Big10 Performance Analysis

A Case Study of Direction-based Bus Services in Bangalore

EMBARQ India

The WRI Centre for Sustainable Transport

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Executive Summary

In February 2009, the Bangalore Metropolitan Transport Corporation (BMTC) launched the Big10 bus service, a direction-based service operating on 10 radial routes (later expanded to 12) connecting the Central Business District of the Bangalore to its suburban areas. With steadily increasing passenger patronage, this service has been widely hailed as a successful innovation in urban bus transport provision in India.

In order to assess the performance of the Big10 services, EMBARQ India, in collaboration with BMTC, conducted a data collection and analysis exercise on four Big10 routes. Performance data was collected through various means, including schedule and GPS data provided by BMTC, and several surveys conducted by EMBARQ India

The analysis shows that Big10 services have been successful in increasing the mode share of public transport in Bangalore. 13% of current Big10 users shifted to the service from private modes of travel. From a financial and operational standpoint, the Big10 services have been performing well, with good daily revenues per bus and high load factors.

This study has also identified certain patterns of usage of Big10 services which will enable better route and operations planning. For example, the majority of passengers on the four Big10 routes use bus passes rather than purchase tickets on-board. A large portion of trips of Big10 routes are short trips of less than 6km, implying that rationalization of route lengths and introduction of short distance services will enable BMTC to reap operational efficiencies.

Although the performance of the Big10 services is generally positive on most parameters, the analysis performed in this study also points out some areas in which service quality can be improved. Reliability of services is one area in which Big10 services can perform better. There is significant inconsistency in the pattern and frequency with which buses arrive at Big10 stops, which negatively impacts passenger opinion of the service. This is largely a result of road traffic conditions, suggesting the need for bus priority measures to improve performance in the future. Similarly, the analysis shows that bus capacity can be deployed in a more efficient manner – currently the majority of bus trips are being performed in the non-peak periods when demand is low.

Finally, this report suggests some next steps for the BMTC to further improve the quality of Big10 services. A major recommendation is the establishment of internal capacity and mechanisms for data collection – continual service improvement requires constant performance monitoring and feedback. Corridor improvement exercises should also be carried out to identify solutions for specific barriers to improved performance on each Big10 route.

Introduction

Bangalore Metropolitan Transport Corporation (BMTC) is a state-owned agency solely responsible for bus-based public transport in Bangalore city. BMTC operates about 6,000 schedules (buses) on 2400 routes covering 1.38 million Kilometers per day. In February 2009, BMTC launched direction-based services on 10 radial routes (later expanded to 12) connecting the Central Business District (CBD) with suburban areas. These services were branded "Big10" and used buses with a distinctive livery. Unlike point-to-point based routes which ply through various sub-arterials and local streets, the direction-based services run on major arterials for most of the route length. Such services attempt to offer faster travel and greater clarity on bus routes.

Patronage for the Big10 services, also known as the 'G' routes, has steadily increased since its inception and most of the routes are generating profits. In this context, the current study is an attempt to analyse the performance of these services, identify its strengths and suggest measures for improvement.

While the direction-based services run on 12 routes in total, four routes have been analysed in this study. The choice of routes was informed by BMTC's suggestion to pick, based on revenue measures, two well-performing routes and two not-so-well performing routes. The four chosen routes are:

- ☐ G1: Trinity Church – Kodugudi
- ☐ G2: Brigade Rd. – Electronic City (Wipro)
- ☐ G6: Shantinagar – Kengeri Satellite Town
- ☐ G9: BRV Grounds – Yelahanka Satellite Town

Study Methodology: Data Collection and Sources

For the purpose of this analysis, various forms of data were collected in addition to the information supplied by BMTC. Field data collection was conducted between 13th and 23rd of December 2010. Following is a summary of the data collection effort.

- **Big10 Schedules:**
  BMTC supplied the list of buses that were plying on the study routes along with their registration numbers, schedule numbers and so on. BMTC also provided historic average monthly revenue earnings and bus run kilometers run. A summary of this information is presented in Table 1 below.

Table 1: Big10 Route Details & Earnings

Parameter	G1	G2	G6	G9
Number of Buses Plying On Route	16	30	6	12
Buses On Which GPS Functional (October 2010)	11	26	5	8
Route Length (One-way) (km)	21.0	20.9	21.0	19.4
Average Scheduled Kilometers (July 2010)	249.2	233.2	209.6	248.0
Earnings Per Kilometer (December 2010) (Rs.)	26.17	27.17	15.00	19.50

- **GPS Travel Logs:**
  While most of the Big10 buses have GPS units installed, some of these are not functional and require maintenance. BMTC shared their latest available GPS travel logs for the week of 25th to 31st October 2010. Of the 64 buses on these routes, 50 buses had a functional GPS unit. Route-wise functional units for this specified date range are provided in Table 1. This data is useful to study travel times at various times of the day and also the arrival patterns of buses at stops along the route. If the logs are available for all the buses on a route, it can also be used to compute the headways and average wait times at stops.

- **Electronic Ticketing Machine (ETM) Log:**
  Conductors on most of the Big10 buses issue paper tickets only. BMTC does have ETM's that are generally used to issue tickets on the higher-end air-conditioned Vajra services. For the purpose of this study, BMTC agreed to allocate an ETM to one schedule on each of the selected Big10 routes for a period of 4 days from 15th to 18th of December 2010.

However, due to various technical problems with the ETM's not all the data recorded was usable. ETM logs contain the following information for each of the tickets issued:

a) Ticket Number
b) Time Stamp
c) Origin Stage
d) Destination Stage
e) # Children on Tickets
f) # Adults on Ticket
g) Total Ticket Fare

- **Boarding & Alighting (B&A) Survey:**

This survey was conducted primarily to establish the total passenger load on the bus as the ETM data does not account for the passengers who use monthly or daily passes for travelling by bus. This survey involves counting the number of passengers getting in and getting out of the bus along every stop on the route. It was conducted on the same buses where the ETM machines were used, in order to establish the percentage of pass-holding passengers on the route. This study was conducted for 6 days from 13th to 18th December 2010.

- **Bus Occupancy Survey:**

The B&A survey was conducted and ETM logs recorded only for one schedule on each of the four Big10 routes. The Bus Occupancy Survey was therefore initiated with a view to establishing the general arrival patterns and occupancy levels of all the Big10 buses on the study routes along various points on the route. For this survey, enumerators were stationed at select bus stops on each of the routes to observe all the Big10 buses passing by the stop and approximately note the occupancy level on the bus as one of the following categories.

a) EMPTY if there are less than 10 passengers on the bus
b) HALF if there are 10 to 30 passengers on the bus
c) FULL if all seats occupied and up to 5 passengers standing
d) STANDING if 5 to 20 passengers standing due to non-availability of seat
e) CROWDED if more than 20 passengers standing on the bus

The enumerators also noted the time at which the bus arrived at the stop. Occupancy information generated from this survey is necessarily subjective in nature as it involves making an assessment in just a few second. However, this data is useful to evaluate the crowdedness of a bus relative to the ones arriving before and after it. The survey was conducted between 19th and 22nd of December 2010. Table 2 shows the locations where the data was collected.

Table 2: Occupancy Survey Locations

Date	G1 – Stop	G2 – Stop	G6 – Stop	G9 - Stop
19-Dec-2010	Domlur	Adugodi	MCTC BS	Jayamahal
20-Dec-2010	Domlur	Adugodi	MCTC BS	Jayamahal
21-Dec-2010	Marathahalli	Madiwala	Kengeri	Yelahanka PS
22-Dec-2010	Ramagondanahalli	Konappana Agrahara	BLR University	Mekhri Circle

- **Passenger Interview Survey:**

  Passenger Interviews were conducted to determine Origin – Destination (OD) patterns of passengers traveling on the study routes, in order to provide data for route-planning purposes. Further, the surveys also sought information on access modes used by passengers for last-mile connectivity. About 1100 passengers were interviewed, approximately 300 on each route, between 13th and 23rd of December 2010.

Big10 Performance Assessment: Data Analysis

The data collected from the various surveys was used to conduct a wide-ranging analysis of the performance of Big10 services on the four selected routes. This analysis is broadly classified into five main categories.

- Impact of Big10 services on mode share
- Passenger Trip Characteristics
- Financial Performance of Routes
- Passenger Demand Analysis
- Service Quality Analysis

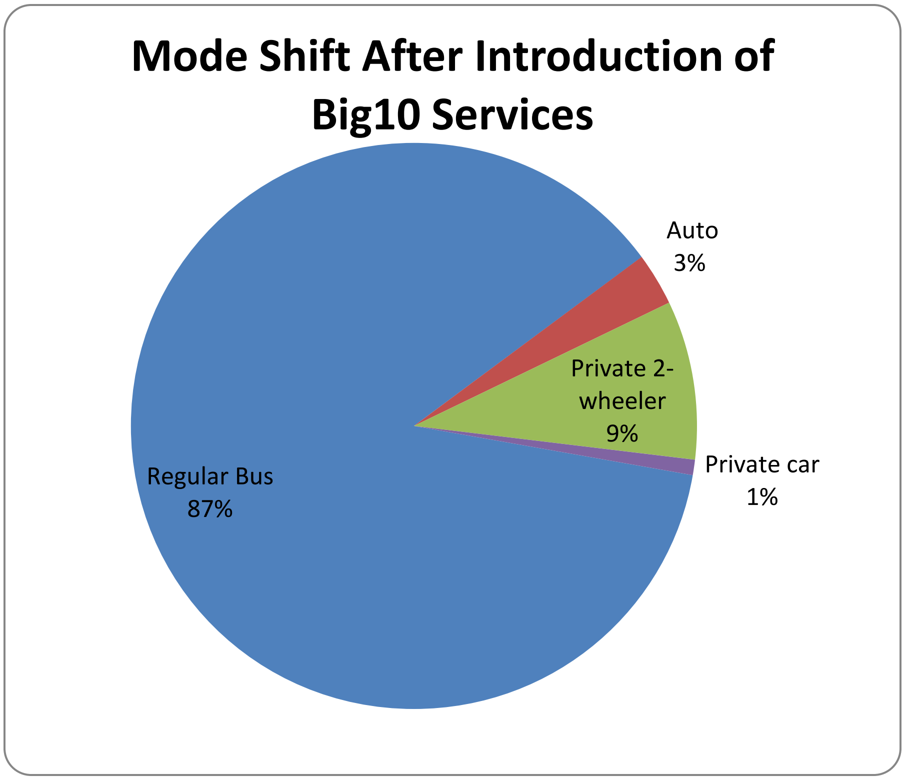
Results from the above analysis and a comparison of services on the four routes are presented in the sections that follow.

Impact of Big10 services on mode share:

The mode share of public transport (PT) is an important indicator of the health of the PT system in an urban area. As urban centers grow rapidly, one of the major challenges is to retain PT mode share. The introduction of Big10 direction-based bus services in Bangalore was an attempt to affect mode shift in favour of PT. In order to determine the success of this attempt, passengers were asked about the mode of travel they used prior to the introduction of Big10 services.

Of the 804 persons who responded to this question during the passenger interviews, 73 persons were using a private two-wheeler, 7 persons a private car, and 24 persons were using auto-rickshaw based paratransit to complete their trips prior to introduction of Big10 buses. The remaining 700 persons were using other BMTC buses on point-to-point routes. This means that the 13% of current Big10 users have shifted to public transport from private modes. Figure 1 shows a detailed break up of this shift.

Figure 1: Mode Shift due to Introduction of Big10



Passenger Trip Characteristics

Trip Lengths:

Electronic Ticketing Machine (ETM) data was used to compute average trip lengths of Big10 passengers. However, as mentioned in the earlier, some of the ETM's that were deployed on the study routes experienced technical problems that resulted in data loss. The extent of the loss was minimal on G1 and G2 routes but was significant on the G6 route. In the case of route G9, ETM's were deployed on two schedules resulting in a significantly larger data set being available for analysis.

The charts presented in Figures 2-5 show the trip-length distribution from the ticketing data for the four study routes.

