FINAL TRAFFIC MANAGEMENT AND CIRCULATION STUDY REPORT

TRAFFIC AND TRANSIT MANAGEMENT CENTER

SHANTINAGAR

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DIRECTORATE OF URBAN LAND TRANSPORT
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CHAPTER 1 – INTRODUCTION

BACKGROUND

Traffic and Transit Management Centres (TTMC) is an outcome of Bangalore Metropolitan Transport Corporation (BMTC) envisaged combined transit management centre for addressing bus transportation issues of Bangalore in an attempt enhance the reach and effectiveness of the public transport system. BMTC has planned to construct a total of 45 TTMCs of which 10 are already constructed and operational, and the TTMC at Shantinagar is one of the 10 TTMCs under operation.

The TTMC at Shantinagar comprises of a bus terminal, office space, retail, park and ride facility and a multilevel car parking facility. TTMC generate Bus, Auto, private vehicle and pedestrian traffic, and directly impact traffic operating conditions on the roadway networks surrounding the TTMC and also along the entrance/exit points due to increased activity from buses, passengers accessing the terminal, Intermediate Public Transport (IPT) (Autos) and other private vehicles accessing the project site.

There is a need to address the existing pedestrian and vehicular circulation at the Shantinagar TTMC location to reduce delay due to congestion, provide safe pedestrian access and to negate conflicting points near the entry and exits points of the TTMC facilities.

PROJECT OBJECTIVE

The objective of the study is to analyze the existing vehicular and pedestrian traffic circulation pattern surrounding roadway network adjacent to the Shantinagar TTMC and the TTMC access points, and to suggest mitigation measures for effective management and circulation of pedestrian and vehicular traffic for safe and effective access to and from the TTMC.

STUDY AREA

TTMC at Shantinagar is located along KH Road between BTS Main Road and Siddaiah Road. The TTMC has access to the Bus Terminal from BTS Main Road and Siddaiah Road, and access to the private vehicles from KH Road and BTS Main Road. Figure 1 shows the location of the Shantinagar TTMC and the major roadways surrounding the study area. The Shantinagar TTMC is approximately 4 Km away from the Kempegowda Bus Station (Majestic
Station) which is a major Bus Terminal in the City and from Bangalore City Railway station. Some of the major land uses near the study area include Lalbagh Botanical Garden, Bangalore Metropolitan Transport Corporation (BMTC) main office, Karnataka State Road Transport Corporation (KSRTC) central office, BMTC and KSRTC Bus Depots.

**Figure 1:** Study Area-Shantinagar TTMC

**ORGANIZATION OF THE REPORT**

This report is organized into four major chapters and each providing an insight about the project location, need for the study, existing traffic operation conditions, identified mitigation measures and necessary improvements proposed near and for Shantinagar TTMC.

- **Chapter 1** provides introduction about the project, need for the study, also identifies the objective of the study and shows the location of the project site including the major roadways near the project site.
• Chapter 2 provides a broad overview about the salient features of the Shantinagar TTMC, with respect to land use type present in the facility and number of buses accessing the terminal. Identifies the existing traffic operations conditions of the roadway segments near the project site and at intersections in the study area. It also identifies traffic circulation with respect to vehicles and pedestrians accessing the TTMC including deficiencies with respect to roadway and pedestrian facilities, and safe accessibility to the auto stand from the TTMC.

• Chapter 3 identifies the proposed mitigation measures for existing traffic operation conditions and also improvements proposed for pedestrian and vehicle circulation and its access to the TTMC.

• Chapter 4 includes conclusion of the study with a major findings and mitigations needed to address the various traffic problems with respect to vehicles and pedestrians.
CHAPTER 2 - EXISTING CONDITIONS

The Shantinagar TTMC is built on the area measuring 7 acres and 15 guntas consists of a Bus terminal, office spaces, commercial space and parking lot in addition to the multi level car parking facility.

The bus terminal provides city, sub-urban, interstate/intercity bus services. The bus terminal includes four bus bays with two currently used by BMTC for its services and the other two are used by the long distance service providers like KSRTC, APSRTC and Tamil Nadu. The number of parking spaces provided at the facility consists of around 700 Equivalent Car Spaces (ECS) which also includes parking facility for commuters to encourage park and ride system.

The Bus Terminal currently has 502 BMTC city and sub-urban schedules of which 27 are starting from the terminal and the rest of the schedules are from passing routes. This would translate into 5678 BMTC trips per day of which 286 trips starts from TTMC Bus station and 5392 trips are passing bus trips. Table 1 shows the detailed number of schedules and trips at the Bus Terminal.

<table>
<thead>
<tr>
<th>Service Type</th>
<th>No. of Schedules</th>
<th>No. of Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting from Bus Station (TTMC)</td>
<td>27</td>
<td>286</td>
</tr>
<tr>
<td>Passing City Routes</td>
<td>160</td>
<td>2,538</td>
</tr>
<tr>
<td>Passing Sub-Urban Routes</td>
<td>315</td>
<td>2,854</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>502</strong></td>
<td><strong>5,678</strong></td>
</tr>
</tbody>
</table>

*Source: BMTC, Dec 2011*

The bus terminal also serves 589 interstate and intercity long distance trips served by KSRTC, APSRTC (Andhra Pradesh) and Tamil Nadu buses. Table 2 shows the number of trips originating at the bus station with respect to long distance trips by service provider type.
Table 2: Long Distance Trips starting at Shantinagar TTMC Bus Terminal

<table>
<thead>
<tr>
<th>Service Type</th>
<th>No. of Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karnataka State Road Transport Corporation (KSRTC)</td>
<td>115</td>
</tr>
<tr>
<td>Andhra Pradesh State Road Transport Corporation (APSRTC)</td>
<td>350</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>124</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>589</strong></td>
</tr>
</tbody>
</table>

*Source: BMTC, Dec 2011*

In total including the local urban and suburban services, and long distance services the Shantinagar Bus Terminal serves around 6,267 trips per day.

