Formulation of a National Framework for the Digital Transformation of Sri Lanka's Public Bus Transport System

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***Abstract*—Public transport play an increasingly important role in human navigation. In a digital world where the technological landscape continues to change, the need for a quality transportation network is critical. Sri Lanka being a developing country has witnessed digital transformations in several sectors although the use of digital practices in Sri Lanka's bus transportation industry is minimal. The proposed research aims to present how IT can be used to deliver a quality transportation experience to each passenger through the use of a real-time bus tracking system that uses GPS coordinates along with a bus arrival time prediction system capable of estimating the arrival time of the desired bus. The framework also aims to introduce a cashless ticketing mechanism to eliminate the problem of carrying change money which is a burden faced by many passengers. When real-time information is available, the passengers could spend their time efficiently and reach the bus stop on time or take alternate paths if the bus is to be delayed. This in return would be capable of solving the problem of traffic congestion as the availability of a high-quality bus transport service would encourage citizens to use public transport instead of their own private vehicles.**

Keywords-GPS; digitalization; bus transport; traffic congestion; passengers

I. INTRODUCTION

Sri Lanka being a developing country has witnessed transformations in several sectors due to the advent of Information technology. However, only few Sri Lankan organizations have managed to acquire the real benefits of digitization. In a digital world where the technological landscape continues to change, the need for a quality transportation network is critical. Hence, majority of the world's developing countries have adapted digital transformation strategies to ensure the delivery of a quality transportation experience to passengers whereas the use of digital practices in Sri Lanka's bus transportation industry is minimal.

According to the Daily Mirror of 12th October 2015, over 500,000 vehicles enter Colombo everyday, carrying over 1.8 million people. Out of around 500,000 vehicles, 87% (443,000) of the vehicles are private vehicles that carry about 44% of the total passengers while majority of the passengers (51%) use public transport to reach Colombo [1]. The availability of more private vehicles with less number of people gives rise to the problem of traffic congestion thus creating a need for an efficient public transport system. This statement is further verified by the Central Bank Report as follows:

"In the absence of an efficient public transportation system, traffic volumes continued to exceed the capacity of roads, and the resultant congestion has been aggravated by the misuse of road space, unauthorized roadside parking and indisciplined driving" [2].

Hence, if the problem of traffic congestion in Colombo is not solved immediately, it will cost us billions and trillions in lost productivity and economic growth.

The proposed research aims to present how IT can be used to deliver a quality transportation experience through the development of a National Framework for the digital transformation of Sri Lanka's public bus transport system. Although several initiatives such as busbooking.lk and routemaster.lk have been previously introduced, they have not shown wide success due to various reasons such as lack of public awareness and lack of trust on new technologies. Hence, this research aims to investigate the challenges currently faced by passengers travelling in and out of Colombo to determine how they can be eliminated through the use of IT.

The proposed research contrasts with other researches as it facilitates the development of a Digitized National framework that would be applicable to the entire bus transport system of the country. Furthermore, it would be beneficial if the passengers are provided with an integrated up-to-date solution where information such as the location of the bus, arrival time, bus fare, duration and journey distance is available in real-time. Besides, the study is also significant as this area has not been much focused academically in the Sri Lankan context.

II. LITERATURE REVIEW

Public transport has been a viable solution for many Sri Lankan citizens who require to travel from one place to another. Hence, many short term and long-term projects have been initiated to improve the quality of public transport in Sri Lanka. Hewage et al. paper on "Factors Affecting the Service Quality in Public Bus Transportation in Sri Lanka" [3] discusses the factors affecting the service quality of public bus transportation and their effect on the development of public bus transport. The paper also explores the current context of Sri Lankan public bus transport that includes characteristics such as the availability of luxury and semi-luxury air-conditioned buses to provide comfort to customers especially when travelling for long distances and the introduction of touch smart card facility for selected routes, to resolve discrepancy issues in giving back ticket balance.

As identified in the paper, the factors affecting the service quality of Sri Lankan public bus transport are: delay in travel time, lack of timetable information, unfavorable situations with bus driver or conductor and longer response times for customer complaints. These factors would facilitate the development of a quality public transport framework which customers could utilize to fulfill their day to day activities more effectively. The availability of a high-quality bus transport service would encourage citizens to use public transport instead of their own private vehicles thereby reducing the traffic congestion. Recommendations provided by the authors include the enforcement of proper standards and policies for public transport, adaption of recent technological advancements such as promoting the use of the existing touch travel card and the display of timetables at bus halts.

