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Analysis of Bus Rapid Transit System and Its Comparison with Conventional Transportation Systems

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ABSTRACT

Considering the increasing amount of traffic congestion and inconvenient travelling experiences a system needs to be designed to provide a hassle free travel which alleviates the travelling experience of the commuter and thrives them to choose this technology over any conventional implemented system or driving by own self. The system is designed to integrate a large number of areas together in order to create an efficient and economical system for the passengers to travel over long distances with comfort and safety. The Bus Rapid Transit System (BRTS) which is a public transport service is designed to mitigate the drawbacks of the previous systems as well as implement technologies in various domains including location tracking , communication services , monitoring and creating a detailed comparison with the conventional transportation services on multiple parameters in order to create a distinction and focus on the factors that make BRTS a much better mode of transportation as compared to the conventional transportation methods.

Keywords – Bus Rapid Transit System (BRTS), public transport service , location tracking , conventional transportation.

I. INTRODUCTION

With increase in the population and traffic density in a particular area, multiple services are designed and extended as far as possible for the people amongst which transportation a prime requirement which is capable enough to carry people in mass. Amongst multiple transportation services such as city buses, cabs and rickshaws an effective solution needs to come in picture to mitigate multiple problems hence BRTS i.e. Bus Rapid Transit System was implemented. Currently this system is implemented in various parts of the country including Pune, Bhopal, Ahmedabad, Jaipur, Vijayawada, Indore and many others. With every city being spread on a large scale comes up with multiple difficulties during transportation. Hence, this paper throws light on the factors that the cities currently faces and how BRTS acts as an effective solution in rectifying those difficulties. Unlike city buses run by the government, BRTS which is developed under Intelligent Transportation System (ITS) introduces its own bus termed as iBus which acts as a medium to commute. It falls under the category of Smart transportation system. The bus is equipped with multiple devices which technologically sound which not only alleviates the travel experience but provides ample security to the commuters.

II. PROBLEM STATEMENT

Conventional transportation systems showcase multiple parameters which are the prime reason for coming up with a solution to limit those challenges in BRTS system. The challenges are -

1. Increased fuel consumption.
2. Increased transportation prices.
3. Traffic congestion.

4. Traffic density per kilometer.
5. Transportation delays.
6. Air pollution
7. Security issues
8. Uncomfortable travelling experience.
9. Difficulties in finding public transportation systems.

III. SCOPE OF WORK

The paper focuses primarily on:-

1. Architectural and route implementation of BRTS.
2. Domains of Integrated Transit Management System
3. Comprehensive analysis of conventional transportation systems and BRTS.

IV. ARCHITECTURAL DESIGN

The infrastructural measures kept in mind while designing the BRTS system are :-

1. Route - BRTS is of about 11.3 kilometer length that includes 21 bus stations within the central city as a route that operates separately without causing hindrance to the regular traffic while including 30 bus stations from Indore to Mhow via a feeder network thus connecting two different towns with the lost possible transportation price.
2. Ticketing methods – Multiple ticketing methods are implemented to ensure feasibility of the commuter.
3. Security systems – Keeping in mind the security of the passengers as well as the staff the bus is equipped with multiple safety measures including cameras, SOS buttons , fire extinguishers etc.
4. Bus tracking systems are designed in order to have a real time track of the location.
5. RFID and photo sensor gates are incorporated in order to avoid unfair means of travelling.
6. A central monitoring system to monitor BRTS buses and ticketing simultaneously via monitors and electronic ticketing machines.
7. To advocate the use of Compressed Natural Gas (CNG) as a primary fuel for commuting between stations.
8. Design a travelling chart to organize the time of travel between stations and Estimated Time of Arrival (ETA) of every station.
9. Construct Point of Sale (POS) booths for commuters to buy ticket in an orderly manner.
10. Setting up televisions to update passengers with current news updates and to generate revenue by putting up advertisements.

Below is the implemented route for BRTS (Indore) which begins from Niranjanpur (A) to Rajiv Gandhi (B).

Fig 1 – Implemented route for BRTS (Indore)

The route implementation is primarily based on following factors :-

1. Width as well as the length of route over which the buses ply.
2. Population density on multiple locations.
3. Traffic density forecasting before and after implementation of route.
4. Ample space to deploy Point of Sale (POS) stations.
5. Number of routes connecting the POS.
6. Ability to deploy underground fiber optic communication cable to interact between stations.

