Report on

Road Safety Audit of Pilot BRTS Corridor at Pune

Submitted to

Pune Municipal Corporation

Submitted by

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ROAD SAFETY AUDIT OF PILOT BRTS CORRIDOR AT PUNE

1. INTRODUCTION

Bus rapid transit, often abbreviated as BRT, refers to a system of buses that operate more like a conventional rail system than the traditional local buses we are all accustomed to riding. These are sophisticated bus systems that have their own lanes on city streets and use bus stations instead of bus stops. This allows for faster, more orderly boarding. When compared to traditional bus systems, bus rapid transit is fast, efficient, safe, and user-friendly.

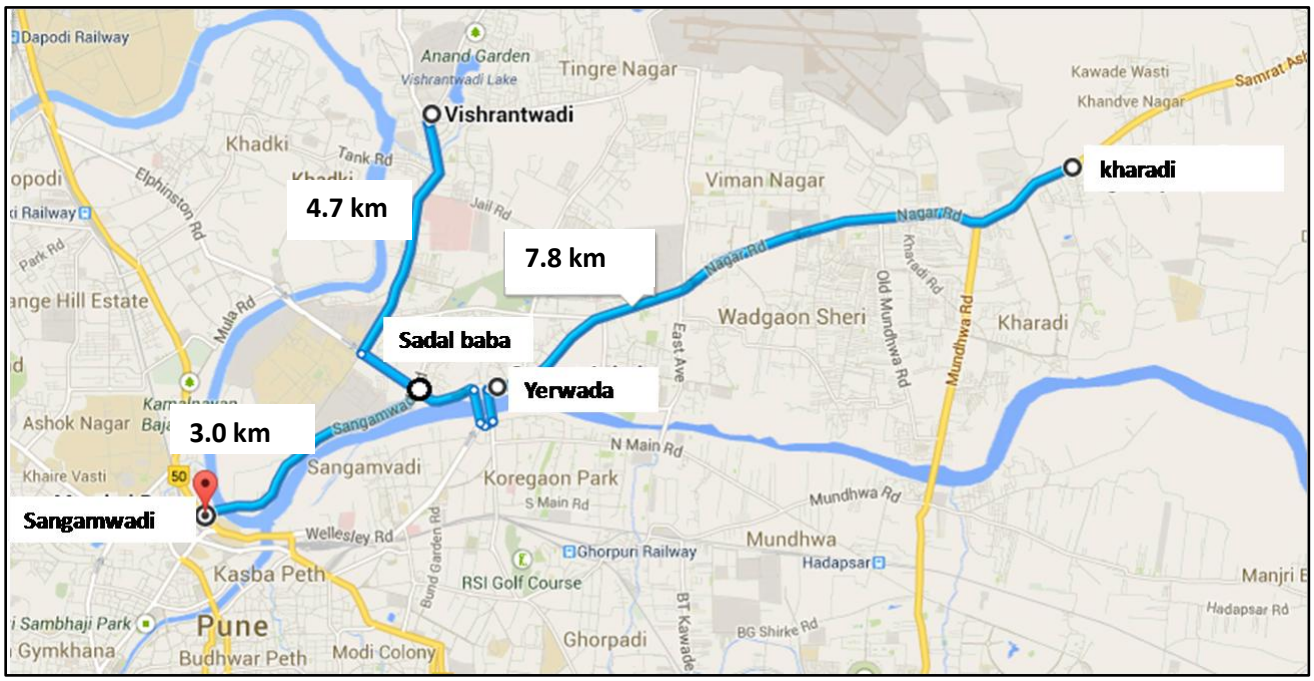
In Pune, the public transport within the city and its suburbs is operated by Pune Mahanagar Parivahan Mahamandal Limited (PMPML). To improve the public transport system of the city, Pune Municipal Corporation (PMC) is implementing a Bus Rapid Transit System (BRTS), which would allow bus users to travel quickly through the city. At this stage, PMC has decided to review the safety aspects of proposed BRTS system before starting the operation of pilot BRTS corridor. In this regard, PMC has approached Transportation Systems Engineering Division, IIT Bombay to undertake a study for proposed pilot BRTS corridor.

2. PILOT BRTS STUDY CORRIDORS

Pune BRTS is a proposed Bus Rapid Transit Project for the city and the Construction of 15.5 km pilot route comprising of stretches from 3 corridors. PMC has decided to carry out a road safety audit of the BRTS corridor before starting the BRTS system to enhance safety of vehicles and pedestrians with minimum disruption to the flow of BRTS buses. The details of the three stretches completing a total of 15.5 km pilot route are given below:

- Corridor 1: Sadalbaba –Bombay Sappers–Vishrantwadi; 4.7 km
- Corridor 2: Yerwada –Kharadi ; 7.8 km
- Corridor 3: Sadalbaba – Sangamwadi ; 3.0 km

BRTS study corridors are shown in figure below :



Map for BRTS Study Corridors

3. STUDY OBJECTIVE

The main objective of the study is to examine the existing road's safety performance and suggest various suitable traffic control and management measures to enhance safety and mobility of proposed BRTS corridor. This task can be achieved by conducting Road Safety Audit to assess the project for potential accident elimination / reduction on the basis of observing traffic movements, spotting potential conflict zones, and inspecting day/night road conditions.

Road Safety Audit (RSA) is a procedure for assessing project's accident potential by an independent audit team. It is a formal examination of a future traffic project, or an existing road, in which an independent and qualified team looks at the project's crash potential and safety performance. RSAs can be viewed as a proactive low-cost approach to improve safety.

The specific purposes of the safety audit study are:

- To ensure a high level of safety in road project
- To minimize accident risk on the road network
- To promote the relevance of road safety engineering in all road design work
- To promote the safety of all road users