Similarly, the goal of any transport research should not only focus on analyzing the theories but should also consider the practical aspects so that a better service could be delivered in future. Hence, C. Wijerathna's paper on "Service Quality Factors Affecting Passenger Satisfaction in Public Bus Transportation: a case study of Kegalle District Passenger Bus Transportation Service Sector reforms for Economic Development" [4] addresses the practical issues faced by citizens of the Kegalle district in using public bus transport. The results of the analysis indicate that there is a significant impact of service planning, reliability, safety, cleanliness and the design of the bus network on passenger satisfaction while there is no significant impact of comfortability on passenger satisfaction. The practical issues faced by passengers in transportation was found to be the absence of a bus information sharing system and a proper complaint management framework. Hence, the researcher believes that the service quality of Sri Lanka's public bus transport could be improved via service planning, reliability, safety and network design.

However, Maha et al. paper on "Strategies for the improvements in the quality and efficiency of public transportation" [5] identified drivers' behaviour, amenities, technology, convenience, controllers' behaviour and price as the factors that provide a general satisfaction to passengers. The paper investigated the perceived quality of transport in Iasi, Romania where the most valued factor was found to be the use of technology while convenience of public transport was least valued to the passengers. The data was obtained through a questionnaire where the passengers had to rate 33 characteristics of public transport on a likert's scale of seven points.

The degree of satisfaction was assessed based on factors such as the driving style of the driver, his respect for travelers and language, the availability of ticket scanners, temperature within the bus, availability of displays and music, safety from thieves and accidents, waiting time, unannounced deviation of a bus, number of buses within a line, convenience, number of passengers in a bus, behaviour of other travelers, display of bus schedule and the connection between different public transportation lines.

It is a widely known fact that the public passenger transport service of Sri Lanka is often criticized for its low service quality. Hence, S. Chandrakumara's paper on "Urban dwellers' satisfaction on public bus passenger transport in Sri Lanka" [6] identified the critical factors that determine the satisfaction of bus passengers in Colombo. The analytical model for the research was based on the MORI model of customer satisfaction that consists of satisfaction drivers such as delivery, timeliness, information, professionalism and the attitude of staff.

The results of the survey indicate that elements such as the availability of seats, quality of driving, safety of crime, cost of bus fare, frequency of service and return of balance money had no significant impact on passenger satisfaction. Thus, the results of the study revealed that the service elements significant to one country may differ from another country due to the changes in socio-economic and cultural setting. The paper further stated that improving the bus service alone is not sufficient as it is linked with several other services such as road infrastructure, town planning and the development of other transport services such as railway.

It is evident from literature that Sri Lanka's current public bus transport system is still in its preliminary stage and has a large space for improvement. Taiwan is a developing country situated in South-east Asia with a population of 20 million similar to Sri Lanka. However, Taiwan's public transport system is of high quality when compared to Sri Lanka's existing public transport system. Yang et al. paper on "The public transportation system of high quality in Taiwan" [7] states that attention should be paid to two main areas in improving public transport.

The first area of focus should be the safety and humane of the service facilities while the other area of focus should be the real-time information systems that could provide transportation information to passengers anywhere anytime. Most of the researches on public bus transport focus on

improving the service quality while the focus on delivering real-time information is neglected. Taiwan has adopted intelligent transportation systems where the users could easily access dynamic bus information via their smart phones. Passengers could enter their current location and desired destination for which the system automatically generates the bus route, the stops and the travel time. Hence, it is understood that a blend of both service quality and real-time information is required to provide a convenient and comfortable transportation experience to the passengers.

The table given below summarizes technologies adapted by different countries in delivering a quality public bus transportation experience.

