WRI INDIA
— ROSS CENTER

BUS
KARO

Data Analytics Tool

SHAKTI
SUSTAINABLE ENERGY
FOUNDATION

A product of WRI Ross Center for Sustainable Cities

About Shakti:
Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support renewable energy, energy efficiency and sustainable transport solutions.

About WRI India Ross Center:
WRI India Ross Center is part of WRI Ross Center for Sustainable Cities. WRI Ross Center for Sustainable Cities works to make urban sustainability a reality. Global research and on-the-ground experience in Brazil, China, India, Mexico, Turkey and the United States combine to spur action that improves life for millions of people.

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1. INTRODUCTION

STUs collect volumes of data using their Intelligent Transport Systems (ITS). This data can be analyzed to measure and improve the performance of their bus systems. Data collected through ITS components like Electronic Ticketing Machines (ETM) and Vehicle Tracking Units (VTU) – which provide ticketing and tracking data - can be used to decipher commuter's travel patterns, plan transit more efficiently, forecast demand, assist in route optimization and improve the overall performance of the network. Additionally, application of data analytics to the data collected from the ETM and VTU devices can help in computing performance metrics like occupancy ratio, excess wait-time, fleet utilization ratio, timeliness, etc. Using the outputs of these performance metrics, corrective measures for improvement of bus services can be recommended and implemented. Currently, WRI India is developing a data analytics tool to assist STUs to utilize their operations data collected via ITS to measure the performance of the bus system for selected performance metrics (listed in the next section) and take corrective measures.

Need for the tool: Traditionally, STUs have relied on unscientific and ad-hoc processes to plan and improve bus operations. This has led to operational inefficiencies which in turn results in financial losses for STUs. With growth in size, role and geographical reach of the STUs, these problems have become more convoluted. Now, with the advancement in technology and reduction in costs, it is possible to store, process and analyze the data generated by ITS devices in real-time and extract meaningful information to measure and improve the operational performance of bus systems.

Partner case city/STU: For developing the analytical tool we partnered with the Bengaluru Metropolitan Transport Corporation (BMTC) as it has one of the most advanced ITS in the country. They have effectively deployed ETM and VTU devices on their buses (approximately 90 percent of the devices are functional at a given point in time) with a fully functional Central Control Centre. Though the ETM and VTU devices collect varying kinds of data, the relevant data points that will be used to compute the selected performance metrics and develop the tool are listed in Table 1.

Table 1: Relevant data points collected via ETM and VTU

Electronic Ticketing Machine Data	Vehicle Tracking Unit Data
Route Number	Latitude
Schedule Number	Longitude
Trip Number	Speed
Origin Bus Stop	Direction
Destination Bus Stop	Maximum Speed
Passenger Count	Accumulated Distance
Fare Amount	Date
Ticket Date	Time
Ticket Time	

2. METHODOLOGY

The flow chart in figure 1, explains the steps followed to develop the analytical tool.

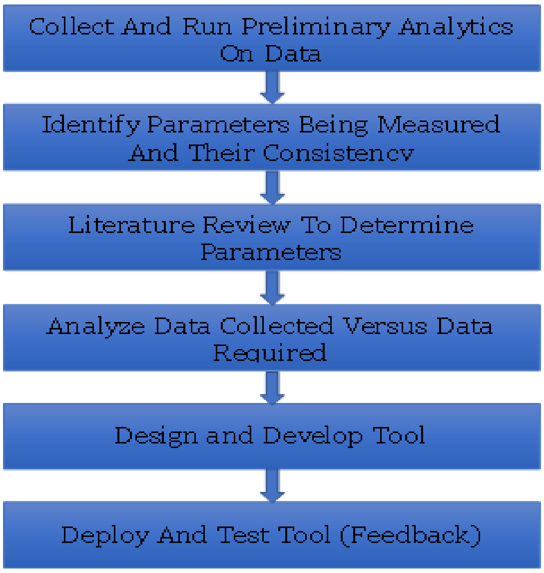


Figure 1: Methodology adopted for development of the tool

Step 1: Collected and cleaned various ETM and VTU datasets provided by BMTC. This was followed by preliminary analytics, on the cleaned data, to gain an understanding of the datasets and their limitations. The findings of this step are detailed below. Used the ETM data to create an Origin-Destination (OD) matrix for the entire city. A time lapse was generated using the top 100 origin-destination mapped pairs for the month of February 2017. A sample result for February 1, 2017 is illustrated in figure 2.