4. FIELD BRTS SAFETY AUDIT

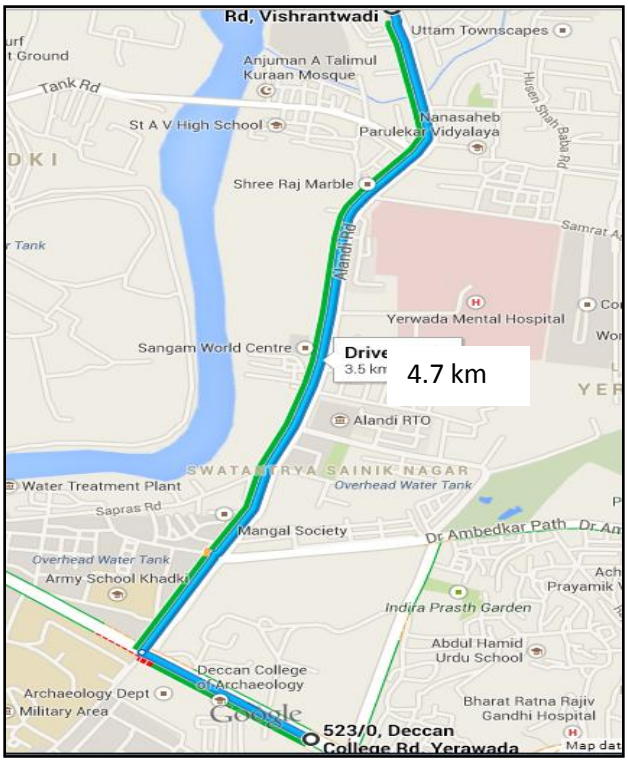
The team of IIT Bombay visited all the three corridors and inspected it closely on 9th and 12th December 2013. To include the safety concerns related to night time a night time audit for the three corridors was conducted on 20th and 21st December 2013. By visiting the corridors during day as well as night time we have observed all the possibilities that should be taken care of related to safety. Road safety audit checklists given in IRC: SP: 88-2010 Manual on Road Safety Audit, ARRB safety audit manual were used to ensure a through coverage of the issues over the full length of the corridor.

5. SAFETY AUDIT OBSERVATIONS

Over all the BRTS corridor planning and construction is generally found to be satisfactory. The following observations, however, need to be considered.

Corridor 1: Alandi Road (Vishrantwadi – Sadal baba junction) – 4.7 km

In this corridor, road width provided for BRTS bus lane at mental corner junction, Tilakmarg junction, Ambedkar junction bus stop and Bombay Sappers bus stop is less than 3.2 m making the zone unsafe for rapid moving buses in opposite direction. But PMC officials explained that this has been done keeping in the mind the driving habits of the Pune bus drivers to give minimum ROW.



Observation 1: Transverse rumble strips are placed very close to signalized intersections, where we have separate signal for BRTS and other vehicles. It is inconvenient for road users and also reduces the overall performance of intersection at Ambedekar bus stop. PMC officials explained that close spacing of rumble strips is only a temporary measure that has been taken to habituate the drivers for safe movement at intersections.

Observation 2: At most of the intersections, pedestrian crossings on both roads are aligned except few locations as shown in the figure below. Lack of connectivity in pedestrian crossing makes very difficult and risky for handicapped pedestrians to cross the road at Ambedekar bus stop. It is desirable to have the straight alignments for pedestrian crossing wherever it is practically possible.

Observation 3: Unwanted openings in barricading and median opening at Deccan College will increase pedestrian vehicle conflict and also affect the performance of BRTS.

Observation 4: Safety issues at Bombay sappers junction (T junction)

(i) Absence of road markings and chanalization to segregate the movement of buses and other types of vehicles.

(ii) Absence of bus lane sign board

(iii) Improper pedestrian crossing facilities, like pedestrian signals, markings etc., at bombay sapper's junction.

(iv) Absence of bus lane signal

The junction improvement measures have to be implemented as per the details given in PMC design drawings.

Observation 5: Bus station markings and bus lane edge line markings are quite unclear at Ambedekar bus stop.

Observation 6: Pavement surface leveling difference/undulation on the service lane near District Home Guard Junction

Observation 7: Absence of BRTS segregation in terms of lane markings and signs

Observation 8: Incomplete ramp construction and seating facilities at bus station of District home guard junction

Observation 9: Pedestrian accessbility from bus station to Subway is missing near district home guard junction

Observation 10: Major obstruction on the BRTS corridor, absence of bus lane markings


Observation 11: Unwanted Midblock opening - Near MES pump house. These openings should be closed before BRTS operations.


Observation 12: Level difference/discontinuity in pedestrain zebra crossing near bus stations (unsafe for physically challenged people)


MES pump house

Mental corner junction

Shanti Nagar Junction

Observation 13: No separate signal for BRTS at Next to bombay sappers bus station

Observation 14: Unfinished bus station access ramp

Observation 15: Absence of exclusive pedestrian phasing at Shanti Nagar junction

Observation 16: Absence of bus bay markings at Bus stations – Near District Home guard junction

Observation 17: Rumble strip is placed on the bus lane without specific purpose. It will reduce the performance of BRTS (e.g. Ambedekar bus station). PMC officials explained that this is a temporary measure to habituate the BRT drivers

Observation 18: Few observations made related to bus station facilities

(i) Lack of seating arrangements/ incomplete seating arrangements

(ii) Automatic door installation is still pending at the bus stations throughout the BRTS lane.

District home guard junction

Near MES pump house

Observation 19: Absence of segregation through marking and information signs at starting/ending point of the corridor which can cause merging/diverging conflicts near Vishrantwadi.

Observation 20: Mixed traffic zone forming bottle neck (from Sadal Baba to Yerwada junction)

Followed by the Sadalbaba bus top, there is a mixed traffic stretch of 900 m, where special safety measures to guide the BRTS and vehicles have to be taken along with proper signal systems, marking and sign boards. Similarly the zone where the mixed traffic road turns to start with Yerwada-Kharadi corridor needs to be focused on in

terms of safety. Near Sadalbaba junction the road width on the left side is 8.4 m and on the right side is 6.3 m making it unsafe for movement of BRTS buses and vehicles.


Night Time Audit: Corridor 1

Observation 21: Insufficient lighting facility at Ambedkar society junction.

High mast lights at this location were not working which needs to be replaced.

Observation 22: Absence of cat eyes/reflectors, futurlux and lack of lighting facilities.


Down lighters need to be provided here.

