This essay discusses the Bus Rapid Transit (BRT) system in Ahmedabad city in western state of Gujarat, India. Ahmedabad BRT currently with its 47% of total km length network is the largest BRT system in India (BRTdata, 2018a). It begins by introducing the definition of BRT. Followed by brief global and local context, information on BRT network, design, features of the BRT and operational statistics. Later it discusses advantages and disadvantages of implementing BRT with evidence within the country and globally where possible. It concludes, Ahmedabad BRT with its silver rating from ITDP, (2018) has issues of equity, inclusion and gap in planning and implementation which limits the reach of benefits resulting from implementing the BRT system.

BRT as per ITDP, (2014) is defined as below:

"a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective services at metro-level capacities. It does this through the provision of dedicated lanes, with busways and iconic stations typically aligned to the center of the road, off-board fare collection, and fast and frequent operations."

Today, 55% of the world population lives in urban areas and is expected to rise to 68% by 2050 (UN, 2018). Future increase in world's urban population are expected to be concentrated in few countries, India, China and Nigeria will account for 35% of the projected growth between 2018 to 2050 (UN, 2018). India's economic growth averaged 5.5% a year during 1990s and 2000 and further to 7.1% during decade of 2000 (Gupta, 2018). The result of higher growth is putting tremendous pressure on infrastructure systems and the urban transformation requires expansion in transport infrastructure and services (BHAGAT, 2011). These demand from urban transport system, many Indian cities have been unable to meet and there is a need for urban transport strategy for cities in India and rapidly urbanizing world (Padam and Singh, 2004). BRT is an attempt to address burgeoning travel demand with current buses and trains services being overcrowded, undependable, slow, inconvenient and dangerous (Pucher et al., 2004). The total network length of Indian BRT is 167.7 km which is 3.4% of the total BRT network worldwide (Kathuria et al., 2016).

Ahmedabad is the largest city located in the western state of Gujarat and serves as its commercial and financial hub (Sharma, 2017) where people are moving away from public transport to private or informal transport modes. It is a growing city with increasing per km^2 population density from 719 in 2001 to 890 in 2011 (Census, 2011). Before BRT, public transit Ahmedabad Municipal Transport Services (AMTS) buses had monopoly and operated in city corporation limits and city agglomeration area in mixed traffic condition (Munshi et al., 2004). AMTS bus fleet since 1990s was declining which by 2005 had fallen to 540 in from 724 in 1996 and fleet utilisation reduced to 67.33% from 80% during the same time period (Mahadevia, Rutul, et al., 2013). Further, vehicle registration in Ahmedabad increased by 92.9% from 2001 to 2005 (Ministry of Transport and Highways, 2017). Also, informal modes of transport like autorickshaw and shared autorickshaws are used on many busy routes (Kumar et al., 2016).

National urban transport policy (NUTP) in 2006 had stated declining share of public transport and non-motorised transport (NMT); focus on supply side with low investments; neglect of pedestrians, cyclists, and transit users; increased use of automobiles resulted into high road fatalities/injuries (Ministry of Urban Transport, 2006). Further in 2006, NTDPC (National

Transport Development Policy Committee) proposed to add BRT of 20 km length per million population in cities with population greater than one million (Mohan et al., 2012).

Ahmedabad BRT was funded under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) of the Ministry of Urban Development with 35%, 15% and 50% funding from the Government of India, Government of Gujarat and Ahmedabad Municipal Corporation (AMC) respectively (Governance Knowledge Centre, 2012). BRT system in India followed a regulatory reform by formation of special purpose vehicle (SPV) for handling operations and maintenance of BRT system (Kathuria et al., 2016). AMC setup an wholly owned SPV the Ahmedabad Janmarg Limited (AJL) to promote, implement, operate and maintain the BRT system (Kumar et al., 2011).