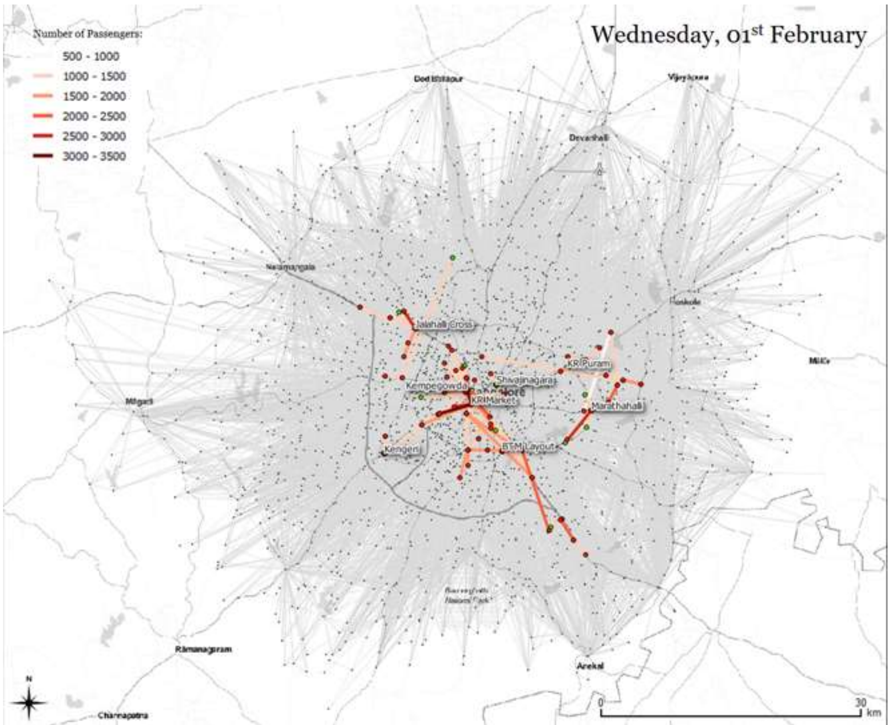
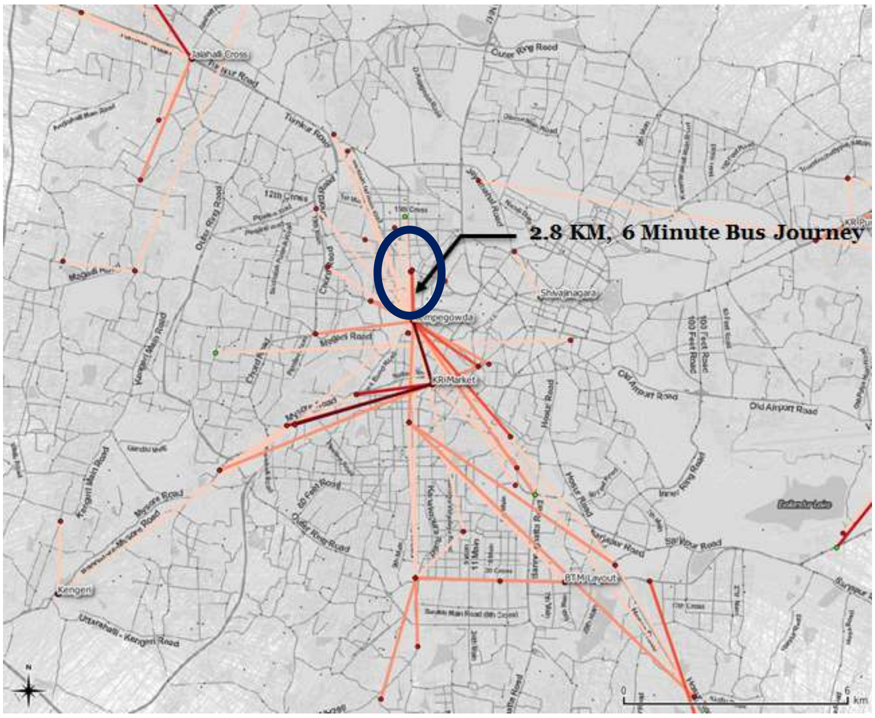


Figure 2: OD patterns in Bangalore (top 100 OD mapped pairs)

The analysis helped infer travel patterns within the city, which can be used by BMTC to reallocate their existing resources to cater unmet demand in the city or meet the new demand that is generated due to new infrastructure investments in the city. For example, a large number of passengers were observed to be commuting between two closely located bus stops - approximately 2.8 kilometers apart- as compared to other high-density OD pairs which are located at a relatively large distance from each other. On taking a closer look, it was observed that the destination bus stop is located close to a terminal metro station. Passengers transferred to the then operational section of the Bangalore Metro via this metro station. The details are illustrated in the figure 3. Taking cognizance of this development, BMTC could have added additional bus services between the two bus stops to serve the additional demand.



