

Smart City Master Planning and Sector-specific Smart City
Infrastructure Projects for Visakhapatnam

**IMPROVEMENT OF BUS RAPID TRANSIT SYSTEM—
FEASIBILITY STUDY FINAL REPORT**



AECOM

IBM

KPMG

Copyright

© 2017 AECOM

3101 Wilson Blvd.
Suite 900
Arlington, VA 22201 USA
Telephone: +1 (703) 682-4900
Internet: www.aecom.com

December 2017



Rights and Permission

The material in this work is subject to copyright. Because AECOM encourages dissemination of its knowledge, this work may be reproduced, in whole or in part, for noncommercial purposes as long as full attribution to this work is given.

AECOM

General Limiting Conditions

AECOM devoted effort consistent with (i) that degree of care and skill ordinarily exercised by members of the same profession currently practicing under same or similar circumstances and (ii) the time and budget available for its work in its efforts to endeavor to ensure that the data contained in this document is accurate as of the date of its preparation. This study is based on estimates, assumptions and other information developed by AECOM from its independent research effort, general knowledge of the industry, and information provided by and consultations with the Client and the Client's representatives. No responsibility is assumed for inaccuracies in reporting by the Client, the Client's agents and representatives, or any third-party data source used in preparing or presenting this study. AECOM assumes no duty to update the information contained herein unless it is separately retained to do so pursuant to a written agreement signed by AECOM and the Client.

AECOM's findings represent its professional judgment. Neither AECOM nor its parent corporation, or their respective subsidiaries and affiliates, makes any warranty, expressed or implied, with respect to any information or methods disclosed in this document. No recipient of this document other than the Client shall have any claim against AECOM, its parent corporation, and its and their subsidiaries and affiliates, for any liability for direct, indirect, consequential, or special loss or damage arising out of its receipt and use of This document whether arising in contract, warranty (express or implied), tort or otherwise, and irrespective of fault, negligence and strict liability.

IBM

KPMG

This page intentionally left blank

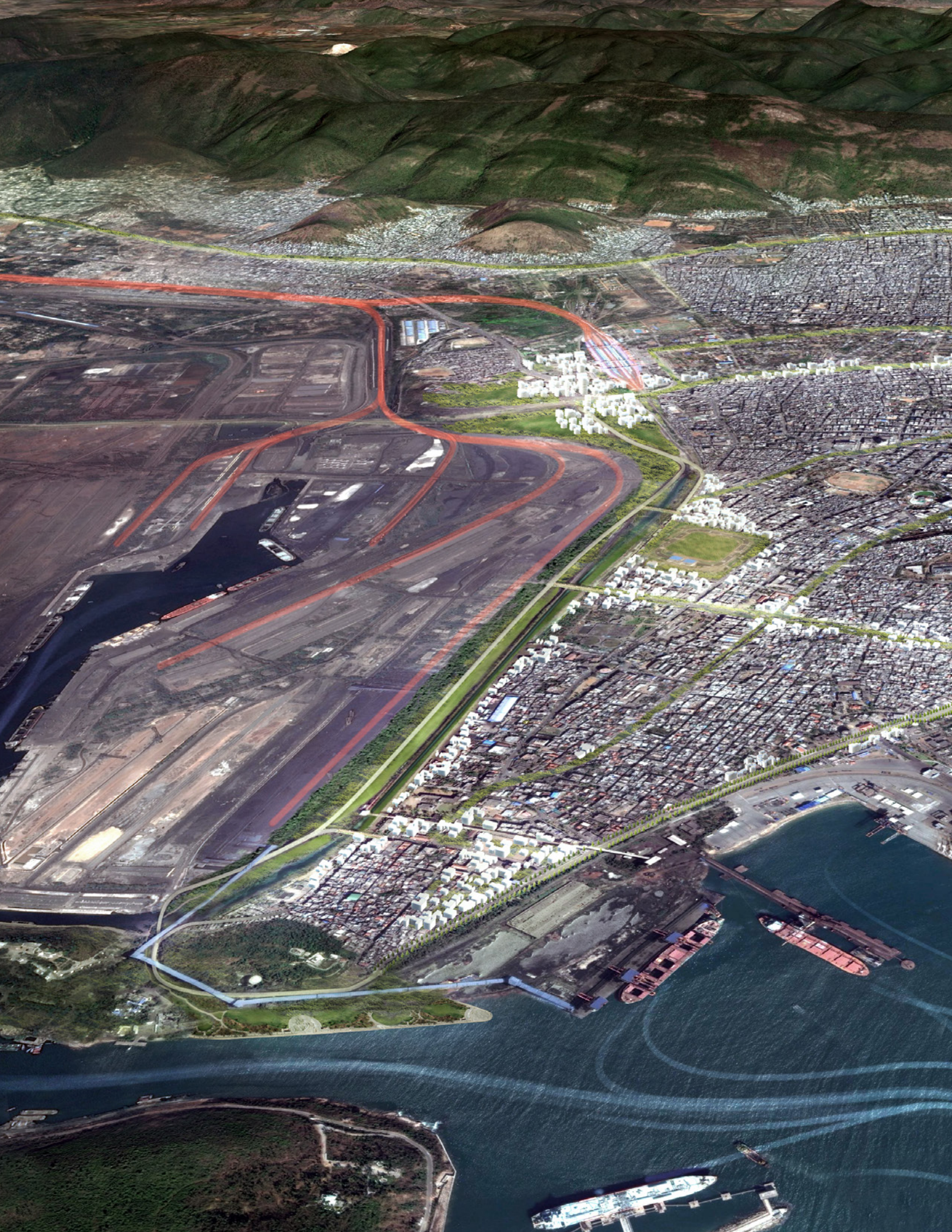
TABLE OF CONTENTS

Executive summary	1
Proposed Improvements	3
Introduction	5
Issues and Concerns	6
Existing Conditions	7
Proposed Improvements	12
Traffic Systems Integration	31
Station Design	39
Estimated Project Costs	52
Prioritization of Improvements (Best Value)	54
Project Implementation Opportunities	63



Acronyms and Abbreviations

APEPDCL	Andhra Pradesh Eastern Power Distribution Company Ltd.
APGENCO	Andhra Pradesh Power Generation Company
CEO	Chief Executive Officer
CMAR	Construction Manager at Risk
DB	Design-Build
DBF	Design-Build-Finance
DBFOM	Design-Build-Finance-Operate-Maintain
DBOM	Design-Build-Operate-Maintain
EoI	Expression of Interest
GHG	Greenhouse Gas
GVMC	Greater Visakhapatnam Municipal Corporation
HPSC	High Powered Steering Committee
IT	Information Technology
kV	Kilovolt
kWP	Kilowatt Peak
MW	megawatts
NREDCAP	New & Renewable Energy Development Corporation of Andhra Pradesh Limited
O&M	Operations and Maintenance
OT	Operational Technology
PV	Photovoltaic
RFP	Request for Proposals
RFQ	Request for Qualifications
SCADA	Supervisory Control and Data Acquisition
SOQ	Statement of Qualification
SPV	Special Purpose Vehicle
ULB	Urban Local Bodies
VfM	Value for Money
VUDA	Visakhapatnam Urban Development Authority



EXECUTIVE SUMMARY

The purpose of this project is to study the feasibility of upgrading Visakhapatnam's existing Pendurthi, Mudasarlova and Simhachalam bus rapid transit (BRT) lines. The project includes retrofitting of bus shelters, signalization of intersections and signal prioritization, improved operational management of the dedicated lanes, and introduction of real-time "Next Bus" tracking systems that can be accessed via a smart phone application and shown on public information displays on the bus shelters. The new shelters are expected to include potential features such as interior lighting powered by solar cells, precision bus docking and all-doors boarding.

In addition, The project offers the opportunity to introduce electric buses and charging infrastructure as part of a pilot initiative to build the foundation for expanded E-bus use.

Bus Station Improvements



Existing BRT stations are challenged with unsafe pedestrian crossings and boarding areas, shelter, and passenger information displays.



Improved BRT stations include safe accessible pedestrian crossings and boarding areas, expanded shelters, passenger information displays, concrete wearing pads and wheel guides, and mode separation barriers.

Over the past several years, Visakhapatnam (Vizag) has developed a series of Bus Rapid Transit (BRT) corridors for improving the access and reliability of bus travel for its passengers. 45 kilometers of dedicated bus lanes, physically separated from all other vehicular traffic, have been implemented along Route 39, the Vepagunta-Sabbavaram Road, the Simhachalam Road, and the Mudasarlova Road. A number of challenges have been identified that have limited the effectiveness of these corridors, including:

- Conflicts between buses and other vehicular traffic at uncontrolled intersections;
- Lack of real-time information for bus passengers at BRT stations or before reaching stations;
- Passenger safety concerns accessing or departing BRT stations and crossing active roadways;
- BRT stations lacking passenger amenities such as real-time bus information, interior lighting, and bus route information;
- Inconvenient and time-consuming transfers for passengers between BRT stations and buses;
- Intrusion of unauthorized vehicles into the BRT dedicated lanes;
- Lack of transit signal priority (TSP) for buses at intersections;
- Intersection design issues impacting passenger movements and bus operations.

Using the existing infrastructure of the BRT segments already constructed, this study recommends the design and implementation of mostly low and medium cost solutions that:

- Improve the appearance, functionality and safety of existing bus stations;
- Increase the travel time reliability of buses using the BRT lanes;
- Reduce conflicts between buses, pedestrians and other vehicles;
- Provide “real-time” information on bus conditions and possible delays to bus passengers at stations and prior to leaving home or work;
- Improve control and monitoring of traffic at intersections;
- Prioritize improvements by available funding in order to maximize public benefit.

Proposed Improvements

The improvements proposed below will all greatly improve bus operations and improve convenience and access to information for bus passengers. These improvements can be phased for implementation based on “best value” of each investment. We use qualitative criteria as the most effective method for assessing the many different factors involved in prioritization, including safety, bus operations, passenger convenience and travel time, and perception of improvements. In the

table below, a multifaceted program is advanced independent of cost, indicating best value improvements by phasing with a brief description of the elements being installed.

- **Phase I** recommendations improve passenger safety and information; reducing bus travel delay; improving bus travel reliability.
- **Phase II** recommendations minimize conflicts between pedestrians and vehicles, reduce non-bus intrusions in the lanes, and improve enforcement of bus lanes and control congestion.
- **Phase III** recommendations improve visibility of bus lanes.

The anticipated total construction costs for upgrading the Visakhapatnam Bus Rapid Transit System are anticipated to be USD 126,318,375.

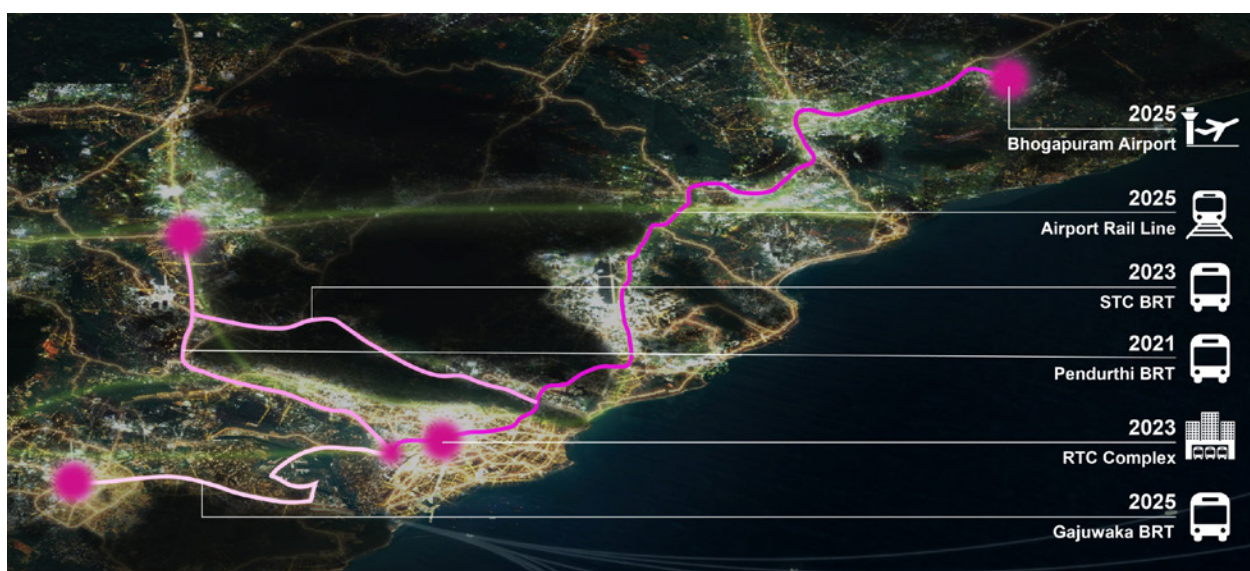
Table 1 Prioritization of Recommended Improvements

Phase	Improvement	Description
Phase I	Install “smart” traffic signals & improved geometry at intersections	Improves safety of intersection for pedestrian and buses; reduces bus delays by reducing bus conflicts.
	Improve BRT lanes in the southern approach of the Pendurthi-NAD & National Highway 5 intersection	Reduces bus delays in crossing the intersection and improve vehicles and pedestrian safety at the southern approach to the intersection.
	Install concrete bus pad and wheel guides at bus stations	Improves safety, reduces bus delays with direct passenger boarding from platform to bus.
	Upgrading of Bus Station: <ul style="list-style-type: none"> ■ New canopies and solar panels ■ Interior lighting ■ Real-time bus information ■ Bus maps and schedules ■ Traffic signals and high visibility crosswalks 	Improves safety and security for passengers, improves passenger information using real-time electronic displays for next bus and delays at stations and by phone, and provides safer pedestrian access to and from stations while crossing vehicle and bus roadways.
	Install signalized pedestrian crossing	Improves safety of pedestrian crossings by extending distances between intersections.
Phase II	Eliminate non-intersection openings to bus lanes	Reduces conflicts from vehicles entering or crossing the bus lanes, reduces bus delays.
	Install new barriers	Improves safety by reducing illegal and dangerous pedestrian crossings, improves roadway safety for vehicles and passengers.
	Install traffic signal prioritization (TSP) at intersections	Reduces delays for buses equipped with TSP by providing priority for buses to cross intersections.
	Install traffic monitoring and “red light” cameras	Reduce illegal vehicle movements and monitor traffic congestion at all intersections.
Phase III	BRT Roadway Markings	Improved definition of BRT Lanes
	Improve BRT Signage	Avoid non-authorized vehicles from entering bus lanes.

