low occupancy vehicles like cars has been in high number and resulted in traffic congestion and wasting of financial resources, moreover polluting the environment badly.

By considering some statistics collected from articles and reports, we identified that traffic is a major concern in urban areas, especially during office hours. It stated there is an Rs.500 million loss due to the daily traffic congestion [5]. Due to the heavy traffic in the rush hours, there is a huge loss of time wasted on the road. The answer is obvious if we can find a way of reducing, the number of vehicles enter the city; we can reduce the traffic congestion up to a certain extent. So we thought of introducing a ride-sharing app,

Which could possibly become a solution to the traffic congestion. The basic idea behind that was to combine professionals who are traveling to work by their private vehicles. Hence, when one vehicle carries several people together, it will reduce the number of vehicles enter the city. To verify our hypothesis, we conducted a survey with a sample of more than 150 office crowd and we were able to identify that majority considered ridesharing as a good solution to reduce traffic in urban areas.

1.4 Research Objectives

1.4.1 Main Objective

The main objective of this research is to develop an effective solution to minimize the traffic congestion during office hours in urban areas. Because of that, we thought of introducing a ride-sharing app for the working people (office staff) which will help to minimize the traffic congestion. Ride sharing service has become a convenient and felicitous transportation system to everyone in

everywhere at any time. Apart from reducing the traffic congestion, there are some other tremendous positive impact on our proposed solution. Some of them are building the network among professionals with similar social status, which will help to reduce the stress and improve the productivity while travelling as a passenger, minimize the environment pollution and fuel consumption cost and help to save the car ownership cost and ensure the security of passengers too.

1.4.2 Specific Objective

The main objective of optimum path recognition is to identify the closest path.In this proposed system, Dijkstra's Algorithm and Travelling Salesman Problem (TSP) Algorithm will be applied to perceive the closest path with least traffic, which connect source and destination while minimizing the traffic congestion. Dijkstra Algorithm find the shortest path by considering weight of the edges in a weighted graph, Depending upon the user's option ,weight of the edges will be vary as distance or time according to the applicable conditions in it.Since we enable the registered users to enter the live updates by uploading images,it will be more helpful to implement crowdsourcing to predict the most efficient route.