V. METHODOLOGY

It comprises of a basic procedure that every commuter needs to follow :-

1. Reach to a Point of Sale (POS) station for ticket issuing.
2. Buy a valid ticket which can comprise of various types of ticketing media such as - Quick response code , Token , Smart card which is issued with a monthly recharge facility.
3. The commuter needs to reach the nearest fare gate and scan his ticketing media through a Radio Frequency Identification (RFID) scanner for its validity.
4. After scanning the ticket the data is transferred to the backend SQL server designed to validate the process and report in case of error.
5. The commuter needs to board a bus as soon as possible in order to avoid expiry of ticket after the ticket crosses its validity time.
6. The passenger needs to rescan the ticket or smart card before getting off at his destination or insert the allotted token at the fare gate.
7. For a smart card , the fare gets deducted at the exit gate.

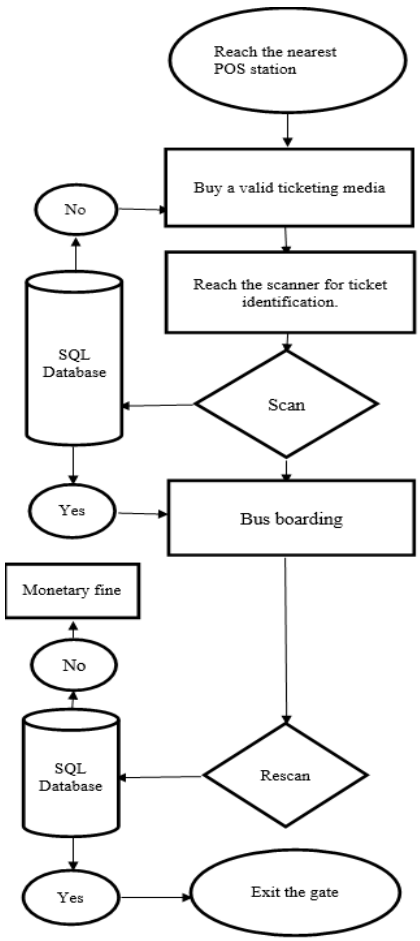
An exceptional case of an invalid ticket or token because of more than the allotted distance travelled needs to pay a monetary fine depending upon the distance travelled.

Key points to remember :

1. In case a commuter scans the smart card but doesn't travel then adjustments are supposed to be done.
2. If the commuter uses a smart card and travels to the feeder network then adjustments are to be made accordingly when he uses his card again.

A flowchart is designed to provide a brief explanation about how a passenger commutes between the stations and how the ticket validation takes place. The flowchart is self- explanatory concerning the methodology.

FLOWCHART



VI. REQUIREMENTS

It comprises of 4 major components –

1. Automatic Fare Collection System
2. Automatic Vehicle Location System
3. Communication Network
4. Transit Management Center

A. Automatic Fare Collection System

The agenda of using a AFC system is to calculate the fare generated because of the passenger ridership which helps in determining the status for the fare generated every day and the passenger density on every bus stations at any point of time. The AFC system is responsible for generating a valid QR code ticket or a RFID token through the POS via an ETM or through a personal computer for the commuter.
The Automatic Fare Collection System must satisfy the following needs –

1. Fare calculation: The fare is calculated according to the distance travelled by the passenger from the entry to the exit station.
2. Fare Verification: Through controlled access at stations with entry/exit fare gates; and through Handheld Electronic Ticketing Machines (ETM) on the buses running in open environment.
3. Enable off-board fare collection system for the BRTS buses running on the project corridor.
4. Enable on-board fare collection system for the BRTS feeder buses and city buses.
5. Fare integration between the BRTS buses running in the city as well as the feeder network.
6. Passenger density on every bus station at any point of time.
7. Calculating the ticket issuing, entry and exit time of the passenger.
8. Generating tickets through Electronic Ticketing Machines and sending the data over the backend server in order to calculate the ridership for an evaluation of its profit and losses.

The two ticketing methods currently under operation are-

1. Off-board ticketing: The buses plying on the BRTS corridor shall have off-board ticketing method wherein the fare will be collected at the bus-stations. The user shall be allowed to travel with various ticketing media facilities including –

   i. Smart card
   ii. Quick Response (QR) code
   iii. RFID token

All these ticketing medias can be purchased at the Point of Sale (POS) terminals. The fare gates will control the access of users into the paid area of the station. The gates will be equipped with QR code , token and smart card readers. A user with valid fare media will be allowed to pass through the fare gates.

2. On-board ticketing: The feeder bus services shall use on-board ticketing. The commuters will be able to buy the tickets after boarding the bus. In case of smart card, the fare will be deducted from commuter's smart card after the destination station is entered by bus conductor and the smart card is tapped against ETM.

The smart card must have an online recharge functionality for the commuters. For this purpose, the AFC system shall be integrated with the selected payment gateway(s) feasible for the user to with an efficient and reliable user interface.