Observation 23: Absence of bus lane markings and reflectors

Near District home guard junction

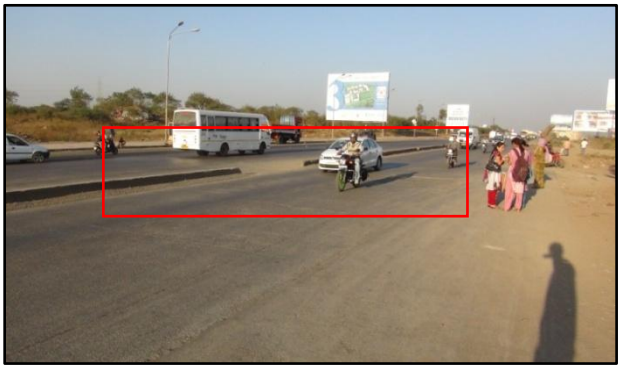
Near MES pump house

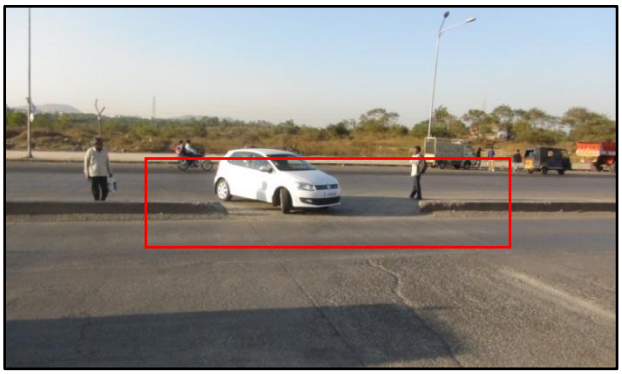
Observation 24: Improper lighting facility on the Foot over Bridge – MES Pump House.

Corridor 2: Yerwada–Kharadi (7.8 km)

This corridor needs to be constructed fully and completely along with a targeted focus on making the entire intersection safe for pedestrian crossing by installing proper barricading, signal systems and sign boards.

Observation 25: Unwanted mid block opening near 1st Bus station at Kharadi. This allows vehicles to take U turns and pedestrians to cross the road, thus results more conflict points and affect BRTS movements.






Observation 26: Unwanted old median amidst foot path around 1st Bus station at Kharadi, absence of markings, signs and proper pedestrian facilities.


Observation 27: Absence of proper marking/sign boards at location where BRT & other vehicles are merging together.


Observation 28: Absence of marking to guide BRTS buses to access bus station and absence of BRTs information sign

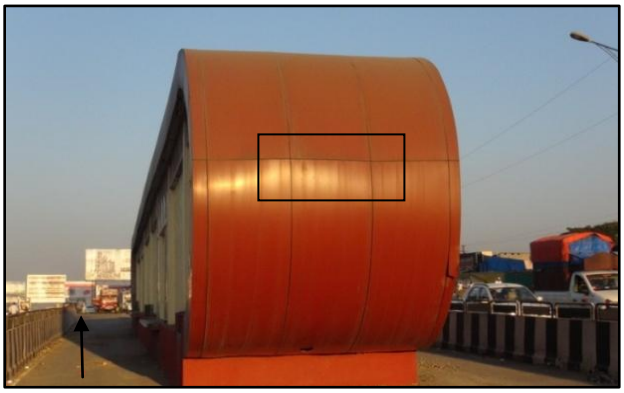

Observation 29: Non standard bus station sign. This bus station sign should be according to IRC 67: 2012.

Observation 30: Improper pedestrian crossing facilities around 1st Bus station at kharadi (absence of pedestrian signal crossing markings etc.)

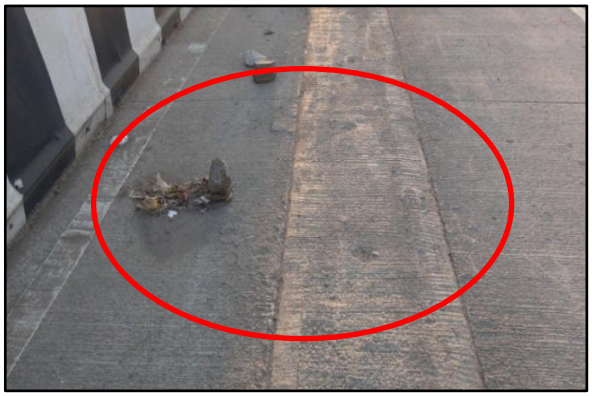
Observation 31: Absence of platform or flooring for pedestrian movement (difficulty for physically challenged)

Observation 32: At 1st Bus station, Kharadi junction, improper alignment of dividers can cause obstruction for the smooth movement BRTS, unnessary rumble strips and chevron, bus lane markings are missing.

Observation 33: There is no possiblity of getting information about bus arrival at bus stations (particularly non ramp side). Information system needs to be installed in each bus stations providing bus schedule details. Glass panel can be made to increase visibility of buses for users.

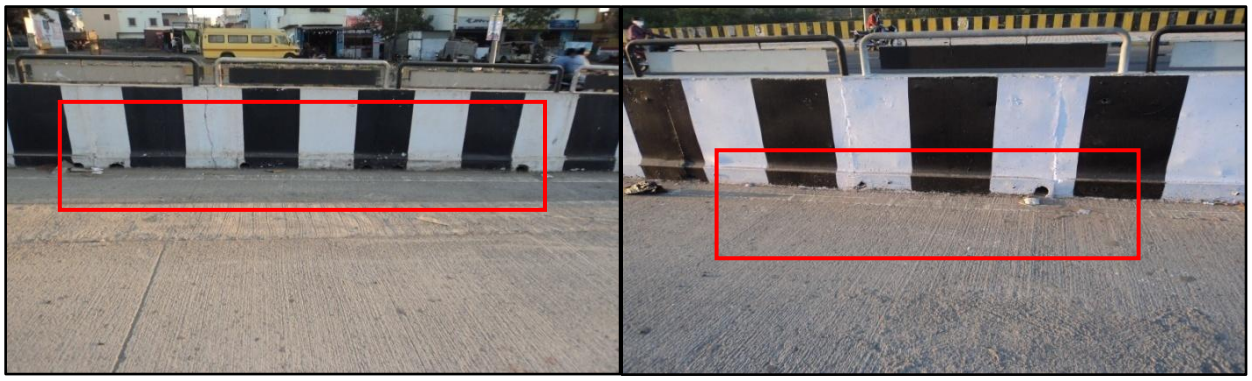



Observation 34: Road surface irregularities are observed on the BRT corridor near Kharadi junction bus station.

Observation 35: Edge line marking & Cat eyes near Kharadi junction bus station are not clear

Observation 36: Temporary blockages of the drainage holes and cleaning needs to be done as this may result in possibility of water logging during rainy seasons.