2. RESEARCH METHODOLOGY

2.1 Methodology

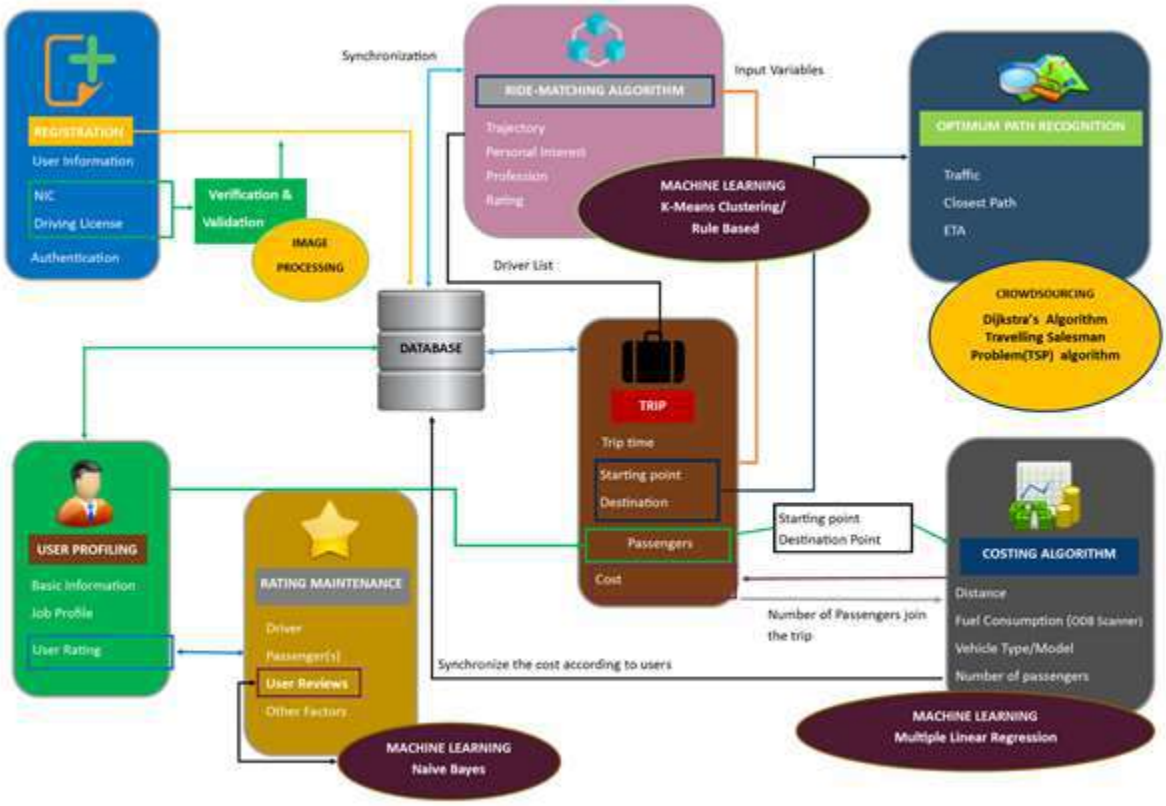

Figure 2.1.1: System Diagram of Plus Go

In optimum path recognition, we use both Dijkstra's Algorithm and Travelling Salesman Problem (TSP) algorithm to identify the closest path with the least traffic. Because of that, it helps to minimize traffic congestion in urban areas. Dijkstra's Algorithm provides the optimal path to reach the destination by considering the weight of the edges. According to the user's concern, the weight of the graph gets vary. If the user's concern is the distance factor, the length of the edges will be identified as the weight. Similarly, if the user's concern is about traffic, accidents or road closures, weight becomes the calculated time duration to cover the specified distance. Travelling Salesman Problem (TSP) Algorithm provides the optimal path to travel through a city, which covers all the

user-specified locations. When users set their locations, our supposed system will identify the order of the locations to visit. Then this algorithm finds the optimal path, which travels, through each location (node) in the listed user-specified locations. In here, registered users will be able to enter the live updates on the relevant path within a specified time range by uploading the pictures of the particular incident. Also, AWS is used to store the images separately to increase efficiency.

The following use case diagram will show the overall functionality of the optimum path recognition.