Indian BRT	Funding Source	Special Purpose Vehicle (SPV)	Responsibilities	Revenue Model
Ahmedabad BRT	35% by JNURM, 15% by Govenrment of Gujarat and 50% by AMC	Ahmedabad Janmarg Limited (AJL)	Run and operate efficiently Increse Reliabilty Maintain bus lanes and shelters Decide Fares Provision of smart card facility and tokens Pay and park facilities for citizens Advertisement rights across the route	Gross Cost

Table-1 Responsibilities of AJL (Kathuria et al., 2016; BRTdata, 2018a)

BRT Network

Ahmedabad BRT network has 151 number of stations and the network map across the city and the areas they service is shown in Fig-1 (Islam et al., 2018). It started with corridor length of 12.5 km in 2009 which increased to 82 km by 2014 (Kathuria et al., 2016). The additional service provided by Ahmedabad BRT is Airport Shuttle Service which is operated 19 hrs a day covering 23.4 km route with 30 pickup and drop points (Ahmedabad Janmarg Limited, 2017) is not included in Fig-1. It is worth noting for reader that the east part of Ahmedabad is the old Ahmedabad from where the city expanded over the west side of the river.

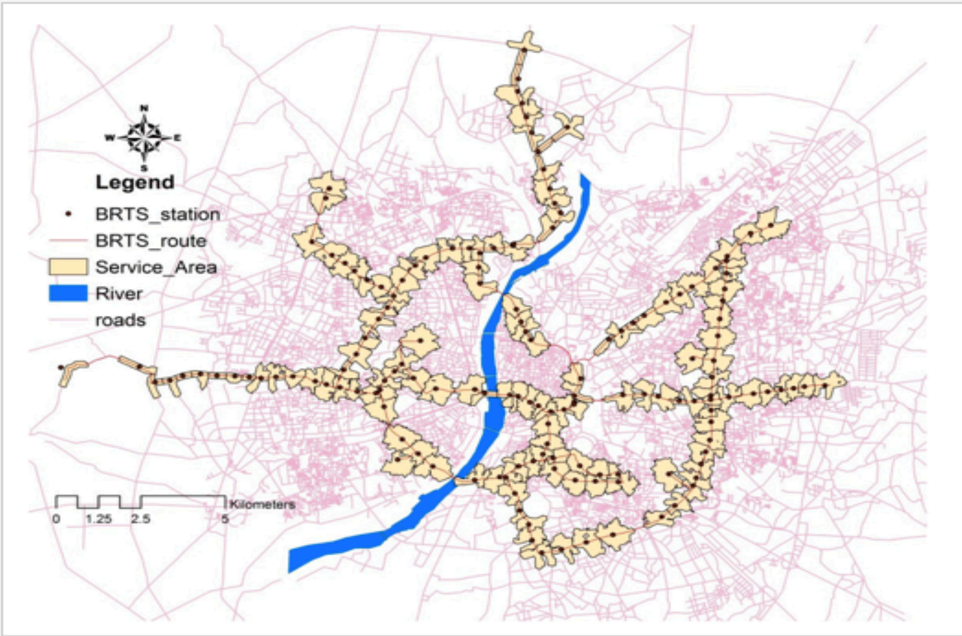

Fig-1 BRT Network Map (Islam et al., 2018)

Design

Carriageway concept designs of Indian BRT are illustrated below. Since BRT had to be accommodated into the existing fabric of city there was need to use variety of carriageways. Based on the availability of 'Right of Way' (ROW) (ITDP, 2017) variety of planned cross sections such as two-way, one way and two with bus stop. ROW's of 24, 30, 35, 40 and 50 meters are commonly used in Ahmedabad BRT (Kathuria et al., 2016). 50m and 30m ROW are briefly explained below.

50 metre carriageway schematics is shown in fig2. Two central bus lanes (3.5m wide) one for each direction of travel replaces existing median. Two mixed traffic lane (8m wide) for each direction of travel. Service lane (3m wide) on each side with parking provision. Cycle track (2m wide) and footpath (2.5m wide) on each direction of travel. Bus stops are located in the middle of the BRT lane (Ahmedabad Municipal Corporation et al., 2015).