Observation 37: Absence of divider, pedestrian crossing facilities, markings and separate signal for BRTS at Indian Oil petrol bulk juncton, Kharadi

Observation 38: Absence of warning sign board/special markings and reflectors at horizontal curve after Oil petrol bulk junction

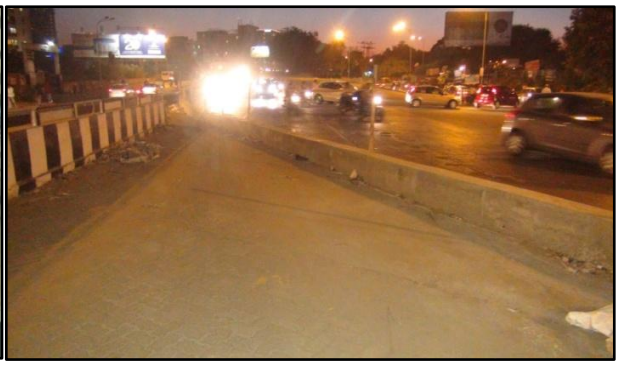

Observation 39: Mixed BRTS operation at 9BRD due to incomplete construction


Observation 40: On-Street parking near Kendriya Vidyalaya. This should be banned before commencing BRTS operations through enforcement.


Observation 41: Absence of divider and markings near Viman Nagar junction


Observation 42: Absence of separate signal for BRTS at intersection near Ramwadi (IBIS Hotel)

Observation 43: Ongoing construction and discontinuity in BRTS lane near Ramwadi Jakatnaka



Observation 44: Lack of enforcement and pedestrian facilities

Observation 45: Ongoing construction for connecting the subway to the BRTS lane should be completed before operation at Viman nagar junction (near Inorbit mall)

Observation 46: Unsafe Midblock opening near four point hotel junction

Observation 47: Markings/ signanges need to be provided to segregate BRTS lane near Shastri nagar.

Observation 48: Absence of pedestrian crosswalk markings/highlighting or facilities near Gandhi Nagar and Ramwadi Jakatnaka

Observation 49: Missing lighting facilities and warning reflectors or sign boards to show the presence of median

Observation 50: Improper barricading near Gandhi Nagar and Ramwadi Jakatnaka

Observation 51: Inside facilities of bus station near Prince Regent is incomplete and presence of median is obstructing the BRTS foot path

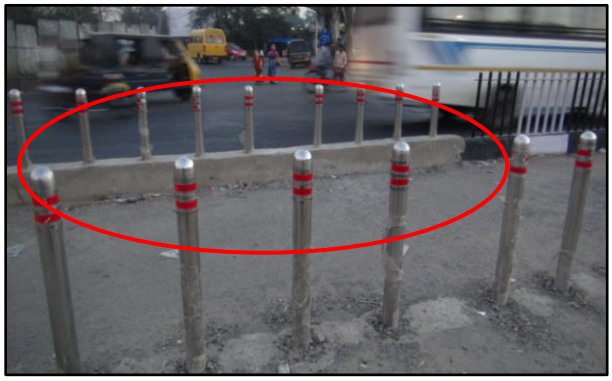
Observation 52: Absence of signals, sign boards at Yerwada junction

Observation 53: Bus stations with missing highlighting/ yellow markings at Yerwada junction and Hotel Prince Regend junction (Gunjan Junction)


Observation 54: Bus stations at Yerwada junction and near Hotel Prince Regend junction (Gunjan Junction) have no seating arrangements and ticket collection booths (Incomplete construction)


Observation 55: Obstruction caused by Tree and pole on the crosswalk from bus station at Gunjan Junction


Observation 56: Near Hyatt unsafe pedestrian crossing facilities like absence of signal, sign boards, improper bollard gaps, presence of cement base on bollards can be dangerous. This needs to be removed before BRTS commencement.



Night Time Audit at Corridor 2

Observation 57: Absence of yellow markings at Bus station before Shastri Nagar

Observation 58: Lack of reflecting LED's, markings and sign boards on BRT pathway near Shastri Nagar

Observation 59: Absence of reflectors and separate signal for BRTS near IBIS hotel

Corridor 3: Sadalbaba – Sangamwadi (3.0 km)

This lane is not fully constructed; lane separators particularly need to be paid attention to. Also there is a spilt bus stop on this lane where special care should be taken in terms of barricading and sign boards.

- For this lane, the total lane separator length: 2.0 km
- Construction has been completed for 1.4 km and still for 0.6 km lane separator construction of separator is pending

Observation 60: No segregation for BRTS at Sadal baba junction

Vehicles entering coridor 3 (Sadalbaba-Sangamwadi) from bombay sappers turning right and from yerwada corridor turning left can cause conflict and congestion at this junction.

Observation 61: Reflectors, pedestrian sign board and separate signal for BRTS missing at Sadalbaba junction

Observation 62: Information board to denote start of BRTS lane is too far near Sadal baba junction

Observation 63: Improper segregation and incomplete median construction of BRTS corridor near Sadal baba junction. This median will be an obstruction during night time and will not be visible.

Observation 64: Absence of chevron marking and dividers for BRTS lane near Sadal baba junction

Observation 65: No warning/direction sign board to give alert for the horizontal curve ahead

Observation 66: Spacing between two BRTS lanes is in the range of 30-58 cm and it should be maintained throughout the BRTS stretch.

Observation 67: No segregation for BRTS near Inter-city bus terminal that can lead to unsafe mix traffic zone. The road width of this place is 24m.

Observation 68: Intercity bus terminal should be relocated to some other place and proper segregation, markings, sign boards should be used for safe and convenient movement of BRT and other vehicle in this zone. The road width should be 30 m for safe BRT and vehicles movement. The movement of intercity buses is likely to create obstruction to BRT flow.

Observation 69: Barricade for BRTS lane missing for one-side bus stop near inter-city terminal

Observation 70: The lane width is narrow considering movement of vehicles taking left turn from lane going inside the residential area, vehicles taking righ turn from intercity terminal and movement of BRTS. Absence of BRTS signal .