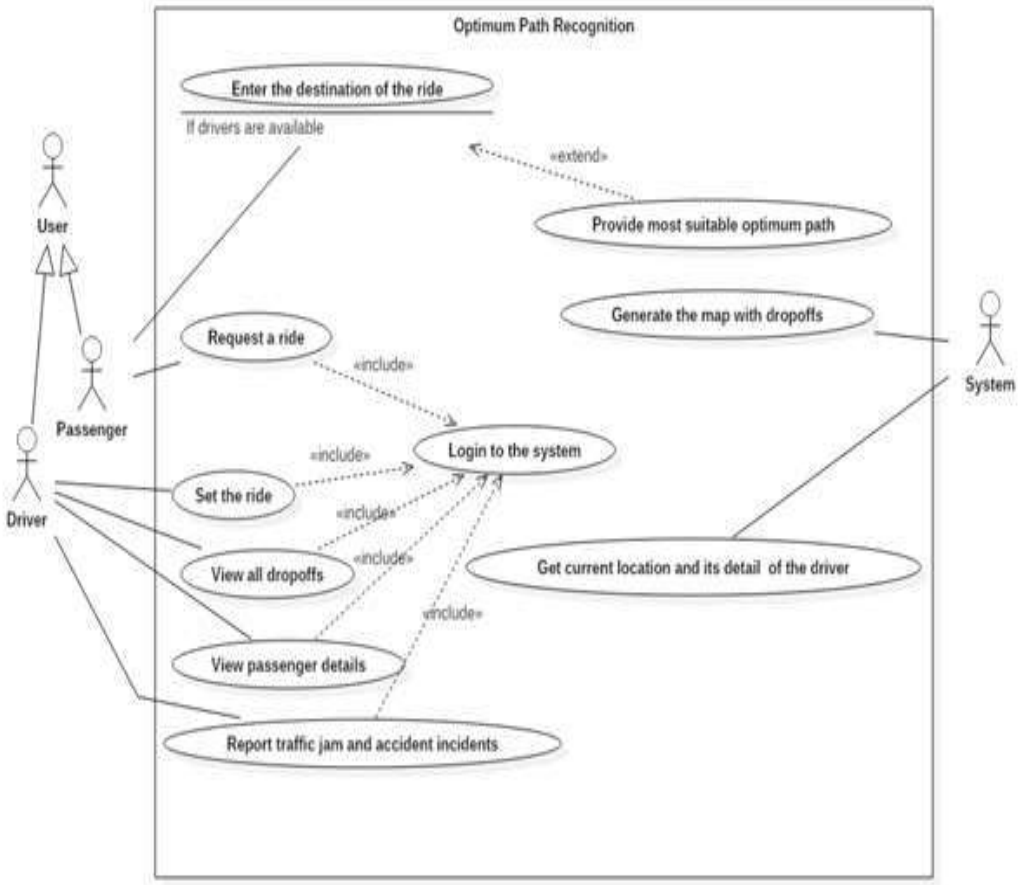

Figure 2.1.2 - Use Case of OPR

2.2 Commercialization aspects of the product

Since our ride-sharing application is mainly focused on working people(office staff), it will help to reduce traffic congestion during rush hours in urban regions. As a result, it will help to minimize environmental pollution too. Very huge business value is superscribed on our system since this project can be further developed and inaugurate. From a business perspective, our system will help to reduce the traveling cost.

Most of the time, diverging a valuable concept into a business is where the significant challenges appear. This proposed ride-sharing application is mainly focused on professionals. Preliminarily, the +Go application is implemented by concerning Colombo city area. This application is precisely free to download. Also, we would charge only 10% of the complete fare expend by the relevant users as revenue. Since all the services in the application are free for the moment, we will add more services in the future for a limited subscription fee.

The beta version will be released among several professionals to test the application before release it to the market. Currently, our application can be only used by Android users. Later on, we hope to develop our application for iOS users as well. To keep the business more profitable, our product will be promoted by using different social media platforms and advertisements.

2.3 Testing & Implementation

2.3.1 Testing

Application testing is done in order to identify the details about the quality of the product or service under test.Testing is not done only for the identification of software bugs or errors,but also for the evolution of new attentiveness too. Progressively integration testing is done in order to recognize the defect or errors in the interfaces and interconnection between all the integrated components.Therefore interfaces were tested by using several test cases as shown as below.At last system testing will be done for the whole integrated system to ensure whether it meets all the requirements.

Table 2.3.1.1 : Test Case 01

Test Case ID	TC01
Test Case Description	Inserting the trip ride information
Pre-Condition	User should be a registered user(driver)
Test Procedure	● Enter the source ● Enter the destination ● Enter the start date ● Enter the start time ● Enter the waiting time ● Click Submit button
Test Input	● Source : Malabe ● Destination : Kollupitiya ● Start Date : 09/08/2019 ● Start Time : 8.30am ● Waiting Time : 5 minutes
Expected Output	Displaying a message after submitting the data.

Actual Output	Submitted the details successfully with a success message

Table 2.3.1.2 : Test Case 02

Test Case ID	TC02
Test Case Description	Request a ride
Pre-Condition	User should be a registered user(passenger)
Test Procedure	● Enter the source ● Enter the destination ● Click Accept Route button
Test Input	● Source : Malabe ● Destination : Kollupitiya
Expected Output	Display optimum route on the map

Actual Output	Show optimum path on map and display the success message after submitting the details successfully.

Table 2.3.1.3 : Test Case 03

Test Case ID	TC03
Test Case Description	Insert traffic jam information
Pre-Condition	User should be a registered user(driver)
Test Procedure	● Enter the traffic location ● Enter the situation type ● Upload the image of the incident by clicking upload button ● Click Report button
Test Input	● Location :Thalahena ● Situation : Heavy ● Thalahen_traffic.png

Expected Output	Displaying a message after submitting the data.
Actual Output	Submitted the details successfully with a success message

Table 2.3.1.4 : Test Case 04

Test Case ID	TC04
Test Case Description	Insert accident information
Pre-Condition	User should be a registered user(driver)
Test Procedure	● Enter the accident location ● Enter the situation type ● Upload the image of the incident by clicking upload button ● Click Report button

Test Input	● Location :Battaramulla ● Situation : Major ● Battaramulla _accident.png
Expected Output	Displaying a message after submitting the data.
Actual Output	Submitted the details successfully with a success message

2.3.2 Implementation

2.3.2.1 Hardware Interfaces

Mobile application is the solution in this proposed system.Therefore it will use only a small amount of hardware.Proposed system will have a mobile phone which should be complement with internet connectivity ,GPS and allow camera to capture the pictures using mobile phone.

