Intelligent Public Transportation System

Khadisha. M. Williams, and Mansour H. Assaf

***Abstract*—**The public transportation system everywhere is under constant pressure for betterment of the customer service, security, safety and contentment while streamlining the process of commuting. This paper proposes a mathematical model for realization of the aforesaid goals in the public bus transportation system through the use of radio frequency identification (RFID). The proposed model is implemented and tested in software in a real-time development environment using the state of the art multi-modal simulator (PTV vision – Vissim) and the JAVA programming language. Different test cases have been considered and the conducted experiment outcomes demonstrate that an efficient and higher quality of service could be provided by emphasizing the improvement of the public transport vehicles, routes, and schedules through the use of sensor-based technology in the transportation infrastructure.

***Keywords*—**Arrival time, stop time, vehicle probability distribution, waiting time.

I. Introduction

THE improvement in road transportation through the use of information, communication and sensing technology has long been the subject of research and development. The advances in technology have been driving concurrent developments in transportation domain from the times of industrial revolution up to the modern day digital era [2]. However, until the 20th century, the technology in transportation was primarily focused on two objectives:

- meeting the demand of faster mobility by different modes; and
- building capacity and expanding network facilities to accommodate the needs of growing traffic.

The constraint thrust upon the available space, growing vehicle population and number of trips to transport the commuters in need of the service daily has led to severe traffic congestion, resulting in degradation of environmental quality.

A preliminary version of this paper was presented at The Seventh International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP 2011), held in Adelaide, Australia during December 6 – 9, 2011. The Proceedings version of the paper has been included in REFERENCE and cited in the text for convenience of the reader

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This situation has resulted in an innovative shift of infrastructure management through advanced technologies to ensure efficient and environment friendly user services [3].

This paper focuses on how the radio frequency identification (RFID) technology along with variable message signs (VMS) can be used to solve the problems faced by commuters and transport (bus) operators. The automated tracking of vehicles could be utilized to provide useful estimates of arrival times and to enhance commuter convenience [1], [20]. The RFID evidently is not a new technology; rather its origin dates back to World War II [12]. It is a programmed identification technology that allows for non-contact reading of data, thereby making it attractive in vehicles. Currently, USA, Europe and Asia are making use of RFID in transportation area to ease traffic congestion, keeping track of the buses when they leave bus stations in order to ensure safety of the passengers (particularly school children) along with identification of the mechanical problems that might occur with the buses [13].

The current research intends to show how the use of RFID technology would result in advancement in the use of the modern transit system and in turn would alleviate some of the traveling woes. The primary thrust of this research is to create a platform for public transport commuters based on the use of RFID technology to track buses and to provide real time information to the commuters and public transport management. The resulting system would be functionally so very efficient and trustworthy that even persons who rely heavily on their own vehicles for transportation would be motivated to use the public transportation. By studying the problems faced by the public transport systems and simultaneously addressing the needs of the commuters, an efficient system could be developed that would eventually benefit everyone concerned.

From a practical viewpoint, RFID cargo tags would be placed on all the buses, while the RD 5000 mobile RFID readers would be put on the bus stops. This would allow bus operators to know which buses in relation to their own are with the integrated wireless local area network (WLAN) radios, resulting in smooth flow of traffic along the route. The commuters would also know at what time the buses should be arriving at the designated stops. If a bus is behind schedule or on time or having mechanical problems could be ascertained as well by the variable message signs, while the information technology (IT) personnel would know where a particular bus is at any given time.

The public transport vehicle (PTV) vision software was used to develop a real time simulation environment which incorporates what would normally exist in reality, viz. the traffic lights, junctions, buses, cars and speed of the vehicles, just to name a few. The bus routes were designed with the required vehicles and mechanics to provide delineation as close as possible to the actual scenario. One of the designed networks incorporates the routes from city A (Port of Spain, Trinidad, WI) to city B (Curepe, Trinidad, WI) and from city A (Port of Spain, Trinidad, WI) to city C (Mt. Hope/Chaguanas, Trinidad, WI). A JAVA code was written in order to run the simulator with RFID features. A real time simulation environment for RFID-enabled public bus transportation system is discussed in the paper.

II. RFID Technology-based Solution

An efficient and reliable bus transport system could be developed utilizing RFID tags and readers as evidenced above, since RFID is more than a technological trend – it is a technological revolution. The IT personnel, bus dispatchers and commuters would all know where the buses are at any given time. Since a bus, which is equipped with a reader, leaves a bus stop which is equipped with a tag, the bus is read by the bus stop and a database is automatically populated allowing the IT personnel to know where the bus could be located [16], as illustrated in (Figure 1). From this point, all the commuters waiting at related bus stops and stations would be informed as to where their respective bus is by VMS, which would be constructed within the bus sheds and depots. The variable message signs are electronic traffic signs often used to give travelers information on their journey. These signs are very dynamic since the information relayed to the commuter can be set automatically or manually by the control room. The signs could be automatically updated every time a bus passes a bus stop with the use of RFID tags and readers.