INTRODUCTION

The proposed BRT system improvements increase reliability, comfort, speed, and safety for the multiple bus routes that use the busways and increases safety and efficiency for all other transport modes as well. These recommendations maximize benefits from the previous investments in building the dedicated busway and investment per kilometer (mile) is significantly lower \$2.8 million/kilometer (\$4.5 million/mile) for the proposed bus corridor than it would be for elevated exclusive guideways for BRT or a new metro rail transit (MRT) system. This excludes the cost of the vehicles. These recommendations increase property values for land surrounding stop locations along the 45 miles of the improved corridor. The proposed BRT system begins the transition to an E-bus fleet by introducing electric battery operated buses as part of a pilot project and sets the stage for success for the future Metro Rail Transit (MRT) network.

In a representative household socio-economic survey conducted by AECOM in 2016, 36% of interviewed households prioritized improvements to Visakhapatnam's bus services as the second most important factor that they wanted to add to their neighborhoods. Vizagites rely heavily on bus transit to commute long daily distances and are concerned with pedestrian safety at crossings. 29% of household members travel more than 15 kilometers each way to reach their places of work. Public buses are an important mode of transport, with 41% of respondents using buses between the 6 am and 10 am rush hour period. More than one quarter of respondents (28%) reported pedestrian crossings are the safety issues about which they worry most. Additionally, 80% of respondents are willing to pay more for access to better road transport options.



A diagram depicting how BRT upgrades connects with other proposed rapid transit enhancements.

Issues and Concerns

Visakhapatnam (Vizag) has developed over the past few years a series of Bus Rapid Transit (BRT) corridors for improving the access and reliability of bus travel for its passengers. Dedicated bus lanes, physically separated from all other vehicular traffic, have been implemented along Route 39, the Vepagunta-Sabbavaram Road, the Simhachalam Road, and the Mudasarlova Road. While most of the dedicated roadways (running ways) have been implemented, parts of the Simhachalam Road are still being implemented. For the nearly 45 kilometers (km) of BRT Corridors currently completed and being used, a number of issues have been identified that have limited the overall effectiveness of these corridors including:

- Conflicts between Buses and Other Vehicular Traffic at uncontrolled intersections;
- Lack of real-time information for bus passengers either at BRT stations or before reaching the Station;



Figure 1 Existing BRT Corridors

- Passenger safety concerns accessing or departing BRT stations and crossing active roadways;
- BRT Stations lacking passenger amenities such as real-time bus information, interior lighting, and bus route information;
- Inconvenient and times consuming transfer between BRT station and buses for passengers;
- Intrusion of unauthorized vehicles into the BRT dedicated lanes;
- Lack of Transit Signal Priority for buses at intersections;
- Intersection design issues impacting passenger movements and bus operations.

Existing Conditions

Three of the four BRT segments noted earlier are completed and operating today (See Figure 1).

- Route 39 between Pendurthi Road (Route 38) and Port Main Road;
- Vepagunta-Sabbavaram Road between Route 38 and Simhachalam Road;
- Mudasarlova Road between Simhachalam Road and Route AH45.

BRT Running Ways

Pavement Conditions:

The completed sections of BRT lanes or running ways vary in condition from fair to good for the newest sections: Vepagunta-Sabbavaram Road and Mudasarlova Road to fair to poor for the oldest section along the Pendurthi-NAD Road (Route 39). Problems in the newest sections include minor flooding of running way due to inconsistent drainage along the route to undulating roadway in sections providing for an uncomfortable, but acceptable ride to passengers.

Along the Pendurthi-NAD Road (Route 38) roadway conditions include potholes in the roadway as well as sections of poor drainage and uneven roadway providing for an uncomfortable ride for passengers and slower bus speeds in those sections.

Roadway Congestion:

In general, while the number of buses can be as high as 60 per hour in the BRT lanes, there is no resulting congestion or stopping due to congestion between intersections due to the volume of buses. Buses are delayed when unauthorized 2 wheel, 3-wheel, auto-rickshaws, and trucks using the BRT lanes. Buses are also delayed by waiting in back of buses either stopping to pick up passengers in the moving lane and/or waiting to picking up passengers due to not being able to pull into the Bus Station area because of a lack of space.

At intersections, buses do encounter delays due to conflict with crossing vehicular and pedestrian activity. Most of these delays are due to the lack of traffic controls and/or police presence at the intersections. The



Figure 2 Pendurthi-NAD and NH5 Intersection



Figure 3 Pendurthi-NAD Road and Simhachalam Road Intersection

length and shape of the current geometry of the intersection also can create delays to the buses. An example of geometry delay is seen at the intersection of the Pendurthi-NAD Road and NH-5/AH45 roadway; where the exclusive BRT lanes end prior to the intersection, significant bus conflicts with other vehicles and pedestrians occurs (See Figure 2).

Other forms of intersection geometry including expansive intersections with pedestrian and vehicles encountering confusion and conflicts between buses, pedestrians and other vehicles due to large intersections without traffic signal controls and vehicle roadway markings to guide vehicle through the intersection more efficiently (See Figure 3) such as the Pendurthi-NAD intersection with Simhachalam Road.

BRT Stations

Existing stations such as the one seen below (See Figure 4) were economically constructed, but lacked interior light for passengers using the facility in the evening hours, have no informational materials related to bus routes or bus schedule and have no passenger amenities other than benches for waiting for their bus to arrive. Physically, the stations are elevated platforms approximately 35cm+/- high from the roadway. Drainage of the roadway due to rain is accomplished by drain slots through the floor of the platform at some stations. However, some of these drains are not covered as they go through the waiting platform, creating a safety issue for passengers waiting.

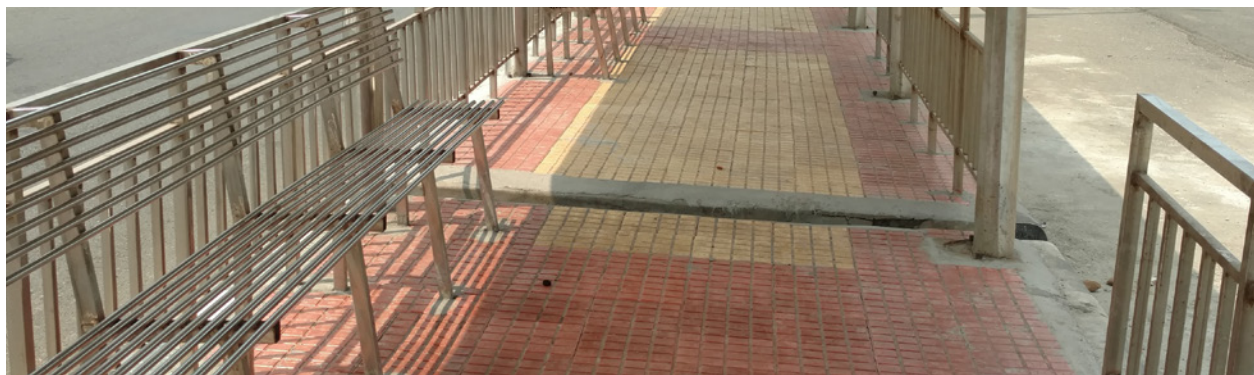


Figure 4 Typical BRT Station

Entering or exiting the stations are accomplished by walking from either the nearest intersection, which is sometimes a significant distance, or crossing in the middle of a block and trying to avoid vehicles on the roadway separating the sidewalk from the bus station. In some instances, residents have created their own access points by cutting through fences adjacent the station to gain access. Where walkways from the station to the nearest intersection exists, the passengers using the walkways are required to maneuver around planting installed for beautification, but end up impeding the effective use of the walkway and in some extreme examples, requiring the passengers to walk in the roadway (see Figure 5).



Figure 5 Obstructed Access to Intersection from Bus Stations

At other stations, the walkways are paved, but are far from the intersection and have no type of traffic control to provide safe pedestrian crossing (See Figures 6).

While the desire, as expressed by the APSRTC, is to provide space for two buses at each station, the current arrange is only large enough for a single vehicle. In addition, the buses to not stop close enough to the station platform to allow easy and fast boarding to, or debarking from the bus (See Figure 7). Currently passengers need to step down from the platform to the road and walk to the bus and step up to board the bus. While inconvenient for the passengers, it also results in longer station stops increasing delay and effecting reliability.

In addition to operational concerns at the stations, within the dedicated bus lanes, buses are seen passing each other and illegal vehicles such 2 and 3 wheelers in the dedicated lanes. These operating conditions, creates conflicts that delay buses and present potential safety concerns impacting everyone.



Figure 6 Access to and from Stations



Figure 7 Bus Loading/Unloading

Project Objectives

Using the existing infrastructure of the BRT segments already constructed and design and implement low and medium cost solutions that:

- Improve the appearance, functionality and safety of existing Bus Stations
- Increase the travel time reliability of buses using the BRT lanes
- Reduce conflicts between buses, pedestrians and other vehicles
- Provided “real-time” information to bus passengers at stations and prior to leaving home or work place bus conditions and possible delays.
- Improve Intersection control and monitoring of traffic.
- Prioritize improvements by funding available to maximize public benefit.

Proposed Improvements

This study does not discuss the still un-finished sections of the Simhachalam Road BRT, but rather identifies improvements to the built segments of both the Simhachalam, Pendurthy-NAD, and Mudasarlova Road BRT corridors.

Current Bus System Map

While the BRT system will not be changing its routes, it is important that an easily readable map is created to clearly illustrate the extent of the service, stops locations, and key destinations served. Service maps are important in clearly communicating to passengers where the bus will take them and what level of service can be expected (e.g. local vs. limited stop, frequency of service). The map should be prominently displayed at bus stations as well as easily accessible online and via smartphone applications (apps).

Bus Running Way (lanes)

Improved Separation between Roadways: Our field observations and assessment indicate that the current barriers separating the dedicated bus lanes from the rest of the vehicular traffic is not sufficient to prevent illegal crossings by pedestrians as well as to prevent accidents occurring on either side of the current barrier from involving traffic on the other side. To improve both pedestrian safety and vehicular safety, the Team has proposed that the current barriers be replaced with new concrete barriers that are approximately 1 meter high and topped with a continuous 1 meter high steel fence to be designed as an integral part of the concrete barrier (See Figure 8 Concrete Barrier).

Improved Signage: As part of our review of the operation of the BRT corridors it was noted that a significant amount number of vehicles other than buses were using the lanes. This illegal usage of the lanes was due to limited enforcement of the exclusive lanes for buses and poor signage defining the lanes for buses versus other vehicles. As part of

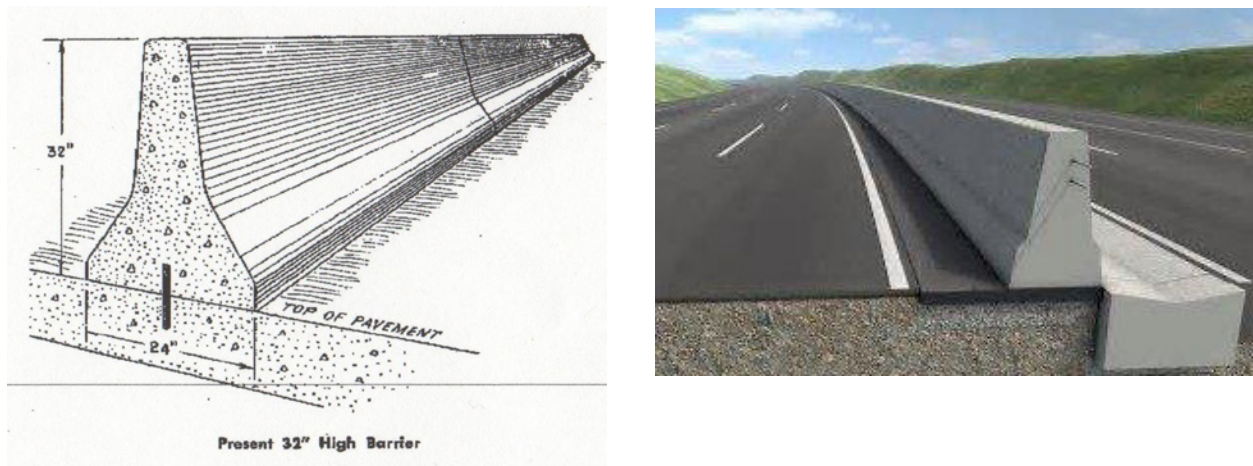


Figure 8 (Top) Typical Dimensions of Barrier; (Bottom) Constructed Roadway Section



Figure 9 Typical Overhead Sign Gantry

our recommendations, improved signage and placement of signs is recommended. This includes use of signage gantries over the lanes in advance of intersections informing drivers of the lanes for buses only and increased enforcement by use of intersection cameras and periodic police enforcement of the lanes. It should be noted that enforcement of the bus lanes by police were seen, and did help limit the intrusions. Potential overhead signage would be developed specifically for each intersection during the engineering phase of the program after completion of this effort. Figure 9 and Figure 10 provides various types of overhead signage that would be utilized for informing drivers of lane restrictions in advance of intersections.

New signage will designate Bus Only lanes versus the Mixed Traffic lanes. Signs will be placed prominently at intersections where buses interact with other traffic to direct vehicles away from the busway and into the outside mixed traffic lanes.



Figure 10 Side Mounted Overhead Bus Signage

Bus Station Improvements

Before



Existing BRT stations are challenged with unsafe pedestrian crossings and boarding areas, shelter, and passenger information displays.

After



Improved BRT stations include safe accessible pedestrian crossings and boarding areas, expanded shelters, passenger information displays, concrete wearing pads and wheel guides, and mode separation barriers.

Installation of Concrete Bus Pads at Bus Stations: Reinforced concrete bus pads are more durable than asphalt and will be better handle the high volume of buses using the busway and stations. This results in a smoother surface that is easier on the buses and provides a gentler ride for passengers. It is recommended that the concrete be installed across the full width of the busway at stops to prevent the creation of different heights of pavement parallel to each other. The height of the bus pads will be set to allow for level boarding from the platform to the bus. The bus pads can have a colored pigment added to the concrete to highlight the bus station area to stop further. Two types of concrete pads are shown below. One is a uncolored concrete surface and the other is a concrete pad that had a colored pigment added in the mixing of the concrete. (Figure 11) The colored pigment version increases the visibility of the stopping location and is more durable than ordinary painting.