2.3.2.2 Software Interfaces

- Android Studio – Used for developing the mobile application
- Firebase - Realtime Database
- Leaflet - Used as an open source javascript library for emphasizing inter maps
- Geolocation API - identify the current location/place on the map.
- Distance matrix API - identify the distance among cities on the map.
- Geocoding API - identify the addresses and convert them into geographic coordinates

- MySQL - Used as backend database server
- SQLite - Used as an in built data storage
- Python - Using for run the background algorithm
- Express.js - Using for development of web API

2.3.2.3 Memory Constraints

The android mobile application is needed,

- Android version should be 6.0 or higher
- 2 GB RAM(Minimum) and 4GB RAM is Recommended
- 100 MB Memory space

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Optimum Path Analysis

Different methodologies were used for the verification and validation of our proposed system. Since the system allows multiple users to engage in work concurrently, it should be able to deliver the requested services without any delays. Therefore, the use of Google API for the identification of the optimum path is a virtuous solution. But manipulation of Google API is not the best when handling multiple requests at once. With the introduction of optimum path analysis using the Dijkstra algorithm and Travelling Salesman Problem, we can provide the optimum path considering traffic and distance as parameters. As a result of that, it would be helpful to handle the substantial amount of requests at once.

Source	Destination	Route	Distance(km)
		Proposed system	Google Map
Malabe	Kollupitiya	16.7	16.7
Dehiwala	Rajagiriya	9.37	9.4
Koswatta	Dematagoda	9.9	9.9
Thalahena	Gothatuwa	7.65	7.7

Figure 3.1.1.1: Distance Comparison

Relevant to the Figure 3.1.1.1, proposed system suggest more optimized path at the current moment using crowdsourcing platform and above mentioned algorithms.Therefore, it is not much contradicted from the Google API ,but it will display the less traffic specific path as the output.

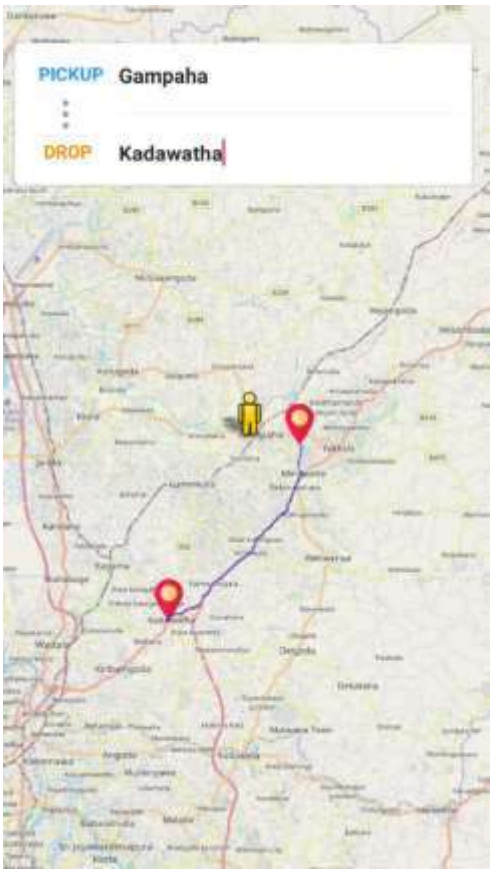

Figure 3.1.1.2 : Optimum Path given by proposed system

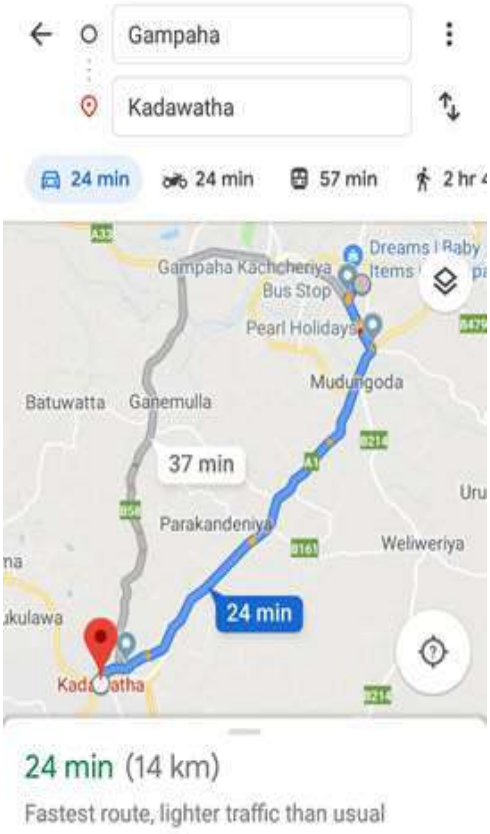

Figure 3.1.1.3: Alternative routes given by the Google Map

Preliminarily the proposed system was compared the Google maps results.Following table 3 ,will show the accuracy level by using the Dijkstra Algorithm and Travelling Salesman Problem (TSP) algorithm.

