WHAT AILS INTELLIGENT TRANSPORT SYSTEMS?

Roadmap for Modernizing Bus Services

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List of acronyms

Abbreviation	Definition
AI	Artificial Intelligence
AIS	Automotive Industry standards
AMC	Annual Maintenance Contract
AVL	Automatic Vehicle Location
BEST	Brihanmumbai Electric Supply and Transport Undertaking
BMTC	Bengaluru Metropolitan Transport Corporation
BRT	Bus Rapid Transit
CCC	Command and Control Centre
CCTV	Closed-Circuit Television
CSV	Comma-separated values
DPR	Detailed project report
DVR	Digital video recorder
EPKM	Earning per kilometre
ERP	Enterprise Resource Planning
ETA	Estimated time of arrival
ETM	Electronic ticketing machine
FCS	Fare collection system
FMS	Fleet Management System
GCC	Gross cost contract
GEF	Global Environmental Facility
GPS	Global Positioning System
IPT	Intermediate Public Transport
ITS	Intelligent Transport Systems
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
KPI	Key Performance Indicator
LED	Light Emitting Diode
MIS	Management Information System
MoHUA	Ministry of Housing and Urban Development
MoUD	Ministry of Urban Development
NCC	Net cost contract
NCMC	National Common Mobility Card
NFC	Near Field Communication
OEM	Original Equipment Manufacturer
ONDC	Open Network for Digital Commerce
P&S	Planning and scheduling

Abbreviation	Definition
PDF	Portable Document Format
PIS	Passenger Information Systems
PPP	Public–private partnership
QR	Quick response
SaaS	Software as a service
SLA	Service-level agreement
SOP	Standard operating procedures
STU	State Transport Undertaking
TIM	Ticket issuing machine
TSP	Transit signal priority
UBS	Urban bus specifications
UPI	Unified Payments Interface
VHMS	Vehicle Health Monitoring System

Why this spotlight?

Over the past two decades, India's public transport infrastructure has witnessed steady integration and expansion of the intelligent transport system (ITS). Despite this progress, the projected potential of its utilization to enhance the operational management of buses is yet to be met. Though there has been notable advancement in electronics, communication, and information technology during the same period, the deployment of ITS within the transit sector, commonly referred to as advanced public transit systems (APTS), is yet to yield the anticipated efficiency enhancement.

Simply put, APTS refers to a range of advanced navigation and communication technologies that include advanced vehicle location system (AVLS), automatic fare collection system (AFCS), and passenger information system (PIS), that enable timely communication of transit information to the passengers to improve the convenience, reliability and safety of the public transit services.

Advanced Public Transit System (APTS) presents an opportunity for implementation of comprehensive fleet management and operations. This can enable integration of automatic passenger counters, automatic vehicle location tracking, scheduling aºnd dispatching mechanisms, geographic information systems (GIS), signal priority systems, and recording of passenger data such as boarding/alighting times and locations.

Technologies including automatic vehicle location with satellite geo-positioning and GIS, enable transport agencies to efficiently collect, store, analyze, and visualize data bases on locations. Beyond enhancing system efficiency, the implementation of APTS is anticipated to yield several additional benefits including improved journey time, reliability, safety, reduced accidents, increase in operational efficiency, assistance in traffic enforcement, mitigation of traffic congestion, provision of real-time information to the public, fostering public awareness, emissions reduction, and enhancement of traffic signal efficiency, among others.

The primary focus of this assessment is to explore the potential of ITS application in enhancing operational management and overall system efficiency and assessing the barriers to realising its full potential. So far international success stories around the observed benefits of APTS and the need for improved data driven governance in cities have encouraged investments in APTS.

Funding schemes such as the Jawaharlal Nehru National Urban Renewal Mission (JnNURM), Global Environment Facility (GEF), Smart Cities Mission have accelerated implementation of APTS in India. In addition, introduction of urban bus specification (UBS) guidelines for procurement of buses in India, which have mandated the technical specification of on-board bus ITS have also fast-forwarded the implementation of APTS.

It is estimated—based on the information available from the bus agencies—that so far transit agencies across India have collectively spent over Rs 1,000 crore (US $120 million) for deployment of APTS systems to improve fleet performance monitoring, decision- support systems, and real-time passenger information services. Initially, the APTS programme in Indian cities was primarily driven by the need to address the complexities and losses associated with urban transit operations. Early APTS have included the deployment of basic systems such as ticket issuing machines (TIMs) and live bus tracking. This has provided rudimentary data summary but without the detailed analysis or data storage capabilities. As these systems were relatively inexpensive and were effective for real-time remote monitoring of day-to-day bus operations, the expectations around the APTS soon grew.

Some steps were initiated to improve data governance. The Ministry of Housing and Urban Affairs (MoHUA) has developed a secured, open-source data sharing and exchange platform called "India Urban Data Exchange (IUDX)". This allows sharing of data between multiple public and private stakeholders for developing citizen- and business-centric solutions. The Automotive Research Association of India has framed the Automotive Standards 140 for ITS to regulate functional aspects of this technology and its application. APTS has been implemented mainly in metro cities. But most of them have utilized only certain aspects of APTS applications. These have not been implemented in their entirety.

Many projects therefore, have not met the expectations. As a result, transit agencies are saddled with costly hardware that has not delivered on the full range of expected functionality beyond the basic systems originally planned. The initial emphasis seems to have been on the demonstration of control centres rather than on gaining a deep understanding of the fundamental requirements of effective transit management in India's expanding cities.

In view of this, the Centre for Science and Environment (CSE) has initiated this technical consultation to investigate and analyse the underlying causes, gaps and failures in the current systems and to identify approaches to extract the maximum value of the existing APTSs and influence the future procurements and deployment to improve bus operations.

CSE has therefore investigated the present APTS deployed by seven key bus transit authorities in India, including Mumbai, Bangalore, Hyderabad, Ahmedabad, Indore, Navi Mumbai and Bhubaneswar.

Key findings

Detailed assessment of the key components of a typical APTS and their application reveal several challenges.

Flawed procurement practices: Current procurement practices focus primarily on the hardware components, such as GPS devices and their technical specifications, but do not pay adequate attention to the processes and expected outputs and outcomes from those GPS devices. Similarly, APTS tender specifications for testing of the system performance lack details such as methods for measuring system performance or properly evaluated tools. The vendors also do not provide IT system health reports.

As a result, it is difficult to measure some of the performance parameters. Developing an overall performance matrix becomes difficult. Additionally, lack of pilot testing before the system deployment leads to inadequate and flawed APTS services. Full purchase of systems instead of adopting software as a service (SaaS) model results in vendor lock-in that leads to interoperability issues and limits the scope of innovation in the system.