Figure 2: Trip Length Distribution – Route G1

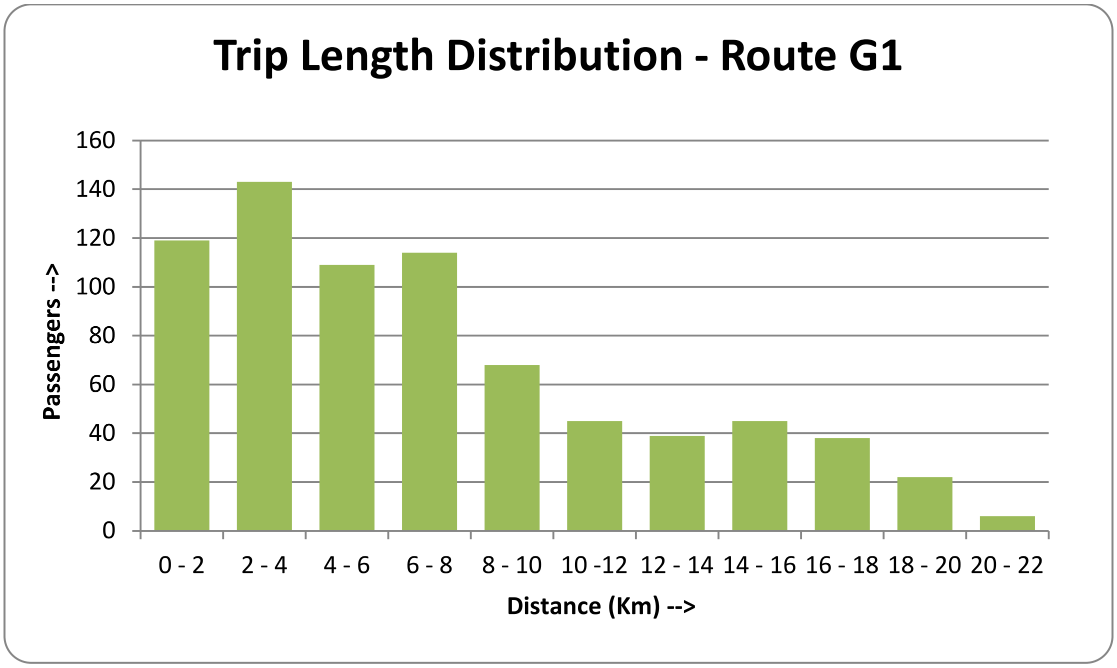


Figure 3: Trip Length Distribution – Route G2

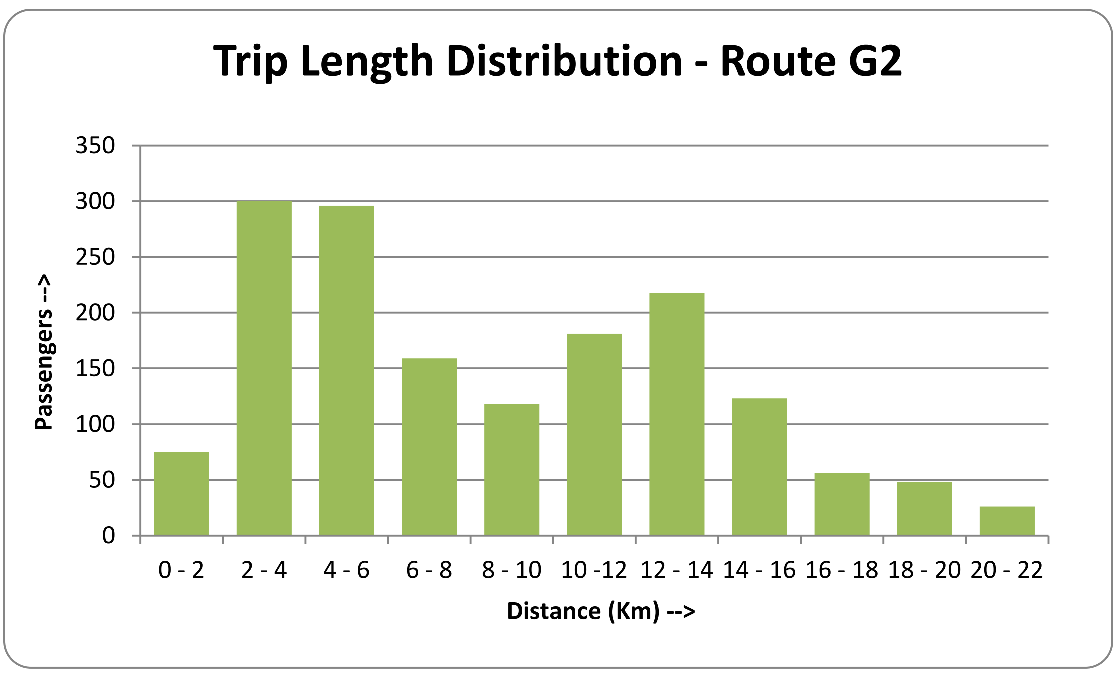


Figure 4: Trip Length Distribution – Route G6

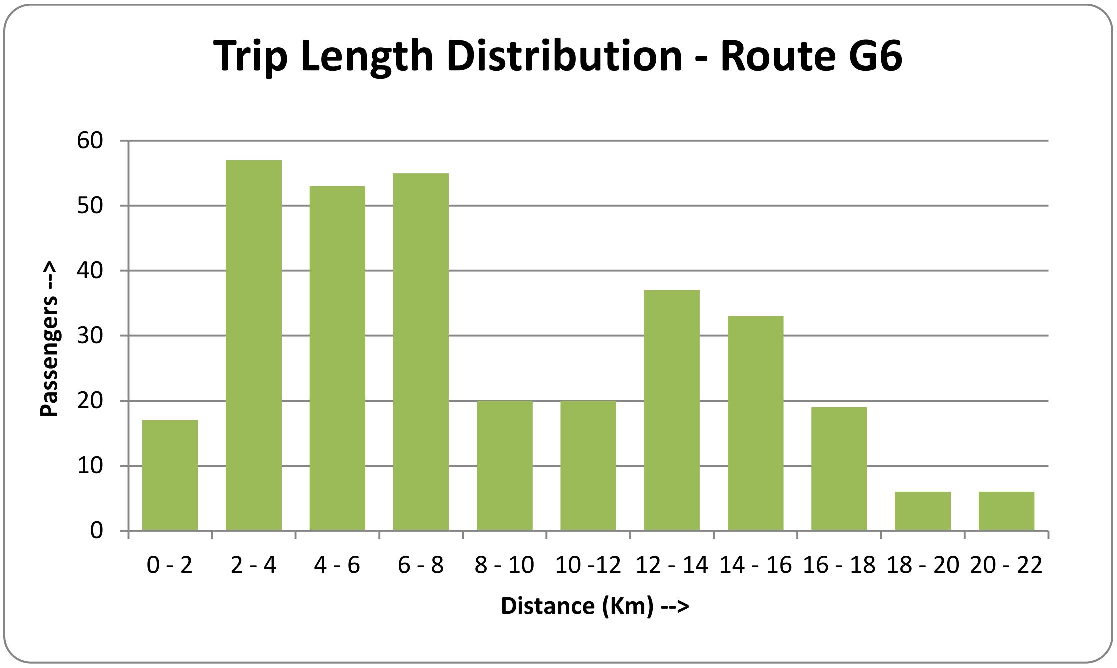
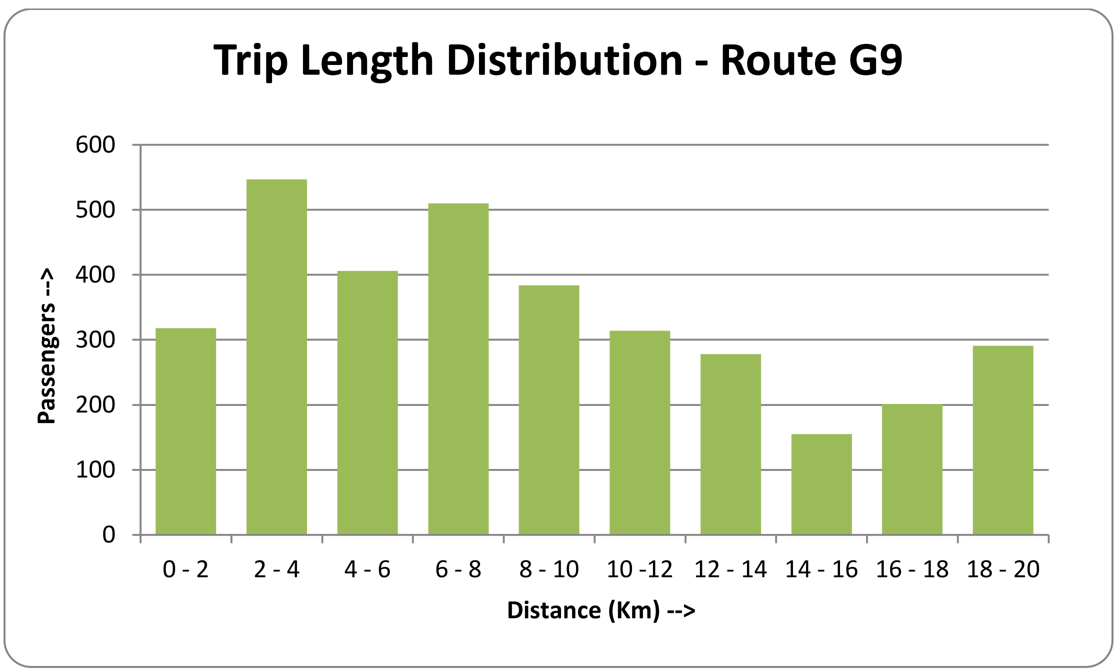


Figure 5: Trip Length Distribution – Route G9



The figures above show that there are a fairly large percentage of short-trips on all four routes. Trips of less than 6km in length account for more than 1/3rd of all tickets sold, with route G1 (49%) having the highest percentage, followed by G2 (42%), G6 (39%) and finally G9 (37%). Route G9, apart from having the lowest percentage of short trips, also has the highest fraction of passengers, 10%, making end-to-end trips. Hence this route also has the highest average trip length per passenger and revenue per passenger among the four routes.

The 'dips' in the graphs on all four routes, indicating a low percentage of medium length trips, are consistent with the fact that many parallel services operate on these routes. For example, the drop in the 8 – 10 km length trips on G2 is because of a large number of transfers that occur at Silk Board Junction. Similarly on route G9, many parallel services run up to Yelahanka Police Station, which is 14 – 16 km from Shivajinagar, and then divert towards Yelahanka. A summary of the results is presented in the Table 3.

Table 3: Ticketing Data

Parameter	**G1**	**G2**	**G6**	**G9**
Number of Tickets Analysed	670	1526	268	2790
Total Number of Ticketed Passengers	748	1600	323	3404
Route Length (km)	21.00	20.90	21.00	19.40
Percentage of Short Trips (0 – 6 km)	49%	42%	39%	37%
Avg. Trip Length of Ticketed Passengers (km)	7.39	8.51	8.53	8.90

Method of Payment:

ETM data does not provide a count of non-ticketed passengers who use passes. Hence, ticketing data from ETM's was compared with passenger load data from the Boarding & Alighting survey to arrive at the percentage of pass-using passengers. Since the ETM's were not functional at all times during the study period, only trips where the ETM data was available for the entire route length were used.

Table 4 shows the results of this computation.

Table 4: Computation of Non-ticketed Passenger Load

Parameter	G1	G2	G6	G9
Total Trips (One-way) Compared	15	24	4	21
Total Distance Traveled By Bus (km)	315.00	501.60	84.00	407.40
Total Passengers Served (B&A Survey)*	1560	3146	380	1766
Total Ticketed Passengers (ETM)	663	1431	143	662
Percentage Ticketed Passengers	42.5%	45.5%	37.6%	37.5%
Percentage Non-ticketed Passengers	57.5%	54.5%	62.4%	62.5%
Average Trip Length (ETM Data) (km)	7.43	8.62	8.25	8.47
Average Ticket Price (ETM Data) (Rs)	8.91	9.15	8.84	9.18

*Includes only those trips with matching ETM data

The above computations show that more than half of all passengers, ranging from 55%- 62% on the four routes, use seasonal passes sold by BMTC rather than buying individual tickets.

BMTC currently evaluates route performance based on ticket sales in the buses. They do not have a mechanism to determine the fraction of passengers using a pass to travel. Revenue from the sale of passes is distributed across all schedules based on scheduled bus kilometers. This leads to a bias in favour of routes having fewer pass-using passengers. This analysis shows that a route's financial performance cannot be ascertained solely from ticket sales.

Financial Performance of Routes

ETM data provides us with the average ticket price paid per passenger, as shown in Table 5 below. It is worth reiterating that this data accounts only for those passengers who purchased tickets on board the bus and excludes revenue from pass users.

Table 5: Average Ticket Price per Passenger

Parameter	G1	G2	G6	G9
Number of Tickets Analysed	670	1526	268	2790
Total Number of Ticketed Passengers	748	1600	323	3404
Average Trip Length of Ticketed Passengers (km)	7.39	8.51	8.53	8.90
Average Ticket Price (per passenger) (Rs.)	8.89	9.06	9.00	9.38

To get a picture of the financial performance of these direction based services, the average rate of return (revenue per bus per day) on buses plying on the study routes is computed as shown in Table 6.

Table 6: Computation of Revenue per Bus per Day

Parameter	G1	G2	G6	G9
Date Range	15-17 Dec	15-17 Dec	15-17 Dec	15-17 Dec
Passengers Served per Day (B&A Data)	1181	1362	1006	1135
Average Ticket Price (per passenger) (ETM Data)	8.89	9.06	9.00	9.38
Revenue per Bus per Day (Rs.)	10,499	12,285	9,054	10,646

The computations show that the study routes have a rate of return ranging from Rs.9,054 to a Rs.12,285. Route G2 has the highest average return per day.

While the above conclusions are generally valid, further analysis is necessary due to the following reasons:

a) The ETM data from route G6 was very limited and only four trips across 3 analysis days could be matched to arrive at the percentage of non-ticketed passengers. Hence, the results for G6 need to be verified over a larger sample.
b) The above analysis assumes and applies the average ticket price paid by the ticketed passengers to the non-ticketed passengers, which may or may not be accurate.

Passengers who generally travel longer distances in a day and/or those having to make multiple transfers to reach their destination opt for passes. A specific purpose study might be necessary to ascertain the price per kilometer from passengers opting for these passes.

Passenger Demand Assessment:

Financial analysis can determine the profitability of various routes but does not give an insight into the efficiency of a route in servicing passenger demand. Observing load patterns along the route can provide the information needed to achieve service improvements. This section of the study will analyse the boarding and alighting patterns of passengers in order to assess the performance of the four Big10 routes.

Indexed Passenger Kilometer (IPK)

Indexed Passenger kilometer (IPK) is a performance indicator commonly used to evaluate the operational productivity of a public transport route. It is computed by dividing the total number of passengers served by bus-kilometers run. Generally, an IPK greater than 4 passengers per bus kilometer is considered a good level of performance.

Parameter	G1	G2	G6	G9
Date Range	15-17 Dec	15-17 Dec	15-17 Dec	15-17 Dec
Average Number Of Passengers Served per Bus per Day (B&A Data)	1181	1362	1006	1135
Scheduled Route Length per Bus per Day (Km)	250.00	250.80	250.00	270.20
Indexed Passenger Kilometers (passengers/bus km)	4.72	5.43	4.02	4.20

By the IPK measure, all four routes are performing well. G1 and G2 are performing particularly well. This measure of performance proves especially vindicating for route G6. Recall from the Financial Performance section that the G6 route has the lowest revenue per bus per day. Based on the relatively poor financial performance of G6 BMTC had curtailed services on this route and currently only a small number of buses are deployed on G6. However, the IPK calculations show that G6 is actually performing well. The low EPKM is a result of the high fraction of pass users on this route. This example illustrates one of the problems with using EPKM alone as a measure of the performance of services along a particular route.

Passenger Load Analysis

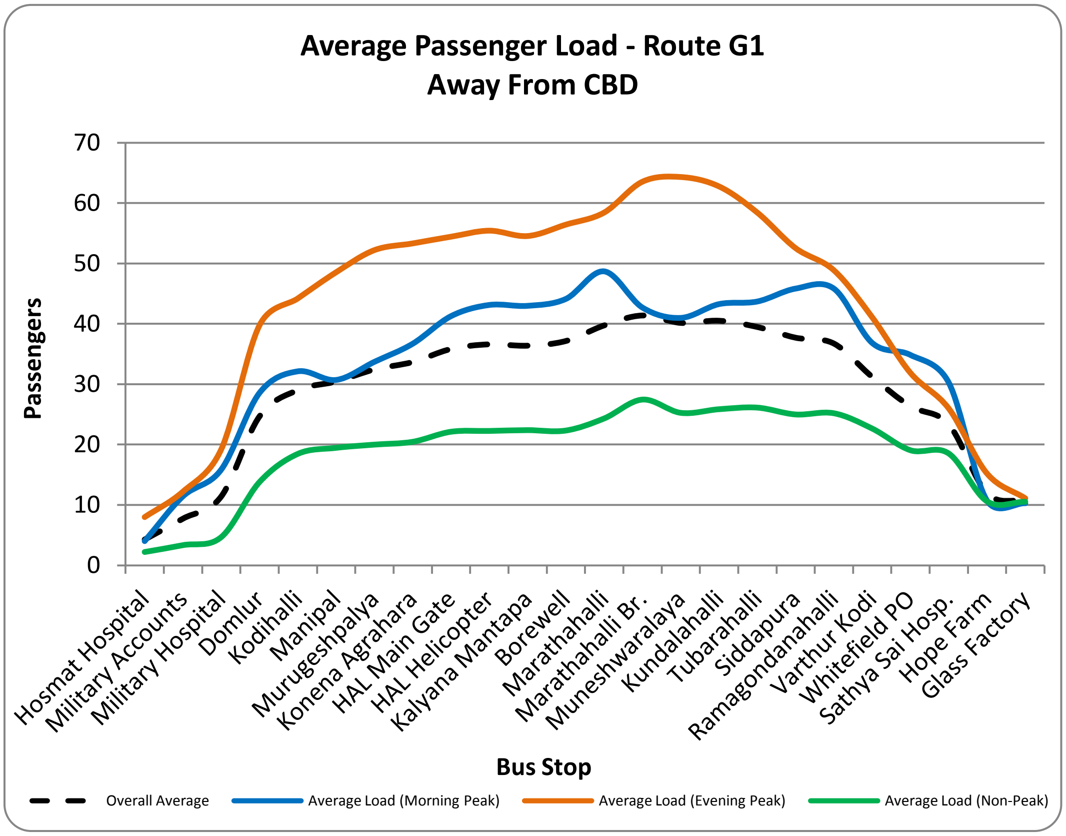
Passenger load data is available from the Boarding & Alighting (B&A) survey which was conducted over a period of six days. By counting the number of passengers that get on and off at every stop, this survey allows us to calculate the number of passengers that are on the bus (load) in every section of the route. The trips that were observed during this period were separated into peak and non-peak time periods as the load patterns vary significantly by time of the day. For the purposes of this study, bus departures from the route ends between 7:00 am and 10:00 am are considered as morning peak trips, between 4:30 pm and 7:30 pm as evening peak trips and the remaining 10 hours (6:00 am – 7:00 am, 10:00 am – 4:30 pm and 7:30 pm - 10:00 pm) as non-peak trips. The results are presented below.

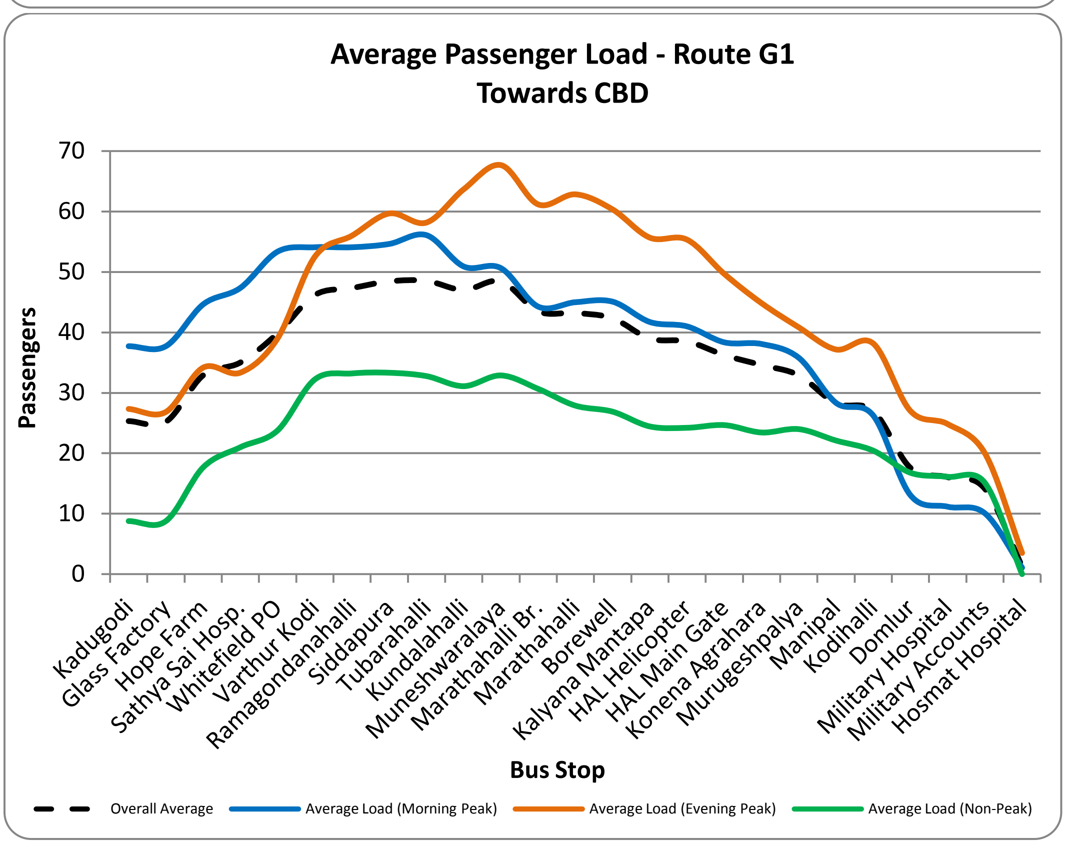
- <u>Route G1:</u>

  The average passenger loads for route G1 is shown in Figure 6. The charts indicate that the average evening peak load is greater than the average morning peak load. The occupancy levels are greater than 30 passengers for most of the route during the peak periods. The passenger load is greater than the full seating capacity of 45 passengers per bus during the peak periods in both directions.

  The off-peak load pattern clearly indicates that there is spare seating capacity on the bus through-out the route during this time period. This suggests the need for a mechanism to increase bus frequency and/or seating capacity during the peak periods and reduce the supply during the non-peak hours.