Table 3.1.1.1 : Algorithms Evaluation

	Results given by the Google Map	Proposed System Results(Plus Go)
Dijikstra's Algorithm	When user provide the starting location and ending location,Google map will suggest all the alternative routes on map. Ex: Figure 3.1.1.3 shows all the alternative routes from Gampaha to Kadawatha as, ● via Colombo - Kandy Rd/Kandy Rd/A1/AH43 ● via Kadawatha - Ganemulla Rd However, optimum path generated by both Google map and proposed system is almost similar.	First user enter the source and destination and then optimum path will be displayed on the map by considering the distance factor,time factor,traffic jam or road conditions. Ex: Figure 3.1.1.2 shows the closest path from Gampaha to Kadawatha
Travelling Salesman Problem Algorithm	Relevant to the studies, Google map doesn't use TSP algorithm for the identification of optimum path.	When the user provides the starting location and ending locations, it will generate the closest path to travel by covering all the user specified locations.

These results emphasize that ,this is a significant option for path identification and analysis with the combination of our crowdsourcing platform.

3.1.2 User Interfaces

To release the version 1of the application, we have designed mobile interfaces to provide the functionalities. We have designed mobile interfaces related to the OPR component.

Figure 3.1.2.1: Chose a role

Figure 3.1.2.2: Driver offer a ride

Figure 3.1.2.3: Passenger finds a route

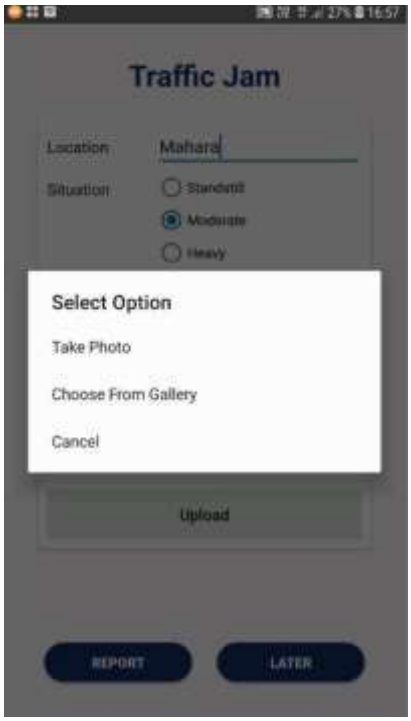

Figure 3.1.2.4 :Select the option for reporting

Figure 3.1.2.5: Report traffic jam

3.2 Research Findings

Intelligent Complementary Ride Sharing System (ICRSS),our proposed solution comprises with various features and benefits. This document emphasizes the usage of Optimum Path Recognition to the users of this application. A good and efficient transportation system is significant to develop the growth of the city and help to increase the economic growth and the productivity.Therefore ,through the primary stage we have recognized that the traffic congestion occurs mainly due to increase of vehicles on road.As a result of that ,this congested road conditions will cause the environmental pollution too.After conducting a literature survey ,we got a conclusion that ride-sharing is a feasible solution to this congestion problem. Followings are some survey results.

