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Bus Rapid Transit System (BRTS) in India: An Overview

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Abstract :- **Bus Rapid Transit System (BRTS) is a high user capacity transport system which delivers very fast, reliable, comfort and cost effective mode of movement for the customers. Since BRTS run in their exclusive lanes, there are very less chances of congestion and accidents. Even due to application of green technologies, air and noise pollution are very less. BRTS has proper provisions for right of ways, easy boarding and alighting facilities for passengers. Moreover with the use of artificial intelligence BRTS stands out quite better than other public transport systems. The first BRTS was implemented in Curitiba, Brazil in the name of Rede Integrada de Transporte in 1974. This service inspired many services around the world. As of November 2016, about 35 million passengers use BRTS every day. Particularly Latin American countries have excelled in their approach towards BRTS. Currently TransJakarta is considered as the longest BRT route in the world with 210 km connecting the Indonesian capital Jakarta. But the operation of such systems fails due to poor planning and management. Government of India has emphasized on creating SMART cities. In this regard, BRTS will definitely ensure to achieve a good smart city in terms of public transportation system. With increasing population and growing demand for speedy inter-city and intra-city transportation services, BRTS will play a major role. This paper examines two successful cases; TransMilenio in Bogota, Colombia and Ahmadabad BRTS, India. It also tries to find out new approaches in terms of cost, quality and time of BRTS in future**

Keywords: **- BRTS, Artificial Intelligence, SMART city, TransMilenio**

I. INTRODUCTION

A country's growth is very much dependent on the adequate transportation systems available to the citizens. Bus Rapid Transit Systems is one of successful mode of transport to solve the congestion, delays, accidents and other issues. The cost involved in the construction of BRTS is quite cheaper than metro rails and light rail transits because existing roads can be converted to BRTS routes. As most of our towns and cities face huge problems of public transport, BRTS stands out very well in achieving the needs of the society. The major advantages lie in it is its way of high capacity design, high durability and use of artificial intelligence for common public. This paper is divided into five sections. First section is introduction. Second section is literature review. This section describes past studies on this field. In the Third section, two case studies have been discussed. Some suggestions are being made in the Fourth section on the basis of the literature and case study. In section five, conclusion is drawn.

In India, currently BRTS is functioning in Ahmadabad, Indore, Jaipur, Rajkot, Bhopal, Delhi and Pune. But the functioning of these systems is not at par with standards set by international authorities except Ahmadabad. Improper design, increase in number of private vehicles, inadequate facilities at bus stops makes life very difficult. Introduction of green systems like pollution free vehicles is still a dream in India. This paper tries to find the new ways that can be introduced in current BRTS so that the efficiency can be increased in terms of cost, time and quality. Government of India has laid emphasis on creating SMART cities across the country. Smart transportation systems can act as major contributor in success of such proposal. BRTS fulfills this basic criterion. In future, BRTS will be flagship system in Indian cities' public transport system.

II. LITERATURE REVIEW

Chen et al. (2007) in their research studied two core techniques of Bus Rapid Transit (BRT): exclusive bus lanes and transit signal priority (TSP). The background of BRT development in China is first introduced, followed by a synthesis of state-of-the-art on the simulation-based evaluation of BRT effectiveness. For a comparison purpose, two BRT scenarios are designed: median bus lanes versus curb bus lanes, and with versus without TSP. The micro-simulation model VISSIM is used to simulate different scenarios, and the traffic flow characteristics under different scenarios are analyzed according to the simulation results. Analysis indicates that: (1) Exclusive bus lanes and signal priority should be implemented simultaneously in order to effectively improve the BRT's operational performance; (2) After the signal priority is applied, the traffic flow status of the intersections along the BRT route is considerably improved; and (3) with respect to the exclusive lane layout, when it is divided from other lanes by physical infrastructure, median bus lane and curb bus lane have different impacts on traffic flows on the roadway and traffic flows at the intersection. The study further depicts that mean delay at intersection, the mean number of stops, and the queue lengths for overall systems increase slightly when the exclusive lanes change from median bus lane to curb bus lane. But after Total Signal Priority has been implemented, the mean queue lengths and mean number of stops have decreased remarkably at each intersection.