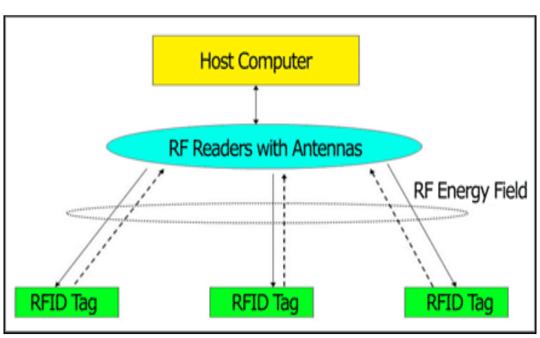

Fig. 1 RFID tag-reader communication scheme [22]

Transit operations are disturbed frequently by stochastic traffic variations and ridership, which may deteriorate schedule/headway adherence, thus lengthen passenger wait times. Providing accurate and accessible information on transit vehicle arrival times is critical to improve transit service quality [3]. The arrival times of buses have been calculated in various ways as shown below:

$$\mathbf{E_{k,i} = p_{k,i-1} + \sum_{j=1}^{m} M_{k,j} = p_{k,i-1} + \Phi_1 (X_j (t))} \quad \mathbf{(1)}$$

Where $p_{k,i-1}$ ($p_{k,i-1} \geq t$) is estimated based on the predicted bus arrival and dwell times at stop i-1.

$\Sigma M_{k,j}$ can be predicted by Φ_1, a function of $X_j(t) = [x_{1,j(t)}, x_{2,j(t)},\ldots,x_{n,j(t)}]^T$ (j=1,…,m) and $X_j(t)$ can be obtained from empirical or simulated traffic surveillance. Φ_1 can be captured by the link-based ANN through training.

The stop time of bus i (t_i), due to passenger transference, is computed by using a variation of the model presented and calibrated by Gibson et al for formal bus stops [21].

$$\mathbf{t_i = \lambda_0 + \lambda_1\theta_1 + max_j \{ \sum_{r\in PBij} [\lambda_2^r + \lambda_3^r \theta_1 + \lambda_4^r \theta_2 (i)] + \sum_{PAij} [\lambda_5^r exp(-\lambda_6^r N(PA_{ij})) + \lambda_7^r \theta_3(i)] \}} \quad \mathbf{(2)}$$

The estimated parameters in vector λ turned out to be greater or equal to zero. Therefore, in this model the marginal boarding time increases if the stop area is crowded. The marginal alighting time goes down with the number of passengers getting off through the same door, and also it increases as long as the bus is highly loaded. The parameter λ_0 is a feature of the bus i, λ_1 depends on the bus stop, while the other vector components are passenger specific. By using this technology (RFID and VMS) in the transport service, there would definitely be vast improvement to the overall public transportation systems.

III. Case Study - Real Scenario

Forty-five percent (45%) of the population in Trinidad and Tobago uses public and private transport systems on a daily basis, with thirty percent (30%) using private taxis since they are much faster and more reliable, while the remaining fifteen percent (15%) gets to their respective destinations by means of the public bus service, mainly for safety reasons besides the cost of travel which is much cheaper [1].

Since a large number of the population uses the existing transport systems, there are not enough vehicles to accommodate them, especially at peak hours, and the natural tendency of the bus transit operation being to deviate from assumed schedules. Poor schedule adherence is undesirable since it increases passenger wait and transfer times and discourages passengers from using the public transit system. On the other hand, the rest of the population that do not use the transport systems use their own vehicles to get to their destinations, leading to the roads being congested most of the times.

The priority bus routes (reserved routes), highways and main roads are the major routes used for transportation of all kinds of vehicles in Trinidad and Tobago. The buses mainly use the priority bus routes but would veer off to the highways for certain destinations since the bus route extends from Port of Spain (capital city of Trinidad and Tobago) to Arima (eastern city) only. The routes Port of Spain/Arima and Port of Spain/Chaguanas (southern city) were used as the areas of study (Figure 2) since the majority of the population would travel along these routes [1].

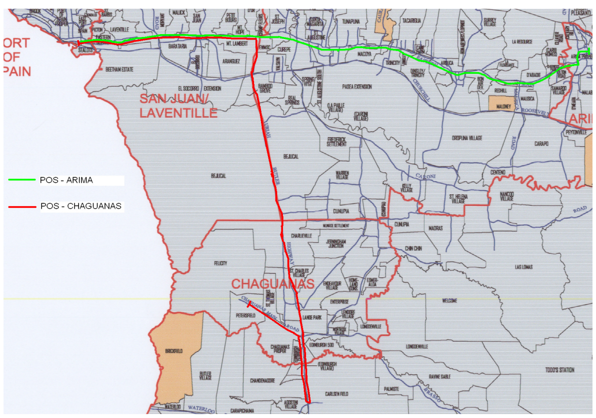

Fig. 2 Location Map showing the POS-Arima and POS-Chaguanas routes [1]

Port of Spain to Arima buses travel along the priority bus routes and this route is 25 km (25000 m) long with forty-three 43 bus stops back and forth. On the routes, there are transit and articulated service buses, not fitted with air-conditioned units that stop at every bus stop. There are also express commuter service (ECS) buses and articulated service buses equipped with air-conditioned units that stop at certain bus stops to ensure that the passengers reach their destinations on time but this is not always the case because the buses are never leaving as scheduled [1].