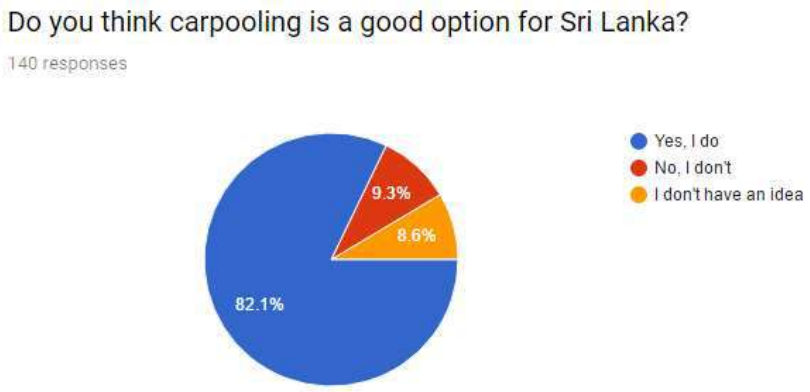

Figure 3.2.1: Interest in Carpooling

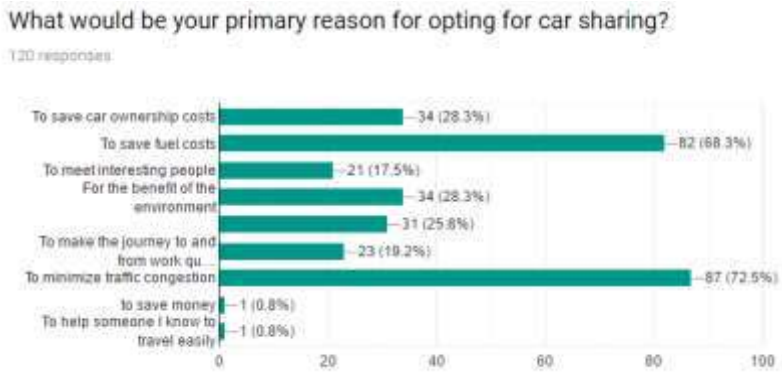

Figure 3.2.2: Reasons for ride-sharing

We have identified that the reliability of the product is way more important. The reliability of analyzing and identifying the most suitable optimum path to a certain destination will be acquired

by using Dijkstra’s Algorithm and Travelling Salesman Problem(TSP) Algorithm.Most of the algorithms which are used in this component will be used in backend.As a result of that ,backend server can be maintained easily.Also,most of the information related to this component are stored in real time database ,firebase. Therefore if the registered users reset their mobile phones,users are capable of recover their past data through the firebase database and meanwhile it will provide the database security too. Security of the proposed system can be maximized by maintaining and controlling the server side.

3.3 Discussion

A Geographic Information System (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. The GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts [22]. Even there are several methods to identify the optimum path, Dijkstra’s algorithm and TSP algorithm will show the most accurate closest path. When comparing Google Map results and our proposed system results after entering the source and destination locations, Google Map will suggest several alternative routes while proposed system show only the optimum path by using Dijkstra's Algorithm by concerning the complete distance of each road and time to travel to the defined destined region. However, resulted routes from both instances are matched. When compared to the Dijkstra's Algorithm, identifying the most suitable solution of a Travelling Salesman Problem is not achievable.A more accurate path can be generated by tracking the current location of the user.

4. CONCLUSION

The objective of this research is to minimize traffic congestion. To meet this objective, we implement a ride-sharing system known as Intelligent Complimentary Ride-Sharing System. The complete system is build up by using different machine learning algorithms and some image processing techniques too. This project is divided among some major components to cater to more functionalities.

In this optimum path recognition component, it shows the fact that Dijkstra's algorithms and TSP algorithm used in our application is way more important than other existing applications. Because it helps to identify the closest path. When comparing these two algorithms, Dijkstra's algorithm is way more feasible than the TSP algorithm. Also, crowdsourcing is used to improve the optimum path by analyzing those algorithms.

Our application proved that this is more competent in providing the trip details to get an accurate path.

From a business perspective, our application can be further expanded and developed in several ways. Initially, when the user provides his or her trip details with the starting location and the ending location, the system will generate the closest path to reach the defined destination. Therefore a more accurate path can be obtained by tracking the current location of the users. Furthermore, our application can be developed to provide the appropriate directions or navigation to the users. However, it is significant to emphasize the fact that the "Intelligent Complementary Ride-Sharing System" which is also known as the application name "+Go" can become a unique and effective solution to minimize traffic congestion in Sri Lanka.

5. REFERENCES

[1] [online] Available at: https://indi.ca/2015/10/colombo-vehicle-statistics-2015/
[Accessed 2 Jan. 2019].

[2] Urban Urban Transport Master Plan for Colombo Metropolitan Region and Suburbs. (2014). [ebook] Colombo ,Sri Lanka: Ministry of Transport, pp.25,26. Available at: http://www.transport.gov.lk/web/images/stories/CoMTrans%20Final%20Report_S.pdf
[Accessed 13 Jan. 2019].