Figure 6: Average Passenger Load for Route G1



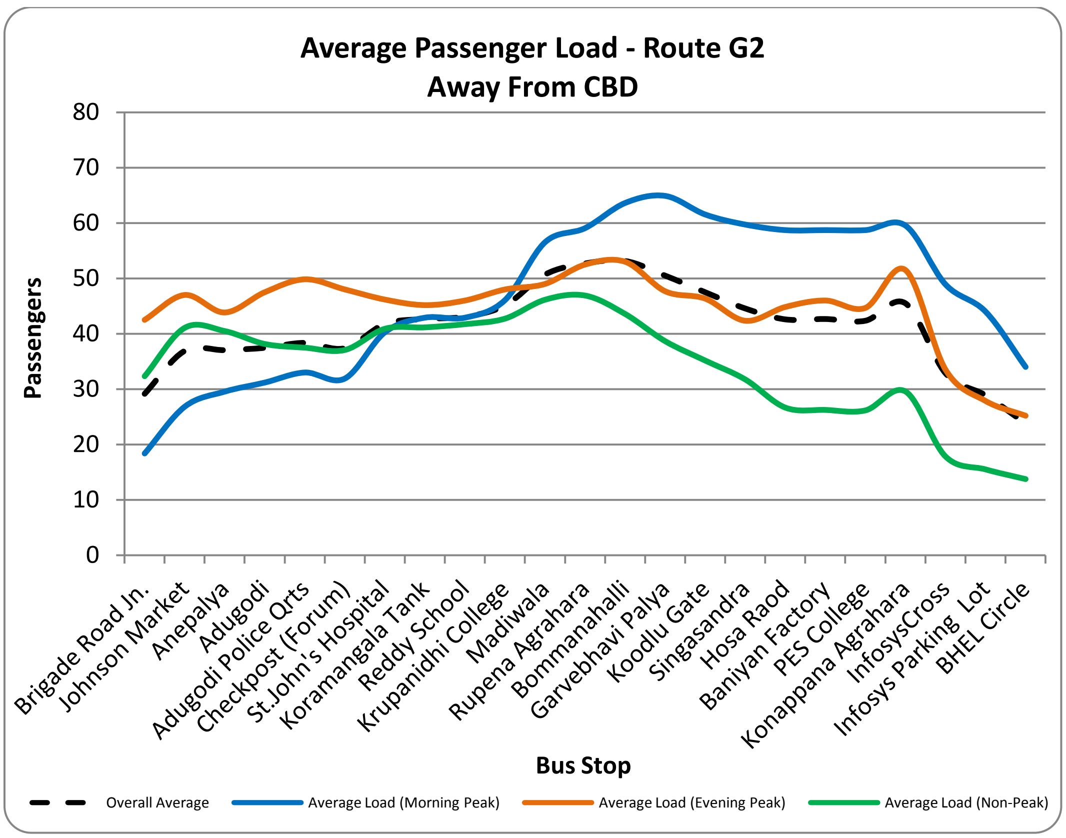


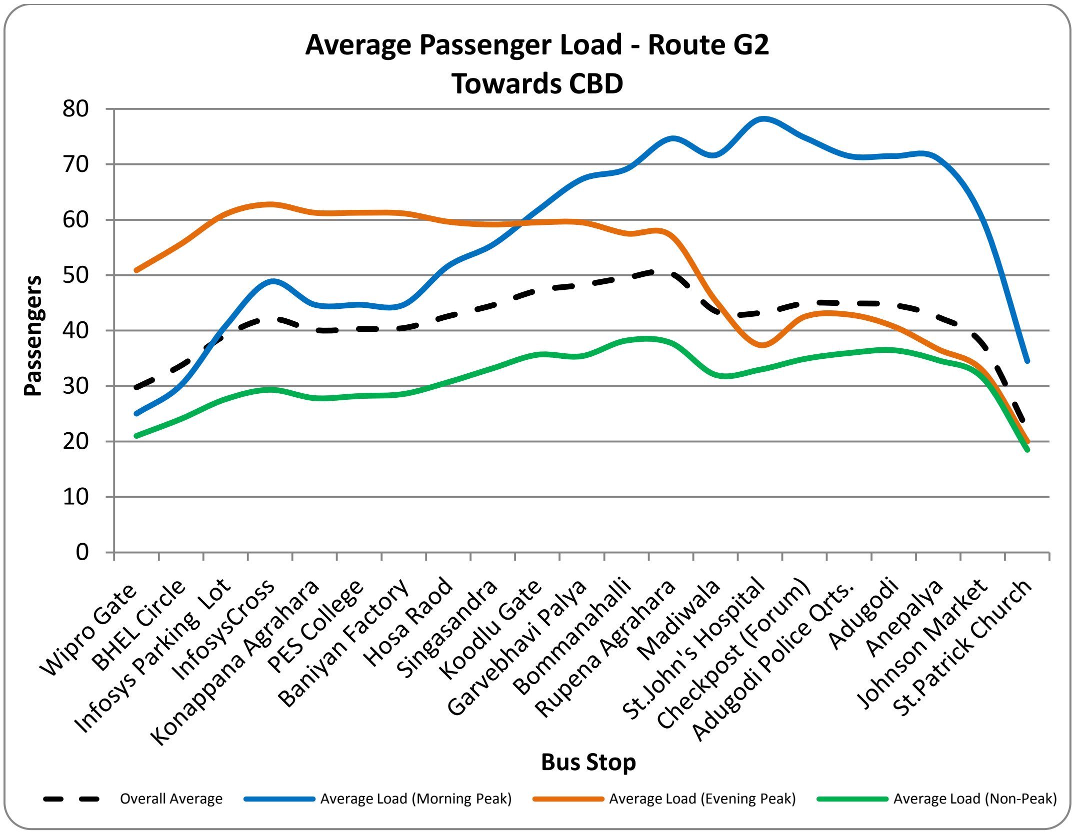
- Route G2:

The passenger load curves for route G2, shown in Figure 7, also offer a similar conclusion. The loads are above seating capacity for more than half the route length during the peak periods. During the non-peak period also, the passenger demand is near capacity, thus resulting in greater EPKM from this route.

An interesting finding on this route is that morning peak passenger traffic is moving away from the Silk Board junction in both directions - towards Brigade Road and also towards Electronic City. The exact reverse pattern is seen in the evenings where the peak direction flow is towards Silk Board junction from both ends.

Figure 7: Average Passenger Load for Route G2



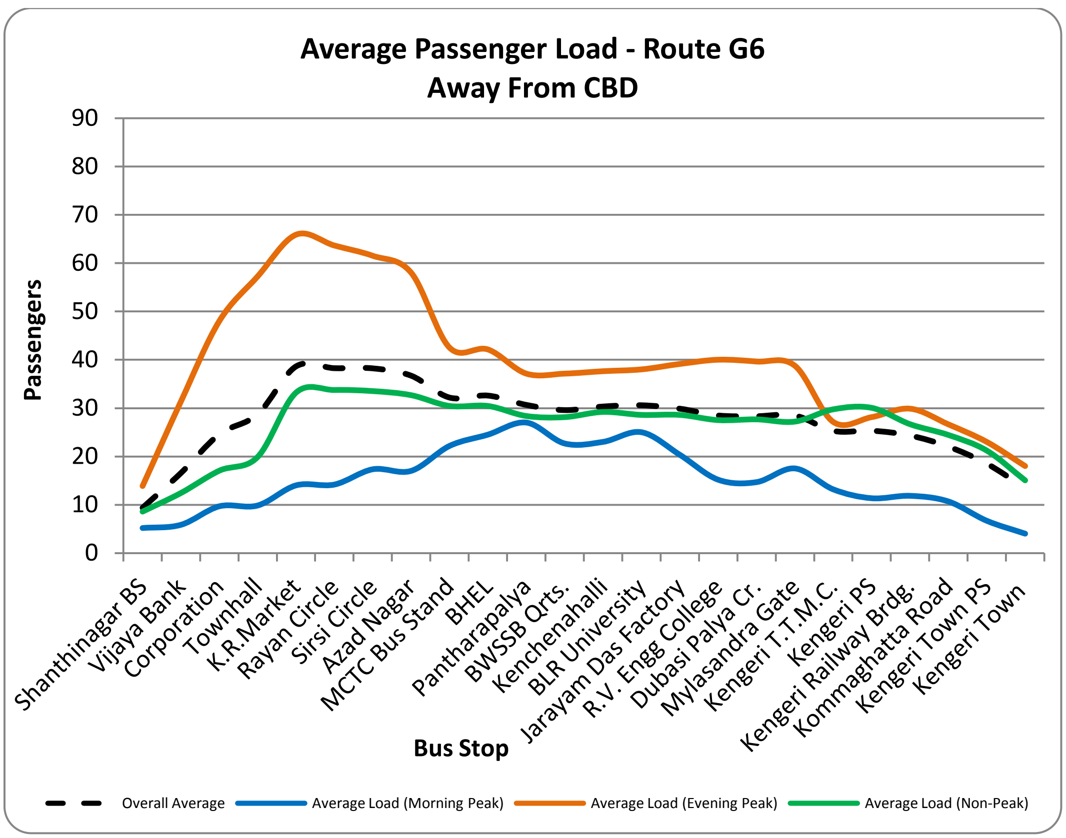


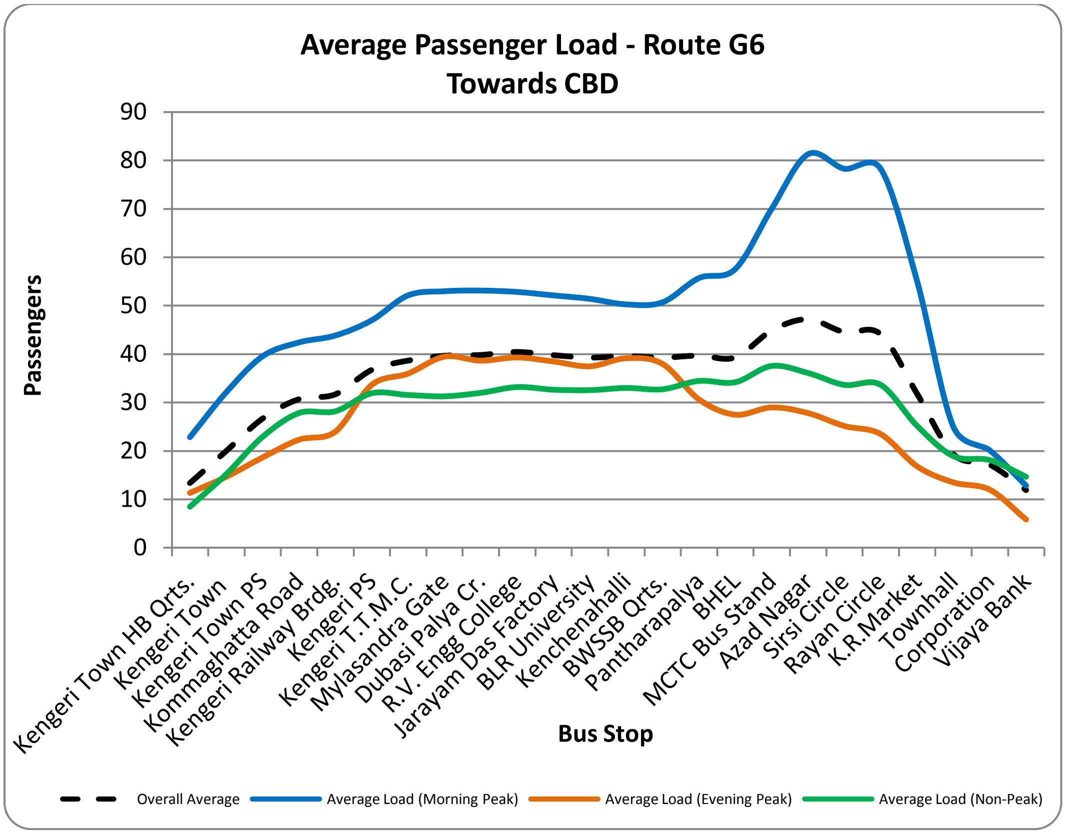
Average Passenger Load - Route G2
Towards CBD
Passengers
80
70
60
50
40
30
20
10
0
Wipro Gate
BHEL Circle
Infosys Parking Lot
InfosysCross
Konappana Agrahara
PES College
Baniyan Factory
Hosa Raod
Singasandra
Koodlu Gate
Garvebhavi Palya
Bommanahalli
Rupena Agrahara
Madiwala
St.John's Hospital
Checkpost (Forum)
Adugodi Police Qrts.
Adugodi
Anepalya
Johnson Market
St.Patrick Church
Bus Stop
Overall Average
Average Load (Morning Peak)
Average Load (Evening Peak)
Average Load (Non-Peak)

- <u>Route G6:</u>

The passenger demand on route G6 is unidirectional during the peaks periods. The demand is heavier towards CBD in the morning peak and towards Kengeri in the evening peak. The demand in the opposite directions during these periods is well below the supply. Such situations are common in many urban areas and result in a reduced average EPKM. Another observation is that the highest demand is seen between Corporation Office and BHEL and then tapers down for the rest of the route. This situation indicates an opportunity to run more short distance buses between these points to improve the level of service and thus attract greater mode-share for public transport. Figure 8 shows the details for the entire route.

Figure 8: Average Passenger Load for Route G6



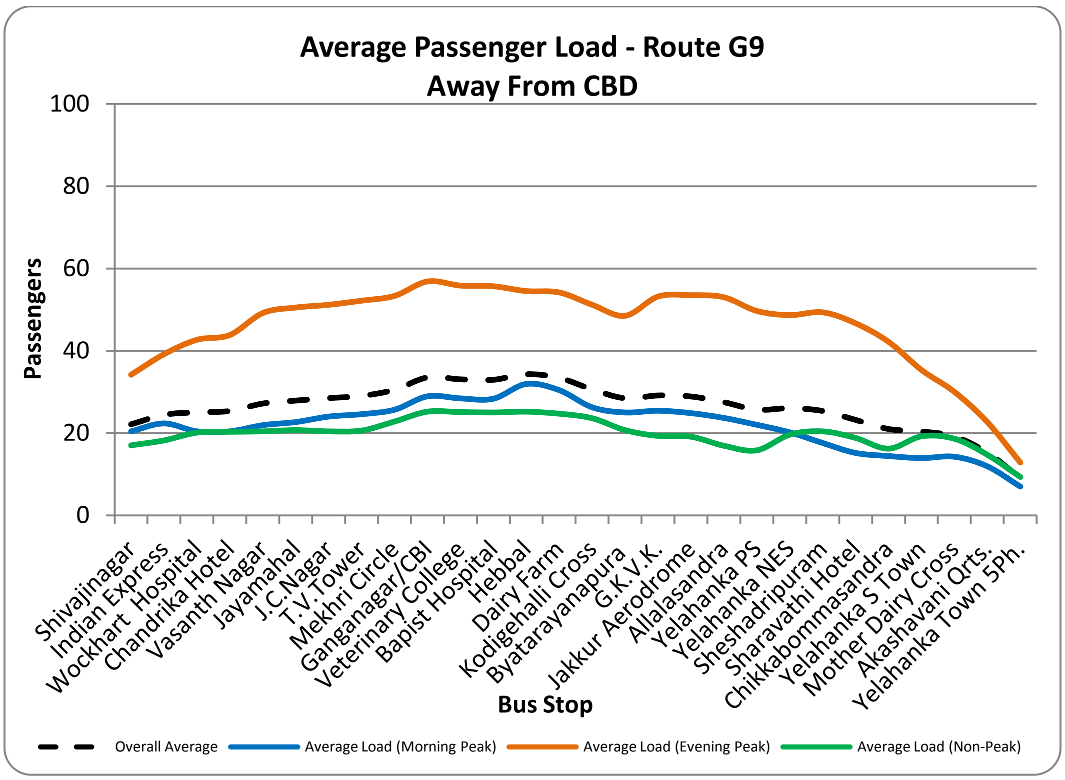


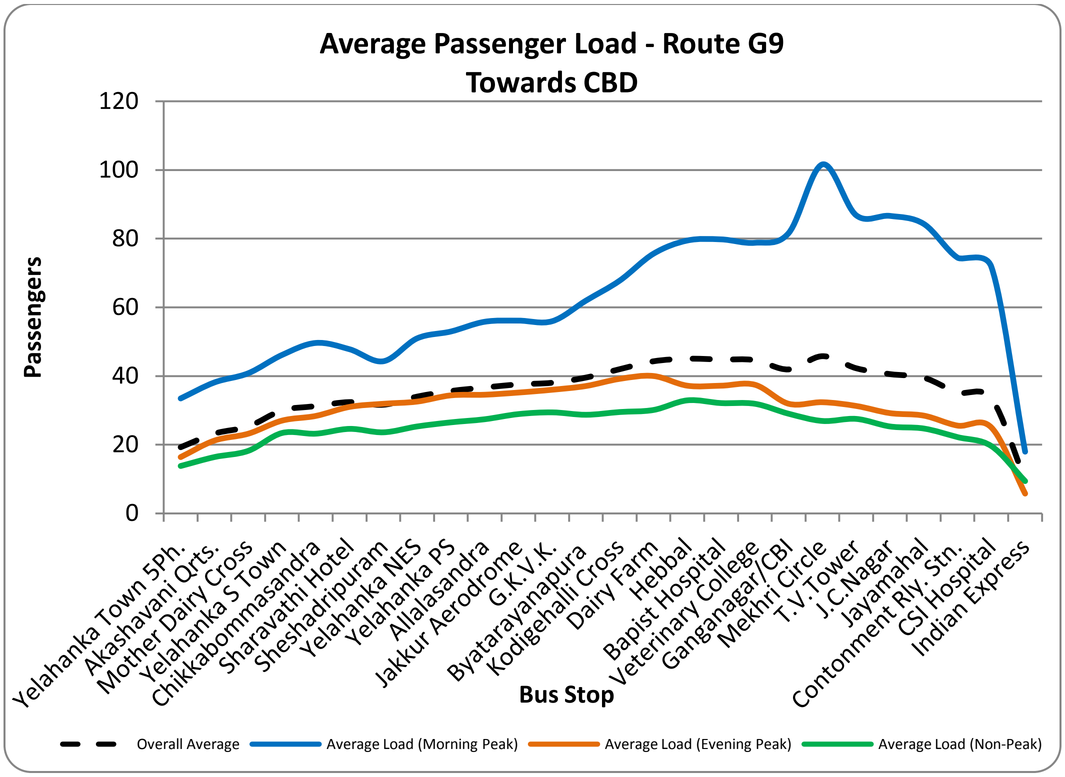
Average Passenger Load - Route G6
Towards CBD
Passengers
90
80
70
60
50
40
30
20
10
0
Kengeri Town HB Qrts.
Kengeri Town
Kengeri Town PS
Kommaghatta Road
Kengeri Railway Brdg.
Kengeri PS
Kengeri T.T.M.C.
Mylasandra Gate
Dubasi Palya Cr.
R.V. Engg College
Jarayam Das Factory
BLR University
Kenchenahalli
BWSSB Qrts.
Pantharapalya
BHEL
MCTC Bus Stand
Azad Nagar
Sirsi Circle
Rayan Circle
K.R.Market
Townhall
Corporation
Vijaya Bank
Bus Stop
Overall Average
Average Load (Morning Peak)
Average Load (Evening Peak)
Average Load (Non-Peak)

- <u>Route G9:</u>

From Figure 9, passenger demand on route G9 is towards the CBD during the morning peak and towards Yelahanka in the evening. The steep increase in demand between Dairy Farm and Cantonment Railway Station indicates a need for additional short distance services between these two locations during the morning peak. The demand in the opposite directions and during non-peak hours is flat but reasonable. This is indicative of longer trip lengths as also concluded from the ETM data analysis.