Absence of network digitization: One of the key characteristics of any transit services is to operate the services within a predefined schedule for a series of trips on a specified route with specific start and end time. Schedules play a vital role in transit system performance and transit services. Even though schedules play such a critical role, many transit agencies still rely on manual processes for data management and scheduling.

The absence of digitization of transit service plans results in inadequate foundational data that is required for deriving intelligence for monitoring performance and optimizing schedules or passenger information systems even though systems are in place.

Lack of data visualization: All the APTS are being used to generate extensive MIS reports, which are none other than excel spreadsheets with numerous columns and rows. As a result, these spreadsheets are too difficult to understand for any action to be easily taken by its users. This information can be translated into insightful graphs and charts which are self-explanatory and easy to interpret and to act on.

Lack of visualization of transit schedules and its adherence, skipped stops and passenger demand among others limit the ability of transit supervisors and operators to take quick action for improvement of services.

Lack of data standardization: Although it has been more than a decade since APTS has been implemented in the bus sector, it has not been possible to develop standardized protocol for data collection and data storage. In the absence of standardized protocol for transmitting and storing vehicle health monitoring system (VHMS) data, vehicle health monitoring and maintenance is not effective and optimum.

Conflict of interest between project management consultancy: Due to lack of in-house technical expertise transit agencies hire Project Management Consultants for deploying APTS, prepare tender documents, bid process management and also supervise the deployment of APTS. It is said that as payment conditions for such contracted project management depend largely on quick deployment of APTS, the interest gets more aligned with the vendors than with the transit agency.

This may lead to conditions in which project management consultants may sometimes prepare tender documents on the basis of what is readily available in the market rather than on what is needed or is important for the transit agency.

Unreasonable timeline for project completion: Unrealistic time duration for project completion also leads to inadequate APTS deployment as transit agencies get less time to conduct proper pilot testing and are forced to accept the user acceptance test results with limited success. Therefore, APTS deployment begins with limited scope and capacity that continues to remain so.

Deployment of rigid proprietary systems: Often, the hardware and software used to carry out different APTS functions are developed with the help of rigid proprietary services. As a result, these systems work in silos and make the overall system ineffective. For similar reasons, many transit agencies are unable to integrate both the Automatic Vehicle Location System (AVLS) and fare collection system for better performance monitoring.

Insufficient internal capacity of public transit agency (PTA): PTAs primarily deal with bus operations, planning, and management. Information technology is typically not the core competence of the PTAs. This makes them fully dependent on the external PMC for the entire process of procurement of APTS that includes detailing out the requirements, drafting of the tender document, selection of vendors, and conducting user-acceptance tests, among others. This creates dissatisfaction and disenchantment in the system. The ITS adds to the workload without yielding tangible benefits. Cumbersome management information system (MIS) reports hinder decision making. Agencies lack access to original data generated by ITS systems and therefore need to rely solely on vendors for information retrieval.

Lack of transition management: Even though the APTS tender permits asset transfer after the end of contractual period, this often does not happen due to use of proprietary solutions and lack of internal capacity of transit agencies. The existing system becomes redundant and unusable once the contract period is over. This leads to operational disruption until the transit agency can procure new hardware or software.

The way forward

This assessment bears out the urgent steps needed for the effective utilization of APTS application to significantly improve bus operations and service levels. It is necessary to change APTs procurement systems and build capacity in the public transit agencies.

Digitization of transit network and time table: To enable the effective functioning of any intelligent data analytic solutions, it is crucial to digitize and manage the transit operation plans, including stops, routes, route timetables, bus schedules, and daily roster. In the absence of digitization of this information, most intelligence functions such as passenger information, contract management (SLA monitoring) etc. become ineffective.

Making MIS reports actionable through data visualization: The existing outputs of transit ITS are cumbersome and rudimentary, providing limited support to decision-making. Better visualization of data and standardized key performance indicators (KPIs) can become highly actionable.

Decoupling hardware and software during procurement: Current procurement practices of integrated APTS deployment including hardware, software and system operations result in a conflict of interest among the system integrators. The PTAs therefore remain ignorant of the defects in the system. Integrated procurement has also resulted in the deployment of components with proprietary protocols. This leads to vendor lock-in and deployment of ineffective technology services.

Decoupling hardware and software procurement can foster interoperability by way of shared communication protocol and/or standardization. This will also provide transit agencies with much greater control over system expansion (hardware), addition of new features (software), and transition to newer technologies. Standardization of protocol also encourages competition by allowing more OEMs to enter the market.

Leasing of APTS components: Leasing model of APTS deployment has several advantages. It can reduce the capital investment required to deploy APTS, shift the performance risk of deployed APTS components to suppliers and it is quite easy to terminate or transition to new technology in-case system is not giving the desired result or performance.

Additionally, leasing can encourage market participation and innovation. Currently, leasing is primarily limited to integrated hardware and software bundles of individual ITS components such as GPS combined with AVL software module etc. Often, these bundles work in silos and do not have the benefits of system integration. There are no vendors who are offering comprehensive ITS solutions specifically tailored for public transport on a lease model. Transitioning to a model where ITS hardware and software are independently procured on lease can encourage greater market participation and innovation.

Standards/protocol for interoperability: Standards play a vital role in technology adoption. Standards like AIS-140 for Automatic Vehicle Locations equipment and data transmission protocol have streamlined technology procurement. Similarly, creation of the General Transit Feed Specification open standard has facilitated the development of various third-party passenger information apps.

So it is imperative to standardize Vehicle Health Monitoring System data, protocol for different transit fare instruments (i.e. stop-to-stop fare, flat fare, tap-in-tap-out, daily/monthly passes and round-trip fare) and other relevant areas to eliminate vendor lock-in and reduce technology costs.

Creating detailed standard operating procedures (SOPs): Presently, due to lack of standardized processes, different agencies handle occasional scenarios such as bus breakdown, accident etc. on an ad hoc basis. This leads to malfunctioning in the ITS output. Developing comprehensive and detailed standard operating procedures (SOPs) for all transit operations involving ITS interaction can eliminate ad-hoc processes and facilitate software development for transit operations management and performance monitoring. Organized and detailed SOPs play a crucial role in ensuring systematic and uniform performance of tasks.

While the general ITS software modules for processing transit data are similar across the industry, the lack of standardized processes for handling uncommon scenarios (such as bus breakdown, accident, etc.) can lead to malfunction in the ITS outputs. Developing comprehensive and detailed SOPs for all transit operations involving ITS interaction can eliminate ad hoc processes and facilitate software development for transit operations management and performance monitoring.