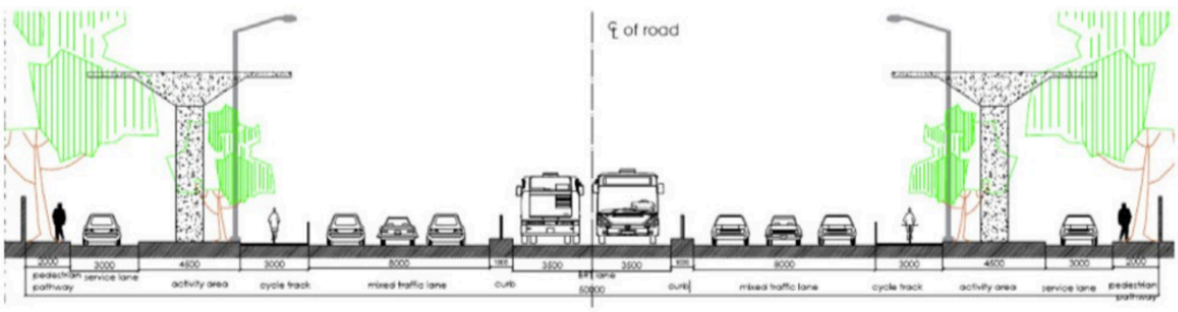

Fig-2 50m ROW cross section (Ahmedabad Municipal Corporation et al., 2015)

30 metre carriageway schematics is shown in fig5. Two central bus lanes (3.5m wide) one for each direction travel replaces existing median. Followed by cycle track (2m wide) and footpath (2m wide) on each direction of travel. Bus stops are located in the middle of BRT lane (Ahmedabad Municipal Corporation et al., 2015).

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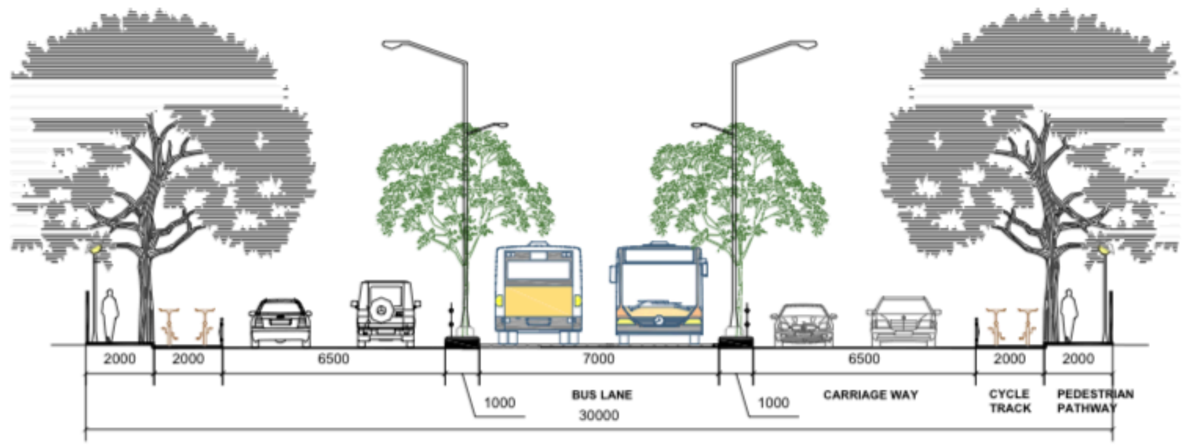

Fig-5 30m ROW cross section (Ahmedabad Municipal Corporation et al., 2015).

Table 2 and 3 below provide details of network, ridership and design of route and station features.

Indian BRT	System Type	Network Length (km)	Avg journey speed (Km/hr)	No. Of Stations	Station location	Stations		Ridership		
						Station spacing (m)	Annual Demand	Daily Demand	Peak hr peak direction	Station boarding level
Ahmedabad BRT	Closed	82	24	127	Far side of intersection	645.7	39,000,000	130,000	1780	High level platform, level boading

Table-2 Summary of Ahmedabad BRT (Kathuria et al., 2016; BRTdata, 2018b)

Indian BRT	Vehicles		On/Off Fare Collection	Real time passenger information	Peak hour (buses/hour)	Bus lane width (m)	Bus lane seperation
	Distinctive Buses	Fleet					
Ahmedabad BRT	High floor and low floor both	136	Off Board	Yes	24	3.5	Railings

Table-3 Ahmedabad BRT system characteristics (Kathuria et al., 2016; BRTdata, 2018b)