Observation 71: Barricade for BRTS lane missing for one-side bus stop near inter-city terminal

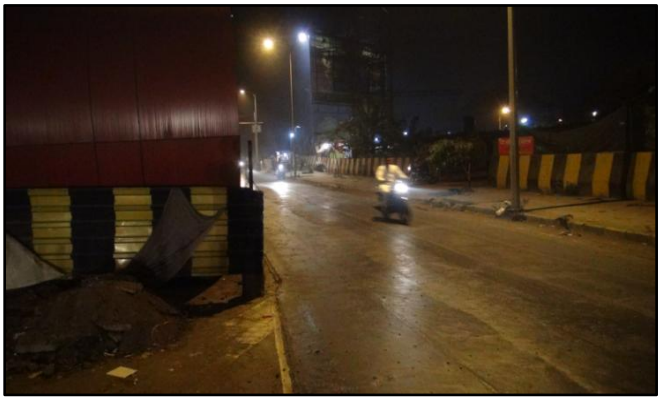
***Observation 72*:** Pedestrian cross walk facility missing near intercity bus terminal

Observation 73: Improper leveling will cause difficulty for physically challenged people to access footpath through pedestrian cross walk


Night Time Audit at Corridor 3

***Observation 74*:** BRT lane reflectors and markings/highlights are missing


Observation 75: Road width is too narrow and is devoid of any information or warning sign board



6. STUDY FINDINGS

On performing the safety audit for 3 BRTS corridor included in the 15.5 km stretch few common issues came out which can be checked and specifically targeted on. These observations are based on actual execution of work at the time of visit and have been listed below:

- At most of the intersections we spotted **lack of pedestrian crossing sign, markings, proper signal system** (that is **absence of BRTS signal**) to make pedestrian aware of BRTS as well as service lanes. (Example: Bombay Sappers junction). Most of the marking, signs shown in the PMC junction designs have not been implemented on field yet.
- At certain stations **pedestrian phasing** is properly done like Sadalbaba chowk but there are few junctions where this is still not been implemented and should be taken care of before commencing BRTS operation.
- Though at many places the **facilities for physically disabled people** have been taken care of, but few places have been spotted with lack of proper facilities and hence, proper action is needed. That is absence of raised platforms, presence of cement base bollards creating obstructions, improper bollard gaps etc. (Example: Bus station at Kharadi)
- Improper or **absence of BRTS barricading and presence of median openings** along the corridor. (Example: Median opening at Deccan College, near Gandhi Nagar)
- The longest stretch of Yerwada-Kharadi seems to be **incomplete in terms of construction** that is, crucial activities like bus station construction, proper barricading, proper signal system and sign boards etc are pending.
- At few places (9BRD, Sadalbaba Junction, Sangamwadi) due to long stretches of lanes with no segregation for BRTS, **mix-traffic zones** can be formed creating bottle necks for smooth traffic flow.
- **Improper leveling** of the service lane or pathways making movement difficult particularly for the physically handicapped pedestrians. (Example: near District Home Guard Junction)
- In Sangamwadi corridor, construction of **lane separator is incomplete**.
- Proper **marking/highlighting** at bus stations missing. (Example: Ambedekar station)
- **Automatic door installation** is still pending at the bus stations throughout the BRTS lane. (Example Ambedekar bus station)

- Common bus station facilities like installation of **bus station sign board and information board** of BRTs is missing. Incomplete construction of Bus station facilities like seating area, ramps etc. (Example: District home guard junction)
- **Lack of visibility** of buses approaching towards the bus stations. (Example: Bus station at Kharadi junction)
- **Accessibility** for riders/pedestrian between **subways and BRT bus stations** should be improved at few locations. At some places subway construction is pending or going on. (Example: Sub way is missing near district home guard junction)
- No proper **segregated lane/sign boards/information board** for BRTS, provided at the start and end points on the lanes which can cause merging or diverging conflicts. (Example: Starting point of Kharadi)
- Improper **lighting facilities, markings/highlightings or cat eyes** at bus stations for night time. (Example: MES pump house bus station, Foot over bridge near MES pump house, Ambedekar society junction)
- Missing/improper **median marking** (Example: Home guard junction)
- **No warning/direction sign board** to give alert to the BRT driver. (Example: narow lanes of the sangamwadi corridor, **horizontal curves** ahead)
- Absence of **speed limit signs** along the BRTS corridor.
- Improper **road surface** at few places on the BRT corridor (Example: near Kharadi junction bus station)

7. MAJOR SAFETY CONCERNS AND DISCUSSIONS

Issue 1: Improper pedestrian facilities at intersections including bus stations

Glimpse of current scenario at Indian Oil petrol bunk junction, Kharadi

Discussion:

- Assume red block indicates a pedestrian attempting to cross the road. Due to lack of proper signal system, pedestrian after crossing the leftmost service lane can lose focus on BRTS lane and accident can occur.
- Similarly riders after getting down from the bus station shown by green block will cross BRTS corridor and will have to very quickly encounter another road crossing, which can be risky without any signal, sign board or markings.
- Considering a situation where pedestrians are crossing from both the sides without proper signal system, with the intention of crossing quickly, collisions can happen between pedestrians or with vehicles.
- By using proper signal systems, signboards, pedestrian crossing platform and markings at intersection can be made safer.

Issue 2: Safety measures at general intersections

If the intersections are not properly designed there can be conflicts between BRT and other modes. Improperly or un-designed intersections will create chaos between all the modes, BRT and pedestrians causing congestion, reducing efficiency and increasing chances of accidents. High speed moving BRT and vehicles trying to change lane at intersections can cause conflict if proper markings, directions to maintain segregation is not done. Example of such a kind of unplanned intersection is the one present near mental corner junction. Intersections can be designed with proper signal / markings/ round or square about to keep traffic organized and mitigate risk. All pedestrian facilities should be paid attention to by involving pedestrian crossing platform, sign boards, signals etc.

Issue 3: Improper/ absence of barricading

Discussions

- This open barricading can be used by pedestrians for crossing or for reaching the bus station quickly, which can be unsafe.
- During the time of high traffic congestion or traffic jam, vehicles can enter the BRTS corridor through this which can cause accidents if BRTS is active.
- Vehicles may enter the BRTS corridor causing mixed traffic zones.

Issue 4: Absence of Rumble Strips on Service Lanes near Intersections

Discussions:

High speed BRTS moving in the same direction as of other vehicles which can prove to be very dangerous. At the start or the end point of BRTS corridor, the buses move towards a mixed traffic zone. In order to avoid conflicts between high speed running

bus and other vehicles on the road, rumble strips should be provided at the end point of the corridor or near junctions on the two service lanes for slowing down the speed of other vehicles before entering the mix traffic zone with BRTS bus. BRTS corridor start or end sections require special treatment for smooth entry and exit of buses. Markings as shown by red arrow can be made to guide the BRTS so that it remains close to median even while travelling in the mix zone.

Issue 5: Lack of Subway- BRTS lane Accessibility

Discussions:

Pedestrians approaching from subway to the bus stations don't have easy access. The pedestrians will have to cover extra distance to reach till crossing if they prefer subway. In such a case, most of them may opt direct road crossing near junction rather using subway thus negating the purpose of subway. Currently, there is an obstruction present in the BRTS lane parallel to the subways without any warning sign board or marking,

which can be dangerous for BRT operations. During night time, to make the obstruction distinctly visible warning sign board becomes more necessary.