**EXISTING ROADWAY NETWORK AND INTERSECTIONS**

**Roadway Network**

The following major roadway segments located near to the TTMC facility were identified for the study to evaluate the existing operation conditions, since these roadway network serves as the access paths for the TTMC facility:

- KH Road from Marigowda Road to Vijaya Bank Circle
- BTS Bus Depot Road from KH Road to Link Road
- Siddaiah Road from KH Road (Meditation center on Siddaiah Road) to 1st Cross Road,

Figure 2 shows the study roadway segments identified for the study.
Study Intersections

The following study intersections were identified for the analysis, since the below intersections effected the though put through the system along the KH Road and also effected the delay and operations conditions of the vehicles entry and exit to the TTMC

1. BTS Main Road and KH Road
2. Siddaiah Road and KH Road
3. Access way to TTMC (Access 1) and BTS Main Road
4. Access 2 (Siddaiah Road)

For the traffic operation analysis, the BTS Road and KH Road Intersection were analyzed along with the Access 1 (located along BTS Road) of the TTMC, and Siddaiah Road and KH Road intersection were analyzed along with Access 2 (located along Siddaiah Road), since the operation conditions of the BTS Road and KH Road Intersection, and Siddaiah Road and KH Road intersection effect the operation conditions of TTMC Access points 1 and 2 respectively in terms of delay and queuing for Buses at TTMC Bus Bays.
Figure 3: Study Intersections at Shantinagar TTMC area

SITE ACCESS AND CIRCULATION PATTERN

Site Access
The TTMC at Shantinagar has a segregated access for the Buses and private vehicles and includes a total of 5 access points, where access point 1 & 2 are used by buses for accessing the bus terminal, access points 3 & 4 are used by private vehicles to access the facility and its parking lots and access 5 is exclusively for the private vehicles exiting the parking facility. However, access point 2 is also used by the private vehicles to enter and exit the parking facility. Figure 4 shows the access points for the TTMC with respect to study roadway network.
**Figure 4:** Access Points of TTMC

**Circulation Pattern**

The TTMC bus terminal has five bus bays and each bay is segregated based on the type of the service provider and direction bound.

- **Bus bay - A:** BMTC (Airport Services), KSRTC, APSRTC and Tamil Nadu
- **Bus bay - B:** BMTC buses bound towards Majestic/ Shivajinagar
- **Bus bay - C:** unused
- **Bus bay - D:** BMTC buses coming from Shivajinagar/Majestic
- **Bus bay - E:** KSRTC, APSRTC and Tamil Nadu

During the peak hours it was found that around 280 buses enter and exit the bus station which translates into around 840 passenger car units (PCUs) and the number of private vehicles entering and exiting the TTMC was found to be around 251 and 106 PCUs respectively.

Figure 5 shows the Bus Bays at the TTMC Bus Terminal and the path taken by the buses to access the bus bays based on their inbound and outbound movements.
The existing circulation pattern includes that Buses from Majestic and Shivajinagar areas enter the TTMC’s Access 1 (BTS Main Road) and use Bus Bay -D to pick and drop off passengers and exit from Access 2 towards Wilson garden, where as buses head towards Airport, Kempegowda Bus Stand and Shivaji Nagar enter from Access Point 2 (Siddaiah Road) and use Bus Bays - A and B to pick and drop off passengers and exit from Access 1 (BTS Main Road).

At the BTS Main Road a conflict point is created due to the buses weaving movement from the BTS Main Road to enter the TTMC Bus Terminal i.e. at access point 1 in conflict with the through vehicles approaching the BTS/ KH Road Intersection bound toward KH road.

The buses entering the TTMC Bus Terminal from Siddaiah Road is in conflict with the vehicles bound towards Wilson Garden; however the buses do find suitable gaps to access the bus terminal due the signal at the Siddaiah intersection.
Figure 6 shows the existing circulation pattern at the TTMC and the major conflicting movement identified at near the TTMC facility.

**Figure 6**: Entry and exit of Existing Bus Circulation at TTMC

**EXISTING OPERATION CONDITIONS**

The existing operation conditions near the TTMC were evaluated with respect to the following to identify the deficiencies with respect to vehicle and pedestrian traffic.

1. Roadway Segments
2. Operation Conditions
   - Existing Intersection Configuration and phase timing plans
   - Measure of Effectiveness
3. Existing Pedestrian facilities
   - Footpath Connectivity
   - Pedestrian Crossings
   - Subway connectivity and usability
4. Intermediate Public Transport Pick Up and Drop off Location
Roadway Segments
The Level of Service (LOS) and the capacity of the Roadway segments computed is based on the Indian Roads Congress (IRC) standards sourced from Guidelines for Capacity of Urban Roads in Plain Areas IRC 106-1990. Table 3 provides the LOS standards adopted based on the volume to capacity (V/C) ratios at the intersections.