<u>Advantages:</u>

BRT system is affordable from capital investment and operations cost perspective, cities like Ottawa and Curitiba built busways because they were more affordable to build and operate compared to Light Rail Transit (LRT) (Cervero, 1998; Hidalgo and Gutiérrez, 2013). Fig-2 shows capital investment versus number of people moved where it is evident BRT can provide benefits LRT and elevated rails with more people transported at less cost. Countries have understood the rationales of BRT investment and BRT is quickly serving as the backbone of new public transit systems across 170 cities around the world (Cervero, 1998; BRTdata, 2018c). The successful implementation in Latin American and Asian cities and low cost, high performance and rapid implementation benefits of BRT has made BRT system a model to be replicated around the world (Hidalgo and Gutiérrez, 2013). This cost effectiveness has made BRT accessible to many budget constrained cities and its residents, helping transition to low carbon transport systems (Deng and Nelson, 2013). As a result, globally BRT has 33.3 million ridership in 170 cities on network of 5046 km (BRTdata, 2018d). For example, metro rail studies show they can cost 10 times as much a BRT for a similar length (Suzuki et al., 2013).

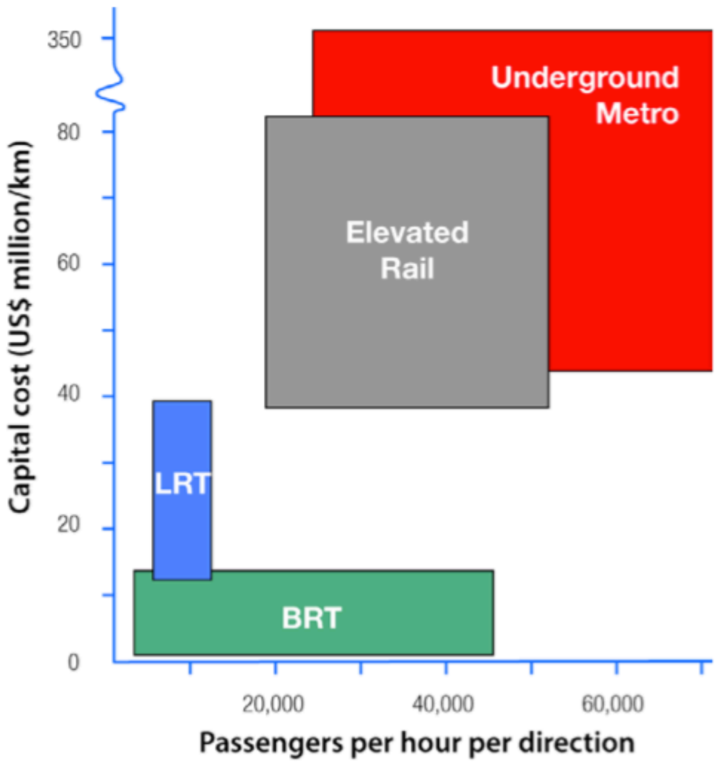

Fig-6 Capital investment vs passenger moved representation (ITDP, 2007b)

BRT with dedicated ROW when complemented with signal prioritisation can reduce the travel time for passengers. Delgado et al., (2015) have shown from simulation experiments traffic signal prioritization strategy can achieve reduction in excess delay for transit users close to 61.4% compared to no control strategy, while general traffic increases only by 1.5%. Zhou et al., (2017) have shown from modelling an intersection with BRT in China with intersections characteristics of BRT having dedicated ROW average passenger delay can be reduced by 13.43 – 25.27%. Signal prioritisation is incorporated in Ahmedabad BRT (Bhatt and Anadkat, 2013) where BRT signal goes green twice in one cycle at intersection (Kathuria et al., 2016). Ahmedabad BRT with dedicated ROW and signal prioritisation can also be expected to reduce passenger delays.

Further, operating speed of Ahmedabad BRT at 24 km/hr is higher compared to average operating speed of 20 Asian cities at 22.35 km/hr (BRTdata, 2018d) and 15 km/hr of AMTS

(Mahadevia, Rutul, et al., 2013). Availability of segregated busways, enclosed stations, level boarding, pre-payment and centralized control also aids in higher operating speed which are features of Ahmedabad BRT (Hidalgo and Graftieaux, 2008). With higher operating speed and above mentioned design features results in travel time savings based on analysis by EMBARQ (King et al., 2013). Johannesburg BRT users save on average 13 minutes each way based on sample of 150 household survey at varying distance from BRT trunk line from December 2010 to April 2011 along 26 km of network including 27 stations by (Vaz and Venter, 2011). BRT passengers in Istanbul saves 50 minutes per day from public transport user survey of 1000 sample and calculations from average speed for different modes by (Alpkokin and Ergun, 2012).