A third arm of the existing subway can be developed in the BRTS lane which is connected to the bus station by a pedestrian pathway with proper barricading and markings.

Issue 6: Presence of mix-traffic zones

Discussions:

Pune BRTS has few zones that have formation of mix-traffic zones. Traffic safety issues should be taken care of while the BRT bus is merging and diverging with heterogeneous traffic here. The two most crucial mix traffic zones that should be paid special attention to are the 900 m stretch (from Sadal Baba to Yerwada junction) and the zone near intercity bus terminal along the third corridor (Sadalbaba - Sangamwadi).

Merging scenario: High speed bus when emerges from BRTS corridor and enters the mix zone region, the vehicles here are at different speed than the bus. There is a possibility that vehicles overtake the bus or the bus is encircled between heterogonous traffic.

Diverging scenario: When BRTS has to again go to corridor, it will have to diverge from the mix traffic. With the intention of going back to the lane and with traffic around trying to move, conflict may occur.

Thus at the merging and diverging zones, to provide segregation, markings, arrows, median directions etc should be used.

8. RECOMMENDATIONS FOR SAFE OPERATION OF BRTS

The recommendations are intended to be as practical and cost effective as possible. The following measures have been recommended to enhance the safe BRTS operation at the pilot study stretches of corridors:

I. ROAD SIGNAGES AND MARKINGS

Signs and road markings are main guiding factors for the road users which are essentially required to be adequate and placed at appropriate places on the road. The road signs are designed scientifically keeping in mind the movement of vehicle maneuver expected at the succeeding intersection catering to different types of road users. Based on this, the signs should be designed and placed at BRTS corridor. Advance Direction Signs should be posted at the corridor at each of the approach arms of the intersections.

Further, regulatory signs such as 'Speed Limit' and 'Keep Left and 'Keep Right' signs also need be placed at appropriate locations in the vicinity of all the existing bus shelters. Typical 'Speed Limit', 'Keep Left' and 'Keep Right' signs and 'Bus Stop' and other important signs as per "IRC:67 (2012): Code of Practice for Road Signs" should be designed and installed on the ground before commencement of BRTS operation. The details about the signs and their images are given below:

(i) Give way to buses exiting bus lay-by ahead:

The sign shall be used to inform vehicles about Give way to Buses exiting from a bus lane ahead. The sign can be placed at the beginning of such area.

(ii) Maximum Speed Limit:

Speed is the single most important causal factor in road accidents that result in a road fatality. We recommend a maximum design speed of 40 kmph for any road upon which a BRT is developed. As far as possible, this speed should be induced through road design, rather than relying on signage and/or enforcement.

These design features include narrower lanes, speed tables, chicanes, etc. It is important to note that in the urban context, achieving a high midblock speed has very little impact on total journey time. This is because of the frequent need to slow down or stop at intersections, which are present at a much more frequent interval than in the context of a regional highway. Further, a slower and more consistent speed, may also improve the capacity of the road. This is because the safe gap or headway required between vehicles is less for slower moving traffic.

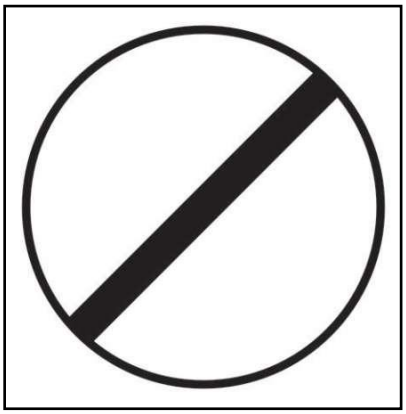
The sign shall be located at the beginning of the section of the road or area displaying speed restriction, with numerals indicating the speed limit in km per hour. The Speed limit should be marked in multiples of 5 km per hour. Separate speed limit signs for BRTS buses and other vehicles should be provided.

(iii) Over taking prohibited (BRTS lanes):

The sign shall be erected at the beginning and at intervals within BRTS lanes, at sections where overtaking will be hazardous. The sign may be dispensed with pavement markings as per IRC provided for "No Overtaking Zones". The "No Overtaking" sign should be erected on each side of the road at the start of the affected length and should be supplemented by repeating signs at intervals not exceeding 400 m.

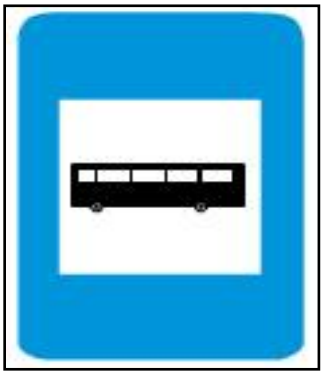
(iv) Restriction Ends Sign:

This sign shall indicate the point at which all prohibitions notified by prohibitory signs for moving vehicles ceases to apply.



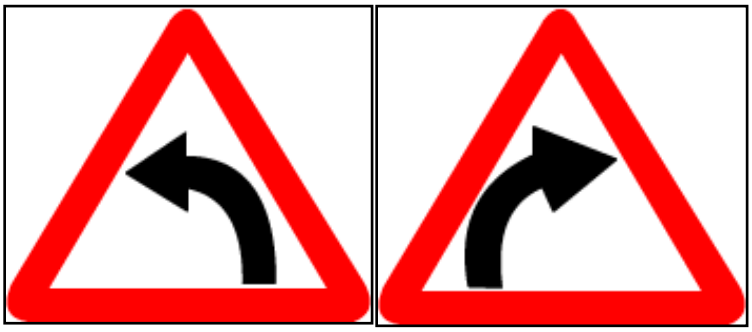
(v) Bus Way/ Buses only:

The sign shall mean that only buses are allowed and the other traffic is not allowed on this road/ carriageway. The sign may be supported by supplementary plate with "BUSES ONLY" written on Pavement surface. (The background color should be as per the code.)