Figure 11 Typical Concrete Bus Station Stopping Pads

Restriping of roadway centerline and bus station pull-in areas:

New striping will clearly delineate where buses and mixed-traffic vehicles are permitted to travel on the roadway, including direction of travel. This will include clearly marking the travel lanes adjacent to the bus station pull-outs, showing where buses not stopping can bypass stopped buses. The proposed new striping is shown in the midblock station diagram (Figure 13)

Roadway markings for Bus Running Way: Clear markings will be updated or added as needed to mark where buses should travel on the busway between stations, including a clear centerline that separates bi-directional travel. New striping is shown in the non-station running way cross section (Figure 14).

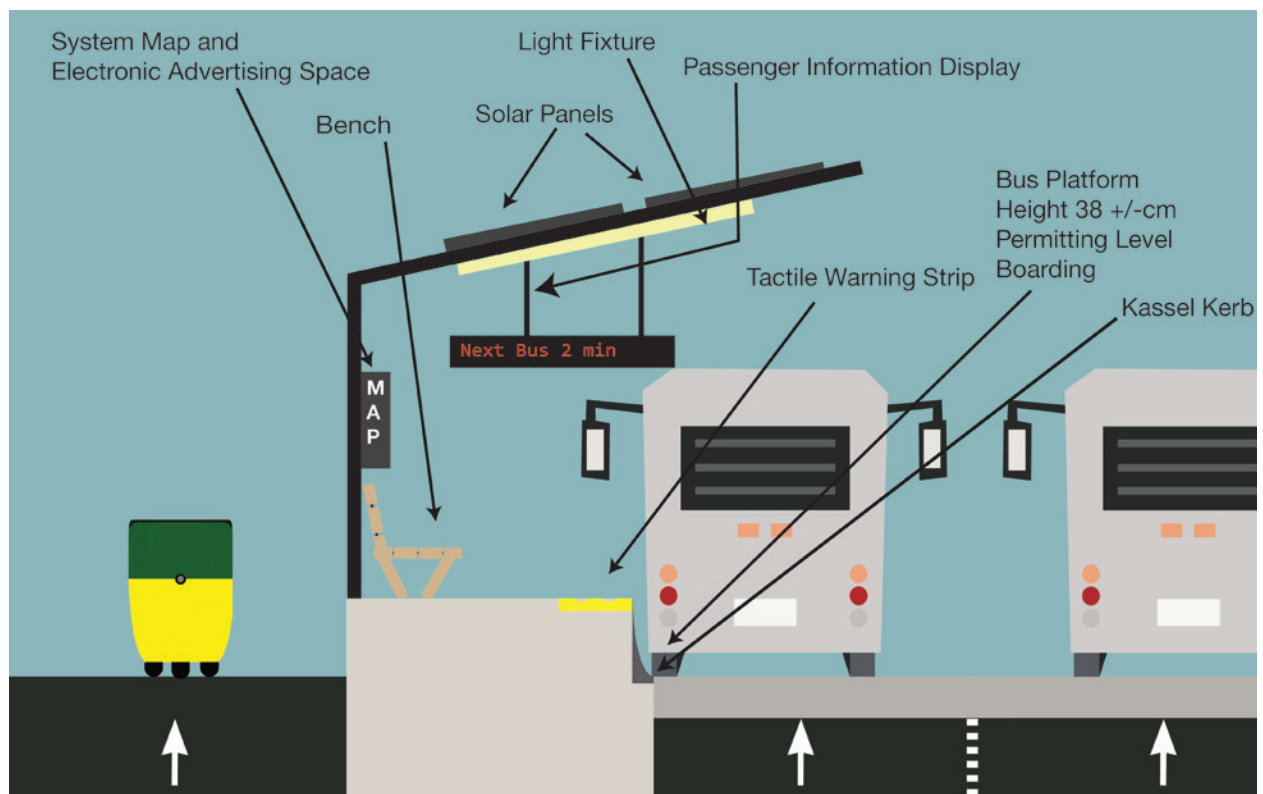


Figure 12 Midblock Station Striping

This page intentionally left blank

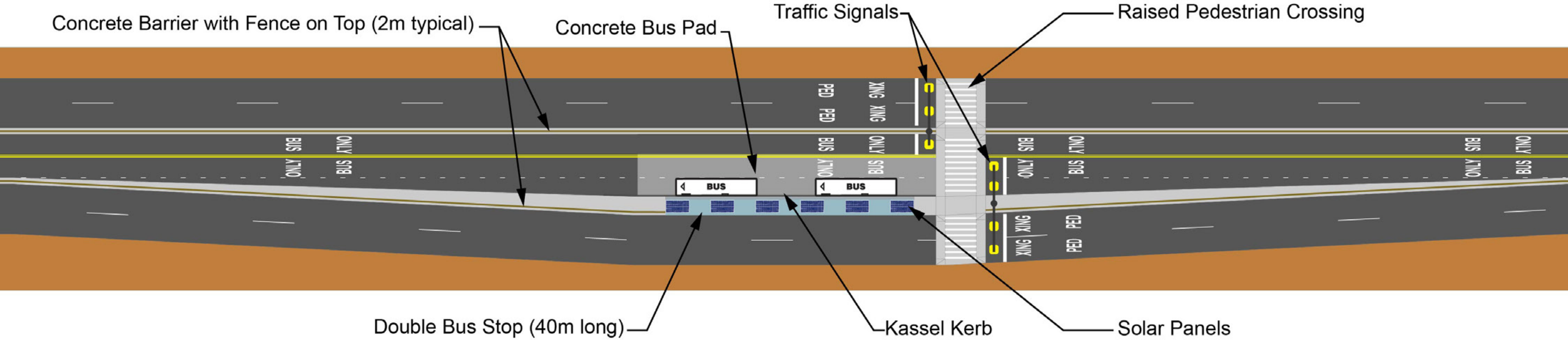


Figure 13 Midblock Station Striping

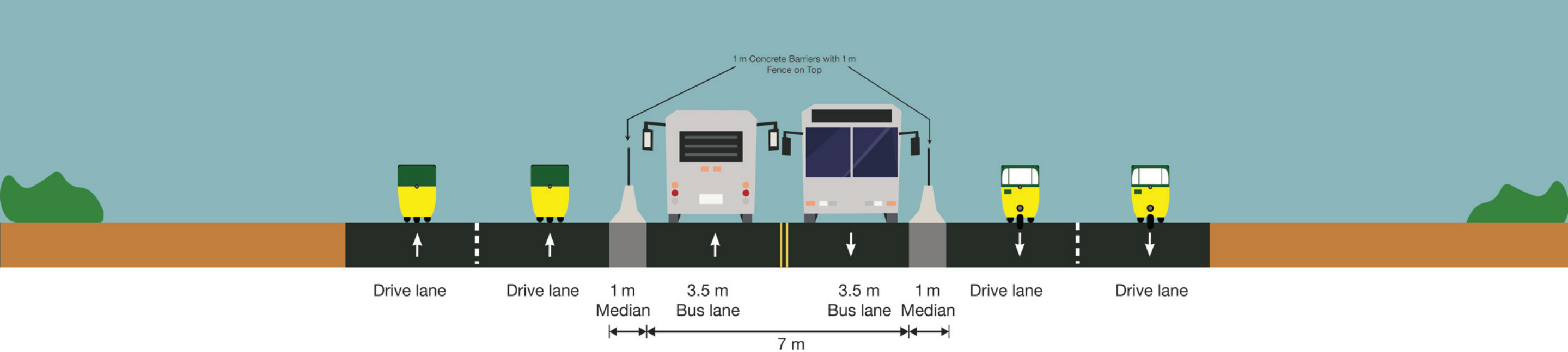


Figure 14 Running Way (Lanes) Cross-Section

This page intentionally left blank

Design & Installation of “Smart” Traffic & Pedestrian Signals at Intersections: A major source of bus delay along the various BRT corridors is the vehicle and pedestrian movements at uncontrolled intersections. Most of the intersections along the completed segments of the BRT corridors have either no traffic signals or non-functioning signals. In either case this has resulted in vehicle, bus and pedestrian conflicts creating delay to buses and pedestrian safety issues. It is recommended that all three-leg and 4 leg intersections will be signalized using Smart Signal technology and that the intersections will be connected to the Police and GVMC Command Centers.

As noted in the Existing Conditions section of this report, along the three built segments of the BRT corridors, there are very few working traffic signals and no traffic signals for non-intersection crossing of pedestrians. We propose to install these pedestrian signals in conjunction with high visibility cross walks at all midblock Bus Stations and non-intersect locations of high pedestrian crossings. In the case of the non-intersection signals, the final decision of the locations will be developed during the engineering design phase when detailed traffic and pedestrian counts can be developed.

The installation of new Traffic Signals with electronic state-of-the-art controllers, Smart Signals, will in conjunction with direct connection to the command center of the Police and GVMC will permit implementation of time of day traffic signal phasing to improve the overall movement of traffic. In addition the introductions of the new technology will permit the implementation of Transit Signal Priority (TSP) to improve Bus reliability and reduce travel time delays. TSP concepts for using the traffic signal to provide enhancement to the movement of buses by either adding extra green time as the bus approaches the intersection, or shortening the red signal time if a bus is approaching the intersection. The concept is based on a transmitter being attached to the bus and communicating with the Smart Signal indicating its relative position to the intersection and requesting priority, this is done automatically by the electronic controller at the intersection, a mini-computer, that determines whether sufficient time exists for increasing the green time for the bus to pass through the intersection, or if the signal is red, advancing the signal timing for the green signal to come up sooner for the bus.

In addition to Smart Traffic Signals, the new intersections would have “Red Light” and Traffic Congestion cameras for enforcement of traffic controls, and for monitoring traffic flow and potential delays due to traffic volumes, accident or other incidents in the area of the intersection. This information would be relayed via fiber optic communications to the command centers. Fiber optic communication is being recommended for connecting the intersections to the Command Centers since:

1. The GVMC is currently initiating installation of fiber optics throughout the city;
2. Fiber optics provides for improved clarity for video transmissions from the camera versus WiFi due to the wider bandwidth of the fiber optic cables.

During the engineering design phase, each of the intersections will have traffic studies to confirm the major and minor vehicle flows, as well as pedestrian volumes. This will enable development of the appropriate signal timings and development of time of day specific phasing programs. These programs specific to the morning, midday, evening traffic volumes will be developed to be inserted automatically by time of day, or if the traffic command center observes an unusual traffic event; the staff can manually insert the appropriate signal timing program.

Each intersection will have its own tailored traffic signal design, including pedestrian signals, pedestrian crosswalks and any minor reconfiguration of the intersection for improved vehicle and pedestrian safety and reduction of conflicts.

Basically, three type of traffic signalization will be installed along the existing bus corridors:

- 4 legged intersection – Traffic lanes are approaching the intersection from 4 different directions.
- 3 legged intersection – Traffic lanes are approaching the intersection from 3 different directions.
- Pedestrian Signal (Midblock) – This is for non-intersection crossing of pedestrians, pedestrian signals are being proposed for all Bus Stations that are near to an intersection or where intersection are far apart and there is extensive pedestrian activities.

Identified below are 3 examples representing each type of signal installation proposed with a typical layout for the location of the signals and a typical phasing diagram. Please note that each intersection will be designed separately, unique to its particular needs, the figures provided are representations of the type of signalization noted above.

An example of a 4-Legged Intersection is the Pendurthi-NAD and Vepagunta-Sabbavaram Road (Figure 15). A typical traffic signal arrangement for this type of intersection is seen below (Figure 16).



Figure 15 Pendurthi-NAD/Vepagunta-Sabbavaram Road, 4-Legged Intersection

This page intentionally left blank

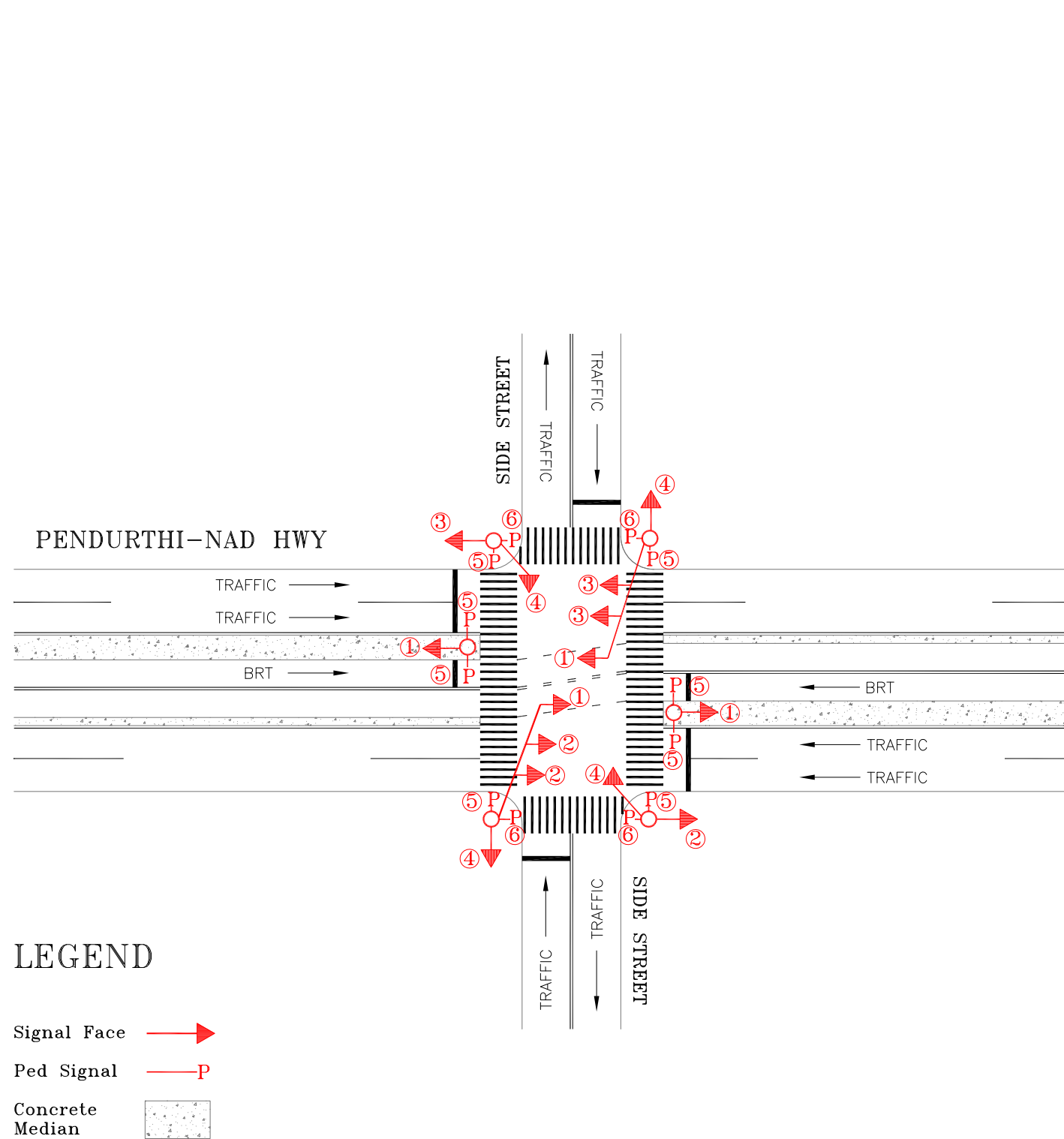


Figure 16 Traffic Signal Layout for 4 Legged Intersection

							<p>PENDURTHI-NAD HWY</p>
PHASE A	G	R	R	R	DW	WK	
VEH CL	A	R	R	R	DW	FLDW	
VEH CL	R	R	R	R	DW	DW	
PHASE B	R	G	R	R	DW	WK	
PED CL	R	A	R	R	DW	FLDW	
VEH CL	R	R	R	R	DW	DW	
PHASE C	R	R	G	R	DW	WK	
PED CL	R	R	A	R	DW	FLDW	
VEH CL	R	R	R	R	DW	DW	
PHASE D	R	R	R	G	WK	DW	
PED CL	R	R	R	A	FLDW	DW	
VEH CL	R	R	R	R	DW	DW	