Extensive training of transit staff: This systematic training of staff and institutional capacity creation is essential not only for better utilization of ITS facilities, but also for developing an understanding of the technology itself to reduce reliance on the external consultants for assessment or procurement of technology.

Payments—avoid one-size-fits-all approach: The vision for the national common mobility card is ambitious. But now technological advancements have enabled transformation of digital payment options. It is evident from the experience of the most advanced transit systems in the world, that transition to cashless transactions may not be possible with any single technology mode due to varying technological adoption among bus passengers in India.

Therefore, it is essential to enable multiple payment channels, such as open and/or closed loop contactless smartcards, integrated mobility apps and QR code or NFC-based mobile payment apps, with the aim to minimize cash transactions and enable user-trip chain pattern analysis.

Need a national ITS platform: Previous iterations of ITS procurement in India over the past decades have not achieved the desired objectives of service reliability and efficiency. It is evident that despite these challenges and limitations, the same procurement model continues to be followed, often with functional requirements copied from previous tenders. This perpetuates the hold of a limited number of vendors and establishes monopoly in the market. Same software that may have not worked previously or not been effective are issued a “go-live” approval elsewhere.

Hence, developing a national APTS platform taking into consideration all the above issues using micro services architecture can help in reducing cost while at the same time enabling training and peer learning can scale up best practices across the transit agencies.

Considering these challenges, it is imperative to reassess the process, learn from past experiences, and approach ITS with a new model that addresses the findings outlined here.

The following key learnings need to be considered:

- A sample of diverse data visualizations should be developed as a reference document for specifying requirements in the MIS module of tender documents.
- A comprehensive compendium of model SOPs is necessary at the central level to guide software development and ensure standardized practices. Also enable transit staff training and eliminate ad hoc action.
- Standardized data protocols should be established for ITS components to facilitate interoperability and prevent vendor lock-in.
- Transit agencies are transitioning to asset-light planning and regulatory entities, but their core functions of bus operations are being outsourced to private partners. In this scenario, ownership of rapidly evolving technology systems that are outside of their core specialization, should be avoided.
- A fully functional Planning and Scheduling software, capable of generating optimized schedules while considering all constraints, is essential for an effective ITS.

It is necessary to adopt innovative procurement strategies to create a value-added asset in public transport. Outdated procurement models for ITS systems that impede interoperability, data access and effective performance monitoring need to change.

Implementing these learnings may not be overly complex and surpass the capabilities of independent state transport undertakings (STUs) or transit agencies. Given the similarities in requirements across the country and the intent to bring about standardization of the performance evaluation (KPIs), it is recommended that a national level APTS platform and protocol are established as a “digital public good”.

Section 1: Components of advanced public transit systems and their usage

ITS procurement in the public bus transport sector in India involves various components aimed at enhancing the efficiency, safety and convenience of public transportation. This section explores some of the key components of ITS procurement and their applications, along with associated challenges.

A. Fare collection system

The fare-collection system plays a crucial role in enabling seamless ticketing and payment processes for passengers. It has evolved over the years from basic Ticket Issuing Machines (TIMs) to advanced electronic ticketing machines (ETMs) capable of accepting multiple payment methods and providing real-time data transmission. The latest generation of smart ETMs includes features such as quick response code (QR code) scanning, near field communication (NFC) payment acceptance, and global positioning system (GPS) location tracking.

In the case of bus rapid transit (BRT) systems, where ticketing is conducted off-board, the fare collection system incorporates fare gates and validators installed at the bus stops. A recent development in this area is the pilot implementation of off-board ticketing by Mumbai's Brihanmumbai Electric Supply & Transport Undertaking (BEST) in 2021. As part of the pilot, a ticket validator was installed at the entry door of the bus, indicating a potential direction for future advancements in the fare collection system approach.

Typical use of fare collection system

The fare collection system is typically used in:

- Reconciliation of cash collected on duty and accurate revenue reporting;
- Facilitation of cashless transactions and convenient fare payment options;
- Generation of unique ticket IDs to prevent revenue pilferage; and
- Provision of live dashboards displaying revenue statistics and passenger KPIs.

Potential use of fare collection system

The fare collection system can be used in:

- Analysis of disaggregated passenger travel patterns captured by ETMs to optimize bus routes and frequencies;

- Understanding trip chaining behaviour through smartcards and mobile tickets to identify new routes and plan convenient interchange facilities;
- Automatic fare collection system can also integrate fare payment for multiple modes of transport and foster multi-modal integration, especially with last-mile and Intermediate Public Transport (IPT); and
- Utilizing boarding-alighting data at individual stops for infrastructure assessment, advertising revenue estimation, planning limited-halts express services, and estimating demand for last-mile and IPT services.

Currently, except in a few ad hoc cases, all the seven public transit authorities (PTAs) are lacking in potential usage of fare collection system to maximize the benefits of the system.

B. Automatic vehicle location system (AVLS)

AVLS utilizes GPS technology to track the real-time location of vehicles. These systems consist of a GPS unit, a backup battery and a communication module that enables the transmission of data to a remote server even when the vehicle's ignition is turned off. The implementation of AVLS is now governed by the AIS 140 specification, which has been made mandatory for the entire public transport fleet since April 2018. In addition to providing live monitoring and passenger information, AVLS data can be utilized to assess driver behaviour, such as cases of over-speeding, route deviations, skipping bus stops and schedule adherence.

Typical use of AVLS

AVLS is used in:

- Real-time passenger information on routes and estimated time of arrival (ETA);
- Distance calculation for evaluating payment to private bus operators; and
- Monitoring driver behaviour, including over speeding and skipping of bus stops.

However, AVLS have largely failed to realize their full potential. Even in cases where they have been deployed, accuracy of data is often inadequate and primarily used for reconciling manual records. Non-functional AVLS have been a major source of operational discord in public–private partnership (PPP) bus operations.

Potential use of AVLS

AVLS can be used in:

- *Operations management and service level monitoring:* The location data obtained from AVLS can be leveraged for real-time operations management, including bus bunching and breakdowns, as well as calculating various key performance indicators (KPIs) like fleet utilization and schedule adherence. Though all the PTAs claim to be using AVLS to manage their bus operations and monitor service levels, in all cases this is being done manually.

- *Data analysis for service planning:* AVLS provide a wealth of data on bus performance, traffic conditions and temporal variations in travel time. By analysing this data, service gaps can be identified, routing can be optimized and overall transit operations can be improved.