Table 3: Existing V/C and Level of Service

<table>
<thead>
<tr>
<th>V/C</th>
<th>LOS</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.2</td>
<td>A</td>
<td>Excellent</td>
</tr>
<tr>
<td>0.2 - 0.4</td>
<td>B</td>
<td>Above Average</td>
</tr>
<tr>
<td>0.4 - 0.6</td>
<td>C</td>
<td>Average</td>
</tr>
<tr>
<td>0.6 - 0.8</td>
<td>D</td>
<td>Below Average</td>
</tr>
<tr>
<td>0.8 - 1.0</td>
<td>E</td>
<td>Poor</td>
</tr>
<tr>
<td>1.0 - 1.2</td>
<td>F</td>
<td>Very Poor</td>
</tr>
</tbody>
</table>

*Note: V= Volume in PCU’s/hr & C= Capacity in PCU’s/hr*

The Existing traffic operation conditions of the study roads are presented below in Table 4. The KH Road segment from Vijaya Bank circle to BTS intersection was found to be operating with LOS F with volume to capacity (V/C) ratio exceeding 1 during both AM and PM peak hour conditions. The KH Road segment from BTS intersection to Siddaiah Road was found to be operating at a LOS F (North Bound (NB)) and D (South Bound (SB)) during AM Peak Hour conditions, where as it was operating at a LOS F (NB) and E (SB) during PM peak hour conditions. The KH Road segment between Siddaiah Road and Marigowda Road was found to be operating at LOS C (NB) and E (SB) during AM peak hour conditions, where as it was operating at a LOS C (NB) and F (SB) during PM peak hour conditions.

The BTS Main Road between KH Road and Link Road was found to be operating at LOS B (East Bound (EB)) and D (West Bound (WB)) during both AM and PM peak hour conditions.

Siddaiah Road between KH Road and 1st Cross Road was found to be operating at LOS F in both EB and WB directions, where as it was operating a LOS F (EB) and D (WB) during PM peak hour conditions. The Siddaiah Road between Meditation Center and KH Road was found to be operating at LOS D (EB) during AM peak hour conditions, where as it was operating a LOS E (EB) during PM peak hour conditions.
Figure 7 shows the Existing worst case LOS at the study roadway segments near the TTMC.

**Figure 7: Existing Operating LOS Conditions**
**Table 4: Rated Capacity of the Intersection along Project Corridor**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Road Name</th>
<th>Roadway Segment</th>
<th>Avg Width of Carriageway (m)</th>
<th>No. of Lanes based on width</th>
<th>Design capacity per lane</th>
<th>Capacity</th>
<th>Existing (AM) Peak Hour Volume (PCU/Hr)</th>
<th>V/C</th>
<th>LOS (AM)</th>
<th>Existing (PM) Peak Hour Volume (PCU/Hr)</th>
<th>V/C</th>
<th>LOS (PM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>KH ROAD – Between Vijaya Bank Circle and BTS Main Road</td>
<td>North Bound (LCW)</td>
<td>10</td>
<td>2.9</td>
<td>1300</td>
<td>3714</td>
<td>6676</td>
<td>1.80</td>
<td>F</td>
<td>6475</td>
<td>1.74</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South Bound (RCW)</td>
<td>11</td>
<td>3.1</td>
<td>1300</td>
<td>4086</td>
<td>4675</td>
<td>1.14</td>
<td>F</td>
<td>4525</td>
<td>1.11</td>
<td>F</td>
</tr>
<tr>
<td>2</td>
<td>KH ROAD – Between BTS Main Road and Siddaiah Road</td>
<td>North Bound (LCW)</td>
<td>11</td>
<td>3.1</td>
<td>1300</td>
<td>4086</td>
<td>4534</td>
<td>1.11</td>
<td>F</td>
<td>4347</td>
<td>1.06</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South Bound (RCW)</td>
<td>11</td>
<td>3.1</td>
<td>1300</td>
<td>4086</td>
<td>2473</td>
<td>0.61</td>
<td>D</td>
<td>3508</td>
<td>0.86</td>
<td>E</td>
</tr>
<tr>
<td>3</td>
<td>KH ROAD – Between Siddaiah Road and Marigowda Road</td>
<td>North Bound (LCW)</td>
<td>9</td>
<td>2.6</td>
<td>1300</td>
<td>3343</td>
<td>1769</td>
<td>0.53</td>
<td>C</td>
<td>1945</td>
<td>0.58</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South Bound (RCW)</td>
<td>9</td>
<td>2.6</td>
<td>1300</td>
<td>3343</td>
<td>2704</td>
<td>0.81</td>
<td>E</td>
<td>4039</td>
<td>1.21</td>
<td>F</td>
</tr>
<tr>
<td>4</td>
<td>BTS Main Road – Between KH Road and Link Road</td>
<td>East Bound (LCW)</td>
<td>9</td>
<td>2.6</td>
<td>1300</td>
<td>3343</td>
<td>1093</td>
<td>0.33</td>
<td>B</td>
<td>1034</td>
<td>0.31</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>West Bound (RCW)</td>
<td>10</td>
<td>2.9</td>
<td>1300</td>
<td>3714</td>
<td>2300</td>
<td>0.62</td>
<td>D</td>
<td>2353</td>
<td>0.63</td>
<td>D</td>
</tr>
<tr>
<td>5</td>
<td>Siddaiah Road – Between KH Road and 1st Cross Road</td>
<td>East Bound (LCW)</td>
<td>6</td>
<td>1.7</td>
<td>1050</td>
<td>1800</td>
<td>2009</td>
<td>1.12</td>
<td>F</td>
<td>2193</td>
<td>1.22</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>West Bound (RCW)</td>
<td>7</td>
<td>2.0</td>
<td>1050</td>
<td>2100</td>
<td>2389</td>
<td>1.14</td>
<td>F</td>
<td>1512</td>
<td>0.72</td>
<td>D</td>
</tr>
<tr>
<td>6</td>
<td>Siddaiah Road – Between Meditation Center and KH Road</td>
<td>East Bound</td>
<td>10</td>
<td>2.9</td>
<td>1300</td>
<td>3714</td>
<td>2798</td>
<td>0.75</td>
<td>D</td>
<td>3614</td>
<td>0.97</td>
<td>E</td>
</tr>
</tbody>
</table>

**NOTE:** Capacity of the roadways was based on the IRC 106-1990.
Operation Conditions

Existing Intersection Configuration and Phase Timing Plans
The BTS Main Road and KH Road intersection, and Siddaiah Road and KH Road intersection geometric configurations are shown below along with the phase timing plans, since these two signalized intersections dictated the operation conditions at the Access points 1 and 2 of the TTMC.