Liu et al. (2007) discussed the benefit of BRT exclusive lanes and analyzed the changes of the vehicle passing capacity and passenger carrying capacity with and without the BRT exclusive lane, as well as proposes an approach for the corresponding calculation. It is shown from the research that (1) the installation of BRT exclusive lane may reduce the vehicle passing capacity of the road, but it can effectively bring benefits the operation efficiency of BRT and improve the passenger carrying capacity of the road; (2) to exert the advantage and benefit of BRT, reasonable coordination between regular bus lines and BRT corridors is very important, especially under the condition that BRT has not formed a network; (3) the reduction of the regular bus volume along the BRT corridor cannot be too big. It is found that for the Beijing North-South Center Axis Corridor, 40 per cent is the critical point to increase the passenger carrying capacity. The other similar cases can be calculated using the method proposed in this paper. The authors observed that the vehicle passing capacity of road with BRT exclusive lanes is lower than that without BRT exclusive lanes (Reduced by 6 per cent) whereas the passenger carrying capacity is increased by 11.9 per cent.

Lu and Chen (2009) stated the cost analysis models of public transport aimed at maximizing social benefits or minimizing total costs, considering both users and operators. To investigate optimal frequency of bus rapid transit (BRT), cost analysis models were established based on the demand data which is described in detail as a matrix of flows between every stops of BRT in a single line service. The optimal conditions for the frequency were established. Taking BRT lines 1 of Changzhou as an example, this paper examined the effect of this method on the optimal values of frequency and provided the suggested values of the frequency. Sensitivity analysis of users' cost and operators' cost were investigated respectively. The theoretical analysis and the example suggest that the cost analysis models can be used to obtain optimal frequency properly. The study has shown that users' cost have descend trend with an increasing of frequency, while the operator's cost have a positive relationship with frequency. The positive relationships between operators' costs and frequency suggested that enterprises in their own interests can't unlimited increase the frequency.

Yang et al. (2007) in their study developed new model using ACO algorithm to maximize the efficiency of bus rapid transit (BRT) system (i.e. maximize direct-through travelers on unit length of BRT route). Since the problem is NP-hard, a heuristic algorithm, based on ant colony optimization, is developed. With a numerical test from Dalian City, China, the effectiveness of the model and the algorithm is examined. The study emphasizes that it is necessary to reduce the public bus routes in the service BRT route. Public special bus lane must be employed to ensure fast operating speed.

Cui et al. (2010) in their analysis stated that since the BRT corridor takes up road resources, thus affecting other vehicles, it is necessary to study how to improve the efficiency of the BRT corridor, so as to enhance the public transport service level and to increase public acceptance of the BRT. This paper proposes a way of appropriately introducing some regular bus lines as the "quasi-BRT" on to BRT corridor under the premise that it does not greatly affect the service level of the BRT lines. The "quasi-BRT" routes can be divided into three categories, namely, on-line, off-line and merging-line, according to the position from where they enter and leave the BRT corridor. Taking Nanning as the background city, it also analyzes the necessity and feasibility of introducing ordinary bus lines onto the BRT corridor, and studies the way to guarantee bus priority at intersections in the presence of ordinary bus lines as well. The study suggests setting up a Bus Waiting Zone before the stop line for buses waiting for the green signal to pass through intersection and forbid other motor vehicles to get into the zone during the red signal.