- *Integration with other systems:* AVLS can be integrated with other ITS components, such as fare collection and scheduling systems, to optimize bus routes and enhance service delivery, thereby providing an enhanced passenger experience. Though some experiments are currently underway on a pilot basis, none of the PTAs are integrating with other systems for their entire services.

- *Identification of traffic bottlenecks:* Travel speed data from AVLS can be used to identify bottlenecks for smooth flow of bus fleet to facilitate remedial actions such as infrastructure improvements, etc.

C. Passenger information systems (PIS)

PIS utilize data from AVL systems to deliver real-time information to passengers regarding the arrival time of buses. This information can be displayed on electronic boards at bus or train stations or transmitted to mobile phones through SMS or mobile apps.

Current approach to PIS

The prevailing approach adopted by most transit agencies and ITS vendors/system integrators is to develop separate customized travel planner and information apps. However, this approach not only adds to the cost for the transit agency but also restricts the application's scope to providing information solely about the bus system.

Transformative approach to PIS

- Alternatively, there are numerous third-party travel information applications (such as Google Maps, Transit App, etc.) which can perform the same function without any additional cost, given that the AVLS data is made available in a standard General Transit Feed Specification format. These third-party apps typically aggregate data from multiple service providers, allowing them to offer a comprehensive multi-modal trip chain from the user's origin to the destination.

- Where automatic fare collection system data is also made available, PIS apps can potentially show occupancy of approaching buses along with the ETAs. Recently, Mumbai's BEST has started experimenting this on a few of their bus routes.

D. Planning and scheduling (P&S) software

P&S software plays a crucial role in automating the complex task of scheduling bus fleets and crew, considering various constraints listed below to optimize fleet operations.

- Spatial constraints: Location of depots, refuelling stations, etc.
- Technical constraints: Distance range before refuelling, and other fleet attributes, and
- Administrative constraints: Labour laws on working hours, overtime payments, time/distance cost of various resources, etc.

This software also incorporates a rostering module that utilizes resource availability from relevant ITS modules to create daily duty rosters. The resulting schedules and rosters are then exported in a structured format, such as General Transit Feed Specification, which serves as an input for the PIS and other analytical modules.

The P&S software is highly intricate, relying on extensive data inputs from various ITS components to generate practical schedules (see *Table 1: Key dependencies for P&S software*).

Current state of P&S software

ITS procurement funded by external sources often include P&S systems in the requirements. However, these requirements lack detailed specifications regarding the functionalities, constraints and optimization functions required for the solution. Consequently, bidders (system integrators) incorporate the lowest-cost solutions available in the market without fully understanding the transit agency's challenges or expectations.

Till date, all the three P&S software solutions used in India have not demonstrated practical success while successful software solutions from the West tend to be prohibitively expensive and may not be able to handle all the requirements of the Indian scenario. Therefore, there is a pressing need to develop a customized transit planning and scheduling solution tailored to the specific needs of India.

An example of the functional requirements specified for the scheduling software in one of the ITS tender is shown in *Annexure A*.

Table 1: Key dependencies for P&S software

Technology module	Data input to P&S
1. Network digitization	• Stops • Routes • Distance between stops
2. ERP software (usually not part of ITS)	• Fleet details • Crew details and availability • Cost of resources • Administrative rules for crew • Depot locations and attributes
3. AVLS	• Travel time between stops (varying by time of day, day of week, and holidays captured from historic data.
4. MIS	• Temporal distribution of passenger demand along routes (to estimate frequency of service)
5. FCS	• ETM availability
6. FMS	• Daily fleet availability • Range before refuelling
7. Direct inputs to P&S	• Route-wise service frequency • Schedule optimization criterion

E. Fleet management system

Fleet management system enables transit agencies to effectively manage the maintenance and repair of their bus fleets. It encompasses a range of features, including vehicle diagnostics, driver and fuel efficiency monitoring, preventive maintenance scheduling and spare parts inventory management. While various transit agencies utilize certain aspects of this solution, private bus fleet operators in India tend to employ a broader range of fleet management system functionalities compared to State Transport Undertakings (STUs).

Current state of fleet management system

Fleet management system is often included in externally funded ITS tenders, there is limited evidence of its practical implementation. In cases where bus operations are undertaken by private partners, these agencies prefer not to use the fleet management system procured by the transit agency. This is primarily due to the challenges of customizing the product to their specific needs as they lack direct access or control over the ITS vendor. Additionally, private agencies may wish to avoid scrutiny of their practices. For instance, in cities like Ahmedabad and Bhubaneswar, private partners have chosen not to utilize the transit agency's fleet management system.

Pune's PMPML conducted a pilot project in May 2020, implementing an independent fleet management system solution provided by a local vendor.

Most STUs have developed their own internal Enterprise Resource Planning (ERP) solutions to manage fleet maintenance and spare part procurement. Some private bus operators in the country have adopted real-time vehicle diagnostic systems offered as software-as-a-service (SaaS) models, which have proven cost effective as well as helped reduce breakdowns.

F. Command and control centre (CCC)

The CCC serves as the central infrastructure for overseeing all operational aspects of a bus transportation system. It functions as the nerve centre for monitoring and controlling bus fleets, incident management and providing passenger information.

Current state of CCC

The inclusion of a CCC is typically found in externally funded ITS procurements. However, the value it provides is often minimal compared to the substantial costs involved in setting up and maintaining such centres. With advancements in cloud technologies, high-speed mobile internet connectivity, and the widespread use of smartphones, the relevance of a CCC for transit operations today is questionable.

Transformative approach to CCC

A CCC can become a useful mechanism when the transit information is relayed to the integrated common services CCC of a city/town that can facilitate inter-departmental coordinated real-time action in case of incidents.

G. Management information system (MIS)

MIS is a computer system that collects data from various online systems, analyses the information, and generates reports to support management decision-making. Aside from the real-time components such as PIS, dashboards and alerts, MIS reports essentially represent the comprehensive analytical output of the ITS deployed within the transit agency.

Current state of MIS

MIS implemented as part of ITS is often rudimentary, presenting data in the form of lengthy tables of numbers that are either printed as PDFs or exported to Microsoft Excel. These tables frequently have an overwhelming number of columns and rows, making it challenging to identify operational issues and implement improvements. Consequently, most operational decisions still rely on a few system-level and route-level KPIs, such as EPKM (earnings per kilometre), occupancy ratio, and vehicle utilization. These KPIs can be assessed manually as well. As a result, transit staff continue to rely on manual processes for operational assessments, with limited dependence on the ITS. In fact, it is observed that the MIS module of ITS is usually utilised by lower-level staff who copy and paste a few numbers or perform basic calculations to communicate information to the entire team each morning.