TABLE 5. TECHNOLOGIES USED IN OTHER COUNTRIES

Type of system	Technologies used	How information is presented to the user
Smart Bus Tracking system	Wi-Fi router and module connected with a cloud server [8]	An interactive mobile application that gives the list of available buses according to the users' source and destination from which users' can select a particular bus number to know the real time location of the bus
	Location Aware Services and QR Codes placed at each bus stop [9]	Passengers with a smart phone with the QR code reader can scan QR codes placed at bus stops to view estimated bus arrival times, buses' current locations, and bus routes on a map. The system is free for any user to access and alerts about expected bus arrival times are sent via SMS and e-mails.
	GPS, RFID tag linked with google maps [10]	The solution employs GPS and RFID technologies to allow commuters to track the bus from their mobile by keying in route id thereby displaying the location of the bus on a Google Map through the use of a RFID tag
Smart Bus Ticketing System	A Conductor less Bus Ticketing System Using RFID [11]	The system detects the passenger using an IR sensor and calculates the distance travelled by him and the corresponding amount is debited from the RFID card.
	Automatic Bus Fare Collection System using RFID [12]	The system uses a smart card which is given to each passenger and when a passenger gets into the bus he/she has to swipe the card in the RFID reader and when he reaches the destination, the device will automatically calculate the fare and deduct the money automatically.
Bus crowd monitoring system	A sensor-based seat occupancy & bus monitoring system [13]	A capacitive sensor is used to determine the number of passengers occupying seats in the bus. The information obtained from the sensors is transmitted to the server through GSM which is then made available to the passengers waiting at the bus stop
	An IR sensor based automatic passenger counting system [14]	The system uses infra-red (IR) sensing, pressure-sensitive mats, horizontal beams and cameras. The IR sensors are mounted above each door and are register passengers boarding and alighting when the doors are open.

III. RESEARCH FINDINGS

A. *Analysis of data*

Data for the research was collected from a sample of 157 individuals that represented the young workforce who daily travelled Colombo for employment. 58.2% of the individuals stated that they use public buses to reach Colombo while 25.5% of the respondents used their own private vehicles. The rest of the individuals used trains and office staff transport vans or buses to reach their workplace. Majority of the respondents (47.3%) stated that they have to travel more than 15 km to reach their workplace which approximately

takes between 1 - 2 hours. Meanwhile, 45.3% of the passengers agreed that they usually spend around 5 – 10 minutes waiting for a bus while 34% of the individuals stated that they usually wait 10 – 20 minutes for a bus. The table given below depicts 20 characteristics of public bus transport rated by the passengers based on their order of importance.

TABLE 6. CHARACTERISTICS OF BUS TRANSPORT

Characteristic	Less important	Somewhat important	Highly important
Safety when travelling	3.5%	36.8%	56.1%
Quality of bus driving	10.5%	31.6%	54.4%
Quality of conductors behaviour	12.3%	40.4%	43.9%
Cleanliness inside the bus	10.5%	40.4%	45.6%
Availability of seats within the bus	26.3%	42.1%	28.1%
Ease of getting on or off a bus	10.5%	38.6%	47.4%
Knowing details on bus the start times	14%	42.1%	40.4%
Knowing details on bus end times	12.3%	49.1%	35.1%
Knowing the journey duration	14%	40.4%	42.1%
Knowing the frequency of bus service	15.8%	43.9%	36.8%
Information on transport routes & timetables	17.5%	35.1%	42.1%
Answer to customer inquiries	12.3%	42.1%	40.4%
Display of bus fares in buses	15.8%	47.4%	31.6%
Issue of tickets for fare paid	12.3%	36.8%	47.4%
Return of balance money	10.5%	28.1%	57.9%
Politeness of the driver & conductor	15.8%	38.6%	42.1%
Information on service delays & disruptions	12.3%	40.4%	43.9%
Cost of travelling in a bus	8.8%	49.1%	38.6%
Ease of paying bus fare	7.01%	43.8%	45.6%
Waiting time for a bus	8.8%	35.1%	52.6%

The findings indicated that the attributes most important to the customer were safety, quality of driving, waiting time and the return of balance money while the availability of seats within the bus, the display of bus fare and knowing the frequency of buses were important only to certain passengers.

Figure 1 compares the level of importance for certain transport characteristics.