The total number of bus stops to and from Arima for the ECS route is thirteen 13. The buses from Port of Spain to Chaguana, on the other hand, travel along the priority bus routes up to Mount Hope junction and then turn onto the Uriah Butler highway towards Chaguanas. This route is 23 km (23000 m) long and has nineteen 19 stops from Port of Spain to Chaguanas and fourteen 14 stops from Chaguanas to Port of Spain. The articulated and ECS buses, which are fully air-conditioned are used on these routes [1], [4].
Presently, with the information given, the non-air-conditioned bus service for Port of Spain to Arima route runs from 4 am to 10 pm, but basically there is no scheduled time, because a bus does not leave every hour or every half an hour. It is much more like whenever a bus arrives, one boards the bus. There are four 4 buses designated for the routes in the morning and three 3 in the afternoon, with each bus making two 2 trips and three 3 trips, respectively. The average number of people alighting from these buses daily is 270 with 80 boarding during the hours of 6 am–9 am (peak hours), 121 during the hours of 2 pm–6 pm (peak hours) and 69 persons for the period of non-peak hours. For the air-conditioned bus service, though it runs from 4:15 am to 9 pm, with a bus leaving either every half an hour, 45 minutes or 1 hour, once again there is no set time. There are seven 7 buses designated for the routes in the morning and six 6 in the afternoon, with each bus making three trips. The number of persons traveling on these buses each day is 376 with 123 boarding during the morning peak hours, 127 in the afternoon peak hours and 126 throughout the non-peak hours. The bus service from Port of Spain to Chaguanas though runs from 4:20 am to 8:00 pm, again there is no scheduled time. There are eight 8 buses designated for these routes, both in the morning and in the evening. During the morning and afternoon peak hours, 117 persons board these buses, respectively, while only 74 people take this journey during the non-peak hours [1]. Since these two are the major routes for commuters, the structure, enhancement and efficiency of the bus service in these routes need to be addressed and that is the major reason for developing this prototype. Having a reliable and coordinated bus service in the country would not only satisfy the commuters but probably and most likely would decrease the number of vehicles on the road, because most people then would rely on the buses and leave their vehicles at home. Peak and non peak hours are as follows:

AM peak hours: 6:00 – 9:00 am;
PM peak hours: 2:00 – 6:00 pm;
AM non-peak hours: 3:30 – 6:00 am;
Non-peak hours 9:00 – 2:00 pm;
PM non-peak hours 6:00 – 10:30 pm.

IV. Design Methodology

The RFID and VMS technologies were used in the paper since they are affordable and focus on giving real time information to commuters and management at strategic locations. The RD 5000 mobile RFID reader as shown in (Figure 5) is designed for true mobility and mobile applications. The device provides real time wireless LAN connectivity and with its rugged design, ensures continuous operation in the most demanding environments. The RD 5000 is built to endure bumps from equipment and rough handling as well as exposure to dust, water and grease [14].

The RFID cargo tag illustrated in (Figure 5) is an all weather tag with a reading range of up to 40 ft/12.19 m. The rugged design tolerates natural and incandescent light, vibration, shock, rain, dust, oil and chemicals. The RFID cargo tag has flexible mounting options and can be attached to nearly any flat surface [14].

The variable message signs are electronic signs that employ information technology services (ITS), which in this case are the RFID tags and readers and a centralized control system, which would be the database used to capture the messages in real time and display them providing commuters with timely and useful information [15]. These signs would be built at the depots and bus stops in order to give the commuters information on the bus departure, delays and arrivals.

The middleware software, RFID anywhere, links the connection between the reader and tag, since the middleware stores the data received from RD 5000 readers and manages the many different readings off the system. In order to portray how this RFID technology can be used in the transit system of Trinidad and Tobago, a real time simulator was designed and implemented using the PTV vision software and JAVA programming. The PTV vision – Vissim – state of the art multi-modal simulator – is a microscopic simulator model which was developed in Germany and it is the most powerful tool available for simulating multi-modal traffic flows. Vissim features 3D animation, as illustrated in (Figure 3).