Zhou and Su (2011) in their study stated that vehicles and stations are crucial elements of a BRT system, and the vehicle-to-station interface is important to the efficiency and functionality of the BRT system; a logical interface will facilitate boarding and alighting for riders to reduce dwell time, ease movement for passengers with disabilities, and enhance customer convenience and safety. The paper discusses the interface between vehicles and stations from three aspects, including vertical gap, horizontal gap, and transverse gap, and then it reviews international and Chinese practices to provide information on some technologies and methods used to eliminate the gap between vehicles and stations. The authors concluded to effectively use PSDs, Kassel Kerb, Mechanical guide wheels, optical guidance, and magnetic guidance to eliminate the transverse and horizontal gaps at bus stops

Sharma and Swami (2013) stated in their study highlighted the availability of bus lanes to other traffic for a reasonable distance before intersection considerably reduces the average queue length, maximum queue length, average delay time per vehicle and emission per vehicle, while there is an increase in vehicle throughput and average speed of all the vehicles. Thus it results in reduction of congestion and performance enhancement of at-grade intersections and network. The authors have further shown that emissions reduced as average delay time reduces. There is net decrease in fuel and energy consumptions. If bus way ends in a good time before the stop line at busy signalized intersection and dedicated bus lanes are made available to all traffic at intersection, average queue length decreases by 45 per cent. Average delay time per vehicle is reduced by is reduced by 34 per cent.

Henke (2013) in his paper analyses to employ bus ways and bus rapid transit running ways that can be converted to future light rail operation. This also examines the reasons why, and the present barriers and costs associated with such convertible BRT/design way approaches. The study suggests that a raised platform could be devised to accommodate low floor BRT vehicles initially which then could be raised to accommodate the higher floor LRVs in future. Standard floor buses could be procured. Alternate bus routes must be established while LRV conversion.

Zhou et al. (2010) in their paper stated that Platform screen Doors (PSD) screens the platform from the bus lane to offer a safe and comfortable environment for passengers. This article discusses the design and implementation of PSDs systems for BRT. The application of PSDs-BRT in China is reviewed first, and then the paper gives a requirement analysis and affordable system design including system architecture, overall dimension and control system. The study concludes that implementation of PSDs in BRT have increased the safety and comfort of passengers. It gives rise to cost affordable system architecture.

Wang and Ye (2015) in their paper examines the influence of bus stop location on bus priority efficiency for arterials with segmented signal progression control. A simulation approach is used to explore the effects for an arterial with five intersections and three bus-bay stops. Analyses are conducted to investigate the relationship between traffic volume and delay (bus or car delay) for given bus stop locations (far-side, near-side, and midblock). The results suggest that a far-side bus stop is generally a better choice than a near-side one, especially when intersection spacing is tight. When intersection spacing increased to 300 or 450 meters, bus stop locations have a smaller effect on the efficiency of bus priority, and results showed that a far-side stop location is still a better choice. The study concludes that bus delay for far side bus stop is lower than for a near side bus stop when volume/capacity ratio is 0.75.With increase in intersection spacing, the effects of bus stop locations on bus priority decreases. But near side stop gains advantages if volume/capacity ratio is more than 0.85.
Wang et al. (2015) in their paper focused BRT as the public transit network's backbone. For achieving a reasonable utilization of public transport resources using minimum total cost of bus transit system and making necessary adjustments to the existing transport network, harmonization of the services and establishment of direct bus line and feeder bus route in the BRT corridor is necessary. The study outlines that feeder bus service has the advantage of attracting passengers to transfer to BRT from regular bus service. Public transport system should clearly focus on planning and management of feeder bus routes.

Wang et al. (2016) in their study describes a multi-objective optimization model developed to minimize the total time of bus system including passenger travel time and bus operating time. In addition, bus emission was introduced to assess the bus operation based on the pollutant emissions CO, HC, and NOx. Finally, the proposed methodology was applied to a bus route in Nanjing, China. The results showed that the total time decreased by 520197s by adding a new station between the Gulou station and the Zhujiang Road station, and the corresponding emissions of CO, HC, and NOx merely increased by 0.87 per cent, 1.07 per cent, and 0.79 per cent, respectively. It indicated that the model was well validated in terms of reliability, and could be used for the analysis and design of bus stop location. Sensitivity analyses were also conducted to investigate the effects of service frequency on the performance of the proposed method. The study concludes that bus operating time will increase because of the increasing service frequency. As a result the total service time increases gradually. Emissions of pollutants increase with increase in number of bus stops. This is caused by low speed and frequent acceleration and deceleration at the bus stop area.