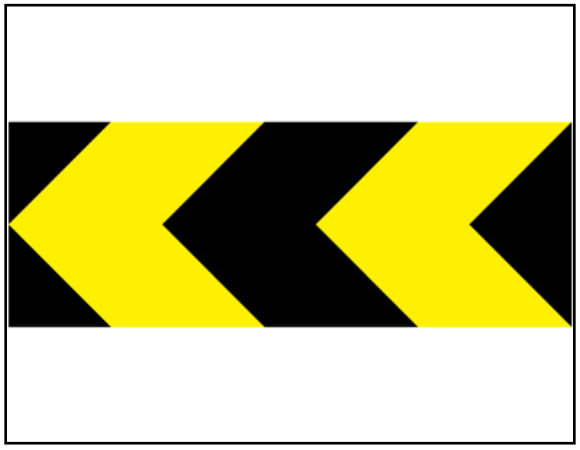
(vi) Right/ Left hand curve (BRTS lane)

These signs are to be used, whenever there is a need for reduction of speed due to change of direction of alignment and radii of the curvature are below the specified limit. These signs are intended to warn the driver to reduce the speed and proceed cautiously. The warning signs are to be used sparingly. If a road has certain curves where vehicles cannot be allowed to negotiate with the absolute speed limit or the general operating speed established for the road, such curves shall be provided with curve warning signs on both approaches. The left hand curve sign should be used to mark curves bending to the left and right hand curve sign for curves bending to the right.



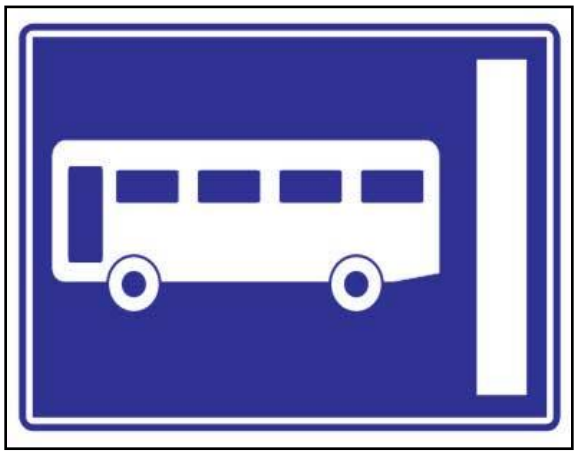
(vii) Chevron sign:

At the curved alignment of a roadway, the chevron signals shall be used to inform the drivers about sharpness of curve. The chevron sign shall be a vertical rectangle and shall be installed always on the outside of a turn or curve, in line with and at approximately right angle to the approaching traffic. Spacing of chevron signs should be such that the road user always has at least two signs in view, until the change in alignment eliminates the need for the sign. Depending upon the sharpness of the curve, Single Chevron, Double Chevron Sign and Triple chevron sign can be installed.



(viii) Bus Lane:

This sign is installed to inform the drivers about the presence of reserved bus lane in the carriageway. The operation of bus lane is supported by appropriate markings on the pavement to delineate the lane indicate the bus only lane markings. These are generally mounted overhead with appropriate support.



II. PEDESTRIAN FACILITIES:

As bus users, people have to cross the road prior to boarding or after alighting from the bus. This would be true for all commuters whether buses are in the central or curb side lanes. Since people live and work on both sides of the road at least half the passengers have to cross the full width of the road in the case of the curb side lane. In the case of the central lane, only half the width of the road has to be covered on foot, the latter arrangement requires a shorter red light signal phase for cars, which increases safety all round.

Improvement in pedestrian facilities can be made by providing proper signals at intersections, sign boards and enhancing BRT user experience by establishment of informative sign boards, handicapped user friendly facilities, convenient accessibility design. The sign should be erected in advance on both approaches of the uncontrolled pedestrian crossings. This sign establishment is absolutely essential when visibility of the crossing is impaired by a bend or hump in the road. If required, the sign can be repeated at a short distance ahead of the pedestrian crossing.

We recommend a minimum footpath width of 3 meters for an urban corridor. The recommended footpath kerb height is 0.10 meters. We recommend that all the pedestrian crossings should be signal controlled. We further recommend that the crossings should be supplemented with speed tables, in order to induce other vehicle users to drive at the design speed.

We strongly recommend that the phases of successive pedestrian crossing signals be synchronized, so as to reduce the probability that vehicles will have to wait at more than one signal in the same midblock. We do not recommend pedestrian actuated

signals in the Indian context; as such signals are only useful when there is a low and infrequent crossing demand.

Speed tables

Since, traffic discipline in most Indian cities is poor; motorists may not always respect pedestrian signals. This can be extremely dangerous, especially if the vehicle in the lane closer to the footpath stops at the signal, while the vehicle away from the footpath doesn't stop. Here, the stopped vehicle in the leftmost lane creates s sense of security for the crossing pedestrian, and also blocks his/her view of the oncoming vehicle in the other lane. This can lead to a fatal collision.

We thus recommend that all signalized pedestrian crossings signs should be placed on top of speed tables. This is an added safety feature to slow down vehicles at the pedestrian crossing, and to induce them to drive at a safe speed. For our design, we have used a gentle speed table of the following dimensions:

Length of Up-slope ramp	1 meter
Length of table-top (pedestrian crossing width)	3 meter
Length of down-slope ramp	1 meter
Height of table-top	0.1 meters

We do not recommend abrupt speed bumps on any urban arterial. Speed bumps force vehicles to come to a complete stop. We recommend the provision of pedestrian refuges between the mixed traffic and BRT lanes in order to accommodate slow-moving pedestrians which may get stranded at the end of a pedestrian green phase. We also recommend that the pedestrian crossing width must be at least as wide as the footpath, which in our case is 3 meters.

III. MITIGATING THE BUS-TO-PLATFORM GAP

The photos below show excessive gaps found during normal operations in BRT systems in other large cities in Asia and the America. During trial run of Pune BRTS, this aspect should be considered carefully. Excessive gaps require passengers to carefully watch the gap when they board or alight, causing delays and creating the risk of injuries as well as line delays. Excessive bus-to-platform gaps at BRT stations can make boarding and alighting more difficult for all passengers and especially for children, elderly and physically challenged people.

As per the information shared by PMC officials the gap observed during pilot run on level boarding is shown below:

Reduce the space between bus and platform to nominal size for all passengers, through different methods of gap reduction. A 10 cm horizontal gap is the absolute maximum and smaller horizontal gaps are highly desirable. Vertical gaps should be minimized as much as possible and it should be no more than 1-2 centimetres. Doors should be operated by sensors to prevent people from getting hit by buses. The doors should only open when a bus arrives, and all buses stops should be in perfect alignment with the shelters. Automatic doors should be installed for all the bus stations.

IV. BRTS LANES AND DIVIDER

A divider marking of minimum 0.5 meters width between BRTS lanes is observed in most of sections and the same is recommended for whole stretch. This vacant space is needed so as to ensure the full utilisation of the adjacent traffic lanes. This is because vehicles tend not to drive very close to a visible vertical obstruction, and thus sufficient space is needed on both sides, so that both the BRT bus makes full use of their respective traffic lanes. It is preferable to have physical divider with the height of 0.15 meters for more safe operations.