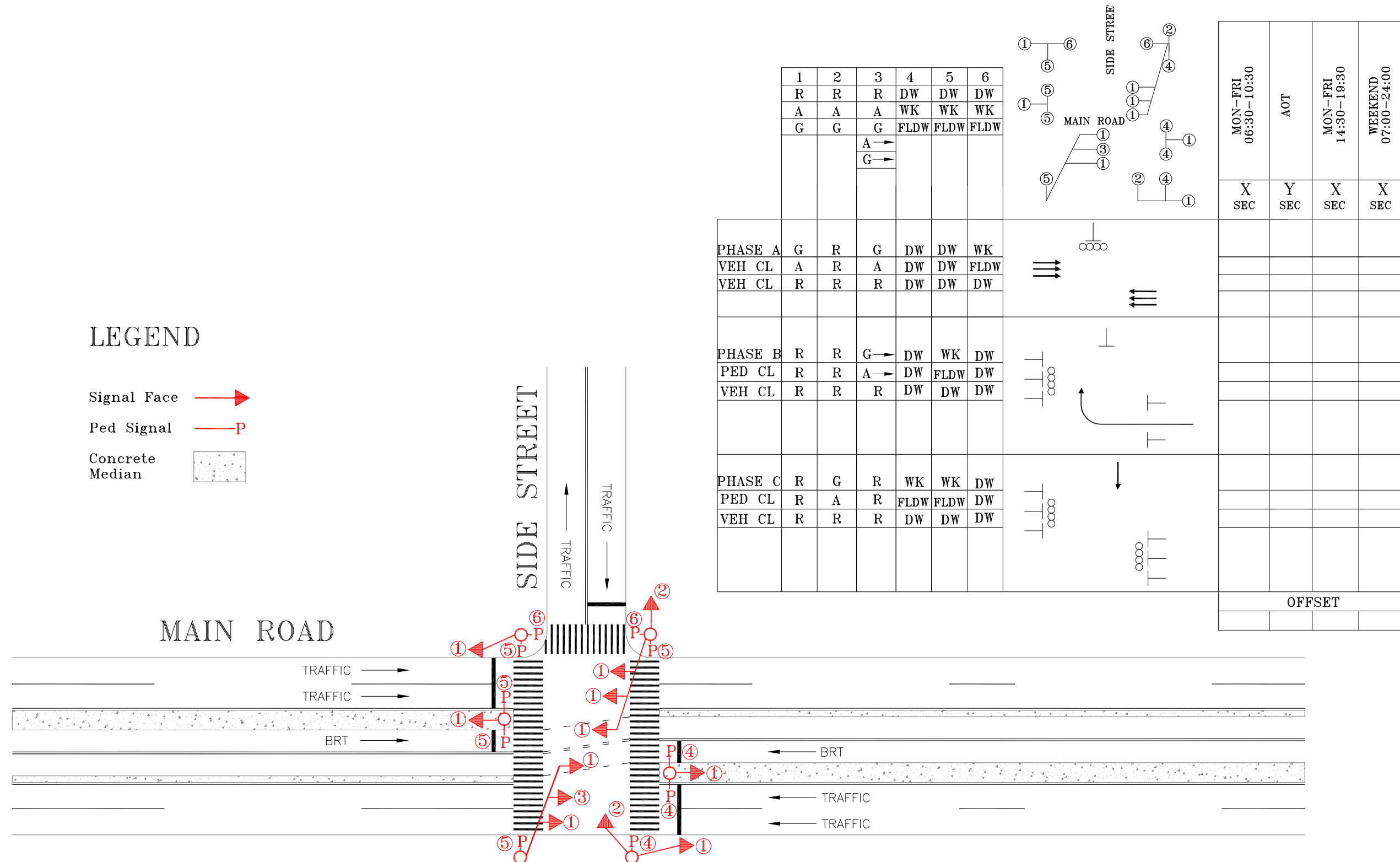


Figure 17 Traffic Signal Layout for 3 Legged Intersection



Figure 18 Pendurthi-NAD/Simhachalam Road



Figure 19 BRT Station Pedestrian Crossing

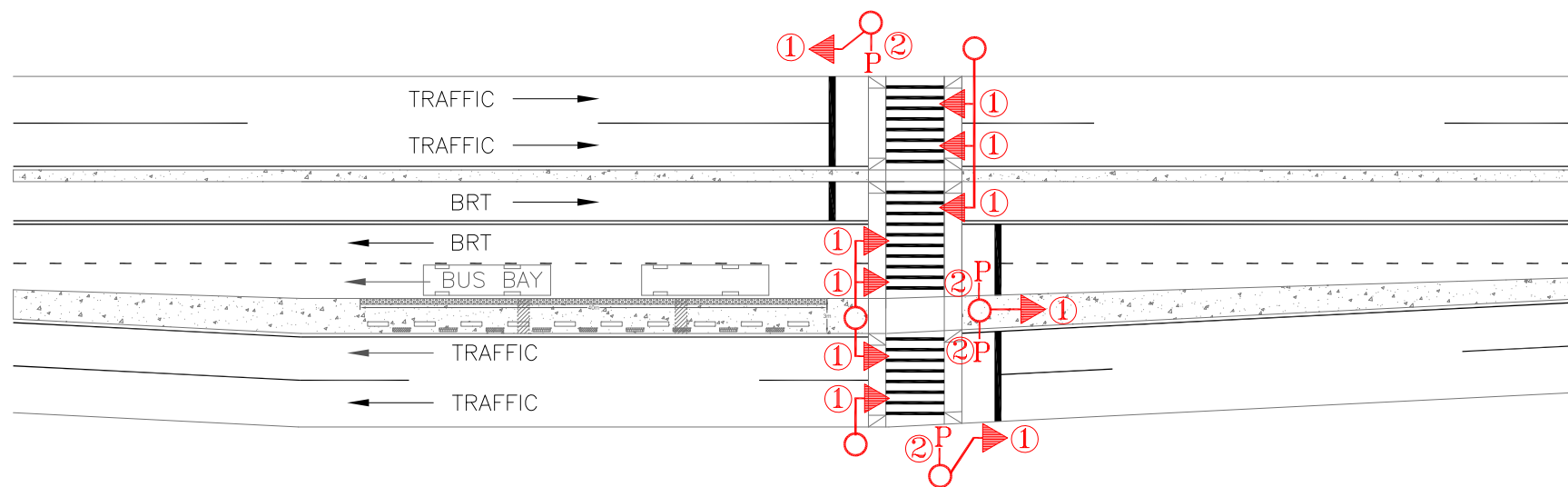
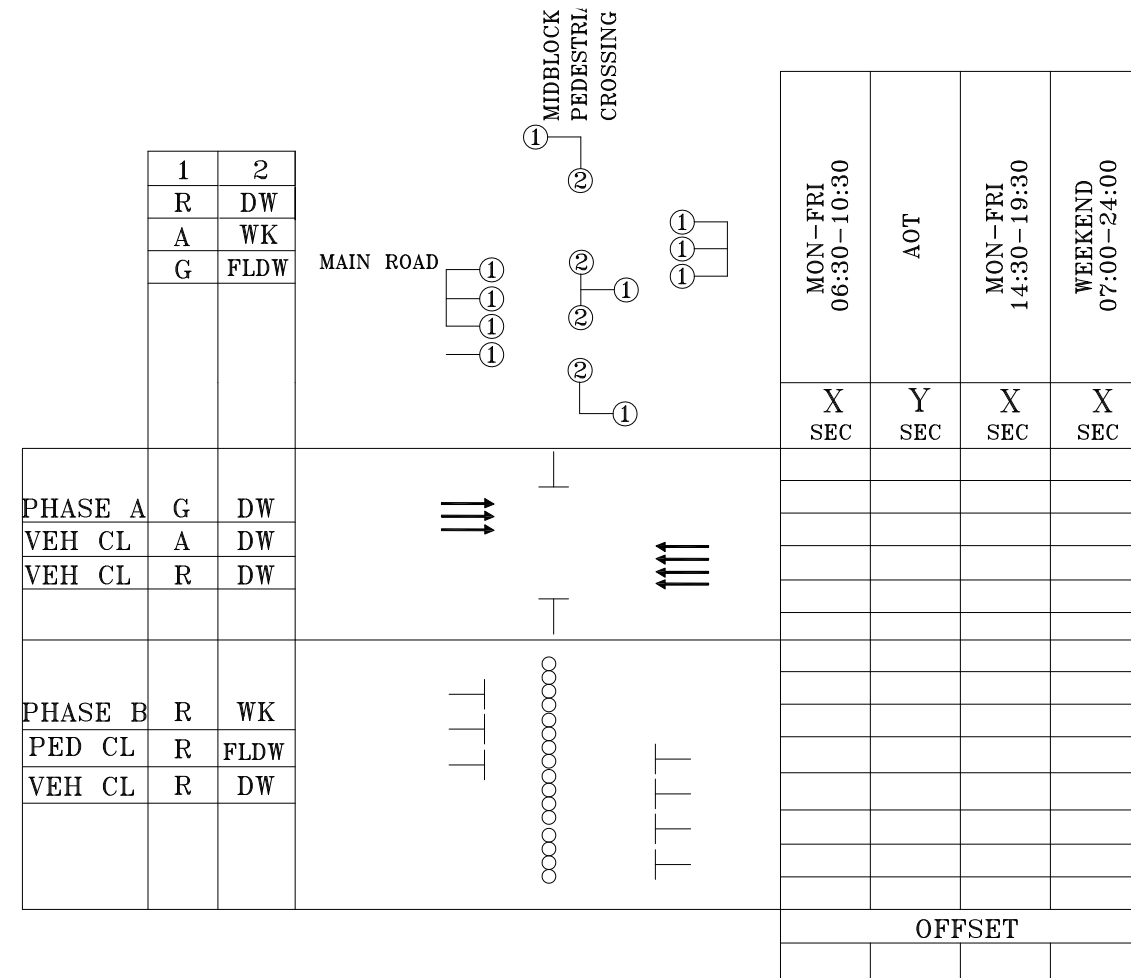



Figure 20 Midblock Traffic Signal Layout

LEGEND

Signal Face 

Ped Signal — P

Concrete Median

This page intentionally left blank

Traffic Systems Integration

The following capabilities are available or being implemented at Vizag

- Traffic Lights being installed
- Red Light cameras being installed at intersections
- GPS on all APSRTC buses available
- Data integration with existing GPS systems to a command center awarded to contractor
- Single line information display signs being installed at bus stops along BRT.

We recommend the addition of the capabilities listed below to improve the quality of service and to provide citizens with near real time information on when the next bus will be available.

- APSRTC currently tracks its buses using GPS. We recommend the addition of real time traffic conditions to better predict when a bus will arrive at a bus stop or terminal. This can be achieved by integrating via API's the existing GPS location with a third party subscription based traffic services.
- Add controllers to existing traffic lights to allow for remote administration of lights
- Reduce congestion at intersections by using either an inductive loop or video based approach.
- Add controllers and traffic cameras to allow for Traffic Signal Prioritization (TSP).
- Consider the addition of emergency vehicle preemption detectors at all major intersections.
- Add solar panels to power bus shelter lights and message signs
- Consider the addition of multimedia devices at bus stops to display advertisements. The content to these devices (like TV's) can be delivered via a fiber network if available or via a cellular network . Advertising revenue may help offset some of the costs .
- Ensure availability of fiber optic network before the installation of cameras. Certain types of data can be transferred over a wireless network and might not need wires to be laid .However, it is currently not recommended to send video feed via a wireless network due to bandwidth requirements.
- Consider the addition of telemetry on buses to allow optimization of assets ,reduce operations and maintenance costs and improve reliability of service

The conceptual architecture of how real time traffic can be incorporated in the existing APSRTC infrastructure is shown below (Figure 21).