III. CASE STUDY

TransMilenio Bogota

TransMilenio is a bus rapid transit system in Bogota, Colombia resulting from successful public-private partnership (Sandoval and Hidalgo 2002). This system comprises of specialized infrastructure including exclusive bus lanes for high capacity articulated buses, efficient private operation, advanced fare collection system and separate authority for planning, developing and controlling the system.

Inspired by Curitiba's Rede Integrada de Transporte (Integrated Transportation Network), TransMilenio consists of several interconnecting BRT lines, each composed of numerous elevated stations in the center of a main avenue, or "troncal". Passengers typically reach the stations via a bridge over the street. Usually, four lanes down the center of the street are dedicated to bus traffic**.** There are both express and local buses, the latter stopping at every station to pick up passengers. The outer lanes allow express buses to bypass buses stopped at a station. Users pay at the station entrance using a smart card, pass through a turnstile, and wait for buses inside the station, which is typically 5 m wide. The bus and station doors open simultaneously, and passengers board by simply walking across the threshold. Like in a subway system, the elevated station platform and the bus floor are at the same height. The buses are diesel-powered, purchased from such manufacturers as the Colombian-Brazilian company Marcopolo-Superior, German conglomerate Mercedes-Benz, and Swedish companies such as Volvo and Scania.

Since the system was quite new to the citizens of Colombia, they needed to be trained by the Government regarding that. Govt. adopted promotional campaigns in TV, radio, and newspapers which stressed the benefits of the system and usage instructions. Community workshops were conducted by local organizations and educational institutions. Telephone service facilities were introduced for enquires regarding bus timings. Though ticketing operations started manually, it got smart cards installed in very less time. The control system was equipped with 6 workforce stations, each able to control 80 articulated buses. The system has voice and permanent communication with all buses and its supervisors.

This system is very easily accessible by youngsters, elders, disabled persons. Strict standards are being followed to maintain the quality and efficiency. The system is very affordable as a single trip costs only US$0.40. This whole money consists of investment, operation and maintenance of bus fleet and ticketing system. But this cost is only 6 per cent higher than the average public transport cost. Total investment for the 41 kilometers of Phase 1 was US $213 million, funded with a local 25 per cent fuel surcharge (46 per cent of investment), general local revenues (28 per cent mainly from a capital reduction from the partially privatized power company), grants from the National Government (20 per cent), and a loan from the World Bank (6 per cent). In 2006, at a cost of US $245 million Phase 2 added 43 km of exclusive BRT corridors. The first phases of the BRT system included feeder routes leading into the BRT corridors and a new integrated fare card system to allow free transfers. Phase 3 is under construction and more corridors are planned, which will expand the length of the bus ways to 388 km.

TransMilenio earned the distinction of becoming the world's first mass transit project registered with the UNFCCC for Clean Development Mechanisms (CDM) credits in 2006. The project generated 277,044 Certified Emission Reduction credits under the Kyoto Protocol's CDM for 2006-2009, which were sold to provide additional funding for bus purchases. The expected additional income from the sale of CER credits is US $25 million by 2012 (assuming a total estimated reduction of 1,725,940 tCO2eq is achieved in the first crediting period 2006-2012 and price of US $14.5/tCO2).

TransMilenio stations comply with easy access regulations because they are elevated and have ramps leading to the entrance. The alimentadores (feeders) are normal buses without handicapped accessibility. A lawsuit by disabled user Daniel Bermúdez caused a ruling that all feeder systems must comply with easy access regulations by 2004, but this has not happened yet.