<u>Figure 9: Average Passenger Load for Route G9</u>



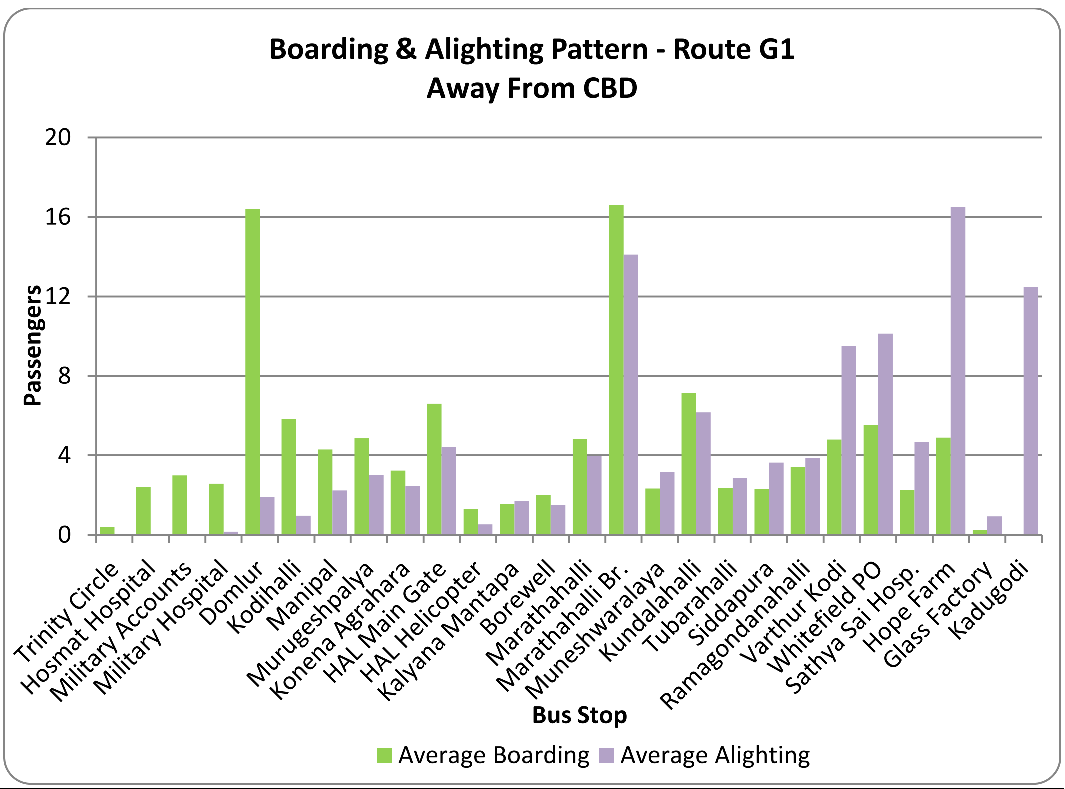

Average Passenger Load - Route G9
Towards CBD
Passengers
120
100
80
60
40
20
0
Yelahanka Town 5Ph.
Akashavani Qrts.
Mother Dairy Cross
Yelahanka S Town
Chikkabommasandra
Sharavathi Hotel
Sheshadripuram
Yelahanka NES
Yelahanka PS
Allalasandra
Jakkur Aerodrome
G.K.V.K.
Byatarayanapura
Kodigehalli Cross
Dairy Farm
Hebbal
Bapist Hospital
Veterinary College
Ganganagar/CBI
Mekhri Circle
T.V.Tower
J.C.Nagar
Jayamahal
Contonment Rly. Stn.
CSI Hospital
Indian Express
Bus Stop
Overall Average
Average Load (Morning Peak)
Average Load (Evening Peak)
Average Load (Non-Peak)

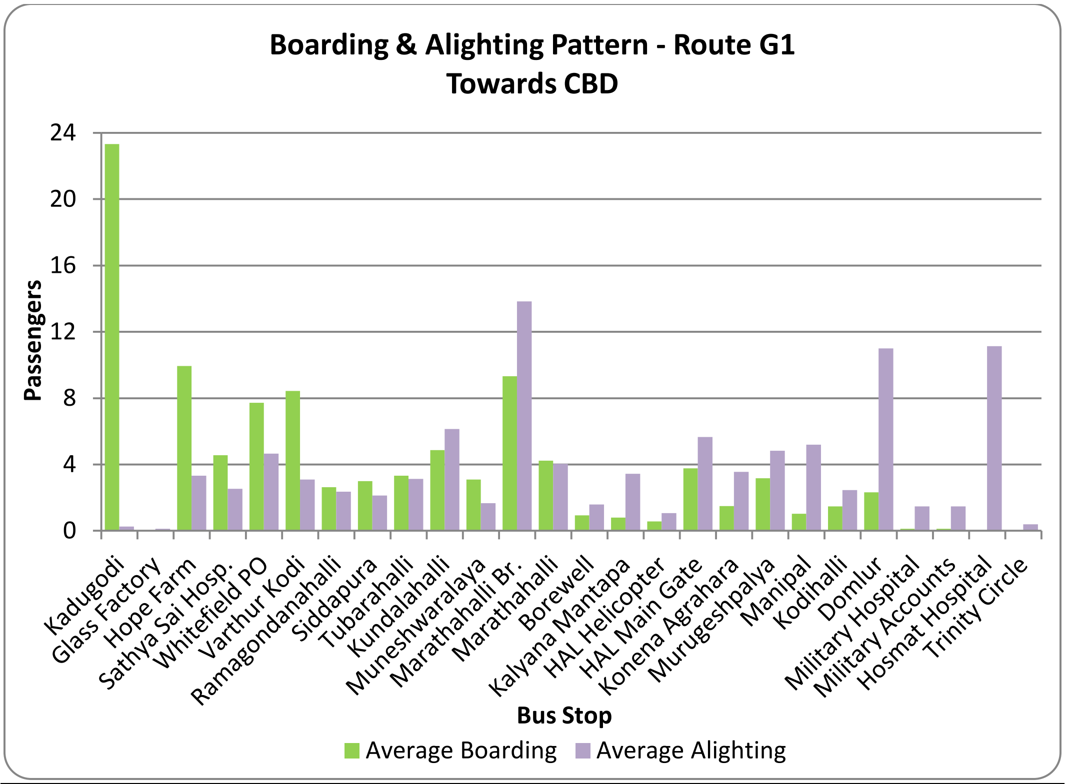
Boarding & Alighting Patterns

This section analyses the demand characteristics of the route based on the actual boarding and alighting pattern of passengers at various stops along the routes. The figures in this section help to visualize the B&A patterns in order to identify stops where there are high levels of activity, possibly implying the need for a transfer hub.

- Route G1:
  From Figure 10, it can be seen that there is significant B&A activity at Marathahalli Bridge stop in both the directions. This one stop accounts for 13% of all boarding and alighting activity along this route. The passenger load graph in the earlier section (Figure 6) however is smooth and does not show this high activity at Marathahalli stop as the number of passengers getting on and off is nearly the same.

Figure 10: Boarding & Alighting Patterns on Route G1



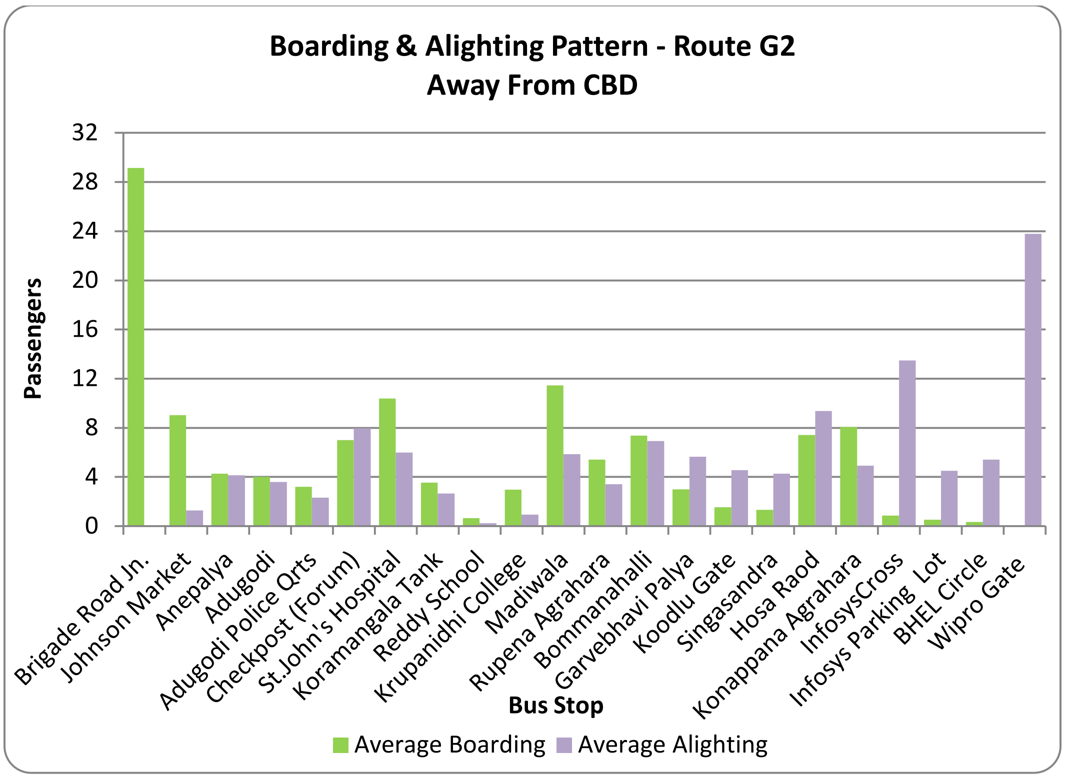


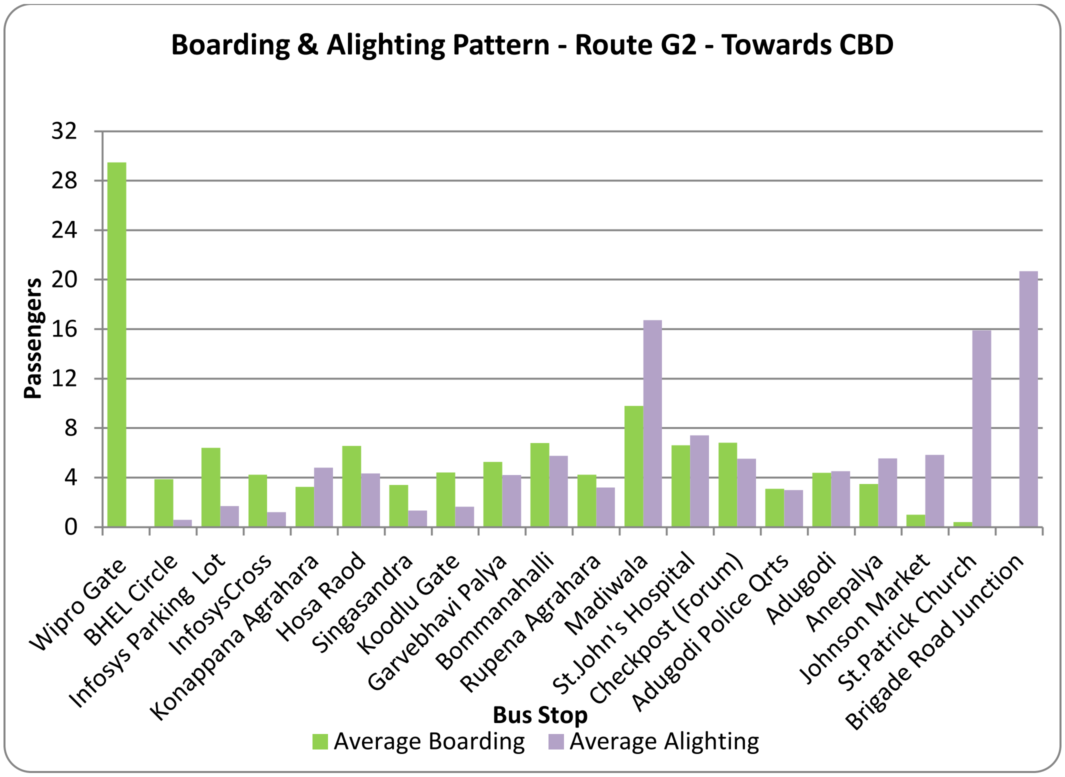
Boarding & Alighting Pattern - Route G1
Towards CBD
Passengers
24
20
16
12
8
4
0
Kadugodi
Glass Factory
Hope Farm
Sathya Sai Hosp.
Whitefield PO
Varthur Kodi
Ramagondanahalli
Siddapura
Tubarahalli
Kundalahalli
Muneshwaralaya
Marathahalli Br.
Marathahalli
Borewell
Kalyana Mantapa
HAL Helicopter
HAL Main Gate
Konena Agrahara
Murugeshpalya
Manipal
Kodihalli
Domlur
Military Hospital
Military Accounts
Hosmat Hospital
Trinity Circle
Bus Stop
Average Boarding
Average Alighting

- <u>Route G2:</u>

  Figure 11 shows that on route G2, there is increased B&A activity at the stops on either side of the Silk Board junction (Madiwala and Roopena Agrahara). On average, 60 of the 472 passengers (13%) either board or alight at these two stops. This indicates that Silk Board junction is a prominent transfer point on this route. Providing a convenient transfer hub at this point with reliable connectivity options will result in a favorable outcome for BMTC.