Most current ITS deployments offer over 50+ MIS reports, although transit agencies typically refer to only a few of them. Sample MIS reports including ETM report, fleet overview report, bus bunching report, schedule and trips report and skipped stop report are provided in *Annexure B*.

The sample reports clearly show that the numerous rows and columns with filled data and a single day report is typically several pages long. Thus, it is quite difficult for any decision-maker, be it depot manager or traffic operation manager, to interpret these reports and take any actionable decisions based on it. As a result, transit agencies generally do not use these reports to improvise their transit services.

Some commonly encountered MIS reports include:

- **Distance travelled report:** Summary of distance travelled of a bus, typically within a calendar day. If bus route information is provided, the system can distinguish between "route distance" and "dead distance".

- **Over-speeding report and alerts:** Provides a list of instances when the vehicle exceeded a predefined speed limit, including timestamps, duration and location. Some hardware units also provide real-time alerts to drivers through flashing lights on the driver console.

- **Skipped stop report**: Lists all bus stops along the route where the bus passed without stopping for boarding or alighting passengers.

- **Route deviation report**: Identifies instances when the bus deviated from its planned route, including timestamps, locations and durations of such deviations.

- **Travelled path/ schedule adherence report**: Compares the scheduled and actual arrival times of buses at each stop along the route, with the ability to filter results based on specified criteria such as starting and ending stops or deviations exceeding a certain threshold.

- o **Daily revenue summary report**: Provides a summary of revenue collected on a given day, categorized by route, trip, conductor, service type, and other relevant factors. It includes the total number of passengers (adults and children), payment methods (cash, digital, or passes) and the overall amount collected.

- o **Boarding and alighting report:** Presents information on the number of passengers boarding and alighting at all bus stops within the network during a specified date range. This data can be filtered by bus route and summarized by the hour of day. It is often displayed on the dashboards of transit officers in cities that employ smart ETMs that transmit data in real time.

Transformative approach to MIS

MISs have undergone significant evolution since their emergence in the early 1990s. Data analytics and visualization have become distinct disciplines that contribute to business intelligence insights. Inclusion of versatile business intelligence suits which allow the user to generate their own data visualizations, reports and dashboards. This is a better approach than offering a pre-defined suite of reports.

More recently, advancements in artificial intelligence (AI) tools have enabled technology systems to learn from past datasets and offer actionable guidance to transit planners and operators.

H. Surveillance systems

CCTV cameras have been included in some of the bus/ITS procurements, mostly funded under the Nirbhaya Scheme to improve safety in public transport. CCTVs for public buses are also covered under the AIS 140 specification and include a Digital Video Recorder (DVR) with the specified storage capacity.

Current state of surveillance system

While the AIS 140 specification covers the installation and features of CCTVs, there is no monitoring mechanism in place for the maintenance of these devices. Transit agencies do not report any indicators regarding the functionality of CCTVs. Furthermore, there have been no efforts thus far to utilize image processing techniques on video logs to extract meaningful insights.

I. Transit signal priority

Transit signal priority is not a common feature of regular ITS implementations for city bus operations and management. It was initially piloted in the Pune BRT system, and later introduced in the Indore and Hubli-Dharwar BRTS systems to provide priority to bus fleets at traffic intersections. However, due to inadequate technical capabilities within the traffic police, who are responsible for operating traffic signals, functional use of these systems has been discontinued.

Note: Apart from the components categorized as ITS, State Transport Undertakings (STUs) employ various in-house software, primarily ERPs and financial management systems, to generate MIS reports and commonly reported financial KPIs.

A comparative assessment of advanced public transit system deployed by seven PTAs is provided in *Annexure C*.

Section 2: Key concerns related to APTS deployment in India

Transit operations in India, particularly urban bus operations, often face financial challenges and operate at a loss. Consequently, transit agencies tend to be conservative in their capital spending, focusing primarily on fleet procurement and maintenance infrastructure. As a result, investments in APTS by transit agencies are typically limited.

In India, large-scale deployment of APTS is primarily driven by government initiatives such as Jawaharlal Nehru National Urban Renewal Mission (JnNURM) and the Smart Cities Mission, which aim to promote sustainable urban development through the deployment of technology solutions. The key differences and similarities between self-funded and externally funded APTS procurements are outlined (see *Table 2: Key differences and similarities between self-funded and externally funded APTS procurements*).

Analysis of root cause

The use of APTS in urban bus transport has been suboptimal as highlighted in the Section 1. The following factors contribute to this situation.

a. Flawed procurement process:

The failure of APTS effectiveness can be attributed to a flawed procurement process, as identified through the analysis of various APTS tenders. A significant imbalance exists in the focus between technology components and the specific domain functions that the technology should enable. Although the tender documents for APTS procurement are often extensive, running into hundreds of pages, they lack crucial details regarding transit functions.

Excessive focus on technology hardware

Tender documents tend to overly emphasize hardware requirements and technical processes, neglecting the intended outcomes that APTS should facilitate. Given the continuous innovation in technology components, multiple cost-effective approaches can achieve the same results. Therefore, it is more practical to approach APTS from an outcomes-driven perspective. Unfortunately, many tenders

Table 2: Key differences and similarities between self-funded and externally funded APTS procurements

STU self-funded APTS procurement	Externally funded APTS procurement
• Procurement mainly consists of critically needed hardware (ETMs, GPS, etc.) directly from Original Equipment Manufacturers (OEMs). • Minimal software is included, primarily for data integration with existing MIS reporting systems of the transit agency. • These procurements are usually low budget, costing a few lakh rupees. • The software and data are deployed either on cloud infrastructure or existing IT systems. • Requirements and scope of services are developed internally, through inquiries with peers and vendors. • Deployment is typically completed within a few weeks. • The components are directly used by transit agency staff, with the vendor responsible for maintaining the hardware under an Annual Maintenance Contract (AMC). • Performance SLAs for the ITS components themselves are rarely measured or audited unless they disrupt the essential day-to-day activities of the transit agency. • The system usually generates multiple MIS reports with rows of data exported in Excel, CSV, and PDF formats. • The procurement costs are included in financial KPI calculations. • Self-funded APTS follows a "make do" piecemeal approach but is adapted to work, even with limited utility.	• Large-scale procurement of various ITS components bundled together by a system integrator. • Includes significant software costs (usually more than 50 per cent) that function as an independent/standalone system. • The available funding determines the scope, typically exceeding Rs 10 crore. • Independent data servers are usually installed in a standalone CCC with large screens (video walls). • The procurement process is usually managed by an external Project Management Consultancy). • System "go-live" often takes several years to complete. • The system is typically managed entirely by the system integrator or Project Management Consultants staff, with transit agency staff rarely using the system directly except for accessing a few reports. • The stringent SLAs specified in the tender are rarely measured or fully understood. Transit agencies continue to rely on manual processes without fully depending on the APTS system. • The reports generated are similar to their cheaper counterparts, although extracting the reports may be slower at times. • Procurement costs are excluded from KPI calculations. • Funded APTS follows a "want all" approach without fully understanding the need (domain knowledge) and procuring what is available.