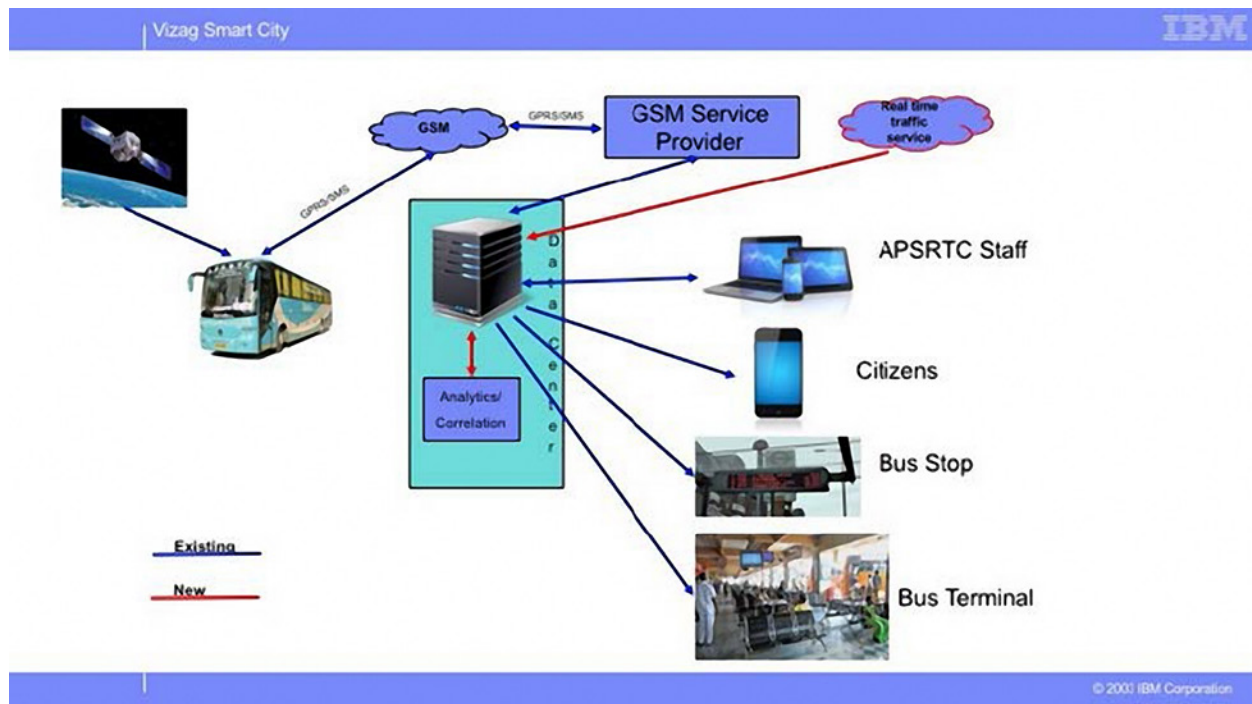


Figure 21 Conceptual Architecture

Vehicle Awareness and Prediction provides vehicle awareness and arrival time prediction capabilities for transit systems. Vehicle Awareness and Prediction is the foundational feature of an Intelligent Transit Analytics platform, helping both transit operations departments and passengers to get a clear picture of the vehicle service in the transportation network.

The Vehicle Awareness and Prediction feature captures and delivers data about the transit vehicles that are being monitored, such as their position, speed, and whether they are on schedule. Incoming and accumulating vehicle data is captured from external systems in the field through SIRI messages. The Vehicle Awareness and Prediction feature also produces estimates for the arrival times of the vehicles at their upcoming planned stops.

The Vehicle Awareness and Prediction feature integrates into the Traffic Awareness system and solution portal.

The following, Table 1, describes the subsystems of the Vehicle Awareness and Prediction feature.

Table 2 Vehicle Awareness and Prediction Subsystems

Subsystem	Provides
Transit Awareness	<p>Processes to collect and store current vehicle awareness data that is collected by sensors in the field for use in transit operations management. Also provides the ability for transit operators to perform the following:</p> <ul style="list-style-type: none"> ▪ Monitor vehicle performance in real time ▪ Visualize the current locations of vehicles in real time on a GIS map ▪ Query information about a vehicle, stop location, or a service ▪ Analyze current problems in transit operations, such as vehicles that are off-schedule, off-route, or that have broken-down ▪ Understand which vehicles and services are continually failing to keep schedule ▪ Visualize stop locations of a service ▪ Understand stop performance issues, for example stops with off-schedule vehicles ▪ Understand the services and individual vehicles that are consistently failing to keep to the planned schedule
Transit Arrival Prediction	<p>Sophisticated algorithms and processes that generate the predicted arrival time of vehicles to a specified location on a route, for example, the arrival times of buses at a particular stop on a route. You can also:</p> <ul style="list-style-type: none"> ▪ Understand which vehicles are not arriving to their destinations as scheduled ▪ Accommodate daily timetable changes
Transit Analytics	<p>KPIs that summarize and analyze the performance of the transit operations. The transit KPIs highlight the under performers and the bottlenecks in the transit system from a schedule adherence perspective.</p>
Administrative and operational interfaces	<ul style="list-style-type: none"> ▪ A browser-based GUI that features an operations view to facilitate transit operations management. The interface also includes role-based administrative features, providing the capability to configure the system so that it can correctly operate within a particular customer environment. ▪ An infrastructure data loader which is a command-line interface for loading basic infrastructure data that includes: <ul style="list-style-type: none"> – Route shapes – Vehicle information – Production timetables ▪ A command-line interface for automatically generating the metadata that is required by the vehicle prediction feature from historical traffic data. A command-line interface for automatically pruning obsolete data in the database. ▪ A subscription client manager, which is a stand-alone agent that is designed to keep the subscription of Service Interface for Real time Information --SIRI vehicle monitoring messages running.
Programming and Client Interfaces	<p>A REST service that provides Request and Response services for retrieving SIRI formatted vehicle monitoring and stop monitoring messages that contain the predicted arrival time for active buses.</p>

The controllers at intersections must be mounted inside weather proof cabinets (Figures 22 and 23) at intersections that can be controlled remotely from the command center or overridden manually and on site by the police. These controllers also usually have a battery backup allowing them to operate normally in the event of a power failure. The controllers can be a combination of networked (which can be controlled from a command center) and non-networked (timers on preset patterns at non-critical intersections). The cabinet typically contains a power panel, to distribute electrical power in the components of the controller; a detector interface, to connect to loop detectors, the controller itself, transfer relays a police panel, to allow the police to disable the signal and/or modify the program locally during an event.



Figure 22 Typical controller mounted at an intersection



Figure 23 Controller with a battery backup at an intersection

Under normal traffic conditions the traffic software controlling a cluster of intersections will signal a string of lights to change color in a time delayed progression (which can be set after traffic patterns are analyzed). This time delayed progression allows vehicles to travel smoothly thru intersections at the posted speed limit. This is a passive approach to Traffic Signal Prioritization (TSP) and requires virtually no hardware. An active TSP approach relies on detecting vehicles as they approach an intersection and adjusting the signal timing dynamically to improve transit service. This typically involves a GPS device on the vehicle coupled with a transmitter and one or more receivers at intersections (Figure 24).

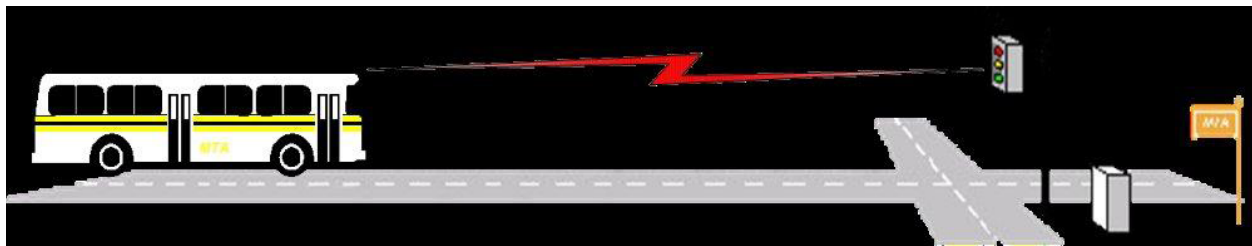


Figure 24 Typical TSP Arrangement

In addition, intersections typically do not have pedestrian crosswalks. In addition to vehicular intersections, it was noted that there were sections of the BRT roadway that had gaps in the barrier that allowed vehicles other than buses to either make U-turns or unprotected crossings of pedestrians. We propose closing these existing breaks to increase safety and to reduce conflicts between vehicles either u-turning or entering the dedicated bus lanes. In recognition of the need for pedestrians to be able to cross the roadway at reasonable intervals, midblock pedestrian signals will be erected with high visibility crosswalks will be created at limited locations based upon local activity (shopping areas, high density residential areas and schools). (See Figure 25)