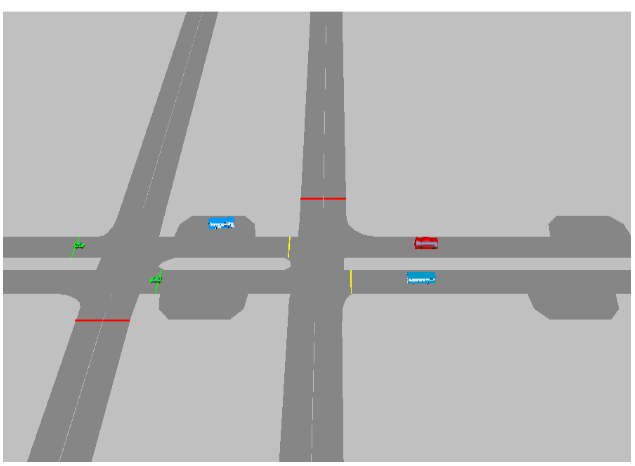

Fig. 3 The 3D feature in PTV Vision Software

Its flexible network structure integrates microscopic simulation with strategic transportation planning and travel demand modeling. The Vissim models transit routes, various transit vehicle types, schedules, stops, stop types and dwell times. The simulation shows in real time the buses approaching and leaving their respective stops in a timely manner, allowing the commuters, bus drivers and public transport system management to know where a bus is at any given time. The pseudo-code description shown below illustrates the simulation process:

```
DECLARE geometries;
GET geometries;
DECLARE vehicles;
GET vehicles;
DECLARE traffic signals;
GET traffic signals;
DECLARE transit info;
GET transit info;

LOAD VIS;
PRINT log file;
PRINT statistics;

LINK database:
Travel and dwell times;
Bus locations;
Bus type;

Trigger message box (bus, location, time);
```

The geometry, signal controls, transit and traffic input were all implemented into the simulator. The log files and statistics were generated giving an analysis of the dwell time and location of the buses in real time. The junctions, curvature, bus stops, routes and signal controls were all created manually from map observation and information provided by the public transportation service corporation (PTSC). The turning ratios at junctions, flows onto the bus route from side streets, traffic signals and routes for vehicles were all placed into the simulator. The buses were categorized into three color coded groups: Transit Arima (Blue), ECS Arima (Black) and Chaguanas (Yellow). Each bus group has their own route and number of stops with passengers alighting from and boarding buses at various stops.

The dwell time TD is the time a bus takes at a bus stop, taking into consideration such factors as the bus doors opening and closing, passengers boarding and alighting from the bus and so on and is given by the equation shown below

$T_D = \mu + \alpha A + \beta B$, where

μ: clearance time (opening and closing of doors), equal to 6 secs;

α: alighting time per passenger, equal to 4 secs;

A: number of alighting passengers;

β: boarding time per passenger, equal to 5 secs; and

B: number of boarding passengers.

The traffic input within the simulator is 150 with the actual vehicle flow from Port of Spain to Curepe [4] being 300, giving a ratio of 1:2. Therefore, the vehicle input within the simulator has been scaled down to half the actual number.

Even though that was the case, in the simulator, we tried to have the number of buses as close as possible to the number in reality.

When the simulator is activated, it shows the traffic light activity and movement of all vehicles. The data was only collected for the buses and then stored in the database where a pop-up window on the screen relays info showing the name, location and travel time of the bus as each bus passes its respective stop. The RFID readers are placed on the buses while the RFID tags are placed on the bus stops. As the bus passes or stops at a bus stop, the reader detects the tag and populates the database with info as to where the bus is located. This occurs for every bus stop and/or bus station where the tags are placed.

Assume T_1 is detected by $R_1 = P_1$;
T_1 is detected by $R_2 = P_2$;
T_1 is detected by $R_3 = P_3$;
… … …
T_1 is detected by $R_{15} = P_{15}$; with
T_1 representing the tag on Bus # 1;
R representing the reader on the bus stop; and
P representing the position (location) of the bus.

The time period that a bus waits is randomly selected using a random number generator. Hence, the time taken at a red traffic light is $T_{TL} = f(\delta, q)$, where δ is the time in secs a red traffic light stays on red, q being dependent on the number of vehicles waiting to go through. T_{TL} takes any value between one (60 secs) to three mins (180 secs) with a probability p, $0 \leq p \leq 1$, that the bus stops at a red traffic light. Here, 1 min (60 secs) $\leq T_{TL} \leq$ 3 mins (180 secs). The following algorithm gives an outline of the bus along its journey:

Declare variables (bus, traffic light, stop, speed);
DECLARE bus stops;
DO start bus journey;
    WHILE bus stops = FALSE;
PROCEED;
If traffic light green;
If passengers not boarding or leaving;
    WHILE bus stops = TRUE;
    COMPUTE η;
    If human conditions;
    COMPUTE Ω;
    If traffic congestion;
    COMPUTE δ;
    If traffic light red;
    COMPUTE $\mu + \alpha A + \beta B$;
    If bus is at bus stop;
    If passenger boarding or leaving;
    If doors opening and closing;
    If bus continues delayed journey;
        ELSE
    COMPUTE ψ;
    If mechanical difficulties;
    Bus = HALT;

The scenario put forward emulates what occurs daily on the bus routes; it is just scaled down to facilitate visual needs as shown in (Figure 4) shown below.