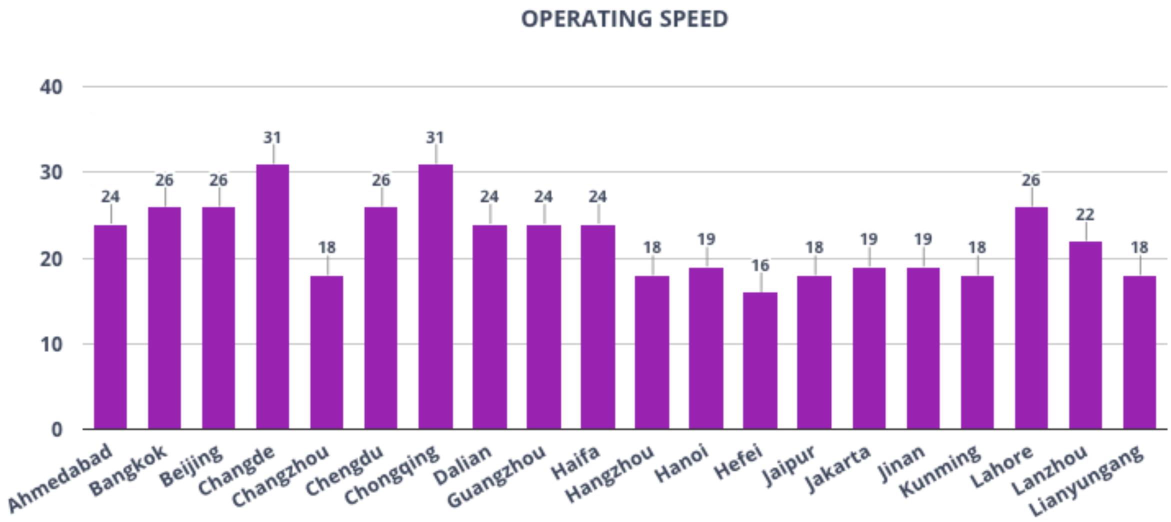

Fig-7 BRT operating speeds across 20 Asian cities (BRTdata, 2018d)

Ahmedabad BRT resulted in modal shift of positive characteristic. Based on the survey of 1040 samples with proportion of boarding at 18 BRT station over network of 44.5 km at 60% in peak hour and 40% in non-peak hours, implementation of Ahmedabad BRT resulted in 47%, 13%, 12%, and 1% modal shift from AMTS, shared/full fared autos, private motorised vehicles and walking respectively (Mahadevia, Joshi, et al., 2013; Joseph et al., 2017). Cost savings from modal shift to BRT for passengers were 7.9% for AMTS users, 42.1% for shared autos, 83.1% for full fare autos, 66.4% for private two-wheelers and 89.1% for private four-wheelers (Rogat et al., 2015). Thus, implementation of BRT delivered economic benefits to commuters except for modal shift from bicycling to BRT.

Transport pollutant like particulate matter 2.5 (PM 2.5) is associated with respiratory and cardiac health impacts (Brunekreef and Holgate, 2002). Swamy et al., (2015) in their empirical study of 10.5 km corridor including 16 stations have shown Air-conditioned BRT bus commuters experience 25% reduction in PM 2.5 exposure compared to Air-conditioned cars and less by 76% when compared to non-Air-conditioned modes. Similarly, post BRT implementation empirical measurements inside 37 conventional buses and 36 minibuses during summer of 2004 and 63 BRT buses on the same route PM2.5 exposure exposures dropped from 152 µg/m^3 and 129 µg/m^3 respectively inside the conventional minibuses and auto buses to 99 µg/m^3 in BRT buses in Mexico city (Wöhrnschimmel et al., 2006). 12% reduction in Bogota in particulate matter exposure after implementation of BRT was shown by (Turner et al., 2012), but information on methodology applied and duration of experiment were not made available.