Note: Some transit agencies that procured expensive integrated APTS also maintain a parallel cheaper AVLS and use it to compare the reports for validation purposes.

limit the scope by specifying detailed hardware requirements and technology processes. Consequently, the procurement of intelligent monitoring tools for transit operations transforms into procuring expensive hardware, with minimal tangible output. This approach also poses challenges when hardware and software components become outdated or incompatible.

Lacking detailing of transit functions and challenges

Custom technology procurement requires tender documentation to clearly specify the exact needs and challenges faced, to enable the vendors to develop suitable tools that efficiently address the requirements. However, APTS tenders often lack descriptions of the transit planning process, the complexity of transit operations scheduling, fleet and crew monitoring methods, physical and administrative constraints, optimization criteria, expected outputs and outcomes, KPIs, and other important aspects. These omissions restrict the bidders' understanding of the domain's contours, thus leaving them guided primarily in terms of assembling technology hardware and data storage packages during the bidding stage.

The significant lack of domain knowledge in transit operations in preparing the tender documents for procuring APTS is hindering the usefulness of the technology being acquired. Despite the requirement of having a senior transport planner on board during the hiring of a Project Management Consultants, it is often the case that individuals with this designation may lack specific knowledge in transit operations due to the vast scope of the domain. Even in cases where transit agency staff draft their own tenders, the responsibility for managing the APTS system, including activities like geo-coding bus stops and defining routes, is often placed solely on the vendor to avoid detailed documentation.

Lacking specifications for testing/measuring system performance:

Furthermore, tender documents specify extensive and sometimes unrealistic Service Level Agreements (SLA) but fail to include tools or methods for measuring system performance. Without details on the measurement methods, the stringent performance and accuracy metrics specified for the ITS system become subjective and irrelevant.

Thus, the detailed requirements that unnecessarily increase the bulk of the tender documents do not accurately represent the actual needs of the transit agency. In the absence of in-depth user requirements, vendors tend to focus on satisfying the literal specifications at the lowest possible cost.

Lack of pilot testing

The tender process often assumes that the bidder's claims are true and proposes an extremely tight timeline for deployment, typically around six months, without incorporating any pilot testing of the software's functionality and suitability. The payment schedule usually involves a payment of approximately 50 per cent of the contract value upon delivery and installation of the hardware components, which more than compensates the vendor for the actual cost of the hardware. At this point, the vendor stands to profit from the investment even if the contract is cancelled and the security deposit forfeited due to non-performance.

User Acceptance Test of the software components is typically scheduled much later in the process, and it is during this phase that the transit agency and project management staff realize that the software does not work as intended. This realization often leads to prolonged disputes between the parties. This is further accentuated when the new ITS system is expected to integrate with hardware and software components that are not part of the ITS procurement, such as the on-board computer unit of the bus, as vendors claim there is no fault with their system. Unfortunately, there is no incentive for technology vendors to ensure that the system software benefits the transit agency. The transit agency is often coerced into giving the "go-live" approval due to significant payments already made, and reversing course becomes an unfeasible option. This is evident from the fact that most large-scale ITS deployments take two to three years to achieve "go-live" despite the system hardware typically being in place within the first few months of issuing the work order.

b. Absence of network digitization

APTS procurement tender document primarily focuses on capturing data using GPS-AVLS for location information, ETMs for ticketing, and various supporting technology infrastructure such as servers and control centres. These documents also include various software applications that are expected to manage and analyse the data. However, unlike the logistics industry, where operations monitoring relies on limited input parameters, public transit has a unique characteristic. The fleet operates on a pre-defined schedule, consisting of a series of trips along specified routes with specific start and end times. Additionally, these schedules are assigned to different buses, staff and other resources on a daily basis through a process known as "duty allocation" or "roster". Analysis of operations, planning optimization and passenger information rely heavily on schedule data and rosters. Surprisingly, the tender documents for APTS procurement lack specifications for convenient spatial tools to digitize the transit agency's route plans and schedules.

Due to the price-sensitive nature of the procurement process, APTS vendors or system integrators often focus on meeting the bare minimum requirements of the tender without addressing practical challenges and ease of use. In the absence of specific guidance, APTS vendors resort to ad hoc methods of manually coding the entire network and schedule information into the database. Some deployments allow for preparing certain inputs, such as stops, routes, and the daily roster, in a specific format in Microsoft Excel, which can be imported into the database. However, the schedule information, which is the most extensive among these inputs and includes timestamps for over 250 bus stops in a single calendar day, must be manually input into the APTS system.

ISSUES WITH NETWORK DIGITIZATION

A bus schedule indicates the entire travel path of a bus for a specified period (usually one shift or 24-hour as per convention of the transit agency), along with the timings when the bus is expected to reach at each stop along the path. An urban bus typically traverses about 180 km during a day. Assuming an average of one bus stop per every 0.7 km (typical average distance between bus stops), the bus passes through more than 250 stops. The bus schedule thus has the time for each of these stops along the travel path.

A printed sheet with timings for each stop along the route is cumbersome for the bus crew to read and follow. Hence, most agencies do not specify the exact time at the intermediate stops. Instead, the schedule only contains a sequence of routes and the timings specified only for the end stops along each route.

The following is a sample of such schedule of Bengaluru Metropolitan Transport Corporation (BMTC), Bangalore.