<u>Figure 11: Boarding & Alighting Patterns on Route G2</u>

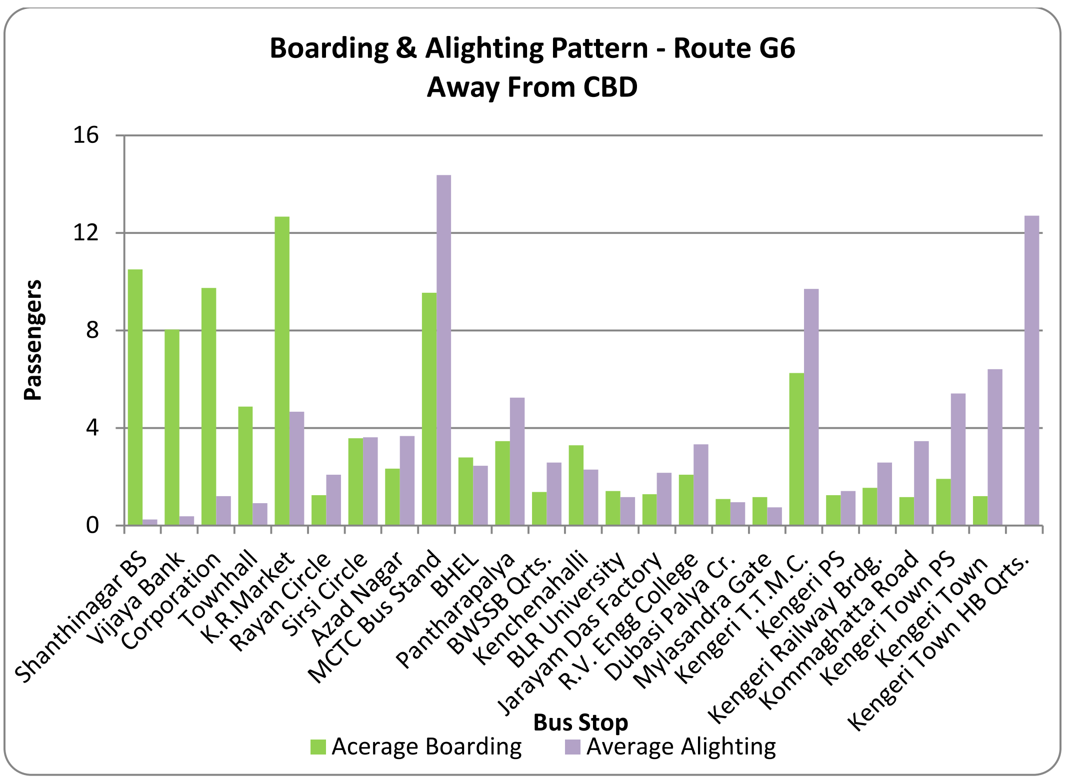


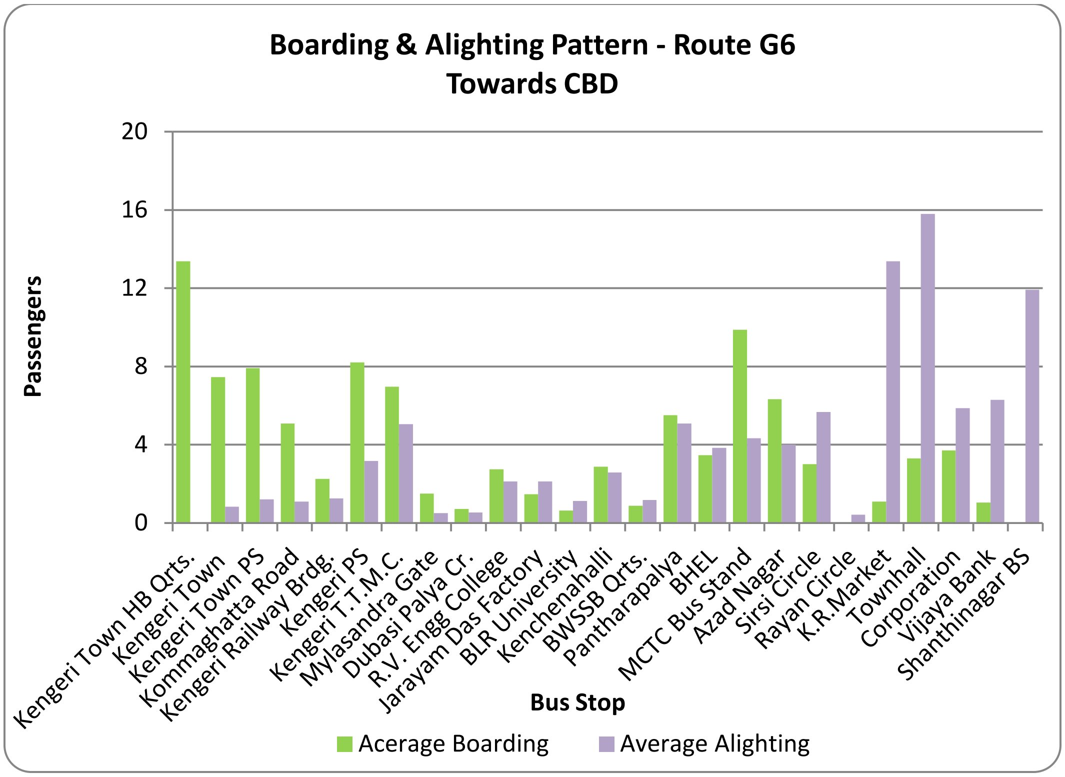

Boarding & Alighting Pattern - Route G2 - Towards CBD
Passengers
32
28
24
20
16
12
8
4
0
Wipro Gate
BHEL Circle
Infosys Parking Lot
InfosysCross
Konappana Agrahara
Hosa Raod
Singasandra
Koodlu Gate
Garvebhavi Palya
Bommanahalli
Rupena Agrahara
Madiwala
St.John's Hospital
Checkpost (Forum)
Adugodi Police Qrts
Adugodi
Anepalya
Johnson Market
St.Patrick Church
Brigade Road Junction
Bus Stop
Average Boarding
Average Alighting

- Route G6:

  On the G6 route, 13% of the entire route's B&A activity in the out-bound direction (CBD to Kengeri) occurs at MCTC, though it is not as pronounced on the in-bound route. This conclusion was also derived from the passenger load curves in the previous section as the boarding and alighting passengers are not equal. On the whole, 10% (38) of the 387 boarding & alighting passengers on the route occur at this stop.

Figure 12: Boarding & Alighting Patterns on Route G6



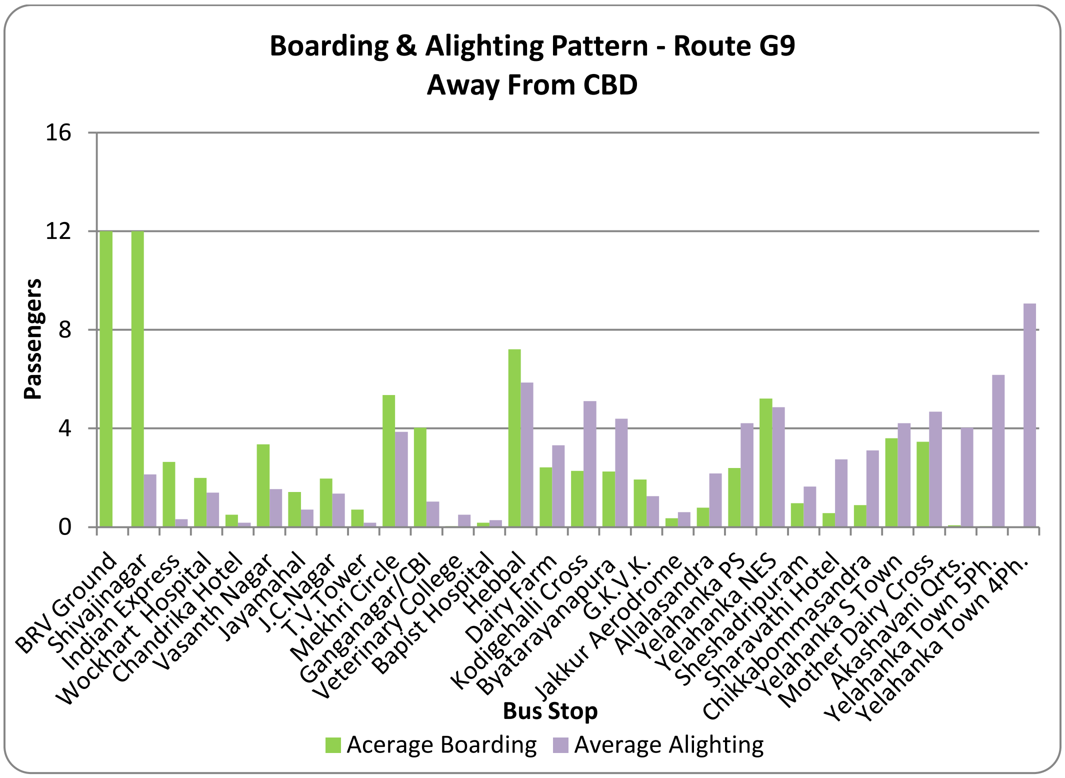


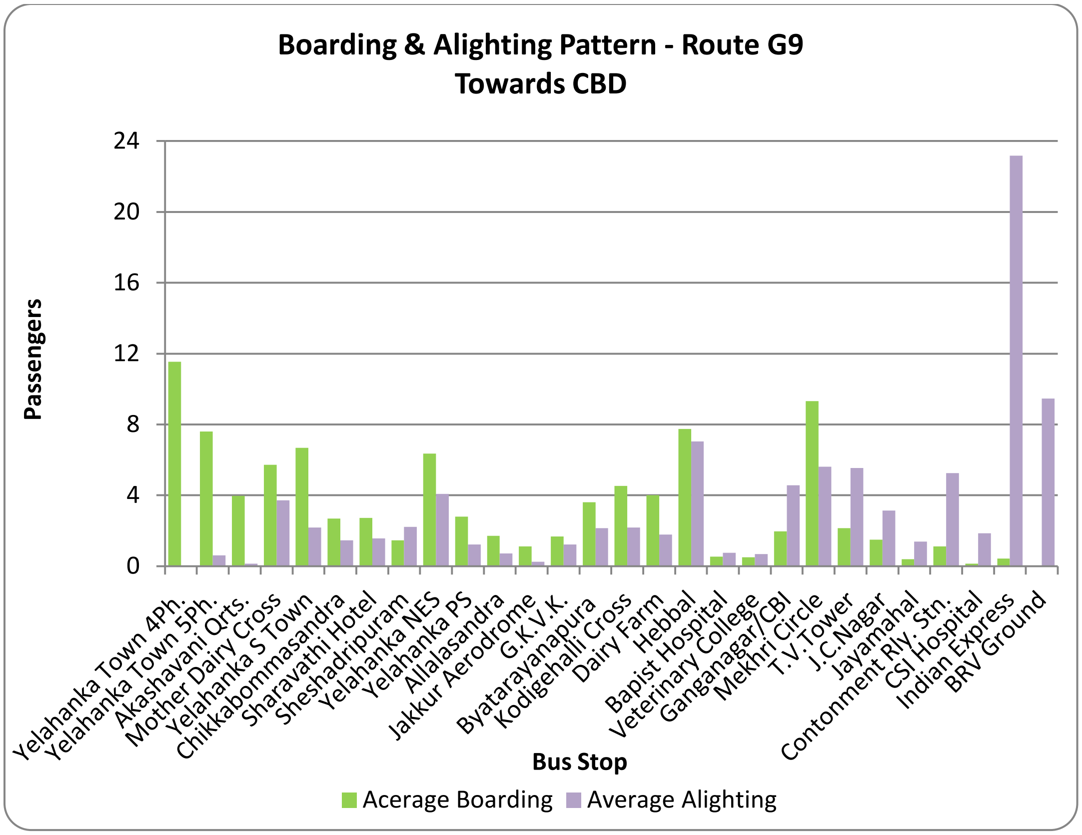
Boarding & Alighting Pattern - Route G6
Towards CBD
Passengers
20
16
12
8
4
0
Kengeri Town HB Qrts.
Kengeri Town
Kengeri Town PS
Kommaghatta Road
Kengeri Railway Brdg.
Kengeri PS
Kengeri T.T.M.C.
Mylasandra Gate
Dubasi Palya Cr.
R.V. Engg College
Jarayam Das Factory
BLR University
Kenchenahalli
BWSSB Qrts.
Pantharapalya
BHEL
MCTC Bus Stand
Azad Nagar
Sirsi Circle
Rayan Circle
K.R.Market
Townhall
Corporation
Vijaya Bank
Shanthinagar BS
Bus Stop
Acerage Boarding
Average Alighting

- <u>Route G9:</u>

  The B&A of passengers on route G9, other than those happening at the end of the routes, are distributed evenly across the route. Hebbala and Mekhri Circle stops on the route account for 8% and 7% of the 350 B&A's respectively.

<u>Figure 13: Boarding & Alighting Patterns on Route G9</u>





The above analysis suggests that there is a significant amount bus-transfer activity occurring at the intersection of the Outer Ring Road (ORR) with the radial routes. Physical examination of these sites shows that there are no provisions for passengers making these transfers. As indicated earlier, providing convenient transfer facilities at these locations will result in improving passengers' opinions of the quality-of-service offered by the public transport system.

Passenger Load Factor Analysis

Passenger Load Factor (LF), which is computed as the ratio of passenger kilometers serviced by a route to seat kilometers supplied, is another important performance indicator. Passenger kilometers serviced is computed by adding the product of number of passengers on a bus between two consecutive stops with the distance between the stops for the entire route.

Table 7 shows the statistics that were computed in order to compare the four study routes on this parameter. If the LF value is less than 1, it indicates spare capacity in the bus. Similarly, a value well above 1 indicates that the buses on the route are crowded. While LF greater than 1 may result in higher revenue, it has an adverse impact on the level-of-service, thus reducing the attractiveness of the service. Hence, scheduling of buses on a route should aim at achieving a LF close to 1 during peak and non-peak periods.

Table 7: Passenger Load Factor Analysis

Parameter	G1	G2	G6	G9
Route Length (Round-trip) (Km)	42.0	41.8	42.0	38.6
Seat Kilometers (assuming 44 seats/bus)	1850	1840	1850	1700
Passenger Kilometers Serviced:				
Daily Average Round-trip	1354	1779	1314	1228
Daily Average Load Factor	0.73	0.97	0.71	0.72
Morning Peak Period Round-trip	1530	2252	1385	1681
Evening Peak Period Round-trip	1844	2016	1423	1517
Non-peak Period Round-trip	901	1423	1143	883

Route G2 has an ideal LF of 0.97 on a daily average basis but varies between 0.77 and 1.23 during non-peak and peak periods. The LF on the other three routes is almost equal at about 0.72 on a daily average. The variation in LF is the least on route G6 with a minimum of 0.62 during non-peak hours and maximum of 0.77 during evening peak.

The above statistic is also of importance as it shows the social/environmental benefits of the public transportation system in terms of carbon emission reductions, de-congestion of roadway space and so on. On the basis of Table 7, route G6 actually measures just as good as route G9 and route G1.

At the current levels of service of the public transport system, every bus kilometer caters to between 31 and 43 passenger kilometers on an average and up to 54 passenger kilometers during peak period. This data can be used to calculate particulate matter and carbon emission saving. However this will require measurements of congestion levels on the routes, mode shares of other transport means, occupancy levels in such modes and emission factors of those vehicle types.

Service Quality Analysis:

This section will deal with an analysis of the quality of supply-side, or operational, characteristics of the Big10 system.

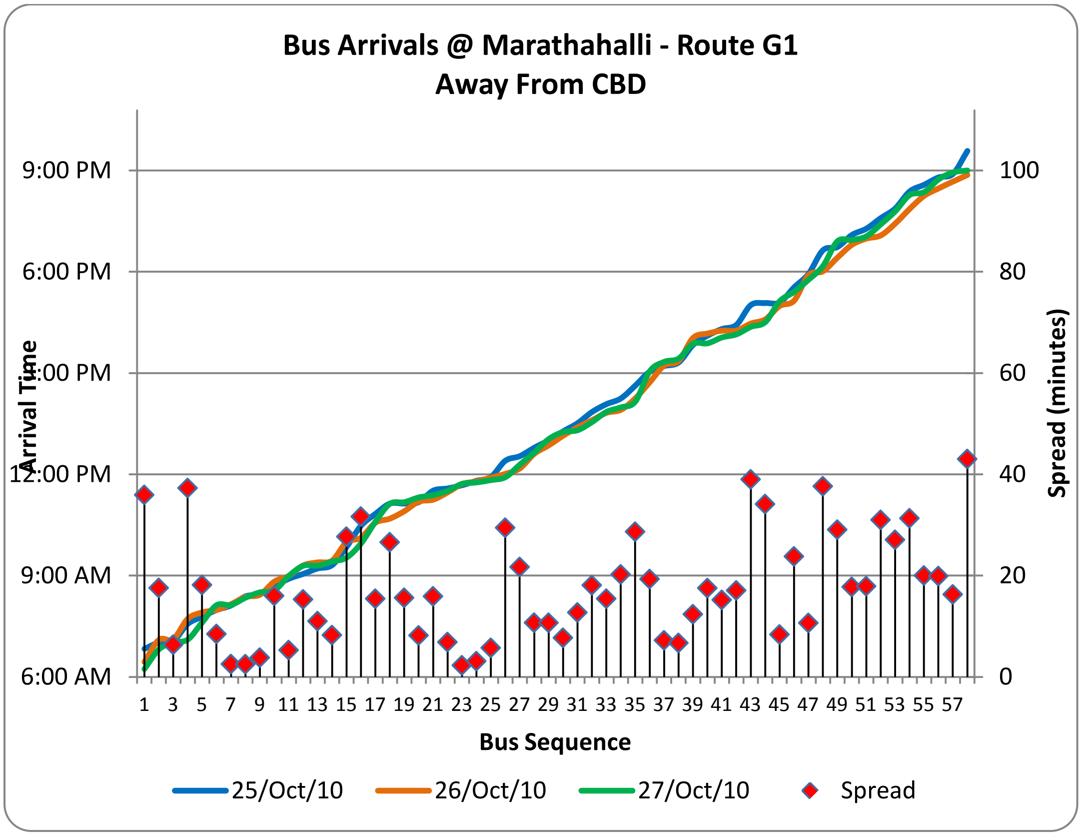
Arrival Patterns

Buses along a single route should follow a predictable arrival pattern, so that passenger wait times are consistent from day to day. By charting the arrival time of buses at different stops on a given route over multiple days, the level of consistency offered by the service can be determined.

Time-stamps from the GPS data were used for the purpose of this analysis. Though the GPS data is not available for all the schedules, bus trip information for the functional units is complete and hence can be compared for the timeliness of bus arrivals at bus-stops over many days. The same data however cannot be used for the head-way analysis as this requires data from all the buses operated on the route.

In the charts below, Figures 14 to 17, each line represents the sequence of arrival of buses at stops along the route for 3 days, from 25th to 27th October 2010. Since the scale of the y-axis is very large, it is difficult to ascertain the actual variation in the arrivals. Hence, the spread (shown as red dotted bars), which represents the time variation in minutes between the arrivals of a particular bus on the three study days is plotted on the secondary Y-axis. The reliability of the services is highest if the arrival sequence curves for different days overlap each other and the spread is closest to 0 on all days.