Further, reduction in greenhouse gases (GHG) post implementation of BRT systems based on calculations of fuel savings resulting in less carbon dioxide emissions from modal shift of commuters are 10% in Latin American cities (Schipper et al., 2011), 17% in Ahmedabad (Rogat et al., 2015), 4.03 million tons per year in China (Wang et al., 2007).

BRT systems running on a dedicated corridor with less exposure to traffic result in reduced road safety impacts which yield social and economic benefits (King et al., 2013). Post implementation of Ahmedabad BRT resulted in per year per km reduction of 28% in traffic injuries and 55% in traffic fatalities (King et al., 2013). However, the study does not provide evidence on methods used to calculate impact in their analysis from the data made available by respective organisation. Similarly, Hidalgo et al., (2013) have shown 20% reduction in traffic fatalities in Bogota based on surveys and information provided by Transmilenio. Duduta et al., (2012) from before and after crash data analysis have shown 69% reduction in traffic injuries and 68% reduction in traffic fatalities in Guadalajara.

Ahmedabad BRT uses Integrated Transit Management System (ITMS) which includes transit signal management, smart card integration, passenger information system and incorporation of Automatic Vehicle Location (AVL) (Bhatt and Anadkat, 2013). Every station has Passenger Information System (PIS) to display expected time of next arriving bus (Kathuria et al., 2016). ITMS systems play crucial role in management of BRT operations and real time information systems are vital to transit users and make their journey more efficient by making choices based on available information (ITDP, 2007a;Shaheen and Finson, 2013).

The Gross Cost revenue model used in Ahmedabad BRT (as shown in table-2) payment to bus operator is paid on kilometres run. Here, the case of revenue risk lies with SPV (AJL) and not with operator (Chaudhary, 2015). Advantage of such model is in event of loss by SPV the system runs consistently with reliability (Chaudhary, 2015). The reason for BRT to operate on this model was due to creation of SPV as shown in table-1 while AMTS did not operate under any SPV rather controlled by AMC (Mahadevia, Rutul, et al., 2013).

Disadvantages:

Rao and Shah, (2012) have shown with framework created from several Indian and international accessibility standards, Ahmedabad BRT as new transit system like AMTS remained unsuccessful in providing access to physically challenged people. Bus stops have wheel-chair friendly access ramps and with level floor access to the bus however it is difficult to reach station. Fig-8 shows concrete pillars at entry and exit of Anjali station from road-side is difficult to access via wheelchair. Further, features of lack of anti-slip floor material, no audible warning sounds and lack of enforcement of zebra crossings makes it more difficult to access and use stations. Such exclusion due to individual's physical condition remained with BRT system, forcing to use other modes of transport violating rights of disabled people under the Right to Person with Disabilities Act (Government of India, 2016).

Fig-8 Concrete pillars preventing wheelchair access to BRT station (Parikh, 2018)

Urban poor in Ahmedabad have not been able to access BRT extensively and problem of exclusion from affordability exists. Survey by Mahadevia, Joshi, et al., (2013) over 44.5 km BRT corridor in 2011 covering 18 BRT stations and sample size of 1040 have shown of total users 13.7% have monthly income up to INR 5000, 25% have up to INR 7500 and 62.2% of users have income above INR 10000. National Sample Survey of 2009-10 consumption expenditures show up to 50% households fall into household income category of up to INR 5000 per month (NSSO, 2011). So, it can be argued that households within the income category up to INR 5000 per month do not use Ahmedabad BRT extensively. Similar relation of use of Ahmedabad BRT via spatial analysis was shown based on monthly boarding and population density in station catchment by Islam et al., (2018) where ridership was higher in the western part (Fig-9) of Ahmedabad while higher population and job density (Fig-10) and majority urban poor living in eastern Ahmedabad have lower ridership. Venter et al., (2018) by measuring direct impacts (benefits to users) and indirect impacts (benefits to non-users and society) have shown operational BRT systems have higher fares compared to competing services in the global south's Bogota, Curitiba, Sao Paulo, Johannesburg, Bangkok and Ahmedabad.