[3] Draft Urban Transport Master Plan - Ministry of Transport. (2013). [ebook] Colombo,Sri Lanka: Ministry of Transport, pp.66,74,75.
Available at: http://www.transport.gov.lk/web/images/stories/comtrans.pdf
[Accessed 21 Jan. 2019].

[4]Vehicleinfo.000webhostapp.com. (2019). *Vehicle Details*. [online] Available at: https://vehicleinfo.000webhostapp.com/

[5] Carpooling.lk. (2019). Carpooling. [online] Available at: http://www.carpooling.lk/
[Accessed 23 Jan. 2019].

[6] Ding, C.; Wang, D.; Liu, C.; Zhang, Y.; Yang, J. Exploring the influence of built environment on travel mode choice considering the mediating effects of car ownership and travel distance. Transp. Res. Part A Policy Pract. 2017, 100, 65–80. [CrossRef]

[7] Schneider, R.J. Theory of routine mode choice decisions: An operational framework to increase sustainable transportation. Transp. Policy 2013, 25, 28–137. [CrossRef]

[8] Efthymiou, D.; Antoniou, C.; Waddell, P. Factors affecting the adoption of vehicle sharing systems by young drivers. Transp. Policy 2013, 29, 64–73

[9] Rayle, L.; Dai, D.; Chan, N.; Cervero, R.; Shaheen, S. Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. Transp. Policy 2016, 45, 168–178

[10] Dewan, K.K. & Ahmad, Israr. (2007). Carpooling: A Step to Reduce Congestion (A Case Study of Delhi). Engineering Letters [Accessed 5 Jan. 2019].

[11] [online] Available at: https://www.newsfirst.lk/2017/03/16/rs-500m-loss-incurred-daily-traffic-congestion-transport-authorities-observe/ [Accessed 30 Dec. 2018].

[12] Vaibhavi Patel and Prof. ChitraBaggar, "A Survey Paper of Bellman-Ford Algorithm and Dijkstra Algorithm For Finding Shortest Path in GIS Application," *International Journal of P2P Network Trends Technology(IJPTT*), vol. 5, February 2014

[13] Ni Kai, Zhang Yaoting, Ma Yuepeng, "Shortest Path Analysis Based on Dijkstra's Algorithm in Emergency Response System," *Indonesian Journal of Electrical Engineering and COmputer Science*, vol. 12, no. 5,pp 133-139, 2015

[14] Dechuan Kong ,Yunjuan Liang, Xiaoqin Ma, Lijun Zhang "Improvement and Realization of Dijkstra Algorithm in GIS of Depot"

[15] Ojaswa S. , Darka M. , Francois A. and Girija D., 2005.TRAVELING SALESPERSON APPROXIMATION ALGORITHM FOR REAL ROAD NETWORKS Technical Report 388, Department of Geomatics Engineering, University of Calgary 2500 University Drive NW, Calgary, AB, Canada, T2N 1N4

[16] Adewole Philip, Akinwale Adio Taofiki and Otunbanowo Kehinde, "A Genetic Algorithm for Solving Travelling Salesman Problem," *(IJACSA) International Journal of Advanced Computer Science and Applications*,vol. 2, no.1, January 2011

[17] Dweepna Garg and Saurabh Shah, "Ant Colony Optimization For Solving Traveling Salesman Problem," *International Journal of Computer Science and System Analysis*,vol. 5, no. 1, January-June 2011, pp. 23-29, ISSN 0973-7448

[18] M.I.C., Tunon and M.R. Lopez. "Design and Use of the CPAN Branch and Bound for The Solution of the Travelling Salesman Problem (TSP)," International Conference on Electronics, Communication and Computers, Conielecomp, 1 August 2005.

[19] Pragya, M.Dutta, and Pratyush. “TSP Solution Using Dimensional Ant Colony Optimization,” International Conference on Advanced Computing & Communication Technologies, 6 April 2015.

[20] M.M. Mena, R.H. Ucan, V.C. Vetina, and F.M. Ramirez, “Web Services Composition using the Bidirectional Dijkstra Algorithm,” IEEE Latin America Transaction, vol. 14, Issue 5, May 2016

[21] A. Ratnasari, F. Ardiani, F. Nurvita. “Penentuan Jarak Terpendek dan Jarak Terpendek Alternatif menggunakan Algoritma Dijkstra serta Estimasi Waktu

[22] What is GIS? [Online].
Available: http://www.esri.com/what-is-gis/overview.html# overview panel [Accessed: 9th September 2012]