Figure 14: Arrival Pattern of Buses on Route G1 at Marathahalli



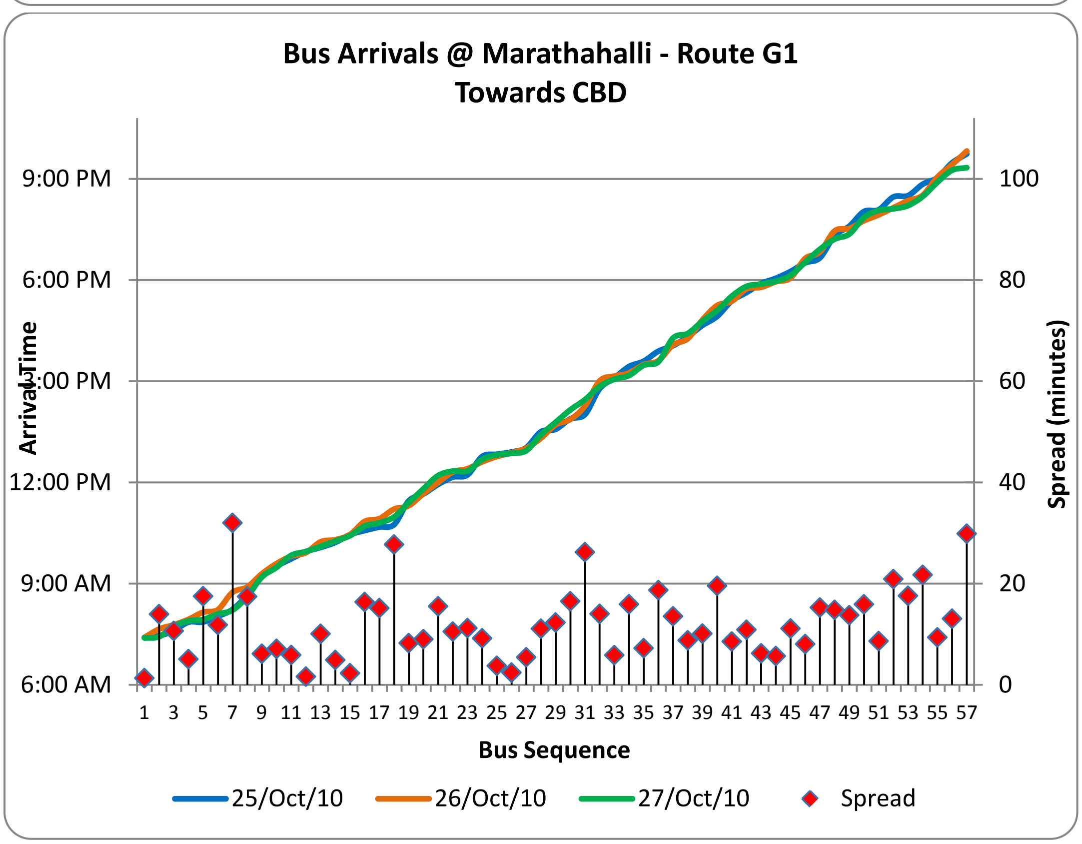
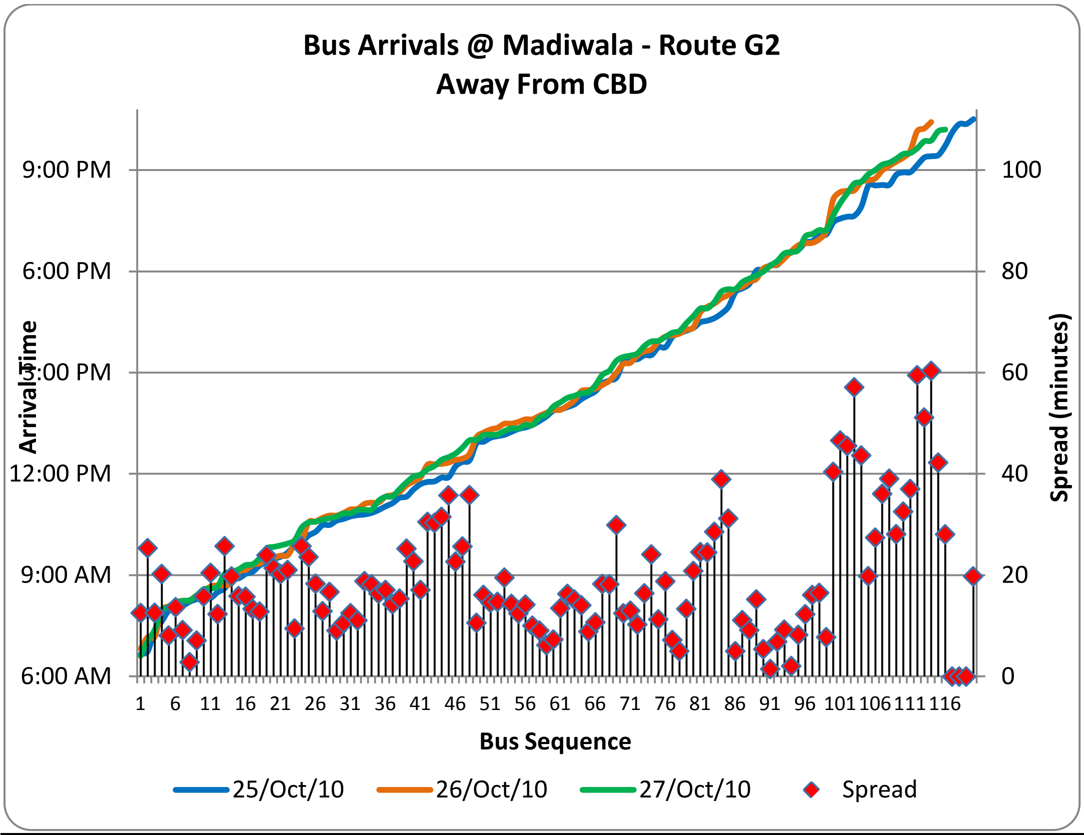


Figure 15: Arrival Pattern of Buses on Route G2 at Madiwala



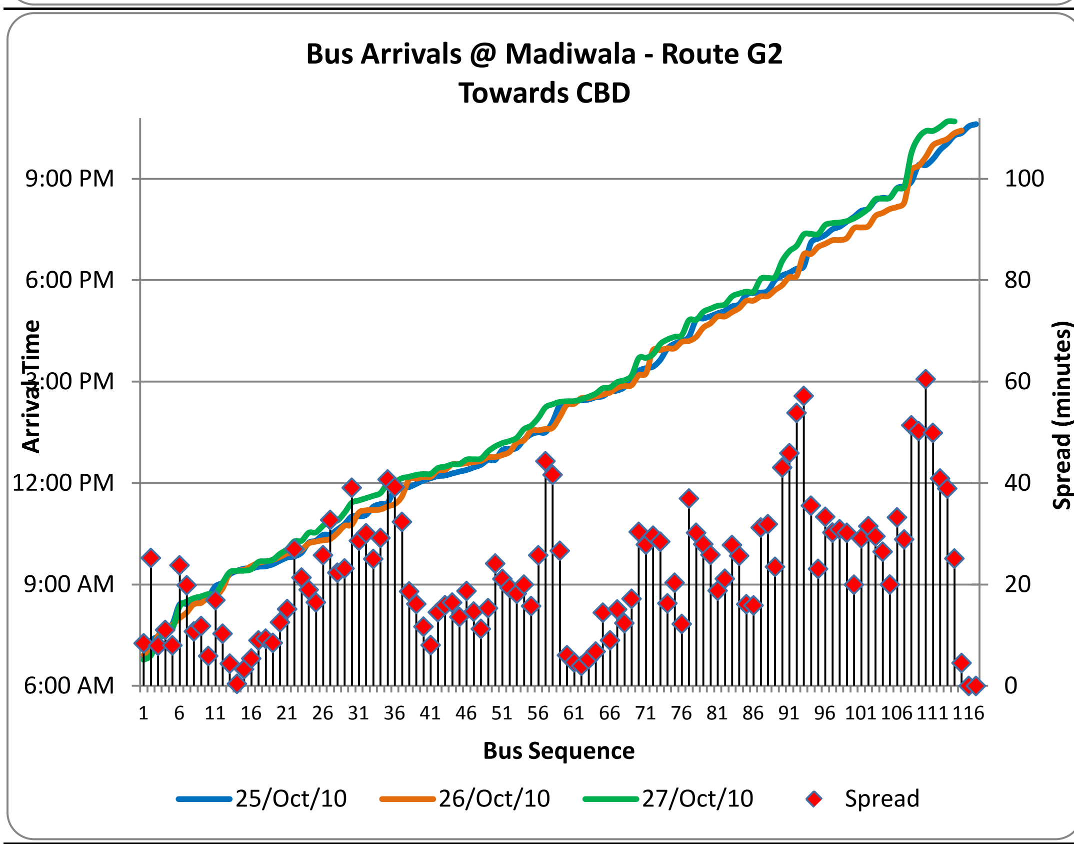
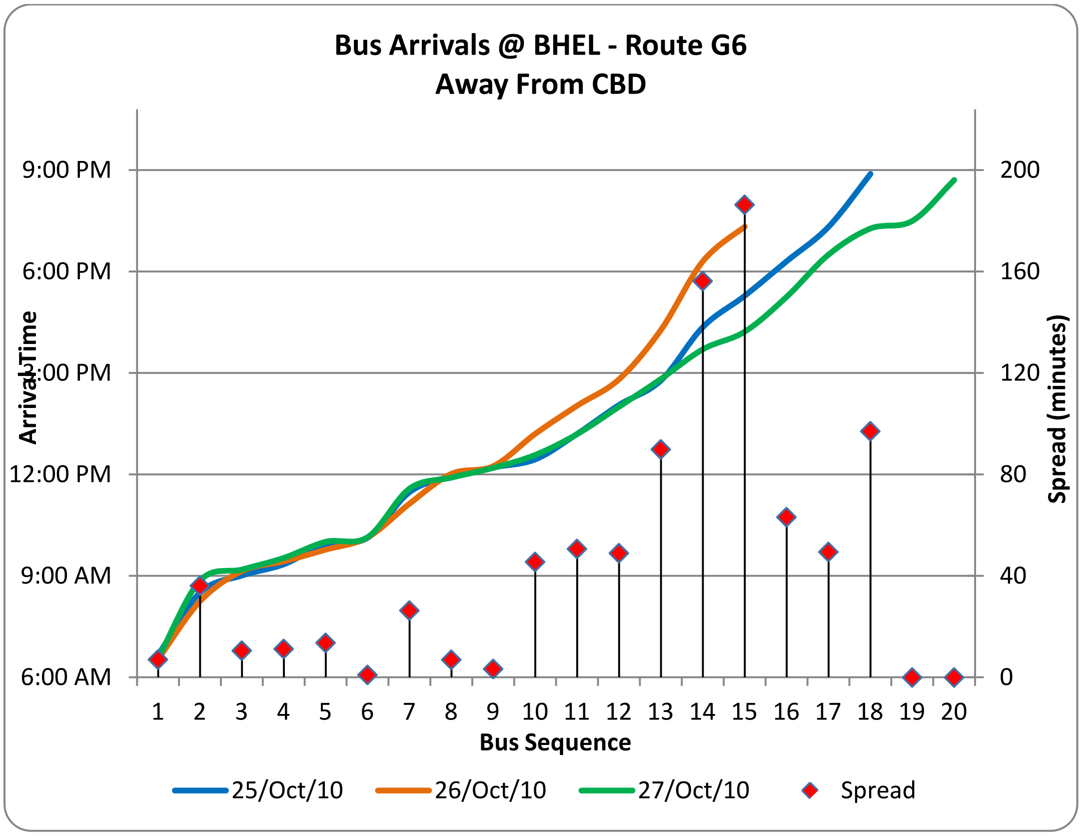


Figure 16: Arrival Pattern of Buses on Route G6 at BHEL



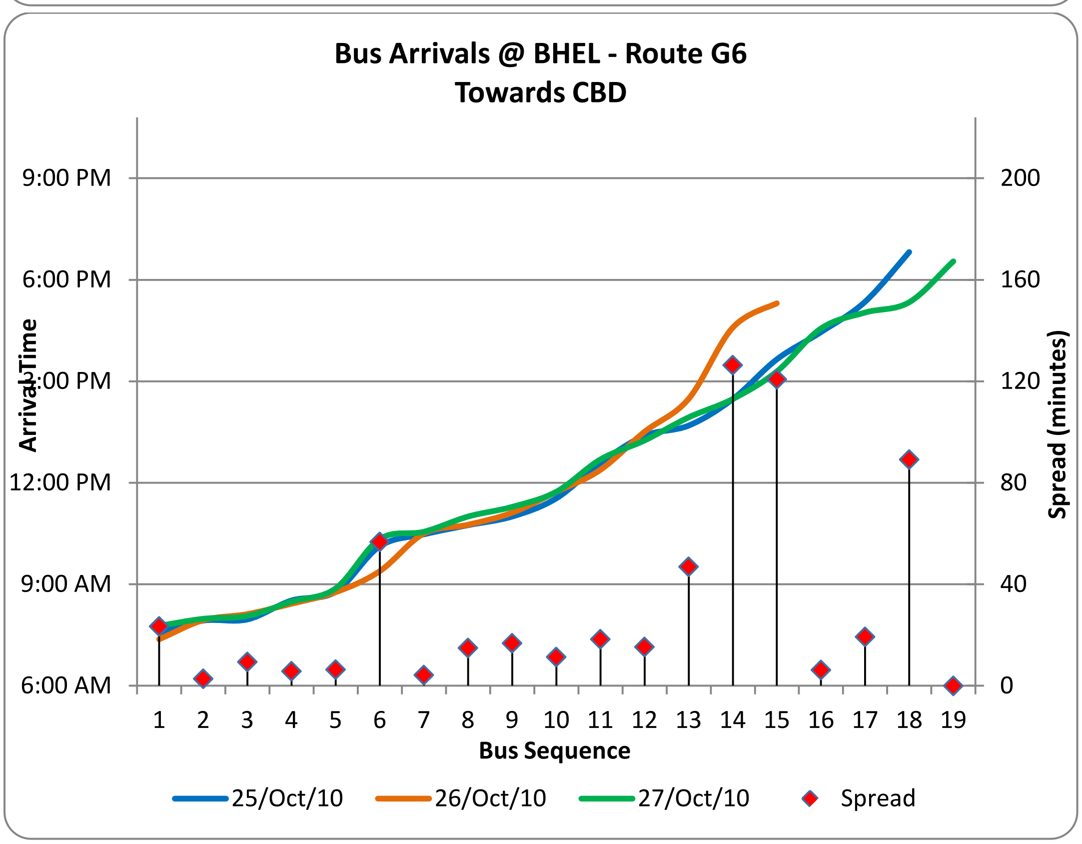
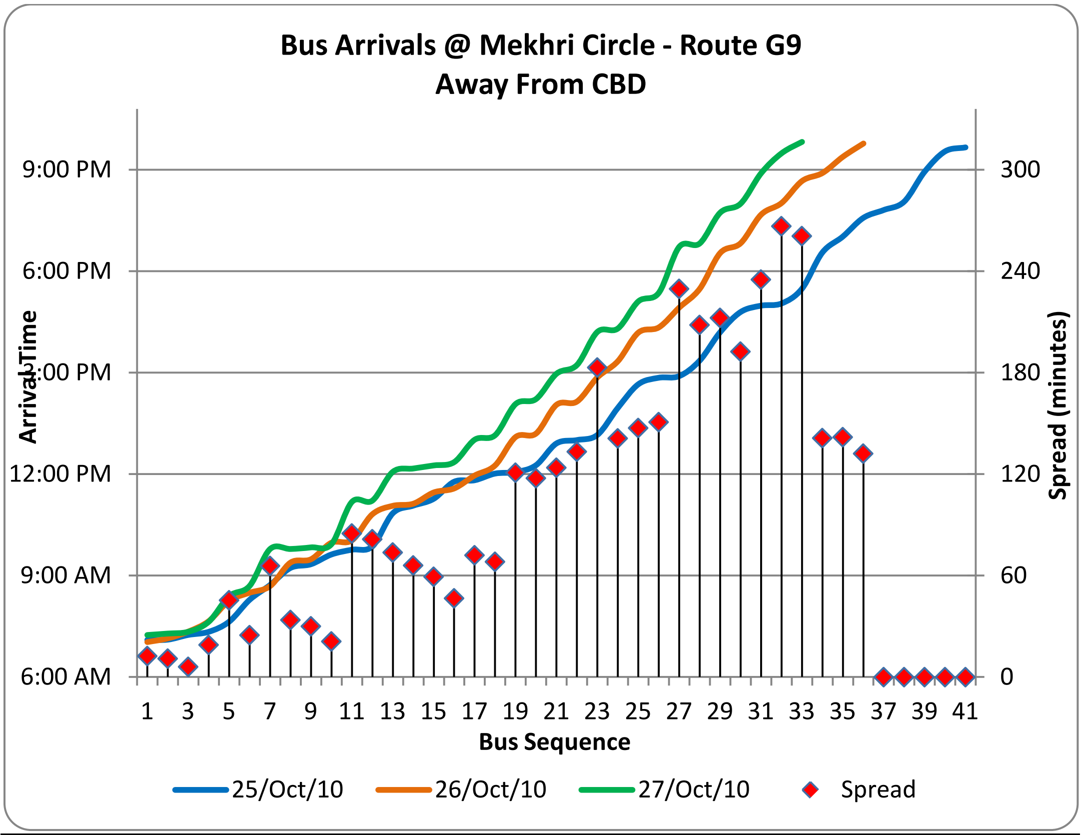
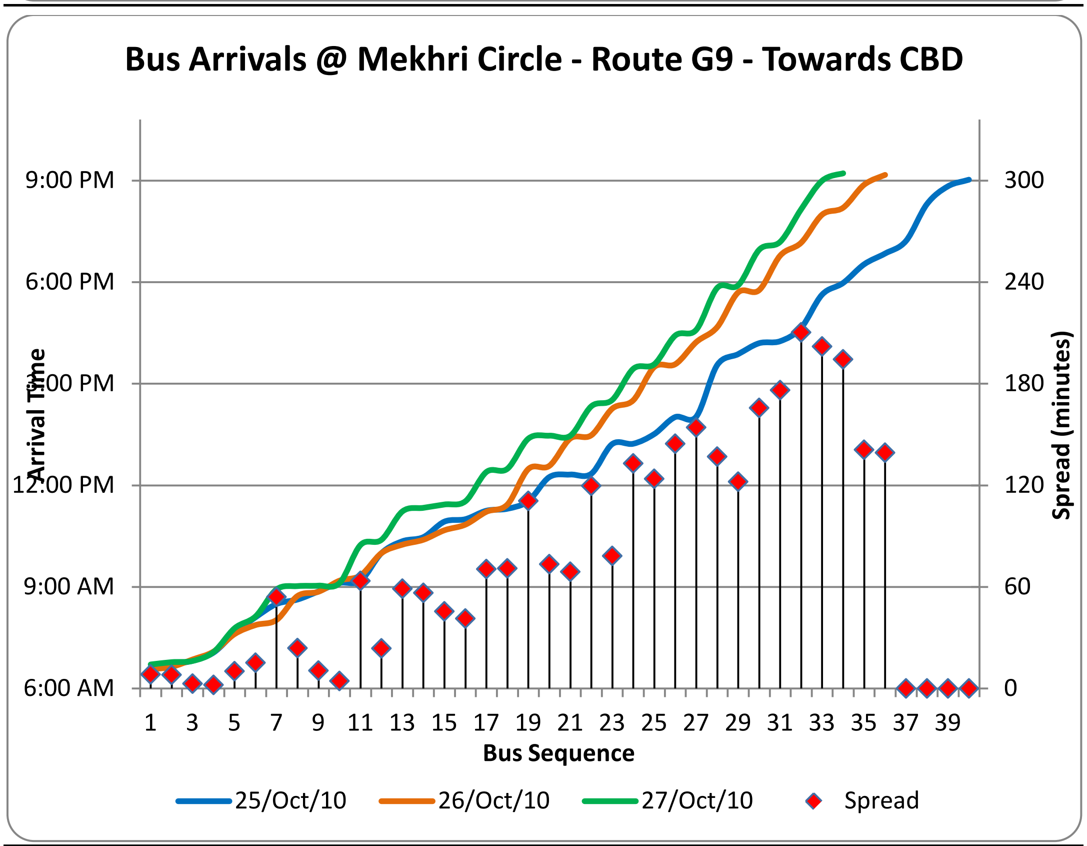


Figure 17: Arrival Pattern of Buses on Route G9 at Mekhri Circle





Following are the observations from the above figures.