This page intentionally left blank

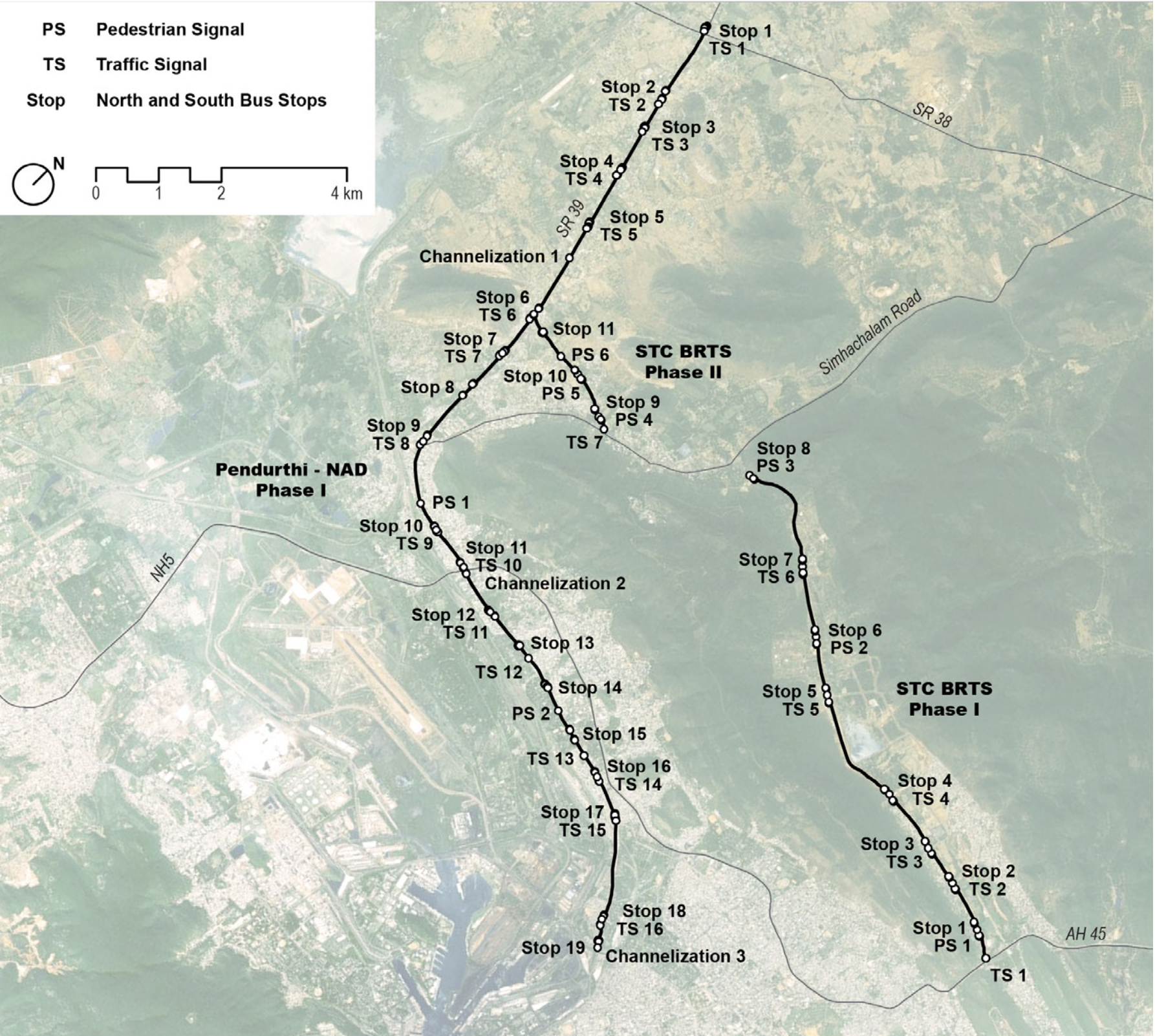


Figure 25 Existing BRT System Map with Modifications

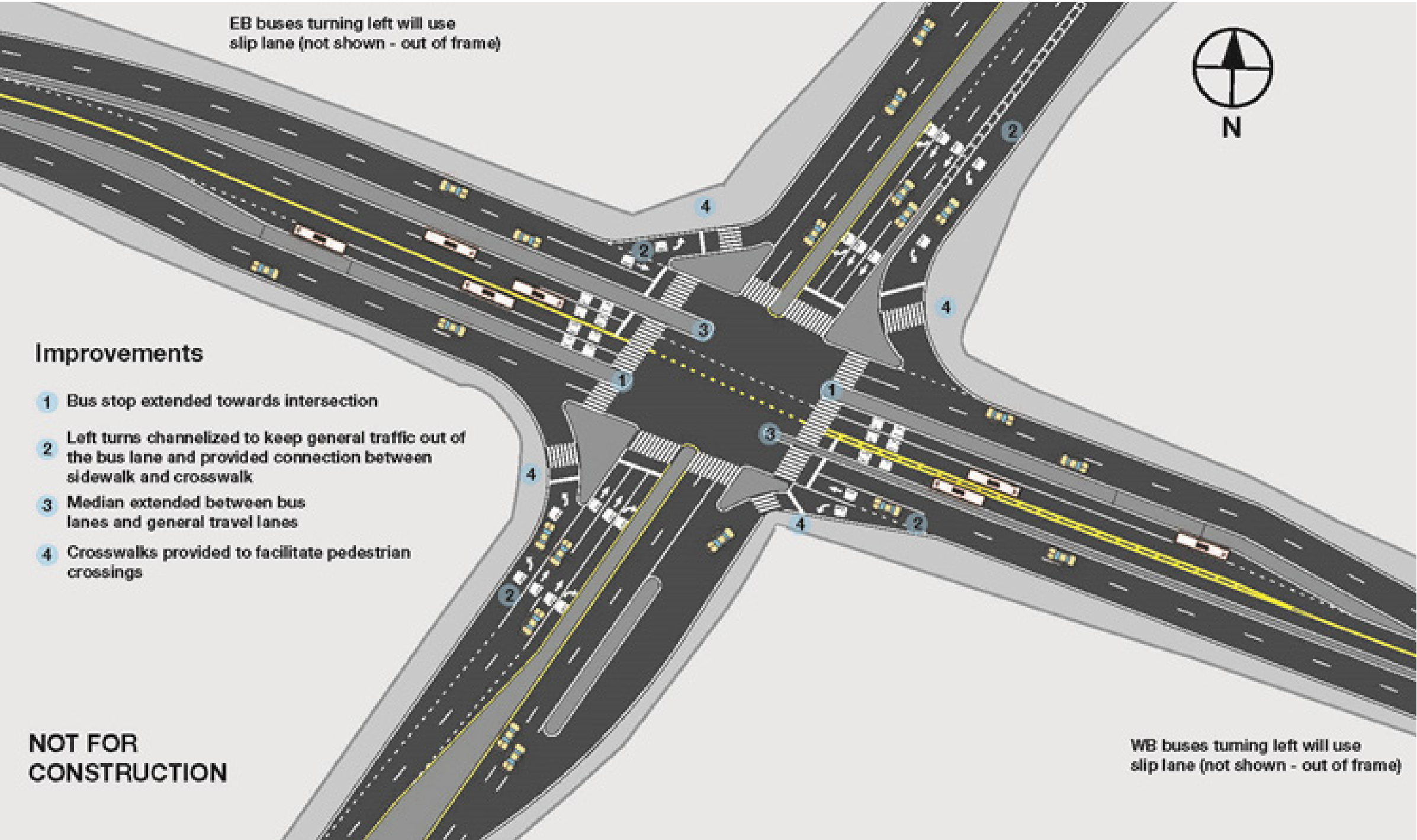


Figure 26 Proposed Pendurthi-NAD/NH5 BRT Improvement

Review and Modification of Specific Intersections: The team's review of field conditions revealed that bus delay at intersections is more than simply the lack of a traffic signal or police presence. In some cases the cause of the congestion and delay is due to the geometry of the intersection. A significant amount of conflict and delay was observed at the southbound approach to the intersection of Pendurthi-NAD Highway and NH5 previously noted in the existing conditions section of this report. Buses travelling south and north are mixing with other vehicular traffic approaching the intersection causing the bus to be delayed. Based upon review of the intersection, it was determined that the designated bus lane barrier is terminating as much as 200 feet or approximately 60 meters before the stop line, providing the opportunity for trucks, 2 and 3 wheelers, and 4-wheelers to compete for the limited space with the buses (Figure 27). It is proposed that the current bus lane separation barriers be lengthened further south and north toward the intersection, and the bus slip off provisions implemented to provide access for buses turning left. The slip offs (a break in the physical separation will be made further away from the intersection to permit the bus needing to make a left turn the time to change lanes before getting into the intersection. In our concept, the slip-offs are provided for both directions of the Pendurthi-NAD roadway, beyond the limits of the drawing. Figure 26 presents a concept for the improvement of the intersection for buses. The engineering details for the improvement would be developed as part of the engineering design contract.



Figure 27 Existing Pendurthi-NAD/NH5 Intersection

Station Design

A key piece of improving BRT in Vizag is upgrading the bus station functionality and appearance. Enhanced stations will facilitate more bus passengers and service, provide useful service information, and create a safe and attractive space to wait for the bus. Recommended improvements include:

Double the station length: Doubling the length of all existing stations will permit simultaneous loading and unloading of two buses, increasing station capacity and allowing buses to move in and out of the stations more efficiently. It will also keep stopped buses out of the moving lane to provide space for other buses to pass by. The proposed new size of the station can be seen in the plan view (Figure 28).

Install a bus “wheel guide” at stations: Wheel guides allow for precision docking at the station platforms, making it much easier for drivers to pull into stations adjacent to the platform. This enables level boarding with no large gaps between the bus and the platform. There are varying ways this system can be implemented, with a final design to be selected in the next phase. Wheel guides can be seen in the station cross-section (Figure 29). For the Vizag BRT system we are currently proposing the “Kassel Kerb” mechanical guidance for precision station

This page intentionally left blank

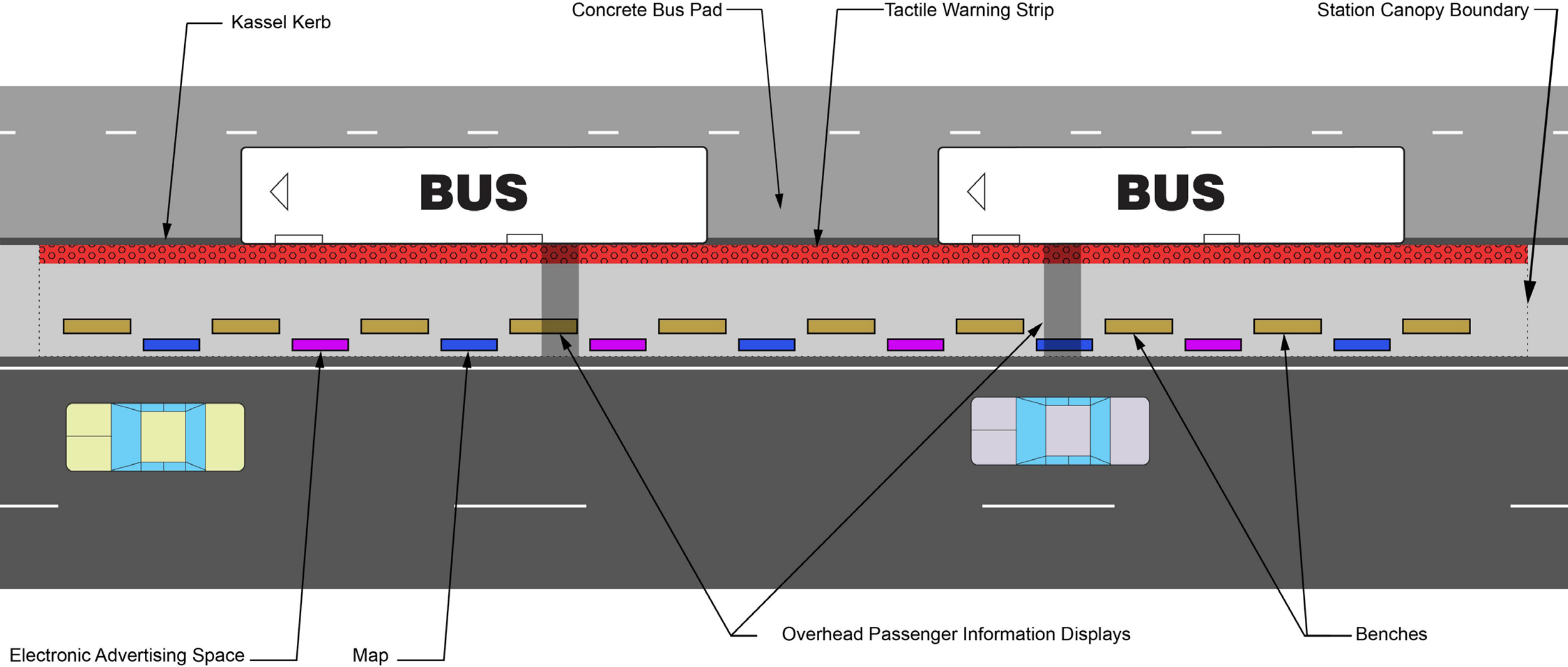


Figure 28 Revised Bus Station (Typical Plan View)

This page intentionally left blank

boarding. The system has been used in England as well as well as Europe. It provides a reason low cost and low technology solution requiring minimum maintenance. In addition, the system does not present ponding issues due to heavy rain, prevalent in Vizag during the Monsoon Season. An example of the guidance system is seen in Figure 30 and is incorporated in the proposed station cross-section (Figure 29).



Figure 29 Bus Station Profile Detail



By Honza Groh (Jagro) - Vlastní fotografie/ Own work, CC BY-SA 3.0,

Figure 30 Bus Station Improvements (Cross-Section) "Precision Docking"

Improve busway drainage at stations: During the field surveys and various observations conducted of the BRT corridors, it became apparent that any upgrade in the Station Area should include addressing drainage of the BRT lanes. As noted in the existing conditions, some of the earlier sections of the BRT corridors lacked sufficient drains under the platform as well as not providing covers for portions that were directly under the pedestrian area (Figure 4-bottom photo). In addition to the station, drainage provision adjacent the station also provided potential hazards to pedestrian using the walkways (figure 5). Our recommendation for the improvement of the stations includes upgrading drainage and installing removable steel plates on the platforms to permit route cleaning of the drainage sections under the platform will ensuring the safety of passengers. This will help prevent standing water, eliminating a potential hurdle to station access and reducing environments conducive to insect breeding.

As part of the assessment for the stations and associated drainage the team looked at using green infrastructure to aid in stormwater management. It is an environmentally sensitive method to reduce the volume of runoff and lessen the burden on adjacent recharge facilities and other stormwater facilities by introducing bioswales immediately adjacent to the roadway and bus stations. An example of this type of drainage can be seen in **Error! Reference source not found.31**. However, the unique conditions of weather in Vizag ,including the Monsoon season with the associated heavy rains and the period of dry season would present problems such as inundating rain during the monsoons that could not be absorbed with the size of the bioswales that could be reasonably constructed adjacent the stations and roadways.



Figure 31 Bioswale at Portland Bus Stop (NACTO/Ben Baldwin)

Redesign station shelters: Completely new shelters should be installed with upgraded amenities. The shelters will provide canopies over the entire station area and extending slightly over the busway, allowing passengers to remain under the canopy while boarding the bus. The front of the shelters, facing the busway, will be completely open to easily allow direct access from the platform to the bus. The shelters will primarily be open on the sides and back to allow for natural ventilation. Fencing on the backside provides a safety barrier between the station and the mixed traffic lanes behind it, while glass panels on portions of the back will display service information. Additional features should include seating, interior lighting, bus route maps, and passenger information displays (PIDs). The PIDs will show real-time arrival information for buses and other service information as needed. The station elements can be seen in the midblock station diagram and the station cross-section. Examples are shown in Figures 32 - 33.



Figure 32 Laurel Canyon Station, Orange City BRT



Figure 33 PID in Dublin (via TheJournal.ie)

Develop safe pedestrian crossings at mid-block stations: Safe crossings are needed near stations as pedestrians will want to cross the road near the station, not at a distant intersection. Crossings should include high visibility crosswalks and signage making drivers aware of the crossing. Additional elements can include pedestrian activated traffic signals and grade separated crossings or raised crosswalks at high volume stations. The midblock station diagram illustrates where the crossing could be placed, and Figures 34, 35 and 36 show other sample crossings.



Figure 34 Midblock Crossing in Seoul (via Far East BRT)



Figure 35 Midblock Crossing in Seoul (via Far East BRT)

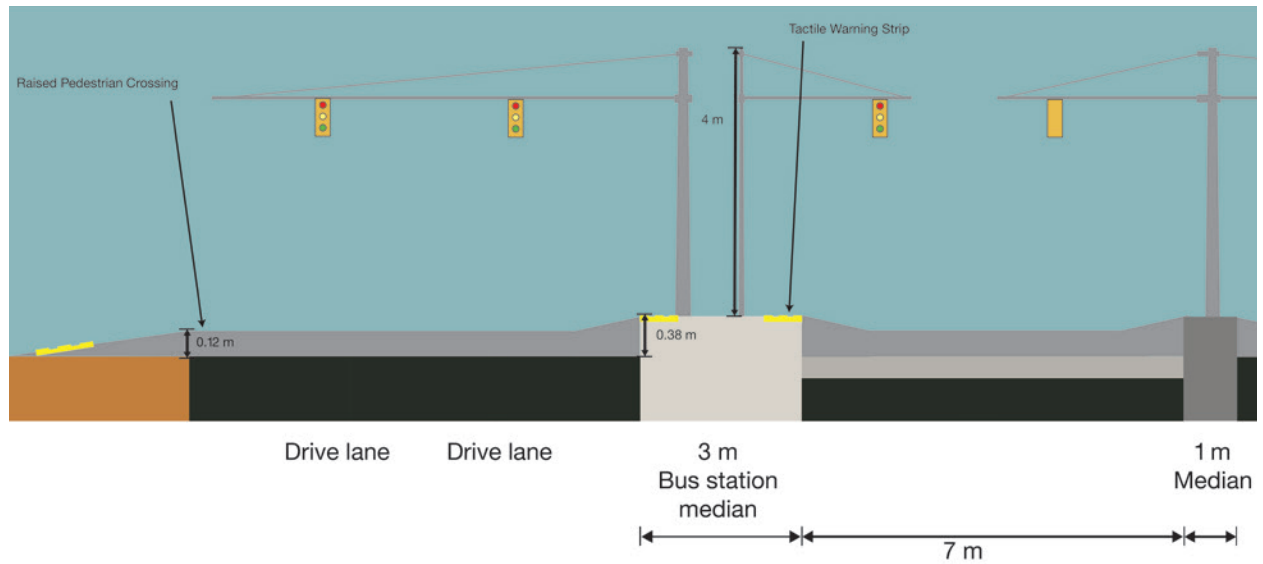


Figure 36 Proposed High Visibility Crosswalks and Signalized Midblock/Bus Station Pedestrian Crossings

Install station lighting: Adding additional lighting at the bus stations will provide safe access after dark and create a more welcoming environment for waiting passengers. The additional lighting is particularly important for those stations located away from busy intersections. Examples of station lighting can be seen in Figure 37.

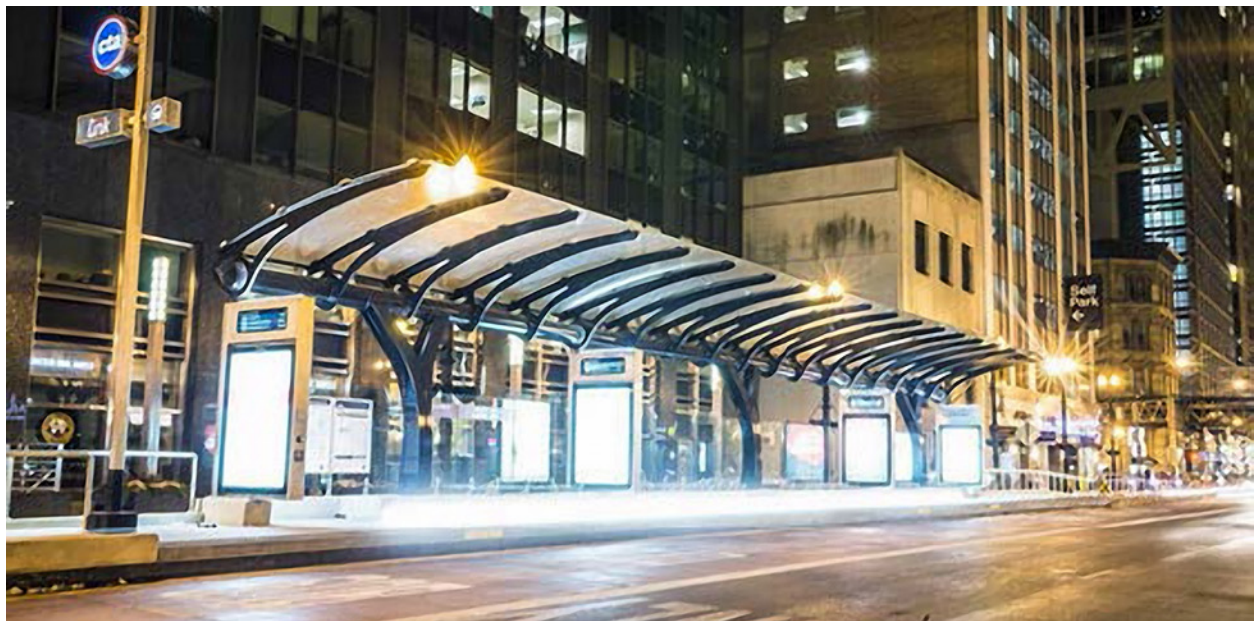


Figure 37 CTA Loop Link BRT Station Chicago (Douglas Rahden Instagram)

Installation of solar panels on station canopies: Solar panels will provide sustainable power to operate station improvements including station lighting and PIDs, helping to conserve energy and costs over time. The panels can come with battery storage for when sunlight is lacking, and power backup will be installed by plugging into the city power network. The placement of the solar panels on the station canopy is illustrated in the station cross section.