Ahmedabad BRTS

Ahmedabad Janmarg Limited (AJL), the parent company which governs BRTS operations in Ahmedabad, was constituted as a Special Purpose Vehicle by Ahmedabad Municipal Corporation, Ahmedabad Urban Development Authority and Government of Gujarat. AJL introduced automated fare collection system through smart cards for commuters. It has a mixed fleet of air conditioned and non-air conditioned buses. It has 220 Euro III and Euro IV-compliant diesel buses. The system runs on Integrated Transportation Management System (IMTS) which includes Advanced Vehicle Tracking System (AVLS), Fleet Management System (FMS), Automatic Fare Collection System (AFCS), Passenger Information System (PIS), Passenger announcement (PA), and Vehicle Scheduling and Dispatching (VSD). These technologies are provided by the consortium of Vayam Technologies and GMV Innovating Solutions since 2010. The bus stops have following characteristics:

- Aesthetic materials used giving distinct and unique look.
- Low maintenance and less wear and tear.
- Safety for all kinds of people for movement
- Good Ventilation and natural light
- Climate consideration of heat and rain

Fuel systems in this BRT are quite efficient. Ahmadabad BRT uses CNG which is quite environment friendly. In Ahmadabad, as per the recommendation of the Supreme Court, AMTS has been operating CNG buses. Gujarat state also has an advantage of CNG resource state and hence use of CNG would be an automatic choice for BRTS buses. Integration of a BRT system in an urban setting presents within itself a challenge and an opportunity to improve and enrich the existing streetscapes. One of the most important roles of the BRT facilities design such as a shelter is to support an appealing, cohesive visual identity for a quality and safe transit service. The shelter roofs should be such that rain water is directed away for the vehicle side.

All the stops are provided with a standard form for presenting passengers information such as signage's, route details and graphics. Specifically they comprise of bold identification signage, transit route maps, neighborhood maps placed at prominent locations. Signage and graphics readily distinguish the BRTS stations from the regular stops. The stops should also facilitate advertising at specific locations that does not conflict with the other directional and information signage. IT Display could be optionally placed at station entries and on platforms indicating the system wide schedule and delay at each platform. Apart from all these, other issues like safety, security, customer friendly attitude are very important which are discussed below:

Safety and security is essential for the safe operation and public acceptance of the transit system. Security is essential as the BRT stops would be open for extended hours and likely to be unattended. Visibility is also an important criterion to security. Passengers should be able to see the surrounding locations and be seen from the locations outside the station. Security equipment such as closed circuit television for monitoring may be used while upgrading the BRT shelters over a longer period of time. Adequate illumination, especially at nights is necessary.

The BRT stations should be made accessible to by the physically challenged. The internal layout of the shelter should be barrier free to facilitate easy circulation. Access via ramps need to be provided for stops having high platforms. Protection from weather is a major consideration in the BRT stations. Ahmadabad, being a city having hot and humid conditions almost through the year, open designs for stations are not preferable. Completely enclosed stops, although preferable due to high concentration of RSPM in the city, would require the provision of air conditioning and ventilator fans. This however escalates the cost involved in the maintenance of the station. Passive solar design and natural cooling techniques could be sought after solutions to overcome climatic extremes.

Fare Collection also forms an important influence on the design of the passenger facilities within the BRT station. Off board fare collection policy reduces the dwell time at bus stations and enables rapid boarding and lighting. The station can be divided into paid areas and free areas. Entry into the paid area of the station can be controlled by introduction of turnstiles or other control devices. Bogotá is one such example of a controlled access station. Since Ahmadabad does not have the high level of passenger traffic that exists in cities like Curitiba, Jakarta and Bogotá, it is not necessary to provide costly infrastructure as ticket vending machines, although provisions are made for incorporating it while upgrading the system.

As we know that despite BRTS being a cost effective method, poor planning by officials destroys the whole design. For example, BRTS in Delhi has failed. It is due to following reasons

- Wrong Place: Construction started in South Delhi which has highest number of car users. Constructing BRTS in rich class area has no meaning at all.
- Failed Trial Run: Even the trial runs started without completing the whole work. This caused heavy confusion among the commuters.
- Less Frequency: Buses didn't run as per the requirement. Passengers faced heavy problems of time wastage at bus stops.
- No Link to Metro: Passengers were more conversant with metros rather these buses. So