1. Number of trips operated on each route is not the same on all the days. Trips were either curtailed due to delays or have been diverted to other routes.
2. Almost all the routes show a step pattern rather than a smooth curve, indicating bunching of buses (more than one bus arriving at the same time). This is also an indication of congestion. This pattern is more predominant on route G9.
3. The variation in arrival is minimal during the early hours of the day but starts to increase continuously from the end of the morning peak, thus reducing the reliability of the operations during the rest of the day.
4. Among the routes considered in the study, route G1 has the least spread in arrivals through the day, even though route G2 has almost double the number of buses running on the route. This is primarily because of fewer intersections and traffic signals on the G1 route. This shows that the reliability of a bus service cannot be achieved merely by increasing the number of trips on a route but also requires some kind of infrastructure improvements and priority for buses.

Headway Analysis

Headway analysis is another method of assessing the performance of public transport operations. Headway is the time between the departure of one bus and the arrival of the next bus at a stop. The average wait time for a passenger equals half the headway of the buses on a particular route. Hence, this is an important measure of operational performance. The statistics presented in Table 8 are based on the arrival times observed at select bus-stops where the bus occupancy survey was conducted. The average headway on a route is a directly dependent on the number of buses plying on that route and the length of the route. The standard deviation is a measure of variation from the mean and hence indicates the reliability. The reliability of a route is high if the standard deviation is close to zero, which means that the headway is constant throughout a certain time-period.

Table 8: Headway Statistics at Select Stops

Route	G1	G2	G6	G9
Place Name:	**Domlur**	**Adugodi**	**MCTC**	**Jayamahal**
Date of Survey	20-Dec-10	20-Dec-10	20-Dec-10	20-Dec-10
No. of trips observed on route	80	168	23	70
Morning Peak – Trips (3hrs)	17	38	7	10
Morning Peak – Average Headway (min)	11	5	28	18
Morning Peak – Std. Deviation (min)	9	4	16	18
Evening Peak – Trips (3hrs)	16	34	6	16
Evening Peak – Average Headway (min)	11	5	33	12
Evening Peak – Std. Deviation (min)	10	4	33	6
Non-Peak – Trips	47	96	10	44
Non-Peak – Average Headway (min)	12	6	63	14
Non-Peak – Std. Deviation (min)	8	5	20	8
Place Name:	**Marathahalli**	**Madiwala**	**BLR University**	**Mekhri Circle**
Date of Survey	21-Dec-10	21-Dec-10	22-Dec-10	22-Dec-10
No. of trips observed on route	84	160	24	67
Morning Peak – Trips (3hrs)	19	34	6	12
Morning Peak – Average Headway (min)	9	5	33	15
Morning Peak – Std. Deviation (min)	6	5	15	13
Evening Peak – Trips (3hrs)	16	32	5	15
Evening Peak – Average Headway (min)	11	6	40	12
Evening Peak – Std. Deviation (min)	8	5	22	9
Non-Peak – Trips	49	94	13	40
Non-Peak – Average Headway (min)	11	6	42	15
Non-Peak – Std. Deviation (min)	8	7	27	8

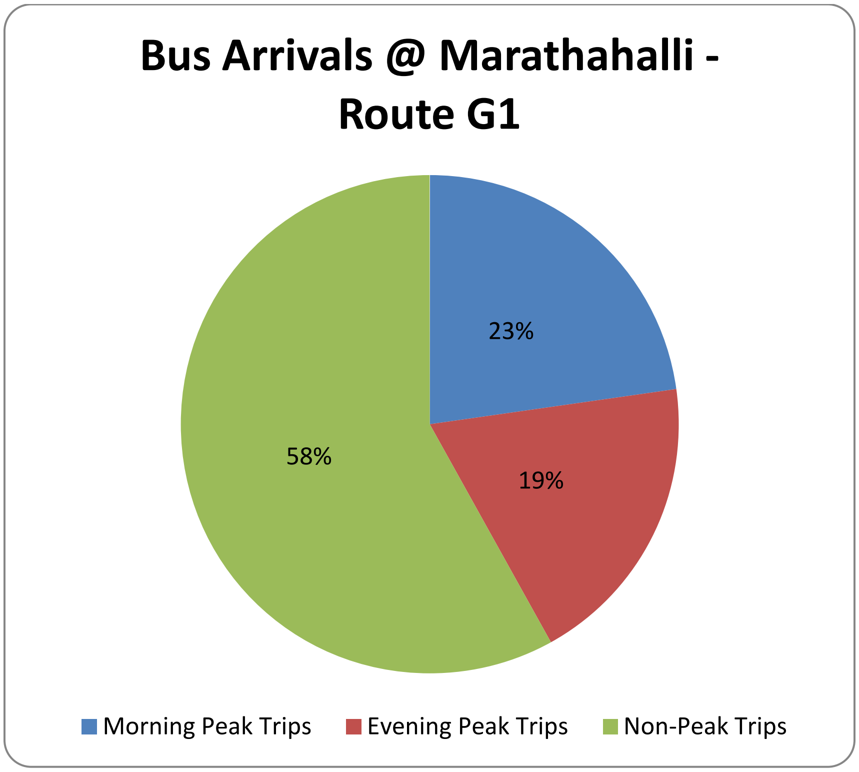
From Table 8, it can be seen that on all four routes the standard deviation is greater than 50% of the average headway in all three time periods. This indicates low reliability of the service from the passenger's point of view. This high degree of variation can be caused either because of scheduling problems or because of varying travel times due to traffic congestion. Hence, these results indicate the need to monitor travel times on the routes and plan the schedules to achieve a constant headway.

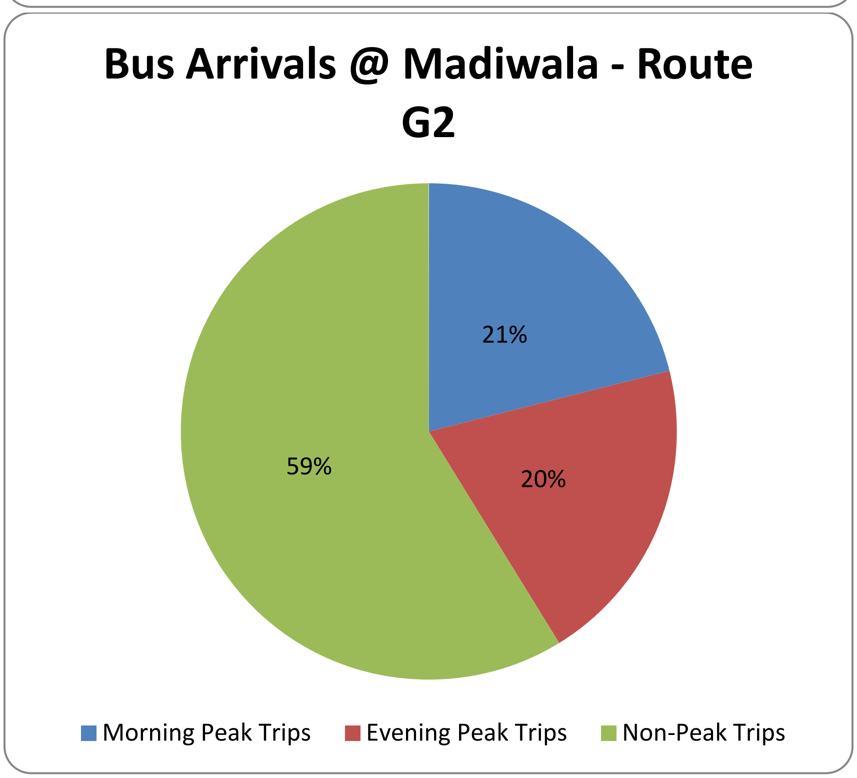
Bus Arrivals by Time Period

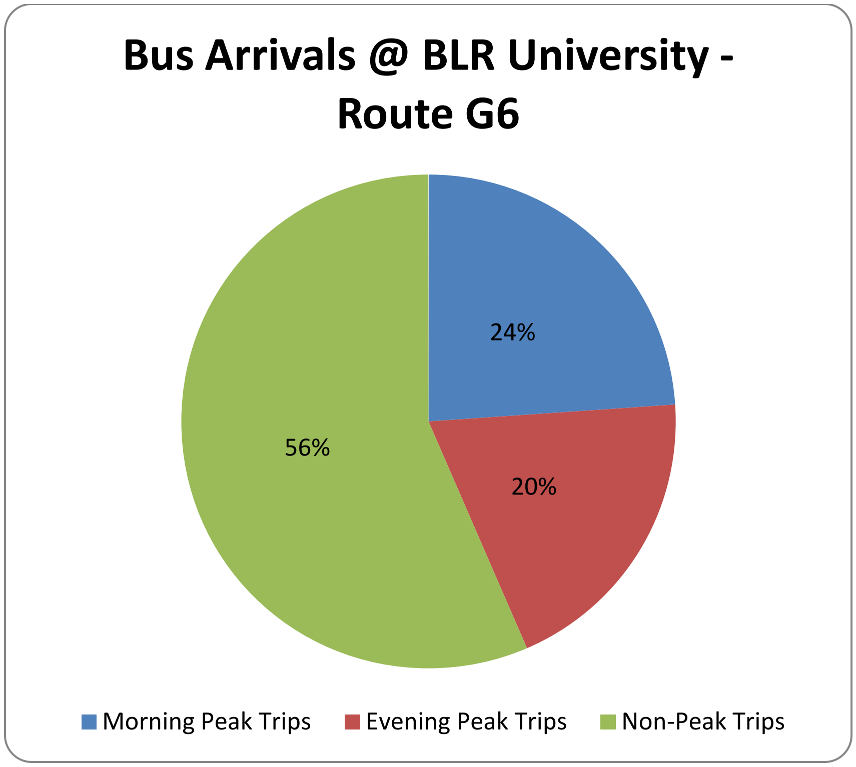
Typical estimates of passenger demand show that peak hour travel demand is about 10% of the daily total passenger demand. Hence, the morning and evening peak periods (covering 6 hours) contribute about 50% of the daily total passenger trips. Ideally, the supply of buses on the routes should also follow the same pattern, with 50% of all trips made during the peak 6 hours of the day and the remaining 50% trips spread in the remaining 10 hours of the day.

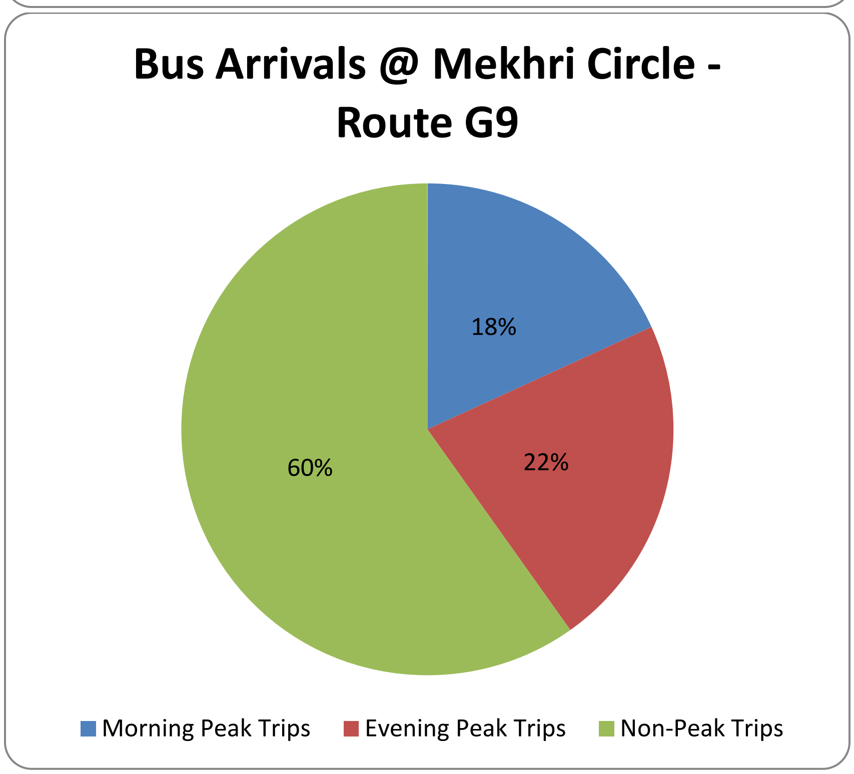
The bus trips by time period data from Table 8 is presented in the form of pie-charts in Figure 18. From this figure, it can be seen that only about 40% of the total bus trips occur during the peak periods on all the study routes. This pattern of supply is the reason for over-crowding of buses during the peak periods and buses running less than capacity during the non-peak periods, as also indicated by the passenger load charts presented in Figures 6 to 9. Hence, the data suggests that some supply optimization can be performed in the form of reducing the number of non-peak trips and yet delivering the same level of service. This also results in a reduction of bus-kilometers operated and associated savings in fuel consumption and maintenance costs.

Figure 18: Proportion of Bus Trips by Time Period






Bus Arrivals @ BLR University - Route G6
24%
20%
56%
Morning Peak Trips
Evening Peak Trips
Non-Peak Trips


Bus Arrivals @ Mekhri Circle - Route G9
18%
22%
60%
Morning Peak Trips
Evening Peak Trips
Non-Peak Trips

Travel Time Assessment

Data from the GPS was used to compute the travel time for each bus trip. The variation in travel time for making a trip is an indicator of congestion on the route. Congestion on the route is an externality for the bus operator as BMTC has no authority on roadway infrastructure. This, however, has severe implications on scheduling of services as well as the reliability of bus services. The analysis of operations thus far indicates less than optimal performance, resulting in poor service quality. The results from travel time assessment presented in Table 9 and Figure 19 clearly indicate large variations in travel times, thus making the arrival patterns and consequently headways unpredictable.