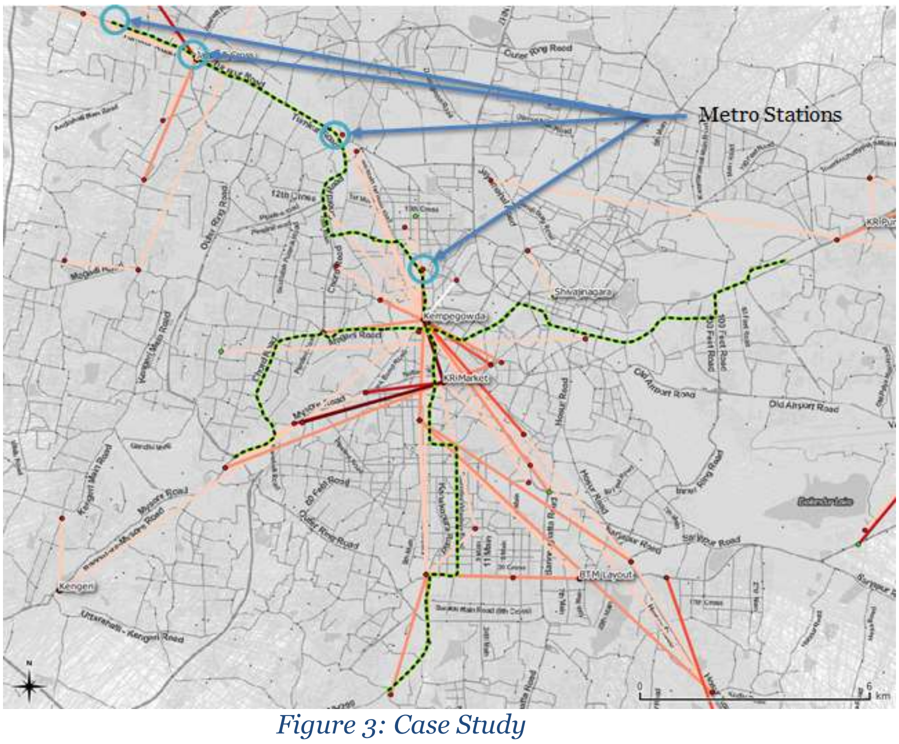


Figure 3: Case Study

Step 2: Identified the current performance metrics/indicators being used by BMTC to ensure redundant parameters are not included in the proposed tool. This step is crucial to ensure that the tool provides new and unexplored insight into the operational performance of the STU. This will ensure that the tool provides a unique value addition which will aid in improving the overall operational performance of the bus system.

Step 3 and 4: Identified and reviewed crucial performance indicators which are being measured and computed by other bus transit agencies across the country and globe. Concurrently, the feasibility of calculating the identified parameters was assessed from the available data. The Key Performance Indicators (KPIs) identified from literature review[1] and in-house discussions are listed in Table 2 along with their formulae.

Table 2: Key Performance Indicators

S.No.	KPIs	Formula
1	Average Bus Utilization	∑ (Live Kilometers Travelled by Bus)/Total No. of buses
2	Staff to Bus Ratio	Total Staff/Total Number of Buses
3	Occupancy Ratio	∑ (Number of Passengers X Distance Travelled)/∑ (Live Kilometers Travelled by Bus X Bus Capacity)
4	Average Fare Per Passenger Per Kilometer	∑ (Fare)/∑ (Number of Passengers X Distance Travelled)
5	Dead Kilometers to Total Kilometers Percentage	∑ (Dead Kilometers Travelled by Bus)/∑ (Total Distance Travelled by Bus) X 100
6	Reliability	(Services on Time/Total Services) X 100
7	Travel Speed as a function of time of the day	

Step 5 and 6: At present, WRII has developed a computer program to integrate the ETM & VTU datasets and has successfully computed several of the parameters listed above for entire fleet of BMTC. The data is processed at the bus stage level and has been aggregated at three levels: 1) route level; 2) depot level and; 3) system wide level.

[1] **References:**

1. Jain, M., Jain, H., Tiwari, G. & Rao, K.R. *Indicators to Measure Performance Efficiency of Bus Systems,* 2016
2. Bus Karo – *A Guidebook on Bus Planning & Operations*, EMBARQ India 2009
3. Potts, John F. *Customer-focused transit: a synthesis of transit practice*. No. 45. Transportation Research Board, 2002.
4. Randall, Eric R., et al. *International bus system benchmarking: Performance measurement development, challenges, and lessons learned.* Transport Research Board 86th Annual Meeting. 2007.

Table 3: Comparison between BMTC ITS dashboard and proposed tool

BMTC ITS Dashboard	BMTC Data Analytics Tool
Tracking and reporting	Management, Optimization and Planning
ETM+VTU: analyzed individually	ETM+VTU: Integrated Analysis
Multiple Complex Layers	Simple 3 level Analysis • Level I – Managing Director • Level II – Chief Traffic Officer • Level III- Depot Manager
Current wait time for a typical report: 3 – 4 weeks	Near real time report generation
Analysis level: Schedule/Route (whole)	Analysis Level: Schedule/Route Stage Breakdown
Daily Report Generation	Data Tracked over a period
Fragmented reports	Integrated reports