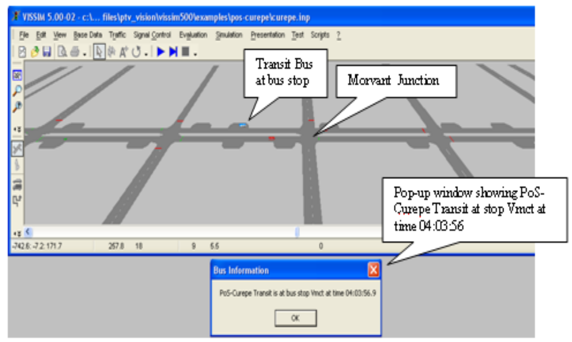

Fig. 4 Illustration of a running simulation [22]

V. EXPERIMENTAL RESULTS

In this section, comparisons are made between the simulation results and actual data. The available information including statistical data on the routes, number of passengers, number of buses, number of bus stops, peak and non-peak hours and number of people that the buses handle during these times are compared to simulation results.

Bus information is stored in real-time in databases and it is presented to user in pop-up windows. Each bus is monitored as it flows through the bus network. When the bus passes a bus stop, the RFID tag is detected by the reader and database tables are populated as seen in (Figure 5), which has a number of relationship tables and associated queries.

curepe_VEH_RECORD : Table

Iteration	ToD	VehNr	Route	Stp
1	04:01:04.6	8	2021	0
1	04:01:04.6	9	2020	0
1	04:01:04.7	8	2021	0
1	04:01:04.7	9	2020	0
1	04:01:04.8	8	2021	0
1	04:01:04.8	9	2020	0
1	04:01:04.9	8	2021	0
1	04:06:20.3	9	2020	1
1	04:01:05.0	8	2021	0
1	04:01:05.0	9	2020	0
1	04:01:05.1	8	2021	0

Fig. 5 Data populated database table

The maximum travel speed on the bus routes is 65 km/hr (18.05 m/sec) and buses would normally travel between 60 km/hr (16.66 m/sec) and 70 km/hr (19.44 m/sec), giving an average speed of 65 km/hr (18.05 m/sec). This was also the speed for the buses on the simulator. On a normal day, it takes approximately 1 hr 30 mins (5400 secs) to travel from Port of Spain to Arima transit while the route from Port of Spain to Curepe that is 11 km (11000 m) long takes roughly 40 mins (2400 secs) to cover; the simulator also shows this approximate time as the bus travels in the simulator.

N.B-: 60 simulator seconds (ss) = 1minute.
The transit bus completes its journey in 780 secs; we have to note that the simulator uses one third of the actual 11 km (11000 m) distance and hence, 780 secs as shown by the simulator is really 39 mins (780x3 secs) which is pretty close to the actual time. (Figure 5) shown below gives an illustration of the transit bus on the simulator being on the same course with the actual transit bus for the 3.2 km (3200 m) distance.

For the route from Port of Spain to Arima ECS which has fifteen (15) bus stops back and forth, the maximum travel time for this bus takes just about 45 mins (2700 secs) due to fewer number of stops, while Port of Spain to Curepe ECS which has five (5) bus stops along its journey takes only 25 mins (1500 secs), but with the simulator, it takes 420 secs or 7 mins. The time of 7 mins is really 21 minutes (420x3 secs), just 240 secs off the actual time. This is illustrated in the graph below (Figure 6).

The other route, Port of Spain to Chaguanas, has maximum travel time of 1 hr 30 mins (5400 secs), while Port of Spain to Mt. Hope travel time is 30 mins (1800 secs). The route from Port of Spain to Mt. Hope is 9.2 km (9200 m) and has ten (10) bus stops to and from Mt. Hope.

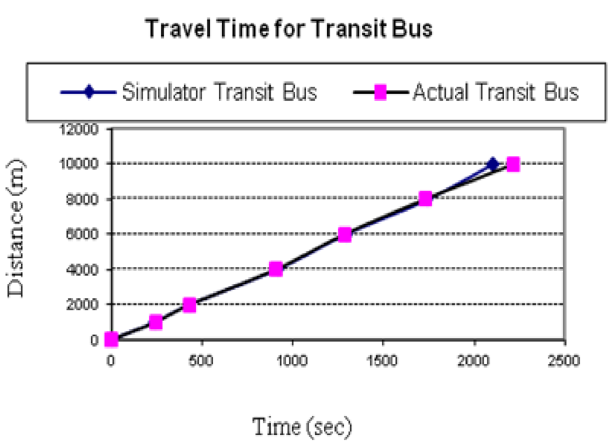

Fig. 5 Simulation travel time vs. actual transit bus time

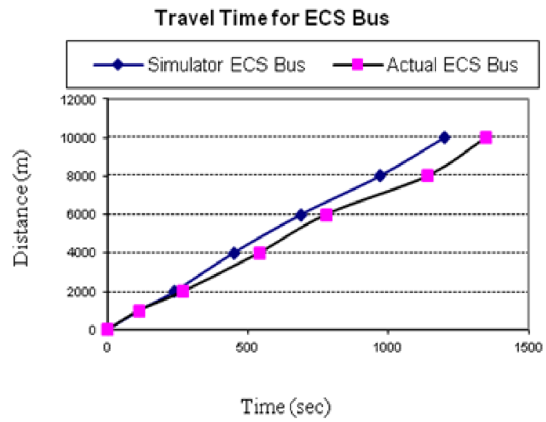

Fig. 6 Simulation travel time vs. actual ECS bus time

Port of Spain to Mt. Hope road data was used with the simulator since the simulator was not designed to include past Mt. Hope for Chaguanas route. The travel time here on the simulator is 540 secs which is equal to 9 mins. Once again, we have to recall that the time of 9 mins is really 27 mins (540x3 secs), which is rather close to the actual time. Graph shown in (Figure 7) portrays this.