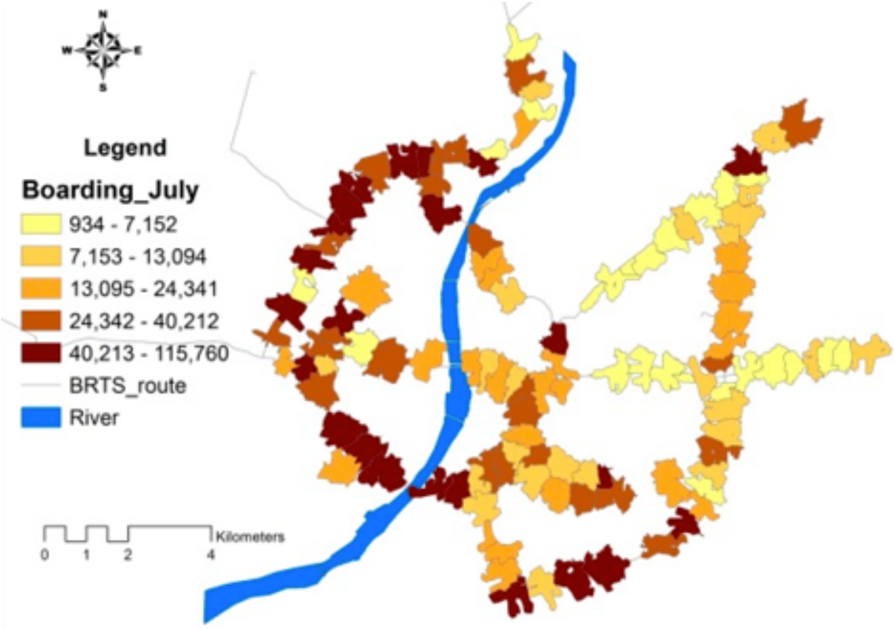

Fig-9 Monthly boarding of each station (Islam et al., 2018)

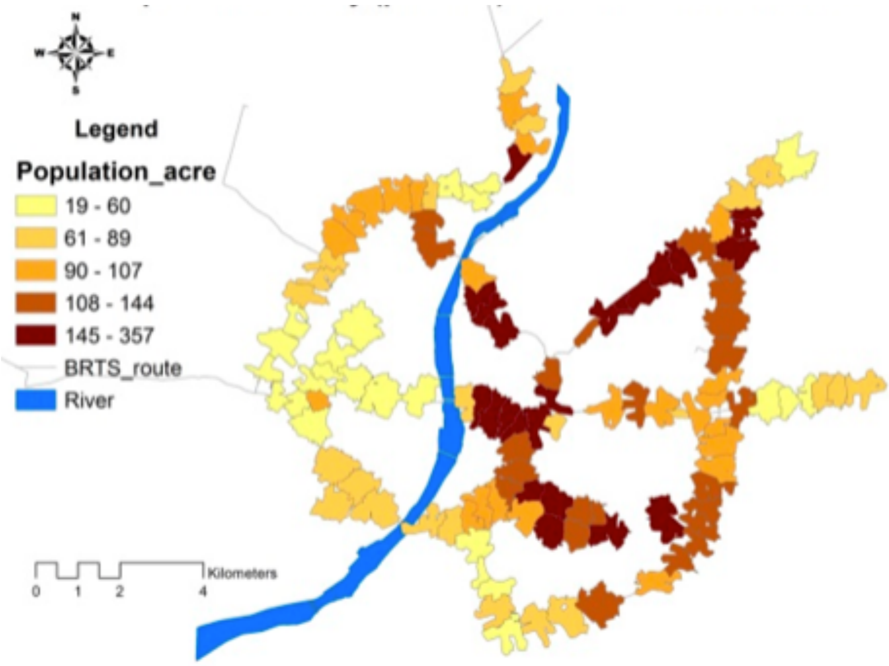

Fig-10 Population density (per acre) of each station catchment (Islam et al., 2018)

Mahadevia et al., (2013) have shown how Ahmedabad BRT was not inclusive to consider street vendors in its design. The double track for Ahmedabad BRT near Geeta Mandir Bus Terminus required shops to be demolished in the area, residents and vendors held a Dharna (protest sit-in) in January 2012 against civic bodies (DNAIndia, 2012). Further, road widening in Nikol Gam, Ahmedabad for BRT resulted in displacement of 600 vendors in the area endangering their livelihoods (Our Inclusive Ahmedabad, 2010) and 2000 vendors of Self Employed Women's Association (SEWA) were displaced in the first phase of BRT (Mahadevia, Joshi, et al., 2013). This shows marginalisation of street vendors in Ahmedabad BRT planning and implementation phase.