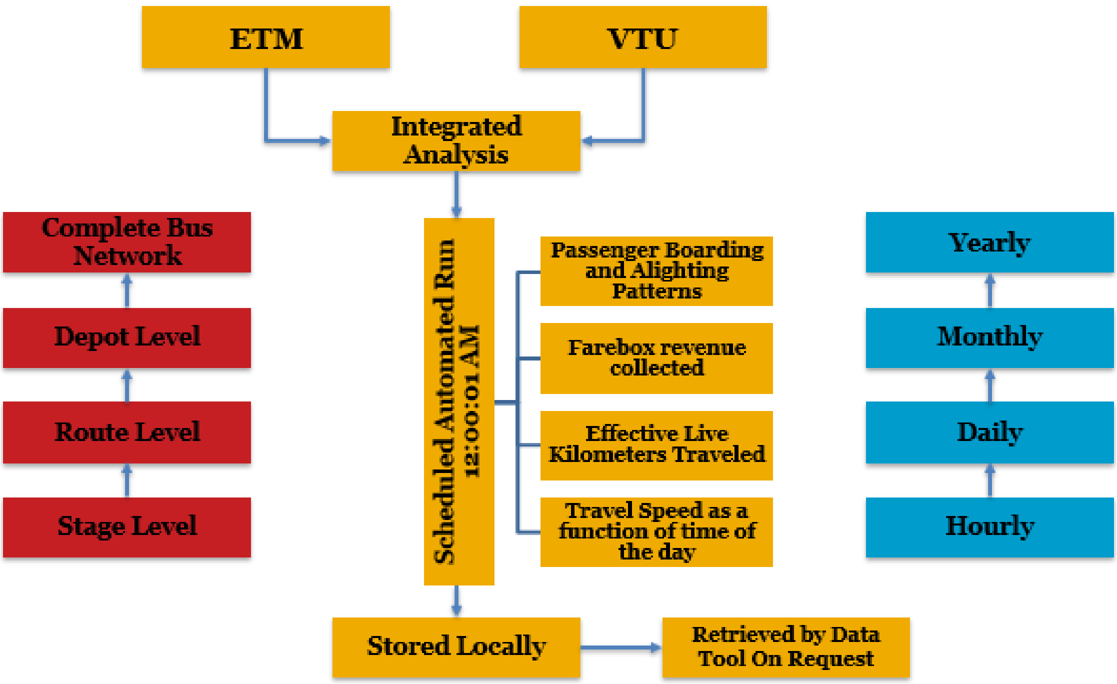


Figure 4: Data Analytics Tool - ETM and VTU data integration

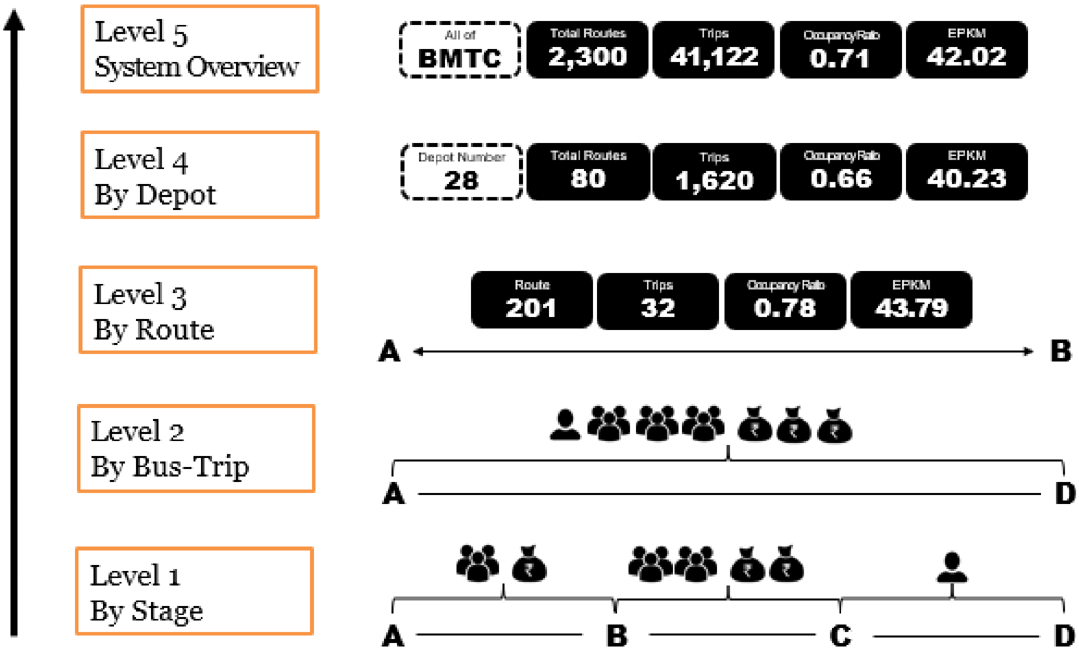


Figure 5: Data Analytics Tool - Levels of Data Aggregation

A dashboard was developed to enable BMTC to:

a) Extract actionable intelligence on the key performance indicators from the processed data
b) Make the data searchable which means that a user can re-call data based on specific queries for example - route no, location of the bus at particular time of the day etc.