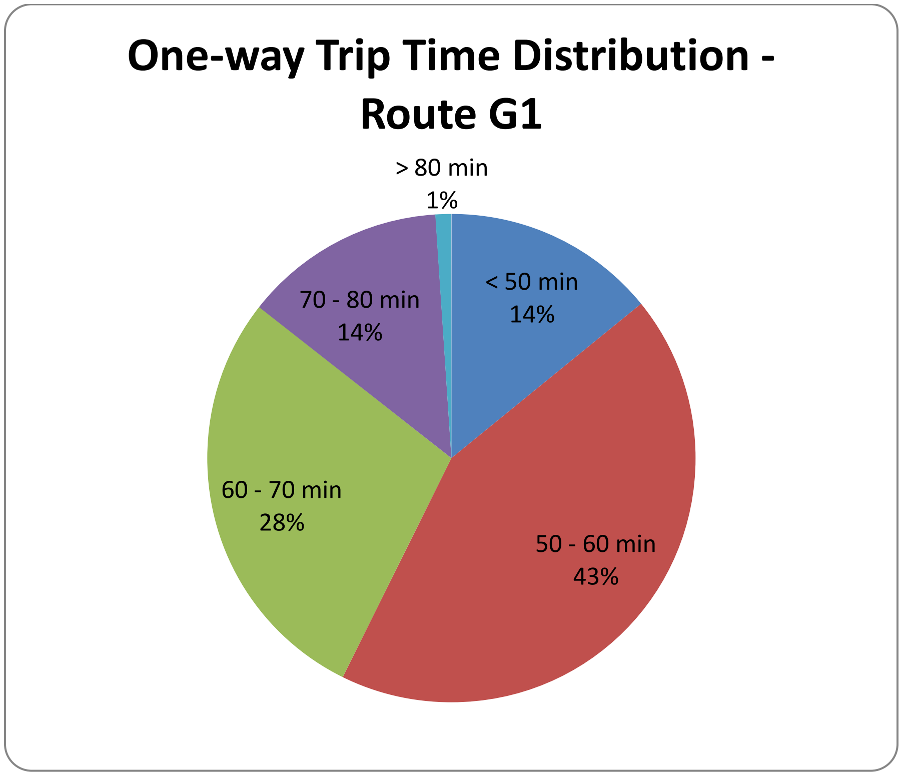
Table 9: Travel Time Variation by Route

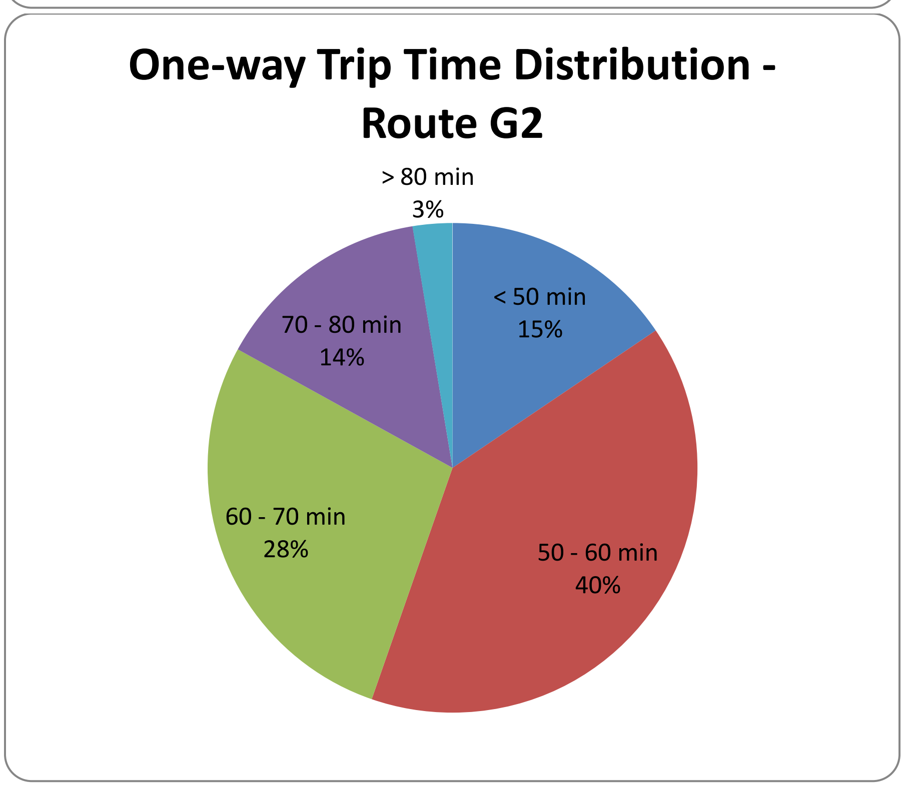
Route	G1	G2	G6	G9
Date of Survey	25-27 Oct	25-27 Oct	25-27 Oct	25-27 Oct
Sample Size (No. of one-way trips)	382	766	117	317
Trip Length (km)	21.0	20.9	21.0	19.4
Average Travel Time (min)	60	60	65	54
Standard Deviation (min)	9	10	12	9

The average travel time on all the routes is consistent with BMTC's bus schedule time. Hence, bus crews are able to complete their scheduled trips within the time allotted to them. However, due to the large standard deviation of 9 to 12 minutes, the individual trip times vary between 40 to 80 minutes. Hence, fewer trips are undertaken during the peak periods where the roads are congested and crews make-up for these lost trips during non-peak periods even though there is less demand during this time. This pattern of operations does not just reduce the level-of-service but also results in reduced EPKM. Figure 19 shows the percentage of total trips in different travel time categories.

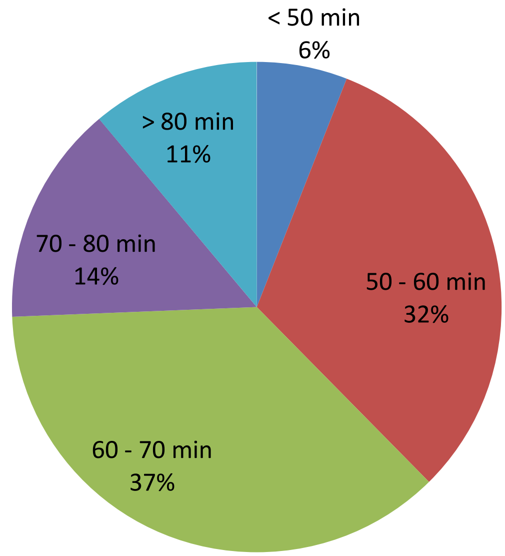
The standard deviation on all the routes is greater than 15% of the average travel time and is the highest on route G6 at 18.5%. The high degree of variability on route G6, combined with very few buses being deployed on this route, result in high levels of unpredictability. This might be a possible reason for lower earnings on this route.

Figure 19: Variation in Trip Time

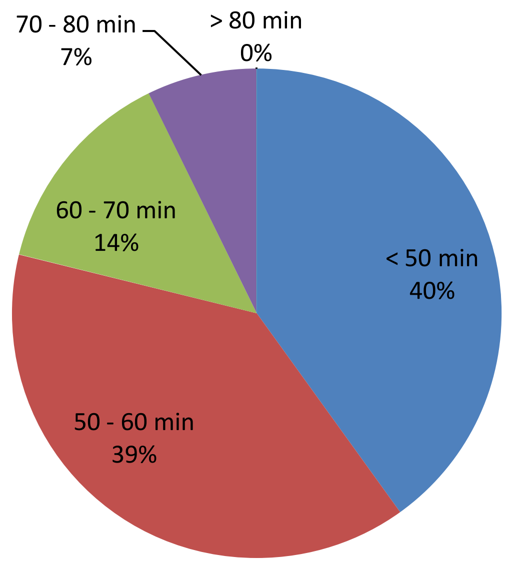




One-way Trip Time Distribution - Route G6



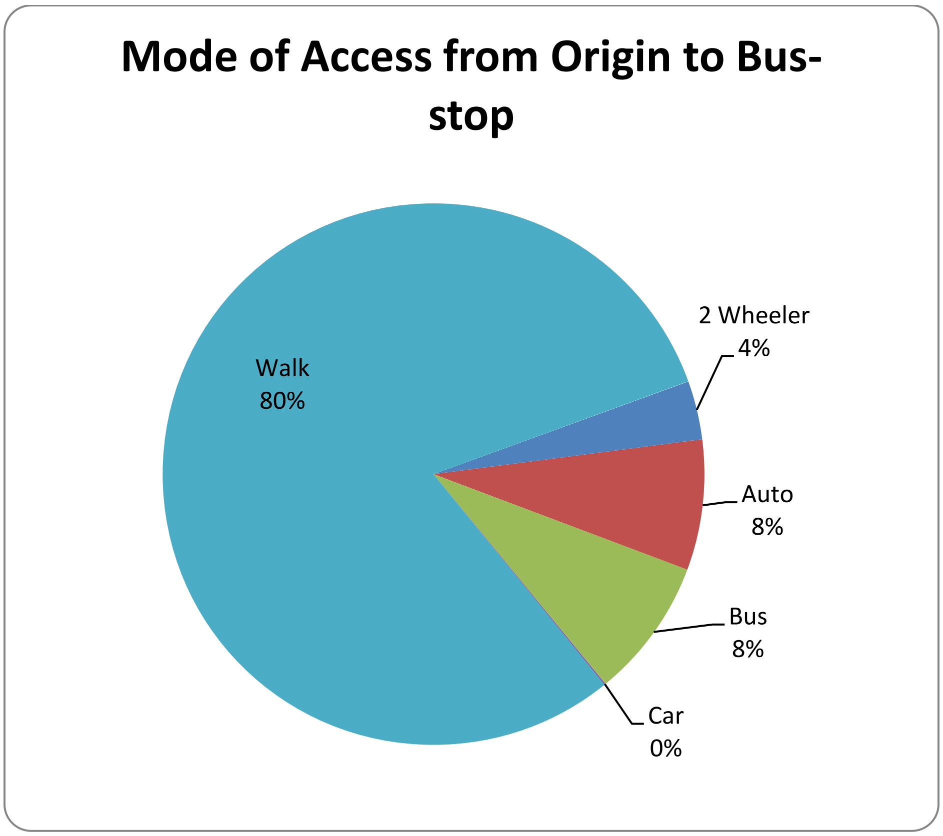
One-way Trip Time Distribution - Route G9

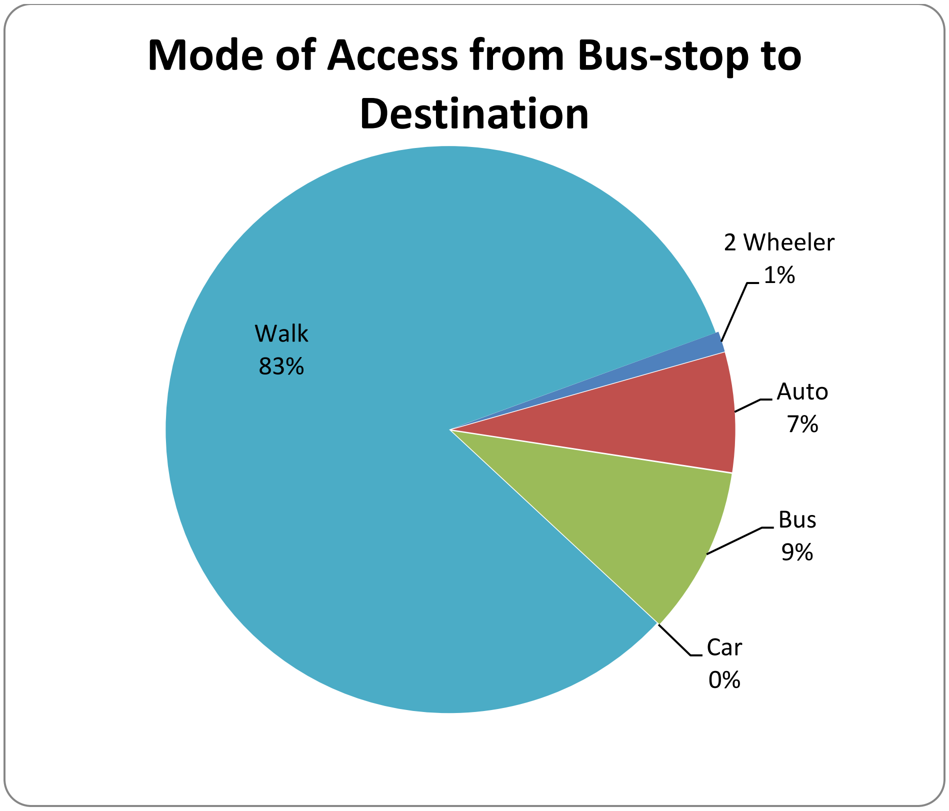


System Accessibility

An important dimension of the quality of a public transport support system is convenience of access to the system. During on-board interviews, passengers were asked about the means used by them to reach bus stops. Figure 20 shows the breakdown of modes used by passengers to reach the stops at both the trip ends.

<u>Figure 20: Access Mode Shares for Big10 system</u>

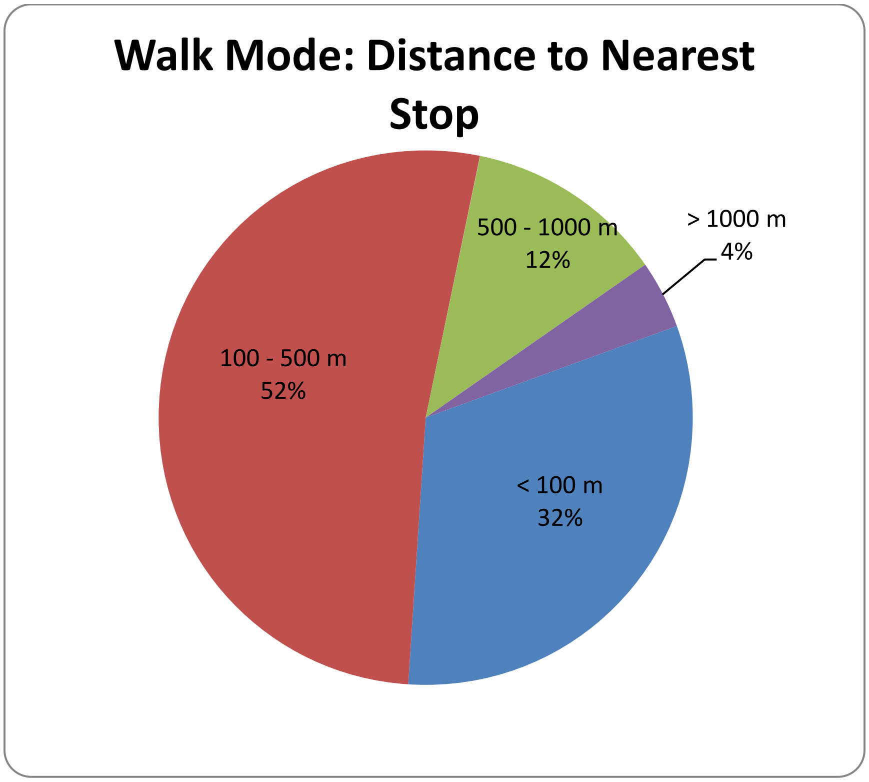




As might be expected, 'walk' is the most predominant mode used by passengers to enter the system and accounts for more than 80% of access mode share. This is followed by 'auto-rickshaw' which is used by about 8% of passengers. Access by 'bus' is indicates a transfer. About 15% of passengers have made at least one transfer to reach their destination. In the absence of park-and-ride facilities, access to bus-stops by '2-wheeler' indicates drop-off or pick-up at the trip ends.

Since 'walk' access is predominant among the modes for last-mile connectivity, it is further examined to determine the distances travelled either to reach a bus stop at the start of a journey or to reach the final destination at the end of the journey. From Figure 20, it can be seen that more than 80 percent of passengers walk less than 0.5 km to access the Big10 system. This is consistent with the actual conditions on ground. Due to lack of adequate pedestrian infrastructure, people residing farther away from the bus-stops do not prefer to use the bus service and choose private travel modes. Improving pedestrian infrastructure around public transport stops is of critical importance in shifting mode share away from private vehicles.

Figure 21: Walk Length to Nearest Bus-stop



Conclusions

Implementation of the direction-based Big10 services is a major shift in strategy for BMTC, which has thus far been focused on end-to-end connectivity. From the analysis of data, it can be concluded that this has been a successful experiment drawing, patronage and appreciation from bus users. Listed below are some conclusions and recommendations derived from the study.

1. Big10 services have resulted in more people using public transport. About 13% of passengers currently using the Big10 services were using private modes before.
2. Passengers using passes to travel form the majority (55% on route G2 and up to 63% on route G6) on all the routes. Route and operations planning should take this into account, rather than focusing solely on revenue from on-board ticket sales as a measure of performance.
3. The IPK for all four study routes is greater than 4, indicating that all of them are performing well. Hence, operations on routes that were considered to be performing poorly, such as G6, should be reviewed and augmented.
4. Trip length distribution shows that nearly 40% of trips on all the routes are shorter than 6 km in length. This suggests that there is an opportunity for initiating 'short loops' on these routes serving only the high demand sections. Load patterns on the routes, except for route G9, provide further evidence for the demand for such short distance bus services.
5. Load factor during the non-peak period is at least 25% lower than that during the peak periods. BMTC can realize operational efficiencies such as lower fuel consumption, maintenance costs and so on by reducing the number of bus trips during the off-peak period. This will also allow for streamlining of operations during the evening to avoid bunching.
6. Boarding & Alighting data shows significant passenger activity at the junction of the Outer Ring Road with radial roads. Convenient transfer hubs and pedestrian facilities are necessary at these places. BMTC should consider implementing these facilities at Silk Board junction and Marathahalli Bridge junctions on a pilot basis.
7. 15% of passengers using Big10 buses make at least one transfer to reach their destination. This number will further increase once this network is expanded in the form of trunk and feeder routes. Rationalisation of the fare structure is necessary to avoid transfer penalties that make the journey expensive.

8. Accessibility analysis indicates that the Big10 service has been able to draw passengers located within half a kilometer of the bus-stops. Providing better pedestrian infrastructure will allow BMTC to extend influence into areas farther than this distance.
9. In the absence of a feeder network, providing park-and-ride facilities can also result in increasing the public transport mode share.
10. Analysis of bus arrival patterns indicates that increasing the number of buses on a route does not necessarily result in increase in passenger throughput. Increasing frequency on congested routes most often results in bunching of buses, thus reducing the efficiency of operations. Throughput can be increased by providing bus priority measures that reduce the effect of traffic congestion on bus services, thus improving consistency and reliability.
11. In the absence of exclusive right-of-way for buses, the scheduling of buses should account for travel times during peak period congestion.

Next Steps: The Way Forward

The way forward for BMTC would be to focus on strengthening and optimizing operations of the Big10 system.

The main barrier to improved quality and reliability of Big10 services is traffic congestion as a result of other vehicular traffic on Big10 corridors. Efforts should be taken to study the suitability of improvements in infrastructure such as exclusive bus lanes and signal priority for buses along these corridors. Passenger experience can also be improved by the provision of high quality pedestrian infrastructure and transfer facilities along the route. Similarly, the existence of several parallel bus routes on Big10 corridors reduces the effectiveness and operational productivity of the service. Route rationalization along these corridors would therefore provide opportunities for improving the performance of Big10 routes and the public bus system in general. Additional operational efficiencies can be realized through such actions as optimizing bus and crew schedules and introducing 'short-loop' services to serve high demand sections of the route. Together this collection of interventions can be termed as a 'corridor improvement plan'. BMTC should consider conducting such an in-depth corridor improvement plan on one Big10 route on a pilot basis, and then scale this up to include all twelve Big10 routes.

Monitoring system performance and collecting feedback from users is the key to achieving continuous improvements in quality of service. This will require BMTC to establish internal capacity and mechanisms for data collection of the types conducted in this study. While this study was conducted only for four routes, BMTC should look into expanding the exercise to include all twelve Big10 routes and training staff in data collection procedures so that the exercise can be repeated on a regular basis.

BMTC should also make efforts to improve passenger information systems. This can include simple measures such as publishing route maps, route numbers, frequencies and destinations of buses that operate from a given stop. Methods for dissemination of information on real-time status of buses, by way of electronic displays for example, should be explored. This will improve the image of PT and will attract additional passengers to the public transport system.