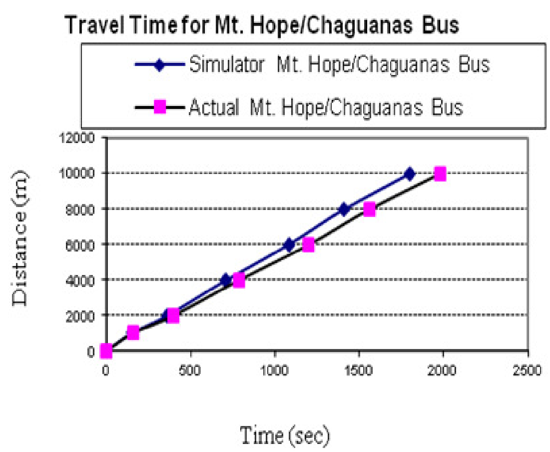

Fig. 7 Simulation travel time vs. actual Mt. Hope/Chaguanas bus time

By analyzing the above graphs, it can be seen that the simulator times and actual times are almost the same in the graphs of Figures 8, 9 and 10, emphasizing the fact that the simulator is a true representation of the actual bus routes.

Factors that affect the free movement of buses are:

(a) Traffic jams caused by licensing officers, accidents or bad weather (represented by $\mathbf{\Omega}$)
(b) Stops made at traffic lights on red (characterized by $\boldsymbol{\delta}$)
(c) Stops made at bus stops for passengers (represented by $\boldsymbol{\gamma} + \boldsymbol{\alpha}A + \boldsymbol{\beta}B$)
(d) Stops made if a passenger or the driver is in need of medical assistance (characterized by $\boldsymbol{\eta}$)
(e) Mechanical difficulties (represented by $\boldsymbol{\psi}$)

The total travel time for a bus with delays can be represented as follows:

$$\sum_{i=0}^{6} T_i = T_0 + T_1 + T_2 + T_3 + T_4 + T_5 \quad (3)$$

Where T_0 represents the time taken for a bus without any delays and T_1 to T_5 symbolizes the delay times due to the factors mentioned above. The diagram below, (Figure 8), shows a transit bus in a running simulation, the bus color is white because it is affected by one of the delaying factors mentioned above. The transit bus is involved in a traffic jam situation, once the bus is out of that condition it changes color back to its original color and continues along its journey.

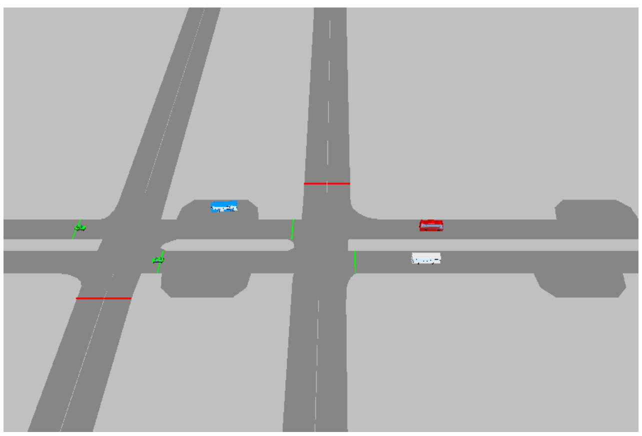

Fig. 8 Transit bus with Traffic Jam delaying factor

When the bus stops at the traffic light though, it has to wait for a period between one to three minutes. The waiting period is randomly selected using a random generator with a seed number.

T_{TL} = f(δ, queue) where **1min ≤T_{TL} ≤ 3 mins** with a probability of **0.4**

This process is depicted in (Figure 9) shown below. This process is modeled as Poisson distribution since it is used to model the number of events occurring within a given time interval and the queue factor at the traffic light is one of the events. The queue factor represents the number of vehicles ahead of the bus, also waiting for the light to change.

The probability that a bus will stop at a bus stop is 0.7 which mean that 70% of the times, and when it does, the bus waits at the bus stop the waiting period depends on the number of passengers boarding and alighting the bus (Figure 10). The collection of bus tickets is also a function of the time the bus takes at a bus stop, thus incorporating the use of Poisson distribution. From data collected the waiting period ranges from thirty seconds to two minutes.