A prototype dashboard (figure 6) was developed and presented to BMTC. Additionally, a route mapping tool (figure 7) was developed to facilitate exploration of data. Currently, the dashboard is being finalized and will be discussed with BMTC for approval and adoption.

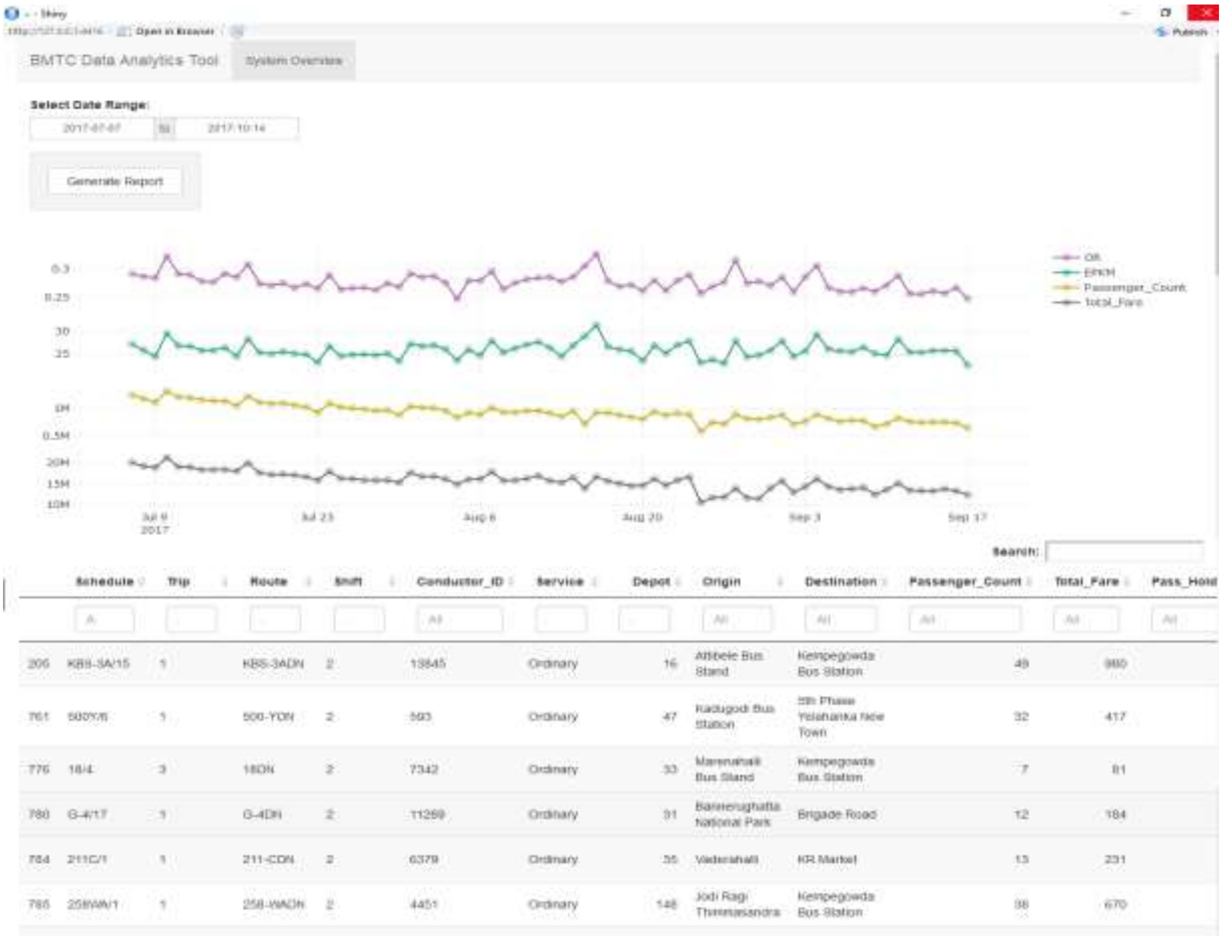


Figure 6: Dashboard Prototype

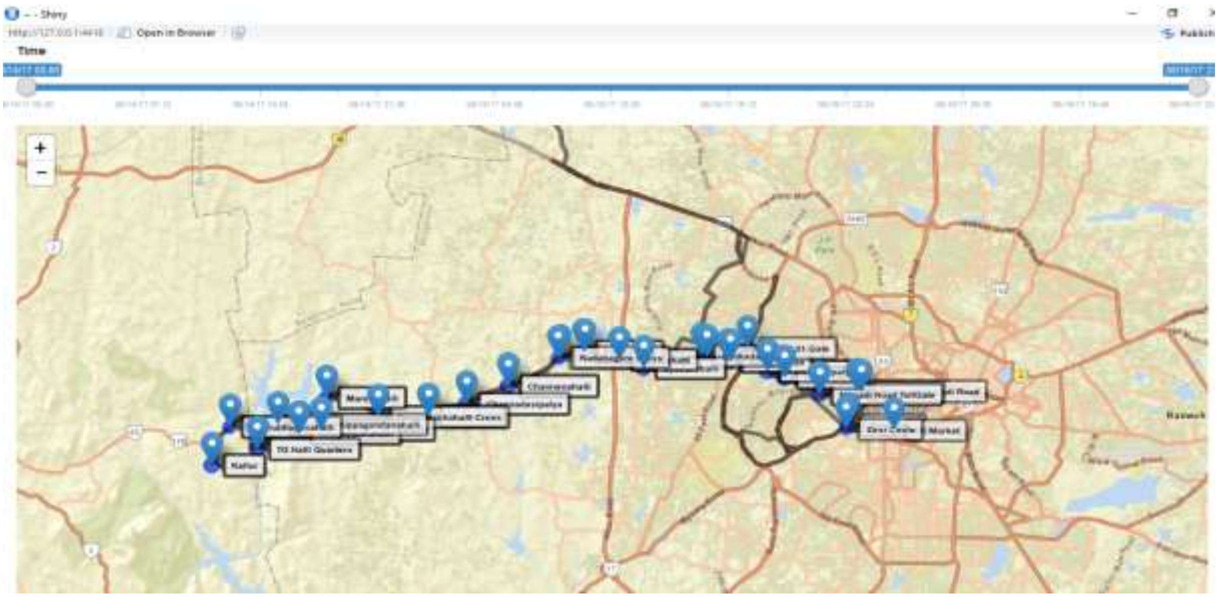


Figure 7: Route Mapping Tool

3. USE CASES OF ITS DATA

The data collected by BMTC can be used for decision making relating to bus operations which can help improve the efficiency of the system. Some of the examples of use cases of ITS data are given below:

1. FARE ANALYSIS

Historical fare data can be used to develop price elasticity models, which can be used to understand the impact of changes in the fare structure on passenger ridership and fare-box revenue. The analysis can be extended to understand the impacts at the stage level for each route. Price elasticity models help gauge the monetary value that passengers are willing to pay to continue using buses or to shift to the bus as a preferred mode.

As shown in figure 8, data can also be used to understand the relationship between the existing fares and the number of passengers traveling for that fare range. It can be seen that as the fare increases, the number of passengers traveling in a fare range decreases, indicating that passengers use BMTC services for shorter distances/stages.