B. Automatic Vehicle Location System

It involves monitoring of the buses over the proposed route through an application that comprises of various features such as –

1. Providing traveler information.
2. Enhancing operational efficiency.
3. Increasing ridership and improving cost-

effectiveness of the system.
4. Real Time tracking of the bus location.
5. Check for the emergency situations (if any) such as breakdown, fire , terrorist attacks through a SOS alarm.
6. To check if the bus is travelling over the desired route or not.
7. Time duration for which the bus travelled from it's initial to the intermediate and final destination.

The components of the AVL system include:

8. Central Control Room with video display and related system equipment.
9. On Board Unit (OBU) which is integrated with a GPS receiver to track the bus in real time.
10. Integration of the existing on-board
11. PIS with a voice announcement facility with the AVL for automatic information announcements and advertising.
12. PIS display boards at Bus Stations for the ease of the commuter.
13. AVL Application Software for tracking and monitoring buses and managing alerts.
14. In vehicle display system: Inside the buses, the visual LED display boards are installed which displays the real time BRTS route traffic information from central control station regarding current and next bus stops and other informative messages.

The PIS shall display:

1. The estimated time of arrival of the buses in an ascending order.
2. A notification when the bus arrives and leaves the station.

The AVL & PIS server shall collect the field data from the OBU's and process it at the TMC and then send back the data to be displayed as Expected Time of Arrival (ETA) on the PIS boards located at the stations. The PIS is hence a sub-system of the AVL system where the functionality of sending customized messages and timing of messages is done.

C. Communication System

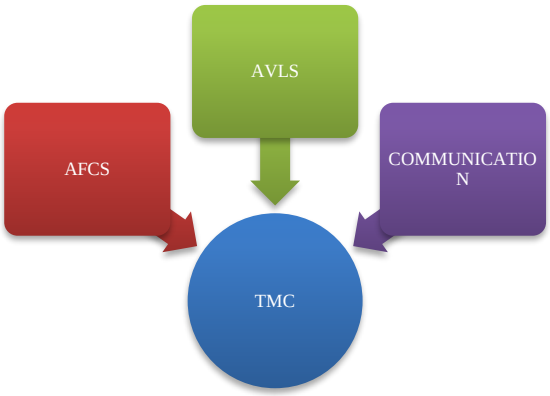
As a part of the requirements, all the Intelligent Transportation systems (ITS) shall have their respective central system hardware and software deployed at a centralized unit for monitoring, and will communicate with each location. To support communications requirements, the project shall include the deployment of a communications system. This communication system shall provide connectivity along the entire corridor using Optical Fiber Cables (OFC) and local distribution.
There must be redundant communication links to interconnect:

1. Traffic Management Centre developed with underground OFC + Asymmetric Digital Subscriber Line (ADSL) with facility of Global System for Mobile (GSM) and Internet.
2. BRT Stations and all Intelligent Transportation system (ITS) equipment in the station (buried OFC + ADSL/GSM)
3. City wide Point Of Sale Stations (Internet).
4. General Packet Radio Service (GPRS) connectivity for all mobile devices such as on-board & back-up ETM's.

D. Transit Management Centre

The center acts as a central hub for AVL, AFC and Communication system where the whole data exchange as well as data collection process takes place. The center is responsible for monitoring the entire BRT System thus this includes reports that are required to be generated to settle payments to the BRT bus operator for which the revenue collected data reports (from AFC System) shall be required to

be integrated with the vehicle kilometers run and the penalties applicable (from the AVL System). The report shall be able to use data from both systems and calculate the amount to be paid to the bus operator indicating the surplus, deficit amount if any compared to the revenue generated from the AFC system. Hence it is important that the reports generated from the AVL System to be used to validate and check the performance of the buses commuting between the proposed route.



VII. CHALLENGES AND SOLUTIONS

The current implemented setup has multiple challenges which needs to be rectified –

1. During the data receiving process their might be a delay in the packet transfer over the internet which can cause the PIS display board another delay in the calculation of Estimated Time of Arrival (ETA) which eventually hampers the Quality of Service (QOS).
2. Since there are no ticket checking systems in the Feeder network due to geographical hindrances hence commuters can travel more than the destination awarded over a particular ticket hence an exact fare calculation and ridership can't be recorded.
3. Operational challenges that can be caused because of the commuters misbehaving with the fare gates flap which leads to mechanical disorders including improper functioning and damaging the gates.
4. Stealing or losing RFID tokens also adds up to another financial loss to the firm.
5. Crumbling the QR ticket can eventually hamper its quality and thus won't be accepted at the fare gate thus adding an obstruction to the Quality of Service.
6. Commuter who is unaware about the photo sensor deployed in the fare gate system can affect the efficiency of the system thereby increasing the time of fare gate transfer for every passenger waiting in the queue thus increasing thereby delaying the transfers.