Sample schedule (Form-IV) of one bus along Route VMF-6 in BMTC, Bengaluru

SERVICE	SUB URBAN		FORM -IV				CENTRAL ZONE
BRAND	A/C						DEPOT-29
ROUTE	VMF-6	S.V. METRO STATION TO CENTRAL SILK BOARD					NIGHT OUT
SCHEDULE	VMF-6/1						W.E.F: 16.05.2022
TRIP	**PLACE**		**ROUTE**	**TIMING**		**JOURNEY**	**REMARKS**
No.	**ORIGIN**	**DESTN.**	**LENGTH**	**FROM**	**TO**	**TIME**	
1	CSB	SVM	9.7	6:00	6:40	0:40	
2	SVM	CSB	9.7	6:45	7:25	0:40	
3	CSB	SVM	9.7	7:30	8:10	0:40	
4	SVM	CSB	9.7	8:15	8:55	0:40	
5	CSB	SVM	9.7	9:00	9:40	0:40	
6	SVM	CSB	9.7	10:10	10:50	0:40	
7	CSB	SVM	9.7	10:55	11:35	0:40	
8	SVM	CSB	9.7	11:40	12:10	0:30	
9	CSB	KRP	24.1	12:15	13:30	1:15	
10	KRP	BMT-29	0.4	13:35	13:40	0:05	
			102.1		**SIGN OFF**	**0:15**	
CREW CHANGE, FUELLING AND MAINTANANCE AT DEPOT							
11	BMT-29	KRP	0.4	14:45	14:50	0:05	
12	KRP	CSB	24.1	14:55	16:10	1:15	
13	CSB	SVM	9.7	16:15	16:45	0:30	
14	SVM	CSB	9.7	16:50	17:30	0:40	
15	CSB	SVM	9.7	17:35	18:15	0:40	
16	SVM	CSB	9.7	18:20	19:00	0:40	
17	CSB	SVM	9.7	19:05	19:45	0:40	
18	SVM	CSB	9.7	19:50	20:30	0:40	
19	CSB	SVM	9.7	21:00	21:40	0:40	
20	SVM	CSB	9.7	21:45	22:25	0:40	
			102.1		SIGN IN	0:15	
VEHICLE UTILISATION			CREW DUTY HOURS				REST FOR CREW
SCH. KMS	101.7	101.7	SPREAD	7:55	7:55		0940-1010
DEAD. KMS	0.4	0.4	STEERING	7:25	7:25		2030-2100
TOTAL KMS	204.2		HALT AT	CSB			
FARE STAGES							
1 S.V.Road Metro Station				5. KRM 80ft & 100ft Road			
2. Indranagara police Station				6. KRM Water tank			
3. Doopanahalli				7. Madivala			
4. Inner Ring Road Military bridge				8. Central Silk Board (Madivala)			

Sample schedule (MTD-141) of one bus along Route 10H in TSRTC, Hyderabad

APSRTC MIYAPUR-II DEPOT

ON ROUTE: 10H W.E.F:30.03.2015 SER NO.-95

KONDAPUR TO SEC-BAD

APSRTC MIYAPUR-II DEPOT

METRO EXPRESS

PLACE	1	2	3	4	5	6
DEPOT	5:45			13:05		
ALLWYN X RD	5:50			13:15		
KONDAPUR		8:00	10:15		15:30	17:45
SEC-BAD	6:55	9:05	11:20	14:20	16:35	18:50
SEC-BAD	7:00	9:10	11:25	14:25	16:40	18:55
KONDAPUR	7:55	10:00		15:25	17:40	
ALLWYN X RD			12:35			20:05
DEPOT			12:45			20:25
KMS	51	42	51	51	42	51
I ST SHIFT	5:45	12:45	7:00	KMS	144	
2 ND SHIFT	13:05	20:25	7:20	KMS	144	
I ST SHIFT	7:00	0:40	7:40	7:30	0:10	
2 ND SHIFT	7:20	0:40	8:00	7:30	0:30	

Similarly, a bus could be also planned to traverse along multiple routes over the period of the crew-shift or the day. Another such sample from Telangana State Road Transport Corporation (TSRTC), Hyderabad is shown below. It is to be noted that in this schedule, the bus is plying along the same route (10H) but has slightly different pattern for different trips in the day.

However, digitizing such schedules in the ITS system create flows in the system, thus the system should either be built to interpolate the timings of intermediate stops, or the person coding this information into the ITS module has to manually interpolate and enter all the details. A sample of all stop timing schedule is providing below, from Indore bus system.

Additionally, due to cumbersome nature of digitizing transit networks and schedules, the transit agency relies on the vendors to code the schedule information in the system and lacks the means to independently verify its correctness.

During user acceptance tests, the APTS vendors employ ground staff to manually input either a sample or all of the transit agency's printed schedules. The transit agency is often unaware of the need to keep the route and schedule information updated and is not given control over the module used for inputting schedules. Additionally, in many cases, particularly for large PTAs, routes and schedules are modified every few weeks, rendering the timetables in the system irrelevant.