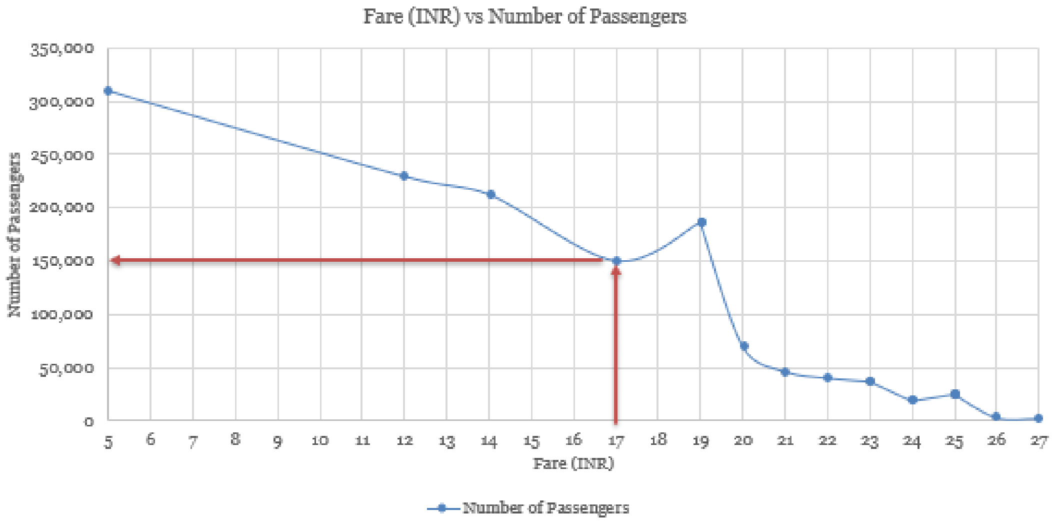
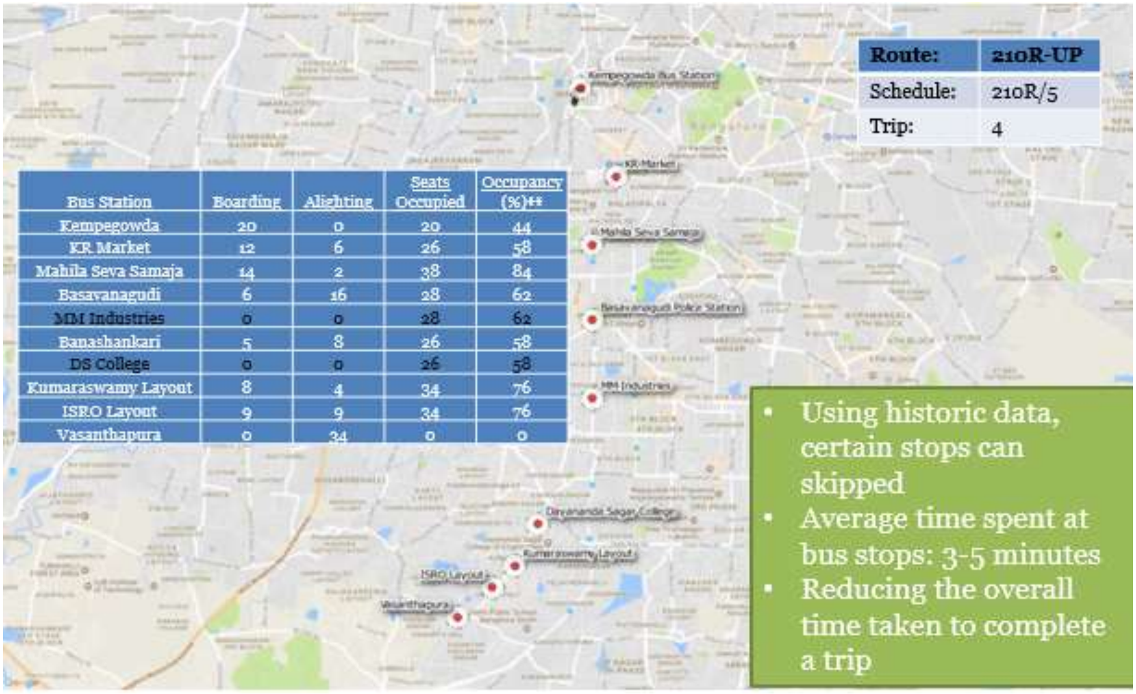


Figure 8: Stage and Fare Analysis

2. OCCUPANCY ANALYSIS

Occupancy ratio gives the weighted average occupancy of the bus over the entire length of the route. Historical data on occupancy ratios can be used to analyze the occupied seats in a bus which can help decision maker decide if a route needs to be curtailed (if occupancy at few stops are extremely low consistently), bus schedules need to be reorganized (if the demand at different hours of the day varies consistently) and plan express routes (encompassing bus stops that yield high occupancy ratio). This will result in improved operational efficiency of the bus and reduced travel time for passengers. Figure 9, represents the occupancy analysis of an existing bus route belonging to BMTC.



Bus Station	Boarding	Alighting	Seats Occupied	Occupancy (%)**
Kempegowda	20	0	20	44
KR Market	12	6	26	58
Mahila Seva Samaja	14	2	38	84
Basavanagudi	6	16	28	62
MM Industries	0	0	28	62
Banashankari	5	8	26	58
DS College	0	0	26	58
Kumaraswamy Layout	8	4	34	76
ISRO Layout	9	9	34	76
Vasanthapura	0	34	0	0

Figure 9: Occupancy Analysis

3. SCHEDULE RATIONALIZATION

Travel times on various routes vary as a function of time of the day depending on traffic conditions in the city. During peak hours the travel times are longer as compared to other times of the day. However, bus schedules are allocated the same amount of time to cover the same distance along the same route throughout the day. The two peaks shown in the graph in figure 10, indicate longer travel times for a schedule during peak traffic. Using this analysis, schedules can be rationalized to account for the time taken to cover the route distance during different times of the day. Road closures and similar disruptions can be taken into account using most recent data to decide the schedules for the day for a route.