BTS Main Road and KH Road Intersection
The KH North Bound approach included three through lanes with the right through lane also acting as a shared right turn lane, where as the South Bound approach included three through lanes with a left through lane also acting as a shared left turn lane. The BTS Main Road approach has three lanes with all the three lanes acting as a right turn lane but the left most lane also acts as a shared left turn lane.

On the BTS Main Road Buses accessing the TTMC is in conflict with the vehicles approaching the BTS Main Road approach (from Wilson Garden) of BTS/ KH Road intersection and it was also found that the vehicles would queue up from the BTS Main Road approach at BTS/ KH Road intersection blocking the access of the buses entering the Access-1 of TTMC facility. Figure 8 shows the geometric configuration of the BTS and KH Road intersection along with the turning movements allowed at each approach and also the conflict point created along the BTS Main Road by the Buses accessing the TTMC.

Figure 8: Existing Roadway Geometric Configuration at BTS/KH Road Intersection
The BTS and KH Road intersection’s traffic signal had a cycle length of around 135 seconds with a total of 4 phases including a pedestrian phase. The signal had a 10 seconds pedestrian phase and it was observed in the field that the 10 seconds pedestrian phase was insufficient to cross the street at this intersection. The Figure 9 shows the phasing plan at the intersection, where as the Table 5 shows the duration of each phase at the intersection.

**Figure 9:** Existing Traffic Signal Phasing Plan at BTS/KH Road Intersection

![Existing Traffic Signal Phasing Plan at BTS/KH Road Intersection](image)

**Table 5:** Existing Signal Phasing Timing Plan at BTS Intersection

<table>
<thead>
<tr>
<th>PHASES</th>
<th>Existing Phase Timings (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GREEN</td>
</tr>
<tr>
<td>PHASE -1</td>
<td>26</td>
</tr>
<tr>
<td>PHASE -2</td>
<td>55</td>
</tr>
<tr>
<td>PHASE -3</td>
<td>35</td>
</tr>
<tr>
<td>PHASE -4</td>
<td>10 (Ped Signal)</td>
</tr>
<tr>
<td>Cycle Length</td>
<td>135</td>
</tr>
</tbody>
</table>

**Siddaiah Road and KH Road Intersection**

The KH North Bound approach included three through lanes and does not include the right turn or left turn movement at the approach, whereas the South Bound approach included three through lanes with a left through lane also acting as a shared left turn lane.

The Siddaiah Road East Bound approach is a one way street with three lanes with the left most lane acts as a de facto left turn lane where as the right most lane acts as a shared right...
turn lane. The Siddaiah Road West Bound approach has 2 lanes for the right turning movement with left lane acting as a shared left turn lane. Figure 10 shows the geometric configuration of the Siddaiah and KH Road intersection along with the turning movements allowed at each approach.

**Figure 10:** Existing Road Geometrics at Siddaiah Intersection

The Siddaiah Road and KH Road intersection traffic signal had a cycle length of around 142 seconds with a total of 4 phases including a pedestrian phase. The signal had a six (6) seconds pedestrian phase and it was observed in the field that the pedestrians phase was insufficient, since pedestrians were not able to cross even half of the street during this phase. The Figure 11 shows the phasing plan at the intersection, where as the Table 5 shows the duration of each phase at the intersection.
Figure 11: Existing Traffic Signal Phasing Plan at Siddaiah Road Intersection

Table 6: Existing Signal Phasing at Siddaiah Intersection

<table>
<thead>
<tr>
<th>PHASES</th>
<th>Existing Phase Timings (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GREEN</td>
</tr>
<tr>
<td>PHASE -1</td>
<td>50</td>
</tr>
<tr>
<td>PHASE -2</td>
<td></td>
</tr>
<tr>
<td>PHASE -3</td>
<td>35</td>
</tr>
<tr>
<td>PHASE -4</td>
<td>42</td>
</tr>
<tr>
<td>Cycle Length</td>
<td></td>
</tr>
</tbody>
</table>
Measure of Effectiveness (MOE’s)
To evaluate the existing operation conditions, the delay and queue lengths along the study corridor and at intersections were considered respectively.

**Delay**
The existing peak hour delay for the study area was computed along the KH Road Corridor for the following sections

- KH Road Corridor Section - From Vijaya Bank to Marigowda Road
- KH Road and BTS Main Road Section – From Vijaya Bank to TTMC Access 1

The KH Road Corridor section from Vijaya Bank to Marigowda Road was evaluated for all vehicles, where as KH Road and BTS Main Road Section from Vijaya Bank to TTMC Access-1 was evaluated for Buses accessing the TTMC. The following delays were considered for evaluation of operation conditions in the study area for the peak hour conditions

- Average Travel Time – Seconds per vehicle
- Total Vehicles Travel Time – Hours
- Total Passengers Travel Time – Hours

Table 7 and Table 8 show the delays at KH Road Corridor section from Vijaya Bank to Marigowda Road and BTS Main Road Section from Vijaya Bank to TTMC Access-1 respectively.