Bus shelters integrated with Solar Power Systems are an efficient means to provide power without the need for standard utility power. Every system provides cost savings by eliminating the need to trench standard electric wires for installation and providing no electric bill for the life of the system. Bus stop and bus shelter integrated with Solar Power Systems provide security, sustainability and an overall green image (Figure 38).



Figure 38 Solar Powered Bus Stations

Solar photovoltaic (SPV) panels will convert the sun's energy into electricity for use by the advertisement boards and interior lighting of the shelter. A small amount of electricity will also power a LED Screen, which will display the bus tracking system for commuters using the shelter.

Size of the Bus Shelter (BRTS, Visakhapatnam):

- Length – 20 meters (mts), Width – 2.5 mts.
- Area Available Roof Area for Solar Panels: 50 square meters (sq. mts.)

Required Area to Install SPV System:

- 1 kilo Watt peak (kWp) or 1000 Watts peak (wp) -10 sq. mts.

Total Power Generated by SPV System:

- 5 kWp or 5000 wp

Proposed Solar Powered Improvements

Lighting for Passenger Waiting Areas:

- Light Emitting Diode (LED) lighting fixtures will be installed to illuminate waiting areas inside of shelters throughout the night providing greater comfort and security for waiting passengers.
- 5 LED fixtures are anticipated to be installed per bus shelter.
- Each LED lighting fixture is connected to an individual SPV system comprising of:
 - Lighting:
 - 10 Watt LED Light
 - More than 1500 Lumens
 - Life span of more than 100,000 Hours
 - SPV System:
 - 100 Watt Poly/Mono Crystalline Solar Panel
 - Voltage(VOC)/Current: 22 Volts DC/5.4 Amps
 - Module Efficiency: Above 15%
 - 10 year's product warranty, 25 years warranty for 80% of rated power output.
 - Total SPV system size for 5 - 10 W LED lights for illuminating the waiting area: 500 W

➤ **Battery Bank:**

- 12 V, 70 Amp Hours (GEL/AGM/Lithium ion Battery)
- Charge Controller: 15 Amp
- The battery backup system provides power for a minimum of 4 days

➤ **Other components:**

- Controller: Auto on/off Controller
- Motion Sensor
- Housing Box made of fiberglass/aluminum/steel.

LED PIDs and Advertisement Boards:

- 3 - 36 inch LED PID to be installed which will display the bus tracking system for commuters using the shelter.

- Power consumption of the LED screen: 60 Watts

➤ Run time: 12 Hours

➤ Power Consumption per day: 720 Watts

- 6 - Advertisement Boards, with 20 Watt LED's.

➤ Run time: 12 Hours

➤ Power Consumption per day: 1440 Watts

- Total Power Consumption of screen and boards: 2160 Watts

- SPV System size required

➤ 1 Kilo Watt peak (kWp) or 1000 Watts peak (Wp)

➤ 250 Watt Polycrystalline Solar Panel – 4 No's

➤ Voltage(VOC)/Current: 38 Volts DC/8.5 Amps

➤ Module Efficiency: Above 15%

➤ 10 year's product warranty, 25 years warranty for 80% of rated power output.

- Battery Bank:

➤ Battery bank Capacity: 1080 Amp Hour

➤ 8 - 12 V, 150 Amp Hour (GEL/AGM/Lithium ion Battery)

➤ Charge Controller: 40 Amp

- Other components:

- Inverter: 250 VA, 12V DC to 230V/50Hz or 110V/60Hz

- Controller: Auto on/off Controller

- Housing Box made of fiberglass/aluminum/steel.

- The battery backup system provides power for a minimum of 3 days.

As part of the feasibility study, the team examined how best to implement the Solar Power lighting and operating of station elements noted above. The options were examined prior to developing our recommended approach:

- Option – 1: Separate Independent Dedicated Solar Panel for Light & Advertising Advertising board/screen.
- Option – 2: Hybrid System – Combination of Utility and Solar Supply

The difference between options 1 and 2 is that option 2 provide for an ancillary connection to the existing power grid for recharging the batteries or powering the stations during extended period, beyond 2-3 days without any sunlight. Such a situation could occur during the monsoon season.

Based upon our review, the Team recommended the Hybrid System – Option 2 (Figure 39).

The parameters considered that led to the recommendation were:

- Availability of Sun days
- Rainy days
- Site prone to storm
- 24/7 Continuity of supply
- Space availability for storage
- Security and theft

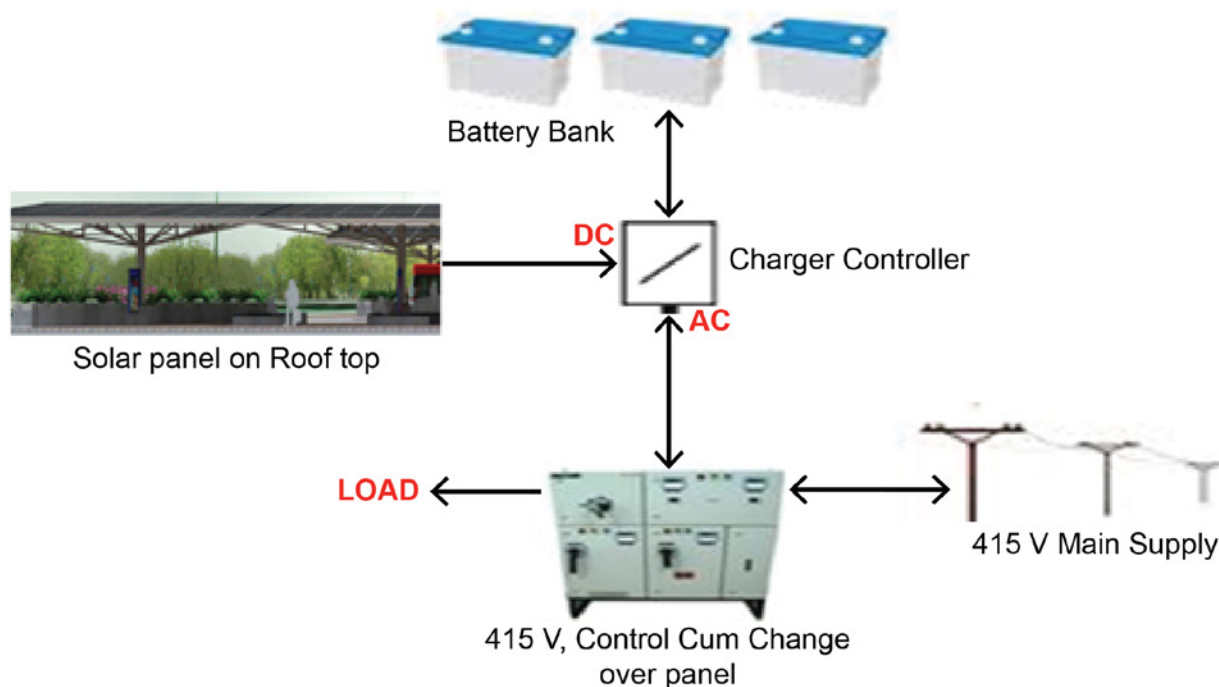


Figure 39 Recommended Hybrid Solar System

Estimated Project Costs

Capital Costs Excluding Vehicles

The attached Table 3 presents a summary of the total the estimated capital cost for improving the operation of the existing BRT corridors. The table presents the items of cost and includes an unallocated cost contingency based upon the lack of a detail design for each element. The estimate is based upon unit costs obtained from other similar projects constructed in India and the United States.

Capital Costs for both the Pendurthi and STC Corridors are presented separately in Table 4. All capital costs are presented in both Rupees and US Dollars (USD). The cost in USD is based upon a conversion rate of 65.000 Rupees to the 1 USD. All construction costs include an unallocated contingency of 30% of construction costs to account for the current level of design. Soft costs include Engineering & Design estimated at 7% of the total construction cost and 8% for construction support services based upon the average costs in India. All costs are expressed in 2017 Rupees or Dollars.

Table 3 Total Project Capital Cost Estimate

Summary of Capital Costs – All BRT Corridors		
Category of Cost	Cost (Indian Rupees)	Cost (US Dollars)
Intersection Traffic Signal/Pedestrian Improvements	77,133,535	1,186,670
BRT Stations (At Intersection)	2,963,158,239	45,587,050
BRT Stations Mid-block (Including pedestrian crosswalks)	571,022,012	8,784,954
Improved Median Protection	1,760,358,000	27,082,431
Pendurthi-NAD/NH5 Intersection Improvement	120,431,470	1,852,792
Construction Subtotal	5,492,103,257	84,493,896
Construction Contingency (30%)	1,647,630,977	25,348,169
Total Construction Cost	7,139,734,234	109,842,065
Engineering & Design Cost (7%)	499,781,396.39	7,688,945
Construction Support Services (8%)	571,178,738.73	8,787,365
Total Capital Cost	8,210,694,369	126,318,375

Table 4 Capital Cost Estimate by Individual BRT Corridor

Pendurthi BRT Corridor – Capital Costs				
Category of Cost	Quantity	Unit Cost (Indian Rupees)	Cost (Indian Rupees)	Cost (US Dollars)
Intersection Traffic Signal/Pedestrian Improvements				
4-Legged Signals	6	2,207,500	13,245,000	203,769
3-Legged Signals	11	1,896,000	20,856,000	320,862
Pedestrian Crossing Signals	2	1,242,500	2,485,000	38,231
Mid-Block Crossing Signals	8	1,242,500	9,940,000	152,923
Raised Pedestrian Crosswalk at Pedestrian Signals Improvements	2 Locations	823,009	823,009	12,662
Total Signal Improvements	27		47,349,009	728,446
BRT Station Upgrades (At Intersection)	30	61,732,463	1,851,973,900	28,491,906
BRT Station Upgrades (Mid-block) (Including raised pedestrian crosswalks)	8	47,585,168	380,681,342	5,856,636
Improved Median Protection	1	1,031,934,000	1,031,934,000	15,875,908
Pendurthi-NAD/NH5 Intersection Improvement	1	120,431,470	120,431,470	1,852,792
Construction Subtotal	NA		3,432,369,720	52,805,688
Construction Contingency (30%)	0		1,029,710,916	15,841,706
Total Construction Cost	0		4,462,080,636	68,647,394
Engineering & Design Cost (7%)	0		312,345,645	4,805,318
Construction Support Services (8%)	0		356,966,451	5,491,792
Total Capital Cost	NA		5,131,392,732	78,944,504

Table 5 STC BRT Corridor – Capital Costs

Pendurthi BRT Corridor – Capital Costs				
Category of Cost	Quantity	Unit Cost (Indian Rupees)	Cost (Indian Rupees)	Cost (US Dollars)
Intersection Traffic Signal/Pedestrian Improvements				
4-Legged Signals	1	2,207,500	2,207,500	33,962
3-Legged Signals	8	1,896,000	15,168,000	233,354
Pedestrian Crossing Signals	4	1,242,500	4,970,000	76,462
Mid-Block Crossing Signals	4	1,242,500	4,970,000	76,462
Raised Pedestrian Crosswalk at Pedestrian Signals Improvements	4 Locations	2,469,026	2,469,026	37,985
Total Signal Improvements	17		29,784,526	458,223
BRT Station Upgrade(At Intersection)	18	61,732,463	1,111,184,340	17,095,144
BRT Station Upgrade (Mid-block) (Including raised pedestrian crosswalks)	4	47,585,168	190,340,671	2,928,318
Improved Median Protection	1	728,424,000	728,424,000	11,206,523
Construction Subtotal	NA		2,059,733,537	31,688,208
Construction Contingency (30%)	0		617,920,061	9,506,462
Total Construction Cost	0		2,677,653,598	41,194,671
Engineering & Design Cost (7%)	0		187,435,752	2,883,627
Construction Support Services (8%)	0		214,212,288	3,295,574
Total Capital Cost	NA		3,079,301,637	47,373,871

Prioritization of Improvements (Best Value)

While the number of improvements developed above will all greatly improve the operation of the buses and improve the convenience and information for bus passengers, as noted in the previous section discussing the estimated costs, they come with a price and not all improvements need be done at once. Rather a phased implementation of improvements based on “Best Value” can be done. Best Value can be a qualitative or quantitative assessment of what should be the priority for implementing improvements. In our assessment since we are dealing with many different factors, including safety, bus operating improvement, and passenger convenience and perception of improvements, we believe that a qualitative assessment was the most efficient method to express and develop the “Best Value” List of Phased Improvement. In Table 6, a multifaceted program is advanced independent of cost indicating Best Value improvements by highest to lowest and a brief explanation of the element being installed.

The hierarchy developed for the Best Value was based on the project goals of improving safety, reducing travel time for passengers, improving information and convenience for passengers, and increasing reliability of bus operating schedules. Based upon these objectives the following guidelines were developed:

- **Phase I** – Improving passenger safety and information; reducing bus travel delay; improving bus travel reliability.
- **Phase II** – Minimize pedestrian/vehicle conflicts; reduce non-bus intrusions in the lanes; improve enforcement of bus lanes and monitor/control congestion.
- **Phase III** – Improve the visibility of the bus lanes.