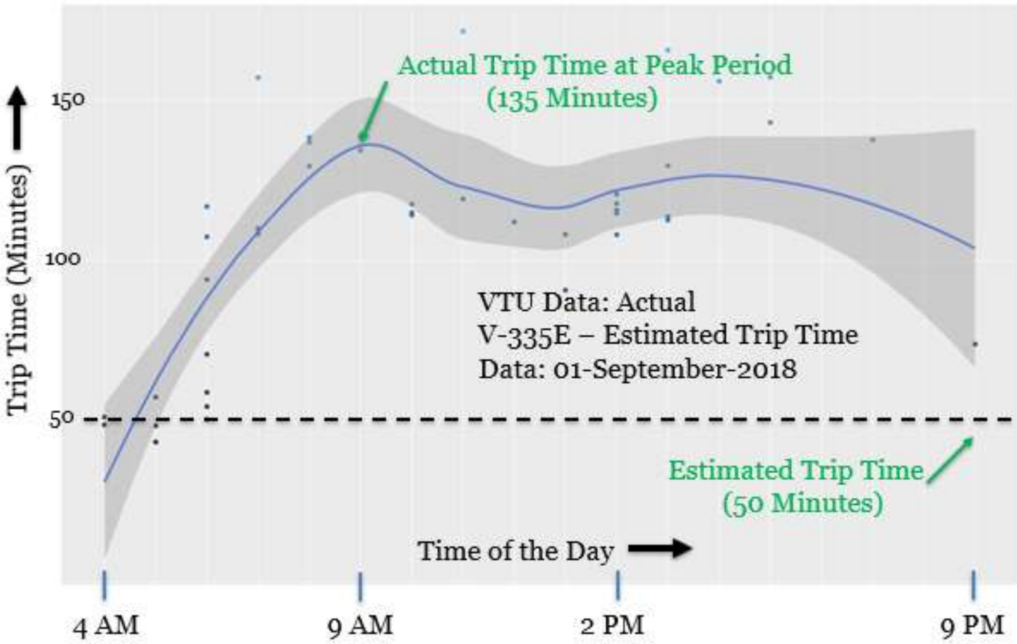


Figure 10: Trip time vs time of the day

4. SCHEDULE ADHERENCE

One of the key challenges that the transit agencies are trying to address is the reliability of their bus services, to achieve this end, they need to ensure that the buses adhere to their schedules. Bus operations data can be used to measure the schedule adherence. The graph shown in figure 11, can be used as a metric to quantify early and late departure for schedules and take corrective measures

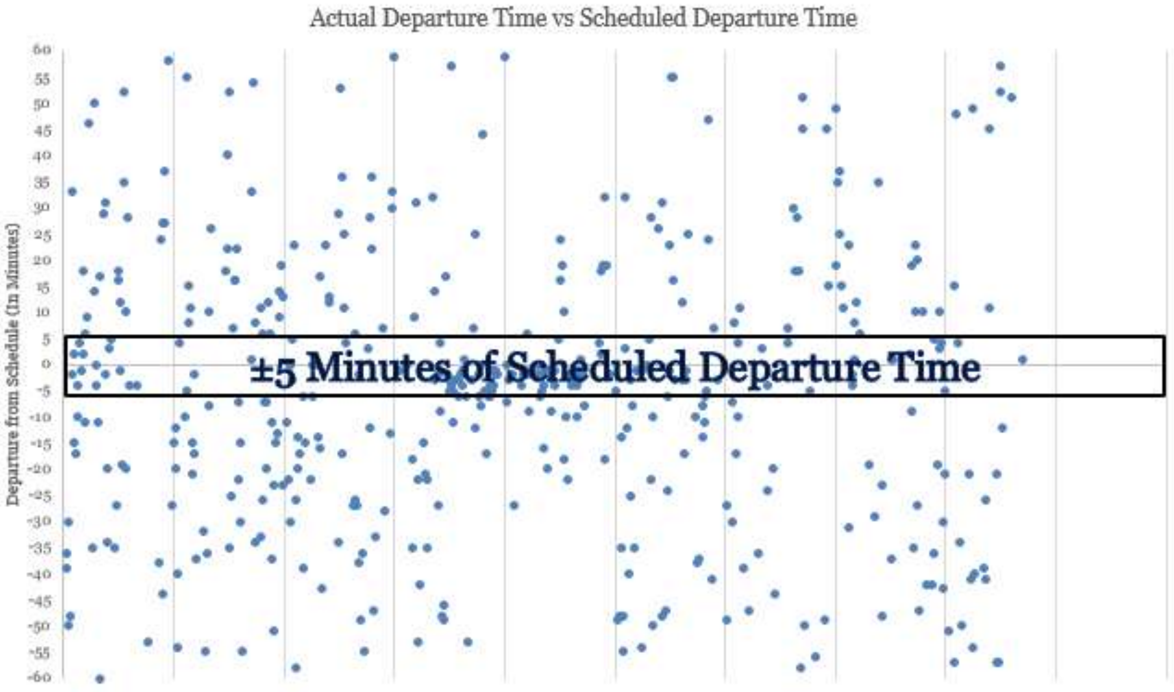


Figure 11: Schedule Adherence

4. CONCLUSION

Bus agencies, across the country, are implementing ITS which enables them to collect bus operations data in real-time. This data can be analyzed in real-time to extract meaningful information on key performance indicators like fare analysis, schedule adherence, schedule rationalization, occupancy analysis etc. and use the outputs to take corrective operational measures. However, as the volumes and nature of the data sets collected is complex, specific tools that use advanced analytical techniques are required. Bus agencies can develop these tools in-house to measure performance indicators that are specific to the priorities of the agency. The need for agency specific data analytics tool also arises from the fact that one tool does not fit all. While the key performance indicators will remain same, the methods and techniques adopted to analyze the data can vary.