**Table 7: Existing Travel Time at KH Road section from Vijaya Bank to Marigowda Road**

<table>
<thead>
<tr>
<th>MOE’s</th>
<th>South Bound</th>
<th>North Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Travel Time (Seconds Per Vehicle)</td>
<td>203</td>
<td>145</td>
</tr>
<tr>
<td>Total Vehicles Travel Time (Hours)</td>
<td>35</td>
<td>31</td>
</tr>
<tr>
<td>Total Passengers Travel Time (Hours)</td>
<td>42</td>
<td>37</td>
</tr>
</tbody>
</table>

The south bound movement had a higher travel time with an average of 3 minutes 27 seconds when compared to the north bound movement which had an average travel time of 2 minutes 25 seconds. The total vehicle travel time in the south bound direction at the KH
Road Section was around 35 hours, whereas the total passengers travel time was around 42 hours. The total vehicle travel time in the north bound direction at the KH Road Section was around 31 hours, whereas the total passengers travel time was around 37 hours.

**Table 8:** Existing Travel Time at KH Road and BTS Main Road Section from Vijaya Bank to TTMC Access-1

<table>
<thead>
<tr>
<th>MOE’s</th>
<th>South Bound</th>
<th>North Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Travel Time (Seconds Per Vehicle)</td>
<td>181</td>
<td>116</td>
</tr>
<tr>
<td>Total Vehicles Travel Time (Hours)</td>
<td>5.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Total Passengers Travel Time (Hours)</td>
<td>184</td>
<td>146</td>
</tr>
</tbody>
</table>

For the Buses accessing the TTMC the average travel time in the south bound direction was found to be 181 seconds, whereas in the north bound direction 116 seconds. The total number vehicle hours was around 5.3 hours and 4.2 hours in the north bound and south bound direction respectively, whereas the total passengers travel time was found to be 184 hours and 146 hours in the north bound and south bound direction respectively. The huge difference between the vehicles and passengers travel time is due to the higher occupancy of the Buses, which carries in an average around 30 people during peak hour conditions.

The following peak hour pedestrian delay were computed at the BTS Main Road and KH Road intersection, and Siddaiah Road and KH Road intersection to understand the existing pedestrian operation conditions at the intersections

- Average Delay – Seconds per Pedestrian
- Total Pedestrian Delay – Hours
Table 9: Existing Peak Hour Pedestrian Delay

<table>
<thead>
<tr>
<th>MOE’s</th>
<th>BTS Main Road /KH Road Intersection</th>
<th>Siddaiah/KH Road Intersection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Delay (Seconds Per Pedestrian)</td>
<td>257</td>
<td>310</td>
</tr>
<tr>
<td>Total Pedestrian Delay (Hours)</td>
<td>20</td>
<td>16</td>
</tr>
</tbody>
</table>

The number of pedestrians crossing at the BTS Main Road and KH Road intersection, and Siddaiah Road and KH Road intersection are high during peak hours because of the passengers accessing the TTMC Bus Terminal. It was found that the total delay for the pedestrians incurred during peak hour was found to be 20 hours and 16 hours at the BTS Main Road and KH Road intersection, and Siddaiah Road and KH Road intersection respectively.

Queue length
The maximum Queue lengths in meters are provided at the following study intersections to show if the vehicles queuing at the intersection would block side streets / access or spills over to the other intersections

- BTS Main Road and KH Road intersection
- Siddaiah Road and KH Road intersection

Table 10: Existing Peak Hour Maximum Queue Lengths

<table>
<thead>
<tr>
<th>Intersections</th>
<th>North Bound Length (m)</th>
<th>South Bound Length (m)</th>
<th>East Bound Length (m)</th>
<th>West Bound Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTS / KH Road</td>
<td>153</td>
<td>373</td>
<td>-</td>
<td>165</td>
</tr>
<tr>
<td>Siddaiah / KH Road</td>
<td>71</td>
<td>91</td>
<td>134</td>
<td>160</td>
</tr>
</tbody>
</table>

The critical queue lengths are the South Bound movement at the BTS Main Road and KH Road Intersection which had a queue length of around 373 meters, blocking the side streets located adjacent to the Vijaya Bank i.e. 4th Cross Road, impede Buses accessing the Bus Stop...
located in near to the KSRTC Main Office Building and also access to the BTS Bus Depot Road. The West Bound movement at the Siddaiah Road and KH Road intersection which had a queue length of around 160 meters, blocking the access of the Buses entering the TTMC Bus Terminal i.e. Access 2 during peak hour conditions. Figure 12 shows the Queue Length on the roadway network and also the blocked traffic movement locations.

**Figure 12** : Queue Lengths at the Intersections

Existing Pedestrian Facilities

**Footpath Connectivity**

The continuous wide footpaths are been located along the KH Road and Siddaiah Road for the pedestrian movement. At BTS Main Road there is a lack of footpath which makes inconvenient for the pedestrians accessing the TTMC, its Bus Terminal and for pedestrians accessing this street. It was observed that pedestrians were using carriageway space to reach their destinations. Figure 13 shows the existing footpath network in the study area and also the locations of footpaths missing links.
Pedestrian Crossings
The availability of pedestrian crossings for the passengers accessing the TTMC Facility were evaluated near the access points of the TTMC facility accessing from BTS Main Road and Siddaiah Road, and it was found that the locations didn’t include any identified or marked pedestrian crossing at the accessibility points increasing conflicts between pedestrian and vehicles including buses accessing the TTMC facility.