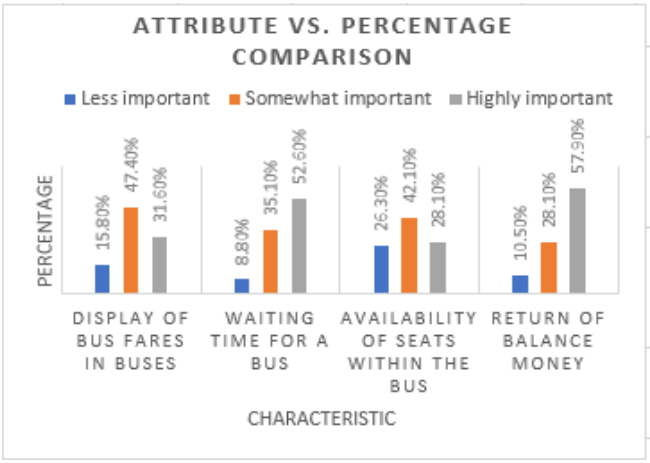

Figure 1. Level of importance for certain transport characteristics

In the meantime, majority of the passengers stated that the most common issues they faced when travelling to work by bus were:

- Heavy traffic
- Poor driving
- Slow travelling
- Overcrowded buses

- Stopping in between bus halts
- Spending too much time on the roads
- Long waiting time at certain stops
- Not receiving the correct amount of balance money
- Inability to track the location of the bus beforehand

Based on the data gathered via the sample survey, it is clearly evident that Sri Lanka needs an efficient public bus transport system capable of providing a quality transportation experience to each passenger. Besides, 72.7% of the respondents agreed that they were willing to use public bus transport more often if a better service was provided even at a higher cost. Hence, it is significant that if Sri Lanka's public bus transport system is improved, more and more citizens would use public transport rather than their own private vehicles thus minimizing the amount of traffic on the roads.

B. The proposed solution

In order to overcome the above-mentioned issues, the authors aimed to develop a national framework that is capable of addressing the two most significant issues namely, the long waiting time for a bus and the non-return of balance money. The framework aims to provide a mechanism to track the location of a bus in real-time, predict its arrival time and also provide a cashless ticketing mechanism to solve the problem of balance money. Figure 2 illustrates the high-level design of the proposed framework.

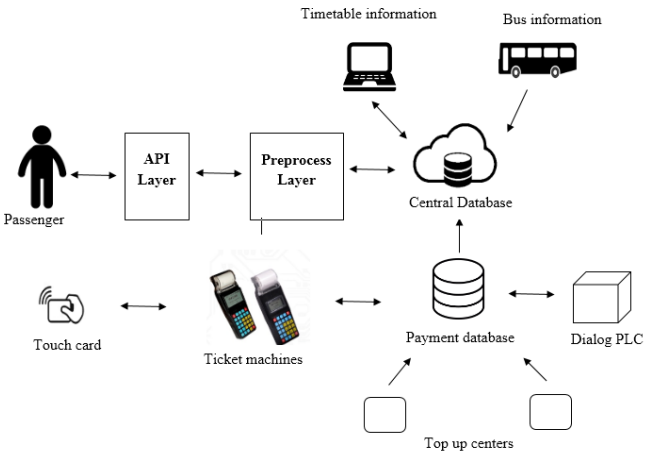

Figure 2. High-level design of the proposed framework

The proposed framework consists of 4 main layers namely, the Data collection layer, API layer, Preprocess layer and the Back-end layer. The data collection layer includes the passengers of the bus who would enter their desired destination and the number of the bus, in addition to the bus conductor who would swipe the touch card on the existing ticket machines to deduct the expense of the travel. For instance, to reach Malabe from Kaduwela, a passenger would enter the destination as "Malabe" and select the bus number as "177". The entering of data by the passenger happens through the API layer which is a mobile app that is platform independent. The API is the key element responsible for handling the overall functionality of the system including the connectivity with the database. Thus, passengers could send and retrieve data from the database via the mobile app that can be used in both Android and iOS platforms.

The preprocess layer uses platform independent middleware to bridge different architectures and infrastructures that uses different protocols and standards so that information received through the API layer can be processed and relevant action can be taken. Furthermore, the preprocess layer also consists of a bus arrival time prediction algorithm that uses GPS coordinates and the speed of the bus to estimate the predicted arrival time. The back-end layer consists of a centralized database deployed in a cloud environment. This database would contain the timetable information and the latitude, longitude and speeds of the desired buses.

Each bus would be equipped with a solar powered GPS tracker that would capture the its existing latitude, longitude and speed. GPS is high in cost and energy consumption but is the most accurate in providing real-time information when compared to RFID and NFC. Besides it also has an unlimited range which makes it ideal for tracking vehicles all over the world. Sri Lanka being a country that receives sunlight throughout the year would solve the problem of GPS's high energy consumption through the use of a solar powered GPS tracker.