The width selected for the BRT lane is recommend to be 3.5 meters. This is consistent with the recommended width for BRT lanes across the world. It is done to ensure that the BRT bus can drive safely at a reasonably good speed, without running with the risk of colliding with the guardrails or a bus approaching from the opposite direction.

V. MIDBLOCK BRTS

In general, pedestrians are at risk when they cross the corridor away from designated crossings. The risk is particularly high near BRT stations, as passengers will often attempt to cut across the bus lanes to go in or out of the station. This suggests that station access design can play a key role in improving safety on bus corridors, along with better provision for pedestrian mid-block crossings.

Pedestrians may have to cross both the BRT lane and the mixed traffic lanes at one go. This is not necessarily dangerous, if the crossing is signalized. However, in the absence of working pedestrian signals, this can lead to a high numbers of pedestrian fatalities.

VI. INTERSECTIONS

As a general principle, minor streets must not be allowed to cut across at BRT corridor; that is, it is better to terminate the minor street into a T-intersection, rather than introducing 4-arm intersection, because of lesser number of conflict points.

We, therefore, recommend eliminating the possibility of right turns, either from the minor street into the BRT corridor, or from the BRT corridor, in to the minor street. We recommend, instead, facilitating a combination of a U-turn and a left turn to complete this maneuver

Right turns, for mixed traffic on a BRT corridor, have huge safety implications, if designed incorrectly. This is due to the positioning of the BRT lanes along the central lanes of the road. As a result, traffic on the BRT corridor that needs to make a right turn, must do so by cutting across the BRT lanes. This can be dangerous, because the BRT bus will, typically, need to move straight, through the intersection. Thus, there is a risk that the right-turning vehicles may collide with the straight-moving BRT bus.

BRT in different cities have adopted various measures to counter this safety risk. One alternative is to terminate the segregation of the BRT lane a few meters before the intersection, and allow right-turning vehicles to merge into the BRT lane, so that they make the right turn form the same lane that the BRT bus continues straight. This can be a safe solution if the merging of the right-turning traffic into the BRT lane is signalized, or if there is adequate merging length and sight distance. However, if none of these features are present, then it may simply result in creating the collision risk from the intersection to the point before the intersection, where the merging happens.

Another design alternative is to continue the segregation of the BRT lane till the intersection, but have separate signal phases for mixed traffic right turns, and BRT straight movement

VII. BRTS LANES TURN INTO MIXED-TRAFFIC ROUTES

BRTS corridors should be designed for the dual function of throughput mobility and local accessibility. In this context, much lower speed is essential in order to ensure safety of all road users. Traffic safety issues should be taken care of while the BRT bus lane is merging and diverging with heterogeneous traffic. Thus at the merging and diverging zones, to provide segregation, markings, arrows, median directions etc should be used. This can be used at 900m long stretch mix traffic zone present in Sangamwadi corridor and at the stretch near intercity bus terminal.

VIII. APPLICATION OF INTELLIGENT TRANSPORTATION SYSTEM MEASURES

Bus signal preference and preemption: In future, preferential treatment of buses at intersections can involve the extension of green time or actuation of the green light at signalized intersections upon detection of an approaching bus. Intersection priority can be particularly helpful when implemented in conjunction with bus lanes or streets, because general-purpose traffic does not intervene between buses and traffic signals.

Improved facilities and amenities: The operational and travel time benefits resulting from the separation of buses from general-purpose traffic can be augmented with improved amenities such as bus shelters and stations. These facilities provide protection from the elements and can also be equipped to furnish information such as printed routes and schedules or electronically transmitted real time schedule data. Space can also be leased to commercial convenience services.

Automatic vehicle location systems – This will enable transit agencies to track their vehicles in real time and provide them with information for making timely schedule adjustments and equipment substitutions.

Passenger information systems – Such systems give passengers the means to make informed decisions about their transit travel. Of the many technologies now available for passengers to access this type of information, the APTS applications most appropriate for Bus Rapid Transit are in-vehicle information systems. These systems automatically announce approaching bus stops, allowing disembarking riders to

position themselves near the doors prior to arriving at their stops, and speeding up the unloading and loading operation.

Prof. Dr. P. Vedagiri and his team have recently developed the real-time transit trip planner and route information system for Mumbai city. For more details, please refer (*http://www.transittripplanner.co.in/).* A similar kind of system is recommended for Pune.

Fare collection system that speeds up the boarding process – This system would decrease dwell time and improve overall system efficiency.

IX. TRAINING FOR BRT PERSONNEL

The design solutions mentioned above are enhanced by proper training of bus drivers to avoid sudden starts and stops, to reduce speed before going around curves, and to drive carefully for the sake of all passengers. Public outreach programs and safety campaigns for public is also recommended.

X. ENFORCEMENT

On-street parking is a typically witnessed on the road stretch causing so much interference traffic on the lane on both directions of travel. Since this is more of an enforcement issue, it can be strictly controlled through law enforcement.

9. CONCLUSION

Safety audit of the pilot BRTs corridor was successfully done by Transportation Systems Engineering Group, IIT Bombay. Overall, the planning and design aspects of pilot BRTS corridor at Pune are satisfactory. Through this study we find out the few safety issues for vehicles as well as pedestrians and we have given effective solutions to improve the performance with minimum disruption to the flow of BRTS buses. The study reveals that no major demolition, construction is warranted at this stage of auditing. The improvement measures suggested are easy to implement and low cost in nature which could be completed without difficulty. These measures have to be implemented before commencement of BRTS operations. We have also provided solution for pedestrian crossing issues and physically challenged people to use BRT service. We also suggest, it is a good idea to conduct safety audits at different stages like (i) during planning and design stage (ii) during construction stage (iii) pre-opening stage of the remaining BRT corridors proposed by PMC, Pune.

But unless there is proper connectivity to BRTS routes, it is difficult to visualize it as a successful system. Only when this has been achieved will the BRTS be able to attract a large number of users. It should be kept in mind that opening day is not a good time to assess what the system will be like a week or a month later, when lessons that are learned can hopefully be put into practice to improve the system. We recommend that the problems identified and finding observed should be shared with the officials. For example, if bus drivers are stopping too far from the platform edge, it will be legit to request the BRT managers to provide them with better training.

Traffic police and other security personnel need to back and help the Municipal Corporation and other levels of government organizations to effectively operate the proposed BRTS system. Targeted public education campaigns should be conducted to involve the user community. Road users are expected to incur maximum use of this facility by following the laws and rules sincerely.