Figure 14 shows the TTMC access locations in need of identified pedestrian crossings. Locations 1, 2 and 3 are located along BTS Main Road, Location 1 is the access used by the private vehicles to access the TTMC facility and there a lack of footpath at this location and in addition there is no marked pedestrian crossing to ensure vehicles to slow down for the crossing pedestrians. Location 2 is the location of the exit ramp from the TTMC parking facility and it can be seen that the pedestrians are in direct conflict with the vehicles exiting form the parking facility. Location 3 shows that there is no marked pedestrian crossing from the Auto Stand to access the TTMC facility, where a marked pedestrian crossing would ensure vehicles slowing down for the pedestrians crossing the street.
Location 4 and 5 are located at the TTMC access point from Siddaiah Road, where Location 4 and 5 show the entry and exit ramp points of the private vehicles and pedestrians are in direct conflict with the vehicles accessing the TTMC Facility.

**Figure 14: Pedestrian Crossing Locations**

---

**Subway Connectivity and Usability**

The Subway runs perpendicular to the Bus Bays and has an access from KH Road for the pedestrians entering and exiting the bus terminal for the Bus Bays B, C and D. The some of the limitations of the subway are

- The **connectivity** of the Subway to **Bay one** is absent
- There is no Access for the people coming from Siddaiah Road
- No **Awareness** among the passengers accessing the bus terminal
- The way finding for the people accessing the subway is absent
- It is not **elderly and disabled friendly** i.e **Escalators/Elevators** are absent
• Sufficient illumination is absent

Figure 15 shows the location of the Sub Way and its connectivity with respect to bus bays and the paths for accessing the sub way from KH Road and from path adjacent to Bus Bay E. Figure 16 shows the existing pictures of subway access from KH Road, Stairs to reach subway, visibility inside subway and access to the subway from path adjacent to Bus Bay E.

Figure 15 : Sub Way Connectivity
Intermediate Public Transport – Pick up and Drop off Location

The auto stand has been constructed in front of the TTMC along the BTS Main Road in the median for passenger pick up from the TTMC, but there is no designated Auto drop off location for the passengers at this location. There is also a need for designated pedestrian crossing for passengers accessing the TTMC from and to Auto Stand connecting TTMC Bus Bay to Auto Stand area.

Figure 17 depicts the existing Auto Stand Layout and Figure 18 shows the existing Auto Stand location along the BTS Main Road.

**Figure 17:** Existing Auto Stand Layout
**Figure 18**: Existing Auto Stand Location
CHAPTER 3 – MITIGATION MEASURES

Based on the existing traffic circulation conditions it was found that the study roadway segments and intersections were congested during the peak period conditions due to large volume of traffic in the study area. The higher volume of pedestrian movement was also observed at the intersections and in and around the TTMC facility. Improvement of the traffic operation conditions, pedestrian movement and parking of IPT (Auto) stand are the key aspect that needs attention in the study area. The following mitigation measures were proposed made to improve traffic circulation in the study area, which are categorised as follows:

1. Operation Conditions
   - Proposed Intersection Configuration and Phase Timing Plans
   - Measure of Effectiveness

2. Pedestrian facilities
   - Footpath Connectivity
   - Pedestrian Crossings
   - Subway Connectivity and Usability

3. Intermediate Public Transport Pick Up and Drop Off Location

Operating Conditions

Proposed Intersection Configuration and Phase Timing Plans
The changes in the intersection configuration and phase timing plans were proposed at the BTS Main Road and KH Road intersection, where as changes in phase timing plans were proposed at Siddaiah Road and KH Road intersection to improve the vehicle and pedestrian operation conditions at the intersections and at access points 1 and 2 of the TTMC.

BTS Main Road and KH Road Intersection
The following improvements were proposed to improve the operation conditions at this intersection

- The North Bound (vehicles from Siddaiah Intersection) right turning movement was prohibited and the signal phasing for this movement was also removed at this intersection, since around only 50 vehicles per hour during peak hour was found to
be using 29 seconds of phase time at this intersection. The right turning movement was accommodated by providing a median opening between the BTS Main Road and Siddaiah intersection as shown in Figure 19.

- To remove the conflict point along the BTS Main Road between the Buses entering TTMC and vehicles from Wilson Garden entering the BTS Main Road Approach at the intersection, a traffic signal is proposed for the vehicles approaching the BTS Approach from Wilson Garden as shown in the Figure 19 which would be synchronized with the signal for BTS Main Road approach i.e. the signal at this approach turns Green when the signal for BTS Main Road approach turn green.

**Figure 19: Existing Auto Stand Location**

- The existing phasing plan has four phases and with the removal of right turning movement at the intersection the number of phases would be reduced to three. The proposed phasing plan has a cycle length of 115 seconds and the phase one includes a green time of 59 seconds for the vehicles from K H Road (both northbound and southbound approaches) and the phase two is the exclusive pedestrian phase of 15 seconds for pedestrian crossing at all approaches and the final phase includes the green time of 35 seconds for BTS main Road approach (vehicles coming from Wilson Garden). Figure 20 depicts the proposed traffic signal phasing plan for the
intersection, where as the Table 11 shows the existing and proposed phase timing plan and cycle lengths at the intersection.