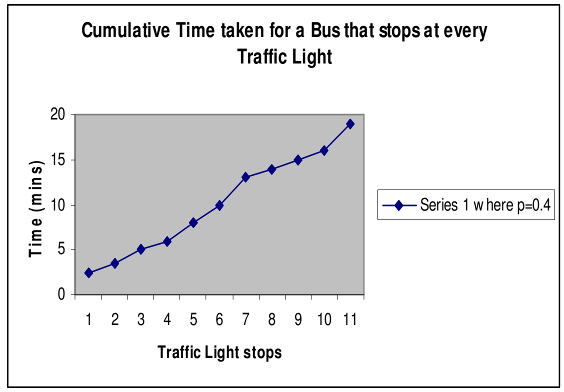

Fig. 9 Bus cumulative time taken at traffic lights

T_{BSt} = f(γ + αA + βB, collection of bus tickets) where **30 secs ≤ T_{BSt} ≤ 2 mins** with a probability of **0.7**

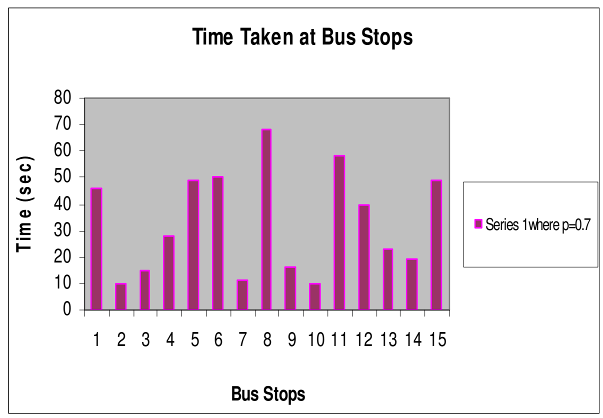

Fig. 10 Time taken at bus stops

The likelihood that a bus stops because it is in traffic is assumed to be 0.7 (which is 70% of the times) during peak hours and 0.2 (which is 20% of the times) throughout the non-peak hours. The period the bus takes while in this stand still position may vary between five to ten minutes

T_{TJ} = f(Ω, queue) where **5 mins ≤T_{TJ}≤ 10 mins** with a probability of **0.7**
T_{TJ} = f(Ω, queue) where **5 mins ≤T_{TJ}≤ 10 mins** with a probability of **0.2**

Figure 11 shown below is a graph depicting the above equation. Once again Poisson distribution is also involved in the schematics. The queue in the equation represents the number of vehicles ahead of the bus.

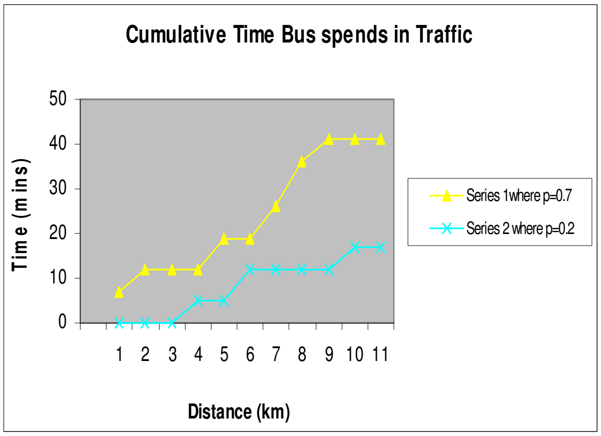

Fig. 11 Cumulative time a bus spends in traffic

The possibility that a bus will stop because of mechanical difficulties is roughly 0.0001 which mean a bus breaks down 0.01% of the times, and the downtime for this bus to be serviced may vary between one to six hours depending on the severity of the problem (Figure 12). The time taken for this down time is randomly selected using a random generator with a seed number.

T_S = **f(ψ, mechanical problem)** where **1hr** $\leq T_S \leq$ **6hrs** with a probability of **0.0001**

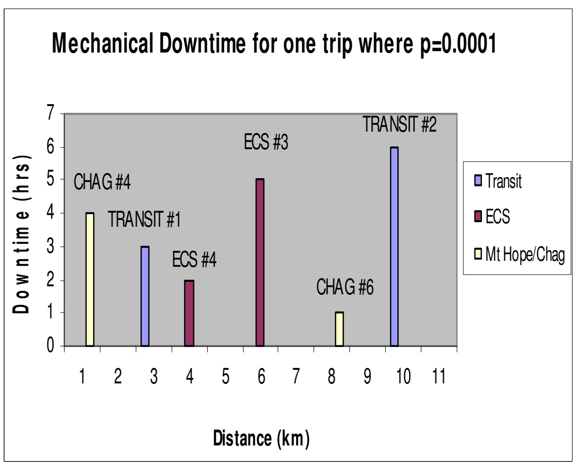

Fig. 12 Mechanical downtime

The final delaying factor of a bus stopping due to an ill passenger or driver has a probability of 0.00001this means that passengers may get sick 0.001% of the times during the day which is very rare (Figure 13). The time taken for the person to expect medical attention should take between five to fifteen minutes.