Table 6 Phasing of Implementation

Order of Implementation Based on Best Value of Improvements			
Phase	Improvement Proposed	Estimated Cost	Reason
Phase I	Installation of “Smart” Traffic Signals & improved geometry at Intersections	–	Improves the safety of intersection for pedestrian and buses; Reduces Bus delay by reducing bus conflicts.
	Improve BRT Lanes at Pendurthi-NAD & NH5 Intersection (South Approach)	–	Reduce bus delay crossing the intersection and improve safety for vehicles and pedestrians at south approach to intersection.
	Bus Station-Concrete Bus Pad & Wheel Guide	–	Improve Safety; Reduce Bus delay; Direct boarding from platform to bus for passengers.
	Upgrading of Bus Station: <ul style="list-style-type: none"> ■ New Canopies & Solar Panels ■ Interior Lighting ■ Real-Time Bus Information ■ Bus Maps/Schedules ■ Traffic Signals and High Visibility Crosswalks 	–	Improved Safety and Security for passengers; Improve passenger information using real-time electronic displays for next bus and delays at stations and by phone; and provide safer access to and from station for pedestrians crossing vehicle and bus roadways.
	Installation of Signalized Pedestrian Crossing	–	Improve safety of pedestrians crossing due to extended distances between intersections.
Phase II	Elimination of non-intersection openings to Bus Lanes	–	Reduce conflicts from vehicles entering or crossing the bus lanes- reduce bus delay.
	Installation of New Barriers	–	Improved safety by reducing illegal and dangerous pedestrian crossings; improves roadway safety for vehicles and passengers.
	Installation of TSP at Intersections	–	Reduce Delays for Buses equipped by providing priority for buses to cross.
	Installation of Traffic Monitoring and “Red Light” Cameras	–	Reduce illegal vehicle movements and monitor traffic congestion at all intersections.
Phase III	BRT Roadway Markings	–	Improved definition of BRT Lanes
Phase III	Improve BRT Signage	–	Avoid non-authorized vehicles from entering bus lanes.

Annual BRT Stations Operating and Maintenance Costs

Attached is the O&M spreadsheet for Vizag. It is setup with unit costs for each element that can easily be modified. I have sourced and put assumptions in for many of the elements. Here are some overarching assumptions:

- Costs are calculated in US dollars, to convert to Rupees I used Google to find the exchange rate which is 65.2 rupees per dollar
- Vehicle operating and maintenance costs are not included as this is done by the operator and is a current cost
- Running way costs are not included except when running way treatments are applied to a station area, the only running way element is the concrete pad (I do cover the guidance system for the buses as part of the station cost)

Fare enforcement is not an issue since fare collection is onboard and police collect fines for evasion

- The individual station elements are as follows:
 - Passenger information display for real-time information – the AVL and most of the architecture would be a per bus cost
 - Public address system
 - Solar panels
 - Lighting
 - Benches
 - Electronic advertising – I am assuming a cost for the architecture although one can argue that the advertising contract would cover this cost
 - Tactile warning strip
 - Wheel guide (guideway system)
 - Platform maintenance
 - Station cleaning – assumed that each station would get about an hour a day of TLC, the question is the salary too high for the station cleaning staff?
- The major assumption is 60 stations (30 stations per direction)

Table 7 BRT Stations Summary Operating & Maintenance Cost Estimate

Item	Unit Type	Units	Cost per Unit (USD)	Cost per Unit (Rupees)	Annual Cost (USD)	Annual Cost (Rupees)
Concrete Pavement (Concrete Bus Pads)	Stations	60	\$9,000	₹ 586,800	\$540,000	₹ 35,208,000
				Sub-total	\$540,000	₹ 35,208,000
Passenger Information Display	Stations	60	\$2,600	₹ 169,520	\$156,000	₹ 10,171,200
Public Address System	Stations	60	\$2,600	₹ 169,520	\$156,000	₹ 10,171,200
Solar Panels	Stations	60	\$500	₹ 32,600	\$30,000	₹ 1,956,000
Lighting	Stations	60	\$250	₹ 16,300	\$15,000	₹ 978,000
Bench	Stations	60	\$500	₹ 32,600	\$30,000	₹ 1,956,000
Electronic Advertising	Stations	60	\$2,600	₹ 169,520	\$156,000	₹ 10,171,200
Tactile Warning Strip	Stations	60	\$1,000	₹ 65,200	\$60,000	₹ 3,912,000
Wheel Guide	Stations	60	\$9,000	₹ 586,800	\$540,000	₹ 35,208,000
Platform	Stations	60	\$1,000	₹ 65,200	\$60,000	₹ 3,912,000
Janitorial	Station Cleaners	8	\$8,760	₹ 571,152	\$70,080	₹ 4,569,216
				Sub-total	\$1,273,080	₹ 83,004,816
				Grand Total	\$1,813,080	₹ 118,212,816

Table 8 Basis of O&M Cost Estimate

Category	Item	Unit Type	Sources
Running Way	Concrete Pavement-Bus Pad	Stations	San Matteo County Bus lanes
Stations	Passenger Information Display	Stations	Minnesota ITS elements station costs
	Public Address System	Stations	Minnesota ITS elements station costs
	Solar Panels	Stations	Inspection and cleaning of Solar Panels
	Lighting	Stations	—
	Bench	Stations	—
	Electronic Advertising	Stations	Minnesota ITS elements station costs
	Tactile Warning Strip	Stations	Minor repairs
	Wheel Guide	Stations	San Matteo County Bus lanes
	Platform	Stations	Minor repairs
	Janitorial	Station Cleaners	8 station cleaners at 24 dollars per day over 365 days

Bus Operations

Equip all buses with GPS: GPS capability on the buses will provide real-time information to passengers at bus stations and via phone apps and web services. The location data can also be used by the transit agency to monitor bus operations, providing data to potentially adjust service.

Equip BRT buses with Transit Signal Priority: Transit Signal Priority, or TSP, will minimize stop time at signalized intersections along the bus routes. It works via the bus communicating with a receiver at a traffic signal as the bus approaches an intersection. The traffic signal can then adjust to either hold the green phase longer for the bus to pass through or move to a green phase sooner to reduce dwell time during a red phase. Implementing TSP requires specially equipped traffic signals that can communicate with the buses, not simply a standard pre-timed signal.

Connect Smart Traffic Signalized Intersections to the Police and GVMC Command Centers: Connecting the smart traffic signals to a centralized command center allows for potential further upgrades to the traffic management system, greater control and coordination from a central hub, and the possibility for interventions during emergency situations.

Precision Board of Passengers: The incorporation of the wheel guide will permit passengers to access the bus without have to get off the platform or walk in the roadway. However, this will require bus operators to pull into the curb and will need to be instructed in how to do, tactile strips installed on the roadway in conjunction with the special curbing will provide the driver with a warning that the bus has been properly positioned. In addition to the increased safety of passengers boarding, the precision boarding should provide sufficient lane to allow following buses not stopping to pass without moving into the on-coming bus traffic lane.

Battery Electric Bus Compatibility: It is anticipated that the implementation of the updated BRT corridors with new stations, passenger information systems, increased travel reliability, reduced travel time, and enhanced passenger access will be implemented utilizing fossil fuel vehicles currently operated by the APSRTC. However, as part of the “Smart City” review for the BRT Corridor upgrades; the ability to operate battery electric buses was examined as city and state administrators aim to transition to a fully-electric bus system in the future. As such, the Government of India and State Government of Andhra Pradesh have initiated enabling policies for the electrification of all transport within the country and state. The results of the review are:

- Anticipated that based upon the current electric bus development, electric buses will retain the same length, overall length and general height of the current fossil fuel vehicles in operation.
- Electric buses will be able to be charged at bus terminals and will require charging stands; although the nature of the stands will vary by manufacturer.

- Provision for electrical conduits at bus terminals and storage yards can be done at time of facility upgrades or when the electric buses are purchased in the future.
- Proposed improvements to the existing BRT Stations should not negatively affect the ability to operate the electric vehicles.
- Based upon the current state of the recharging of buses, on-line recharging of buses, while available as an option by some manufacturers; requires as much as 5 minutes of charging at each station along the route. Given the goal of the BRT is to reduce overall passenger travel, it is anticipated that on-line charging will not be implemented during the initial change from fossil to electric powered vehicles.
- If eventually the time for on-line charging of buses is reduced to be practical for the BRT, power for the charging stations could be provided by connecting into the electrical circuits for the existing street lighting.
- Use of Solar Power for charging buses at on-line BRT stations is not currently feasible due to the lack of significant area for generating as much as an additional 80 Kw for the charging of the buses.
- Currently, the existing buses have a higher height to the first step of the bus than current electric buses being produced. While it is possible that the height difference between the bus station platform and the bus entry could be adjusted by either replacing the proposed concrete bus pad or more simply by specifying matching the bus floor height to the existing station platform height.

There are currently a number of commercially available electric manufacturers around the world including in India. The electric buses tend to be low floor vehicles; meaning that there are no steps up to the floor of the vehicle other than the initial step and no steps in the interior of the bus. Typical heights from the roadway to the floor are between 39 and 40 centimeters (cm). The length of the buses are from as short as 35 feet to as long as 60 feet with typical buses matching the current 40 foot bus fleet and our proposed expansion of the station to 90 meters.

The current proposed updating of the existing Pendurthi and STC corridors is approximately 35 to 37 cm. in height or a difference in height from our proposed bus stations of 2-4 cm, which would provide for easy access and egress to and from the buses. Based upon the current information, the proposed updating of the BRT stations and BRT corridor would be totally consistent with the eventual conversion of the bus fleet from fossil fuels to electric battery technology. Included below are examples of current electric battery powered buses. Based upon the current review of the technology, nothing that is being proposed for the upgrade of the BRT corridors would be incompatible with the future operation of battery powered electric buses. Figures 40, 41 and 42, below represent battery powered electric buses currently available in India and the United States.

Capital Costs for electric buses range from \$500, 000 USD to \$750,000 USD per bus depending on the manufacturer and the optional equipment added to the bus.



Figure 40 Proterra – Battery Powered Electric Bus – USA



Figure 41 Ashok Leyland – Battery Powered Electric Bus – India



Figure 42 Utopia - India

BRT Capital and Financial Considerations

Business Model and Project Financing: The proposed project components have high impact on the quality improvement of the BRTs corridor; however, these components do not have any significant revenue generating potential. In order to finance the estimated capital and operational expenses for the proposed project components as well as other future urban transport projects, an 'Urban Transport Fund' should be created at the GVMC level. Such fund can be pooled from the following sources:

- User charges/fares received from the city bus passengers. Further, the fares can be increased by nominal values to support better quality of services envisaged.
- Monetizing outdoor (and within the bust stops areas) advertisement potential at bus stops, traffic signals / major intersections and on the public city buses.
- Selling of Naming Rights / Commercial Sponsorship for the smart bus stop(s) – i.e., this bus stop is sponsored by "XYZ Company".
- Leverage Corporate Social Responsibility (CSR) funds available from major companies (e.g., Visakhapatnam Port Trust, National Thermal Power Corporation, etc.).

- Monetizing the commercial potential of vacant land resources near bus stops along the BRTS corridor.
- Collecting premium/fee for permitting extra FAR / FSI on the lands along both sides of the BRTS corridor.
- Funding supports from state government, central government, bi-lateral/multilateral donor agencies, etc., as and when available.

Institutional Arrangements for Project Implementation: From the procurement perspective, the project owner / sponsor has several the project procurement options available ranging from a traditional Design-Bid-Build (DBB) to an alternative procurement delivery methods where the private sector expertise on financing and maintenance can be leveraged to support the planned improvements. The project owner / sponsor could explore the option of implementing the proposed project through Public-Private Partnership mode; however, taking into account the size, scope and complexity of the proposed project / components, it may not attract the level of interest typical for a large scale transportation project.

From the private sector's perspective of commercial and financial viability, either a Design-Build (DB) or a Design-Build-Operate-Maintain (DBOM) model could be a more suitable procurement structure for implementation of the proposed project / components, wherein the private partner will take on the responsibility for the following obligations:

- a. Taking up construction or improvement activities as per the design specifications provided by the public partner (project owner / sponsor),
- b. Procurement of equipment and machinery (including the buses, if there is any additional requirement) as per the output specifications provided by the public partner (project owner / sponsor),
- c. Collections of user charges / fare from the city bus passengers and depositing the same to the public partner (project owner / sponsor), and
- d. Operating and maintaining the project components (including the O&M of the city bus fleet) for a pre-determined period in accordance with KPIs set by the public partner (project owner / sponsor).

The private partner will assume the long-term operations and maintenance (O&M) risks of the project. While the project owner / sponsor will retain the revenue / financial risk and will be responsible for financing both the capital as well as operational expenses. A performance based payment mechanism – similar to that of an Availability Payment based on a strict performance regime – can be adopted by the project owner / sponsor for making payments to the selected private agency.

Project Implementation Opportunities

Two options for the implementation of the upgrading of the BRT Corridors have been identified. The two options are Base Option for Implementation and Operation and the Base Option plus “BRT” Battery Electric Buses.

Option 1 – Base BRT Upgrades Implemented

The initial or Base option for implementation assumes that all of the improvements to the BRT stations, intersections and right-of-way would be done with the funding being the responsibility of the GVMC. Under this option the APSRTC would continue to operate the current bus routes and provide the same level of service with the existing fleet of fossil fueled vehicles. One or two selected bus routes making station stops would be equipped with the Transit Signal Priority transmitters for improved throughput at intersections. The cost of the maintenance of the BRT stations would be a GVMC responsibility as it is today. The maintenance of the buses would be an APSRTC responsibility.

Option 2 – Base BRT Upgrades + BRT Electric Bus Routes Implemented

Provides all of the improvements in the Base Option and introduces a BRT Service that includes the purchase of Battery Electric Buses. The buses would be used for one of the existing routes which would be formally designated as a BRT and only this would have the new fleet. One route for each of the corridors would be upgraded to a BRT service. Key elements of this option are:

- Private Operator who will purchase, operate and maintain the new electric fleet.
- The BRT Operation would be a DBOM contract.
- BRT SPV would be activated and would be responsible for the contracting out of the work for the privatization of the 2 BRT services and the maintenance of the BRT stations.
- A new maintenance facility for the electric bus fleet would be built as part of the DBOM contract.
- Bus charging facilities would be installed by the DBOM operator at the terminals.
- Existing funds spent on the buses replaced by the new electric buses would be transferred as partial payment to the BRT SPV for the new BRT service.