IV. SUGGESTATIONS

- Exclusive bus lanes and signal priority are not implemented simultaneously in order to improve the BRT's operational performance. Traffic flow conditions will surely improve after this.
- The installation of BRT exclusive lane can effectively bring benefits to improve the operation efficiency of BRT and the passenger carrying capacity of the road. But regular bus lines along the BRT corridor are not well coordinated with the BRT lines in order to fully take the advantage of express corridor.
- Sensitivity analysis of users' cost and operators' cost suggested that bus enterprises can reduce passengers' waiting time costs by increasing the frequency, but it does not have a good effect on reducing the in-vehicle time costs. The optimal frequency is rarely decided to provide a efficiency bus services under the lower operating costs.
- The major problem lies in developing more effective models for BRT. ACO algorithm can be used as an optimization model of BRT routes which helps in maximizing the density of direct travelers flow and minimizing transfer times.
- Regular bus services are not introduced in BRT routes with proper signal priority process.
- For safety and comfort of passengers, concept of vertical, horizontal and transverse gap should be studied before constructing bus stops. Newer technologies such as PSDs must be introduced as practiced in other countries.
- For creating a greener environment, engineers must optimize the road system at intersection for better benefits of BRT. Bus way should end in good time before stop line because it decreases average queue, maximum queue length and average delay time per vehicle. This reduces pollution also.
- *C*ity authorities should plan for the future conversion of BRT into LRT. BRT should be designed keeping in mind the structural loading and geometrical constraints of LRT.
- Location of bus stop is a major challenge in India for BRT. Far side bus stop is a better choice than a near side one when segmented signal progression is implemented properly. Even if intersection spacing is increased to 400-500m bus stop locations have minimal effect on the efficiency of bus priority.
- Inadequate direct and feeder bus services creates inconveniency for the commuters. These services must be introduced to minimize total cost and time of service.
- Sensitivity analysis may be used to predict the effect of toxic gases on environment. A multi objective optimization model must be developed which can study passenger travel time, passenger walking time and passenger waiting time.
- The rate of road accidents can be minimized significantly with clear Road Signs and Markings. For example GIVE WAY signs, SPEED LIMITS, OVERTAKINGS, BUS WAYS, CURVES, CHEVRONS and LANES must be clearly visible to driver.
- Successive pedestrian signalized crossings must be synchronized to reduce the probability that vehicles will have to wait at more than one signal in same midblock.
- Excessive gaps in horizontal and vertical directions must be reduced between bus and platform so as to reduce any injury and risk of accidents. PSDs with electronic sensors can be introduced to avoid all these.
- A divider marking must be clearly present between BRTS lanes. Also pedestrian mid block crossings should be introduced for the safety of passengers.
- Intelligent transport systems consisting of bus signal time preference, automatic vehicle location systems, passenger information systems, smart fare collection must be thought of quickly. Application of ITS will be great boost to the smart city proposal of Indian Government.
- Traffic calming measures, pricing, parking policy and land use planning must be extensively studied.
- Training of employees and staff is a major concern. Customer's satisfaction should be major agenda. Following the Bogota example, employees should be customer centric.
- Providing a customer service leadership and innovative management with client focused strategies must be taken care of.
- Green energy technologies like having solar panels installed above buses and bus stops can be thought of. Solar buses can be implemented in less dense areas with less speed.
- Service should be such that it is suitable for old/young; students/workers; men/women.
- For physically disabled persons BRT buses should be specially designed to carry the person easily. Special seats should be designed as per

medical standards for the comfort of such passengers.

- Walk over Bridges should be provided for the pedestrians to cross safely. Waiting places with proper lighting arrangements is necessary to ensure safety during night.

V. CONCLUSION

As the government of India is planning for building 100 smarts cities across the country, BRT will be a major contribution towards a sustainable and cost effective mode of transport system. With the increasing population, with expansion of the city limits geographically there is a tremendous pressure on the existing modes of transport systems in the cities. Adoption of better techno-management practices, and proper planning, adequate budgetary provision for funding etc. can make BRTS an effective and efficient mode of public transport system in India.

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