T_{MA} = **f(η, time to make the call)** where **5 mins** $\leq T_{MA} \leq$ **15 mins** with a probability of **0.00001**

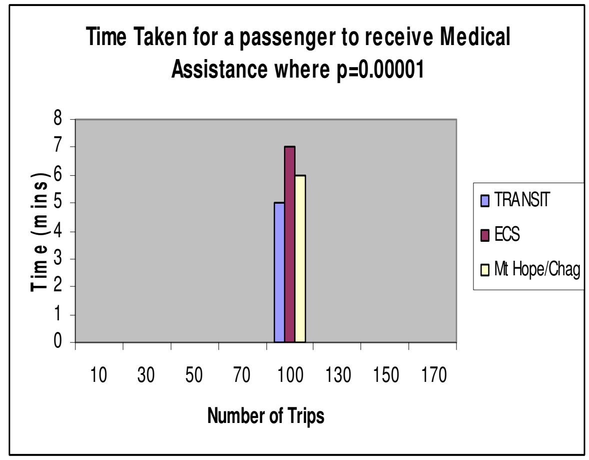

Fig. 13 Time taken waiting for medical assistance

Figure 14 shown below compares actual bus delayed by traffic and simulation traffic delay.

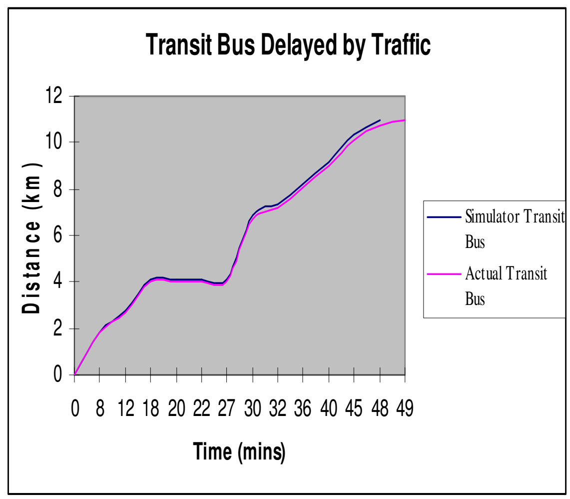

Fig. 14 Comparison of the simulated and actual bus in traffic

The simulation graph is relatively close to the actual depiction. It is observed that the delay time that occurred once, was for a period of 540 simulator seconds which is equivalent to 9 minutes. This 9 minutes falls in between **5 mins** $\leq T_{TJ} \leq$ **10** mins thus causing the bus to take a total of 2880ss or 48minutes to reach its destination which is 9 minutes later than scheduled.

If we implement most of the factors, which assumed taken place once to each bus causing a worst case scenario, it can be observed by the diagram below (Figure 15) that passengers can be delayed for 30mins.

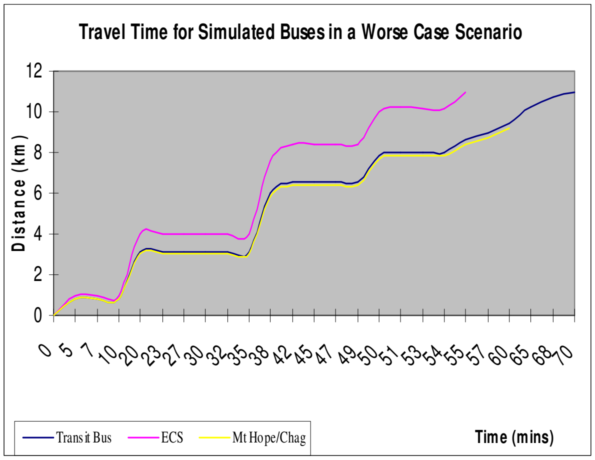

Fig. 15 Bus delay time in a worst case Scenario

By minimizing these factors an optimum graph can be obtained showing an improved travel time for commuters, where they would reach their destinations on time. This optimal graph shown below (Figure 16) is ideal for bus everyday bus users.

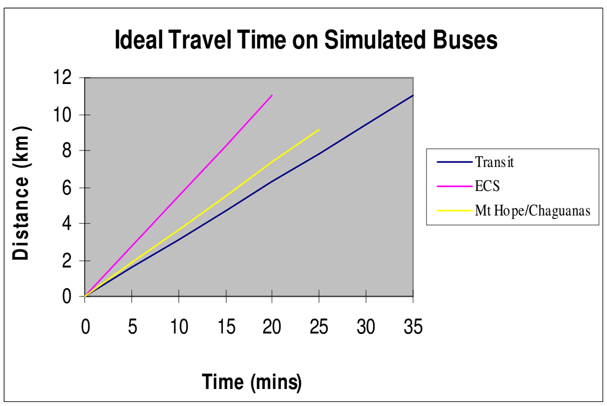

Fig. 16 Optimal travel time for everyday bus users

With the installment of RFID tags, readers, and the Variable Message Signs, bus routes are monitored and commuters are informed about delayed buses in real time.

VI. Conclusion

This paper discusses the design, implementation, and testing details of using RFID technology and VMS in the public bus transportation system. A real public transport system scenario of Trinidad and Tobago bus system is considered in this work as study case. The RFID-based public transport system is designed in real-time simulation environment using Vissim software together with JAVA programming language. The bus route networks and related statistical analysis efficiently and accurately emulate a general public bus transport system with emphasis on the practical case of the public transport system in Trinidad and Tobago. The simulation environment is interactive and shows the movement of the buses in the traffic along the routes with designated stops. The buses can be tracked in real time. In sequel, the simulator shows how RFID and VMS would work together to optimize any public transportation system.

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