**Figure 20:** Proposed Traffic Signal Phasing Plan at BTS/ KH Road Intersection

![Figure 20: Proposed Traffic Signal Phasing Plan at BTS/ KH Road Intersection](image)

**Table 11:** Existing and Proposed Signal Timing Plan at BTS/ KH Road Intersection

<table>
<thead>
<tr>
<th>PHASES</th>
<th>Existing Phase Timings (Seconds)</th>
<th>Proposed Phase Timings (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GREEN</td>
<td>YELLOW</td>
</tr>
<tr>
<td>PHASE -1</td>
<td>26</td>
<td>3</td>
</tr>
<tr>
<td>PHASE -2</td>
<td>55</td>
<td>3</td>
</tr>
<tr>
<td>PHASE -3</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>PHASE -4</td>
<td>10 (Ped Signal)</td>
<td></td>
</tr>
<tr>
<td>Cycle Length</td>
<td>135</td>
<td></td>
</tr>
</tbody>
</table>

**Siddaiah Road and KH Road Intersection**

The signal timing plans were optimized based on the volumes at the intersection during peak hour and it was found that the proposed cycle length of 145 seconds and the phase timings plans would improve the operation conditions at the intersection and reduce the queue length at the West Bound Siddaiah Road Approach in turn improving the operation at Access 2 of TTMC facility. Figure 21 depicts the proposed traffic signal phasing plan for the intersection, where as the Table 12 shows the existing and proposed phase timing plan and cycle lengths at the intersection.
**Figure 21:** Proposed Traffic Signal Phasing Plan at Siddaiah / KH Road Intersection

![Proposed Traffic Signal Phasing Plan at Siddaiah / KH Road Intersection](image)

**Table 12:** Existing and Proposed Signal Timing Plan at Siddaiah / KH Road Intersection

<table>
<thead>
<tr>
<th>PHASES</th>
<th>Existing Phase Timings (Seconds)</th>
<th>Proposed Phase Timings (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GREEN</td>
<td>YELLOW</td>
</tr>
<tr>
<td>PHASE -1</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>PHASE -2</td>
<td></td>
<td>6 (Ped Signal)</td>
</tr>
<tr>
<td>PHASE -3</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>PHASE -4</td>
<td>42</td>
<td>3</td>
</tr>
<tr>
<td>Cycle Length</td>
<td>142</td>
<td></td>
</tr>
</tbody>
</table>

**Measure of Effectiveness (MOE’s)**

To evaluate the effect of the above proposed geometric and phase timings improvements at the intersections, the operation conditions in the study area after the implementation of the proposed improvements were compared with the existing operation conditions with respect to delay and queue lengths along the study corridor and at study intersections respectively.
Delay
The peak hour delay for the study area after the implementation of the above improvements was computed along the KH Road Corridor for the following sections:

- KH Road Corridor Section - From Vijaya Bank to Marigowda Road
- KH Road and BTS Main Road Section – From Vijaya Bank to TTMC Access 1

Significant improvements were found with the proposed improvements along the southbound direction with the reduction of delay by 23 seconds from Vijaya Bank to Marigowda Corridor, where as the delay increased for the vehicles in the northbound direction by about 14 seconds along the corridor. Table 13 and 14 show the improvements through reduction in delay along the study corridor.

Table 13: KH Road Corridor Section - From Vijaya Bank to Marigowda Road

<table>
<thead>
<tr>
<th>Direction</th>
<th>Existing</th>
<th>Proposed</th>
<th>Difference in Average Delay (Seconds/Vehicle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Bound</td>
<td>203</td>
<td>180</td>
<td>-23</td>
</tr>
<tr>
<td>North Bound</td>
<td>145</td>
<td>159</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Direction</th>
<th>Existing</th>
<th>Proposed</th>
<th>Delay (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VHT</td>
<td>VHT</td>
<td></td>
</tr>
<tr>
<td>South Bound</td>
<td>35</td>
<td>31</td>
<td>-4</td>
</tr>
<tr>
<td>North Bound</td>
<td>31</td>
<td>34</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Direction</th>
<th>Existing</th>
<th>Proposed</th>
<th>Delay (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PHT</td>
<td>PHT</td>
<td></td>
</tr>
<tr>
<td>South Bound</td>
<td>42</td>
<td>37</td>
<td>-5</td>
</tr>
<tr>
<td>North Bound</td>
<td>37</td>
<td>41</td>
<td>4</td>
</tr>
</tbody>
</table>
Table 14: KH Road and BTS Main Road Section – From Vijaya Bank to TTMC Access 1

<table>
<thead>
<tr>
<th>Direction</th>
<th>Existing</th>
<th>Proposed</th>
<th>Average Delay (Seconds/Vehicle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Bound</td>
<td>181</td>
<td>100</td>
<td>-81</td>
</tr>
<tr>
<td>North Bound</td>
<td>116</td>
<td>111</td>
<td>-5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Direction</th>
<th>Existing-VHT</th>
<th>Proposed-VHT</th>
<th>Delay (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Bound</td>
<td>5.3</td>
<td>2.9</td>
<td>-2.4</td>
</tr>
<tr>
<td>North Bound</td>
<td>4.2</td>
<td>4.0</td>
<td>-0.2</td>
</tr>
</tbody>
</table>

The change in the signal timings plans at the intersections and increase in the pedestrian phase to 15 seconds at the intersection reduced the delay for the pedestrians crossing the intersection and also provided a safe passage for the crossing pedestrians respectively. The average delay at the BTS Main Road and KH Road Intersection reduced by 48 seconds per pedestrian, where as total pedestrian hour delay reduced by around 4 hours. The average delay at the Siddaiah Road and KH Road Intersection reduced by 15 seconds per pedestrian, where as total pedestrian hour delay reduced by around an hour.
Table 15: Pedestrian Delay at the Intersections

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Average Delay (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTS Intersection</td>
<td>257</td>
</tr>
<tr>
<td>Siddiaah Intersection</td>
<td>310</td>
</tr>
<tr>
<td>Proposed</td>
<td>209</td>
</tr>
<tr>
<td></td>
<td>295</td>
</tr>
<tr>
<td><strong>Average Delay / Pedestrian</strong></td>
<td><strong>- 48</strong></td>
</tr>
<tr>
<td></td>
<td><strong>-15</strong></td>
</tr>
</tbody>
</table>

Queue length
The queue length was computed for the existing condition and after the implementation of proposed improvements at the intersection and it was found that the queue lengths were significantly reduced for the SB KH Road Approach at BTS Main Road and KH Road intersection and WB Siddaiah Road Approach at Siddaiah Road and KH Road Intersection, whereas increased for the NB KH Road Approach at BTS Main Road and KH Road intersection but was limited to within the storage space of the intersection. Figure XX shows queue lengths for the Existing and for proposed conditions.