The proposed cashless ticketing mechanism would include the use of the "Touch travel card" which was introduced by Dialog Axiata PLC. The Touch Travel Card is an NFC enabled prepaid card that can be used to pay transport fares. Dialog is the only organization licensed by the Central Bank of Sri Lanka to issue and operate this single purpose stored value card along with its fare collection system. This card could be purchased and topped up at any registered merchant point across the island [15]. Passengers could simply handover the touch card to the bus conductor who would swipe the card on the existing ticket machine and enter the travel fare which would later be deducted from the amount in card. The payment information would be stored in a separate payment database which is connected to the central database. Connectivity for the proposed framework could be provided through mobile data and public Wi-Fi access points. Figure 3 illustrates the workflow of the proposed framework.

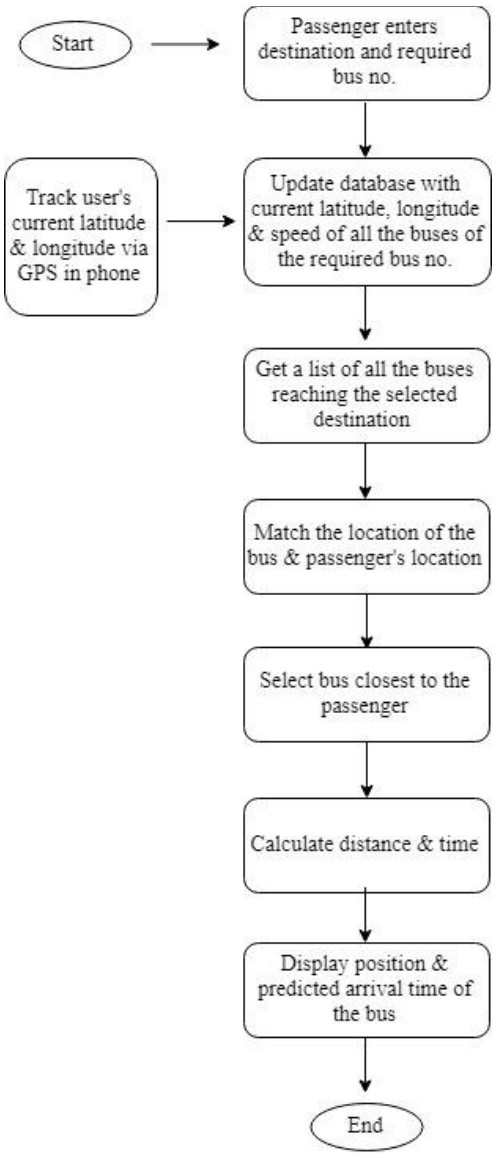

Figure 3. Workflow of the proposed framework

The bus arrival time could be predicted using the haversine formula [16] which first identifies the distance between the passenger and the bus and then calculates the arrival time based on the speed of the bus.

$$Distance\ between\ passenger\ and\ bus = radius\ x\ c \quad (1)$$

Where;

$$radius = radius\ of\ the\ earth\ (6371\ km)$$

$$C = 2\ x\ b \tan^{-1}(\sqrt{b}, \sqrt{b} - 1)$$

$$b = sin^2\ \frac{latitude}{2} + \cos latitude\ 1\ x\ \cos latitude\ 2\ x\ sin^2\ \frac{longitude}{2}$$

$$Latitude = difference\ in\ latitude = latitude\ 2 - latitude\ 1$$

$$Longitude = difference\ in\ longitude = longitude\ 2 - longitude\ 1$$

$$Time = \frac{distance}{speed} \quad (2)$$

Where;

$$distance = distance\ between\ passenger\ and\ bus$$

$$speed = current\ speed\ of\ the\ bus$$

IV. Evaluation and Discussion

The proposed framework has several benefits. The framework can be easily designed and deployed in Sri Lanka's bus transport system as it mainly focuses on using existing infrastructure such as ticket machines and touch cards. Besides, there will be no loss of jobs to the conductors as the ticketing mechanism is not entirely automated. Connectivity could be obtained through public Wi-Fi access points which the government wishes to provide free of charge. Furthermore, the touch card could be topped up via any top center available island wide while it adopts a green strategy as no tickets will be issued. The proposed framework takes advantage of the increasing number of mobile phone users in Sri Lanka through the use of a mobile app that could be used by both android and iPhone users. Additionally, the proposed framework facilitates the tracking of information such as the number of daily trips, the number of passengers and the amount of bus fare earned daily.