It took four years to integrate Ahmedabad BRT and AMTS operations, AMTS routes getting rationalized by withdrawing and diverting the service in phased manner as the BRT network expanded (Mahadevia, Joshi, et al., 2013). Also, AMTS and Ahmedabad BRT operate in complete isolation in terms of infrastructure, ticketing and social marketing (Mahadevia, Rutul, et al., 2013). Feeder services are integral part of BRT design as per (ITDP, 2007a) guidelines which is missing feature of Ahmedabad BRT (Islam et al., 2018). AMTS buses are not allowed on BRTS corridor which means for common operating routes the AMTS buses cause inconvenience to other road users by sharing road space for mixed traffic. Lack of AMTS-BRT system commuter integration as AMTS being feeder service has reduced the reach of BRT and preventing increase in modal shift and resulting cumulative benefits. Hidalgo et al., (2013) have shown in their evaluation of BRT in Bogota with 88 km of BRT lane and 663 km of feeder bus network users of BRT network from feeder buses is 48%. Similar integration between AMTS and BRT can result in increased ridership.

NMT modes are critical aspect of BRT as it is required to bring passengers to the BRT network. Above it has been shown in the design of Ahmedabad BRT for various ROW bicycle tracks and footpaths have been included in order to promote NMT. However, Tiwari and Jain, (2013) have shown implementation of footpaths have been obstructed and discontinuous. Further, design widths also do not meet standard of 2m. Fig-11 shows bicycle lane obstructed by two wheelers. Sekhar et al., (2018) have shown by applying regression analysis on connectivity index (CI) and walkway availability and quality index (WAQI) indicators for 2015 ridership data of 15 weekdays of 10 stations of Ahmedabad BRT which showed positive relationship with higher ridership. In 2013 AJL had decided to remove the cycle tracks along the corridors which represents gaps in planning and implementation (DNAIndia, 2013) and can result in reduced ridership.

Fig-11 Bicycle lane obstructed from two-wheelers (Khatri, 2018)

Preventing entry of other vehicles into a BRT lane is an issue and entry of other vehicles in BRT lane is prevented by chain as barricade which is held by security personnel (Fig-12). The chain is only lowered down (Fig-13) for BRT buses to pass by and for which security personnel have been deployed at junctions where there is a possibility of other vehicles to enter into BRT lane. The system is let on reliability of a traffic personal which can result in disruption by other vehicles entering In absence of security personnel and BRT systems efficiency is reduced due to loss of dedicated lane (Mahadevia, Rutul, et al., 2013). Such design flaws can be counterproductive for commuters.

Fig-12 Security personnel holding chain as barricade (Khatri, 2018)

Fig-13 Chain lowered by security personnel for bus to pass by (Khatri, 2018)

Damor et al., (2014) in their 45 km long survey including 8 BRT stations and 5 AMTS stations in eastern Ahmedabad have shown 46% of the commuters find it difficult to approach the station. Also, high fare for shorter trip distance in BRT was more in comparison to AMTS and was one of the reasons to choose AMTS or another mode of transport for shorter distances. However, survey does not provide information on sample size which is important to understand the representation to the population. Yet, results of survey corroborate the findings by Islam et al., (2018) on less passenger boarding in eastern part of Ahmedabad as shown in Fig-9.

To conclude, BRT systems can be an important ingredient of future sustainable transport in cities around the world as they continue to grow. Ahmedabad BRT has won several accolades (ITDP, 2018b) and is often used as a model for other BRT systems in India. While addition of BRT system in Ahmedabad as discussed above has benefited the city compared to business as usual (BAU) scenario by improving air quality and safety, less GHG emissions, increased efficiency by reducing travel times and cost savings. It stands as an example for other cities to consider lessons learned of affordability for urban poor, access equity to physically challenged, design inclusive for street vendors, wider network of feeder services and minimum gap in planning and implementation from and implementing future BRT systems in a more sustainable way.

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