The reduction in queue length at WB Siddaiah Road Approach at Siddaiah Road and KH Road Intersection improved the access of the buses entering and exiting the bus terminal thereby improving the operation conditions at the Access 2 of the TTMC.
Pedestrian Facilities

Footpath Connectivity
Footpaths are found absent at the opposite side of TTMC along BTS Main road. Footpaths of 2.0 m width were proposed to have footpath connectivity for the pedestrians at this segment. A small stretch of footpath in front of the TTMC is also proposed to ensure connectivity at this section. The Figure 23 shows the proposed footpaths locations.

Figure 22: Queue Lengths at the Intersection
The existing and proposed cross sections along the BTS Main Road after the implementation of footpath are depicted in Figure 24 and 25 showing the cross sections at various locations.
Figure 24: Existing and Proposed Cross Sections
Figure 25: Existing and Proposed Cross Sections
Proposed Table-Top Crossing
At few locations conflicts occur between the vehicles and the pedestrians near the TTMC facility. The identified locations are:

1. Entry of the Big Bazaar
2. Car/Two wheeler parking Exit at the front side of TTMC
3. Pedestrian crossing at the Auto Stand
4. Car/Two wheeler parking Exit at the backside of TTMC
5. Car/Two wheeler parking Exit at the backside of TTMC

Figure 26 shows the proposed Table-Top crossings locations which would reduce vehicle speeds, so pedestrians can safely cross without much difficulty.

Figure 26: Proposed Table Top Crossing Locations

Proposals for Subway
The following proposals were proposed to improve the usability of subway for pedestrian access to the Bus terminal
1. Awareness through way finding with the help of signs/ signage’s should be provided.

2. Connectivity should be provided from Bay 1 to Bay 2

3. Limited accessibility provision between the bays to negate the bus and passengers conflict and to ensure subway use.

4. Illumination to ensure visibility.

Proposal for the Auto Stand
A pre-paid Auto Stand is constructed opposite to the TTMC as shown in the Figure 27. The current Auto Stand has only pick up zone at the location, the drop off zone is also proposed for the effectiveness of the Auto Stand and also to stop autos from dropping off passengers at undesignated locations.

**Figure 27: Auto Stand Drop off Location**
**Speed Breakers**

During the survey it was observed that the vehicles need to maneuver sharp right while moving towards link Road and has not enough sight distance for the oncoming vehicles at this locations. To ensure safety at this location the speed breakers are proposed as a traffic calming measure along the BTS Main Road at the locations as shown in the Figure 28.

A speed breaker is also proposed near the drop off zone of Auto, so the autos can get into the drop off zone sue to the slowing of the oncoming vehicles.

**Figure 28: Speed Breaker Locations**
CHAPTER 4 – CONCLUSIONS

The following improvements are recommended for the effective operation of study intersections, access points of the TTMC, to improve pedestrian circulation pattern and intermodal public transportation.

**Intersections**

- At BTS Main Road and KH Road intersection - changes in the intersection configuration and phase timing plans
- Siddaiah Road and KH Road intersection - changes in the phase timing plans

**Pedestrian facilities**

- Foot path addition along the BTS Main Road for foot path Connectivity for both the passengers accessing the TTMC and for the pedestrians using the corridor.
- Table top crossing at the Access Points of the TTMC for designated pedestrian crossings and also ensure safety of the pedestrians.
- Ensure subway usability through awareness, signages, connectivity and illumination for visibility.

**Intermediate Public Transport Pick Up and Drop Off Location**

- To create drop off bay for passengers at the proposed Auto Stand as recommend in the mitigation measures.

- Speed breakers near auto drop of zone and at the junction where the BTS Main Road makes a ‘Y’ to reduce speeds and ensure safety one due to sight distance and other for the autos to get into the drop off zone.

The Table 16 below shows the proposed improvements in the study area based on the location type and the agencies responsible for implementing the same.
**Table 16: List of Proposals with Implementing Agencies**

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Proposal</th>
<th>Location</th>
<th>Intervention</th>
<th>Reference</th>
<th>Implementing Agency</th>
</tr>
</thead>
</table>
| 1     | Proposed Intersection Configuration | BTS Main Road and KH Road Intersection | • New Traffic Signal  
• Signal Retiming | Figure 20, pg 29 | Traffic Police |
|       |                                   |                                   | Proposed U-Turn                        | Figure 19, pg 28 | BMTC |
|       |                                   | Siddaihay Road and KH Road       | Signal Retiming                        | Figure 21, pg 30 | Traffic Police |
| 2     | Footpath Connectivity              | Along BTS Main Road               | Footpath of 2m wide                    | Figure 23, pg 41 | BMTC |
| 3     | Pedestrian Crossing                | Access Points to TTMC             | Table Top Crossings                    | Figure 26, pg 39 | BMTC |
| 4     | Subway                             | Access to the Bus Terminal        | • Connectivity  
• Illumination | pg 39           | BMTC |
| 5     | Traffic Calming                    | Along BTS Main Road               | Speed Breakers                         | Figure 28, pg 41 | BBMP |
| 6     | Intermediate Public Transport (IPT) | Besides BMTC Bus Terminal         | Drop Off Zone                          | Figure 27, pg 40 | BMTC |