V. Conclusion

Public transport plays an increasingly important role in human navigation. Sri Lanka being a developing country has witnessed digital transformations in several sectors although the use of digital practices in Sri Lanka's bus transportation industry has been minimal. Hence, the proposed research presented how IT could be used to deliver a quality transportation experience to each passenger through the use of a real-time bus tracking system that uses GPS coordinates along with a bus arrival time prediction system capable of estimating the arrival time of the desired bus. The framework also introduced a cashless ticketing mechanism to eliminate the problem of carrying change money which is a burden faced by many passengers. When real-time information is available, the passengers could spend their time efficiently and reach the bus stop just before the bus arrives or take alternate paths if the bus is delayed. Limitations of the study include limiting the data collection to the young workforce employed in Colombo. Future research work would focus on implementing the framework in real and extending it to include other stakeholders of public bus transport such as the Ministry of Transport, NTC and SLTB.

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REFERENCES

[1] Daily mirror, "INDI.CA," 12 October 2015. [Online]. Available: http://indi.ca/2015/10/colombo-vehicle-statistics-2015/. [Accessed 14 June 2018].

[2] Central Bank of Sri Lanka, "Central Bank Annual Report," Central Bank of Sri Lanka, 2015.

[3] H. W. M. I. S. Ranawana and D. Hewage, "Factors Affecting the Service Quality in Public Bus Transportation in Sri Lanka," *Research Gate*, 2015.

[4] I. D. C. Wijerathna, "Service Quality Factors Affecting Passenger Satisfaction in Public Bus Transportation: a case study of Kegalle District Passenger Bus Transportation Service Sector reforms for Economic Development," *A Paradigm Shift of Thoughts and Policies: The Need of the Hour for Developing Economies*, no. December, pp. 232-236, 2015.

[5] A. Maha, C. Bobalca and O. Tugulea , "Strategies for the improvements in the quality and efficiency of public transportation," *Procedia Economics and Finance*, vol. 15, p. 877 – 885, 2014.

[6] D. P. S. Chandrakumara, "Urban dwellers' satisfaction on public bus passenger transport in Sri Lanka," *Asian Journal of Empirical Research*, vol. 4, no. 11, pp. 514-525, 2014.

[7] X. Yang and Y. Shi, "The public transportation system of high quality in Taiwan," *Procedia - Social and Behavioral Sciences*, vol. 96, p. 1350 – 1361, 2013.

[8] D. D. Bhavani and R. S. C. V. S. L. S. Kiran, "Implementation of Smart Bus Tracking System Using Wi-Fi," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 6, no. 7, pp. 12940-12946, 2017.

[9] S. Eken and A. Sayar, "A Smart Bus Tracking System Based on Location Aware Services and QR Codes," *IEEE*, 2014.

[10] S. Sankarananrayanan and P. Hamilton, "Mobile Enabled Bus Tracking and Ticketing System," *IEEE*, 2014.

[11] T. Manikandan, G. Kalaiyarasi, R. Priyanga and K. Priyadharshini, "Conductor less Bus Ticketing System Using RFID and Accident Information through GPS and GSM," *International Journal of Innovative Science, Engineering & Technology*, vol. 2, no. 9, pp. 884-893, 2015.

[12] S. Nandhini, "Automatic Bus Fare Collection System using RFID," *International Journal of Advanced Research in Computer Engineering & Technology*, vol. 6, no. 3, pp. 218-223, 2017.

[13] S. Austalekshmi, A. Rani and A. Sneha, "Sensor based seat occupancy & monitoring bus routes in public transport," 2014.

[14] I. Pinna and B. D. Chiara, "Automatic passenger counting systems for public transport," 15 December 2010. [Online]. Available: https://www.intelligenttransport.com/transport-articles/3116/automatic-passenger-counting-systems-for-public-transport/. [Accessed 14 June 2018].

[15] Dialog Axiata PLC, "Dialog.lk," Dialog Axiata PLC, [Online]. Available: https://www.dialog.lk/touch-travel/. [Accessed 14 June 2018].

[16] S. Sivaraman and P. M. Bala, "GPS Based Bus Tracking System," *International Journal of Electronics and Communication Engineering*, pp. 151-156, 2017.