The proposed solutions can be:

1. Applying a color coding technique in the Feeder network to easily identify the
2. distance travelled by the passenger according to the fare and distance awarded in the ticket.
3. Instructing people inside the bus about the problems arising because of improper handling of tickets and Radio Frequency Identification (RFID) tokens.
4. Punishing the passengers with a considerable fine for hampering with the property such as the fare gates, RFID tokens.
5. Continuous monitoring of the LAN and GSM systems to avoid packet delays if any in the PIS boards to have an efficient working without missing out any information.

VIII. AUTHOR AND AFFILIATION

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IX. RESULTS

Below is the list of Point of Sale (POS) stations operating in the city amongst which some random

stations are selected and accordingly the data is analyzed. The analysis is based on calculating the distance between selective Point of Sale (POS) stations and Auto Rickshaw, Cabs and Personal vehicles such on few parameters mentioned below :

1. Passenger carrying capacity,
2. Fare comparison on the basis of distance travelled
3. Time efficiency of transportation services at peak hours of traffic.

S. No .	Bus Stops
1.	Niranjanpur
2.	Scheme Number 78
3.	Shalimar Township
4.	Satya Sai
5.	Vijaynagar
6.	MR 9 Square
7.	Press Complex
8.	L I G Square
9.	Industry House
10.	Palasiya
11.	Gita Bhawan
12.	AICTSL
13.	Sivaji Vatika
14.	GPO
15.	Indira Pratima
16.	Navlakha Square
17.	Holkar Subway
18.	Bhawarkuan Square
19.	Vishnupuri
20.	Mara Gujari
21.	Rajiv Gandhi

Table 1 – List of Point of Sale (POS) stations

S. No.	Auto Rickshaw	Cab / Personal vehicle	BRTS*
1.	3-4	4-5	39-55

*- Carrying capacity can vary depending upon number of sitting and standing passengers

Table 1 – Passenger carrying capacity

S. No.	Start point	End point	Distance between stops (km)	*Cost of travelling by – Auto Rickshaw / Cab / #Personal Vehicle (INR)	Fare price by BRTS (INR)
1.	Rajiv Gandhi	Bhawarkuan	1.3	43 – 45 / 50 – 60 / 8 – 12	5
2.	Navlakha	Sivaji Vatika	2.9	46 – 50 / 58 – 65 / 11 – 16	5
3.	Gita Bhawan	Vijaynagar	3.6	45 – 48 / 81 – 116 / 25 – 35	10
4.	Holkar Subway	Niranjanpur	9.4	190 – 210 / 259 – 275 / 54 – 83	20

*- Cost of travelling by Personal Vehicle is calculated with an average mileage of car ranging from 8 to 12 km / litre and price of Diesel being Rs.70 / litre.

- Cost of travelling by Auto Rickshaw or Cab can vary depending upon the time of travelling and traffic density.

Table 2 – Fare comparison according to the distance travelled

S. No.	Start point	End point	Distance between stops (km)	Auto Rickshaw*	Cab*	BRTS*
1.	Rajiv Gandhi	Bhawarkuan	1.3	10 – 12 minutes	9 – 11 minutes	6 – 7 minutes
2.	Navlakha	Shivaji Vatika	1.8	15 – 20 minutes	19 – 25 minutes	8 – 10 minutes
3.	Gita Bhawan	Vijaynagar	3.6	25 – 30 minutes	28 – 32 minutes	15 – 19 minutes
4.	Holkar Subway	Niranjanpur	9.4	55 – 80 minutes	45 – 70 minutes	30 – 35 minutes

* - The average time of travel is based on estimation and traffic density. It can vary depending upon the time of travel.

Table 4 – Efficiency of various transportation services at peak time

X. CONCLUSION

The results describe the efficiency of BRTS and its comparison with some of the parameters by clearly depicting its credibility in the field of smart transportation systems. It not only alleviates the travelling experience but also reduces the impact of factors mentioned above . To control the amount of pollution the buses are designed to run on Compressed Natural Gas (CNG) which is currently

implemented and the results analysed are sufficient to prove the benefits of implementation of BRTS in multiple regions depending upon the geographical requirements and traffic density . The fact that public transportation systems have never been reliable and secured enough to travel hence this system is designed keeping in mind the cons of the previous implemented systems without disturbing the environment and current methods of transportation. There are multiple parameters which needs to be identified and studied in order to make it more comprehensive and eliminating the nuances that degrade the quality of transportation. The key benefits of implementing this system include:-

1. Reduced carbon – dioxide (CO_2) emissions.
2. Reduced transportation cost .
3. Increased passenger carrying capacity .
4. Better efficiency in peak hours with minimum travel time .
5. Secured travel with multiple safety systems in case of a tragedy .
6. Reduced traffic density .

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