Sample schedule of one bus along Route M-22 in Indore, Madhya Pradesh

Sr	Bus Stop Name	KM	Stop Timings - Route M-22: Schedule 1 of 10												
1	Lakhani Bypass	0.0		8:11	8:21	10:51	11:01	13:31	13:41	16:11	16:21	18:51	19:01	21:31	21:41
2	Jairam Toll Kata	0.7		8:09	8:23	10:49	11:03	13:29	13:43	16:09	16:23	18:49	19:03	21:29	21:43
3	Prabhu Toll Kata	1.6		8:06	8:26	10:46	11:06	13:26	13:46	16:06	16:26	18:46	19:06	21:26	21:46
4	Udyog Nagar	2.2		8:04	8:28	10:44	11:08	13:24	13:48	16:04	16:28	18:44	19:08	21:24	21:48
5	Babul Nagar	2.8		8:02	8:30	10:42	11:10	13:22	13:50	16:02	16:30	18:42	19:10	21:22	21:50
6	Palda Naka	3.5		8:00	8:32	10:40	11:12	13:20	13:52	16:00	16:32	18:40	19:12	21:20	21:52
7	Teen Imli	4.0		7:58	8:34	10:38	11:14	13:18	13:54	15:58	16:34	18:38	19:14	21:18	21:54
8	Chitawad	4.5		7:52	8:40	10:32	11:20	13:12	14:00	15:52	16:40	18:32	19:20	21:12	22:00
9	Prakash Nagar	5.0		7:50	8:42	10:30	11:22	13:10	14:02	15:50	16:42	18:30	19:22	21:10	22:02
10	Navlakha Bus Stand	5.3		7:49	8:43	10:29	11:23	13:09	14:03	15:49	16:43	18:29	19:23	21:09	22:03
11	Zoo	6.1		7:46	8:46	10:26	11:26	13:06	14:06	15:46	16:46	18:26	19:26	21:06	22:06
12	G.P.O.	6.5		7:44	8:48	10:24	11:28	13:04	14:08	15:44	16:48	18:24	19:28	21:04	22:08
13	Shivaji Vatika	7.1		7:42	8:50	10:22	11:30	13:02	14:10	15:42	16:50	18:22	19:30	21:02	22:10
14	M Y Hospital	7.6		7:40	8:52	10:20	11:32	13:00	14:12	15:40	16:52	18:20	19:32	21:00	22:12
15	M Y Hospital Gate	7.7		7:39	8:53	10:19	11:33	12:59	14:13	15:39	16:53	18:19	19:33	20:59	22:13
16	Dawa Bazaar	8.0		7:38	8:54	10:18	11:34	12:58	14:14	15:38	16:54	18:18	19:34	20:58	22:14
17	Madhumilan Chauraha	8.2		7:36	8:56	10:16	11:36	12:56	14:16	15:36	16:56	18:16	19:36	20:56	22:16
18	Chhoti Gwaltoli	8.5		7:34	8:58	10:14	11:38	12:54	14:18	15:34	16:58	18:14	19:38	20:54	22:18
19	Sarvate Bus Stand	8.9		7:32	9:00	10:12	11:40	12:52	14:20	15:32	17:00	18:12	19:40	20:52	22:20
20	Indore Railway Station	9.3	6:22	7:30	9:02	10:10	11:42	12:50	14:22	15:30	17:02	18:10	19:42	20:50	22:22
21	Regal Squre	9.9	6:27	7:25	9:07	10:05	11:47	12:45	14:27	15:25	17:07	18:05	19:47	20:45	
22	Gandhi Hall	10.6	6:30	7:22	9:10	10:02	11:50	12:42	14:30	15:22	17:10	18:02	19:50	20:42	
23	Kothari Market/Mth	10.8	6:31	7:21	9:11	10:01	11:51	12:41	14:31	15:21	17:11	18:01	19:51	20:41	
24	Krishnapura Pull	11.4	6:33	7:19	9:13	9:59	11:53	12:39	14:33	15:19	17:13	17:59	19:53	20:39	
25	Sanjay Setu	11.5	6:34	7:18	9:14	9:58	11:54	12:38	14:34	15:18	17:14	17:58	19:54	20:38	
26	Nandlalpura	11.9	6:37	7:15	9:17	9:55	11:57	12:35	14:37	15:15	17:17	17:55	19:57	20:35	
27	Gurudwara	12.1	6:38	7:14	9:18	9:54	11:58	12:34	14:38	15:14	17:18	17:54	19:58	20:34	
28	Pipli Bazar	12.4	6:40	7:12	9:20	9:52	12:00	12:32	14:40	15:12	17:20	17:52	20:00	20:32	
29	Narsingh Bazar	12.7	6:42	7:10	9:22	9:50	12:02	12:30	14:42	15:10	17:22	17:50	20:02	20:30	
30	Malganj	13.1	6:45	7:07	9:25	9:47	12:05	12:27	14:45	15:07	17:25	17:47	20:05	20:27	
31	Rajmohalla	13.7	6:48	7:04	9:28	9:44	12:08	12:24	14:48	15:04	17:28	17:44	20:08	20:24	
32	Gangwal Bus Stand	14.1	6:51	7:01	9:31	9:41	12:11	12:21	14:51	15:01	17:31	17:41	20:11	20:21	

Without accurate schedule data, monitoring transit operations (such as schedule adherence, route deviations, crew performance, SLA monitoring in PPP, etc.), route optimization in planning, and passenger information becomes impossible. This is the most significant reason why existing APTS deployments across India are rendered ineffective.

c. Lack of data visualization

Almost all the transit agencies implement MIS as a part of the overall APTS deployment to generate extensive MIS reports. These spreadsheets are quite difficult to understand to take any actions by its users.

TRANSIT DATA VISUALIZATION—WHAT CAN BE DONE WITH THE TRANSIT DATA?

Transit operations, especially in urban areas, is a complex exercise. While there are many aspects to the success of a transit service, the key factors in acquiring passenger mode share are:

a) **Service availability:** Characterised by the frequency of the transit service towards the desired destination where the bus is not already crowded at the place of boarding.
b) **Reliability of service:** The guarantee of finding a bus within the specified headway/wait-time or arrival of the bus as per the pre-defined schedule.
c) **Affordability:** The availability of a transit service at a cost that is within the paying capacity of the passenger.

In the current scenario where the costs of urban bus operation are made loss-making due to the levy of various taxes, technology may have a limited role in making bus services affordable. However, ITS can reduce the financial viability gap by bringing efficiency and optimization that will reduce costs while also make the service reliable, thus increasing ridership as well as revenue.

The following sections present some sample data visualizations that can make the ITS data and reports easily actionable and amenable to decision-making.

Assessing transit schedule correctness

The very first step in transit operations is the creation of routes and their timetables. The routes are designed based on primary demand surveys or user requests and feedback. The frequency of service is then defined by the estimated demand (which is the preferred option). However, in the Indian scenario, it has been seen that the timetable along a route is defined based on the available fleet and the technical/administrative constraints of operation. Thus, the scheduler prepares schedules for each individual bus in the fleet. However, such presentation of timetable makes it impossible for the supervisor or approving authority to identify issues with the plan or mistakes in the data.

A visualization of the same schedule (Route M-22, Indore) of all the 10 buses, along with a few key parameters, lends itself to quickly assess the reasonableness and correctness of the plan (see *Figure 1: Daily schedule of Route M-22 [Indore]*).

Figure 1: Daily schedule of Route M-22 (Indore)

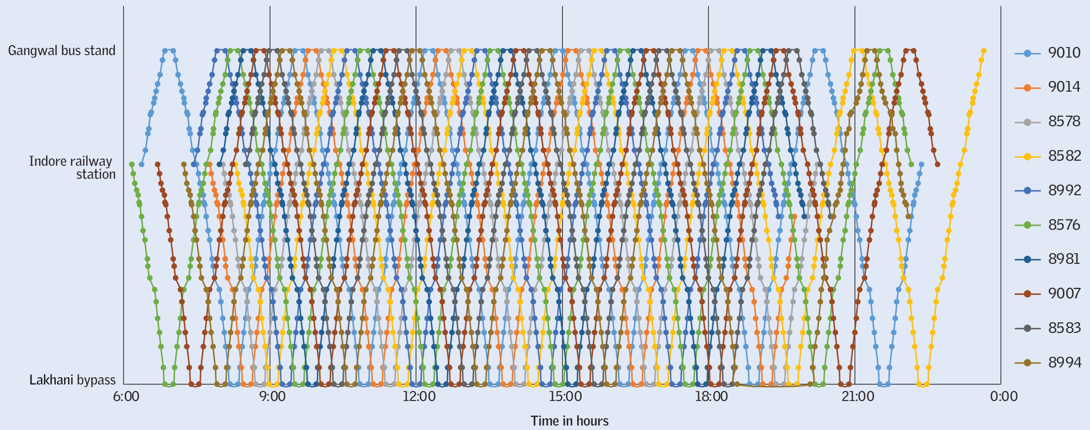


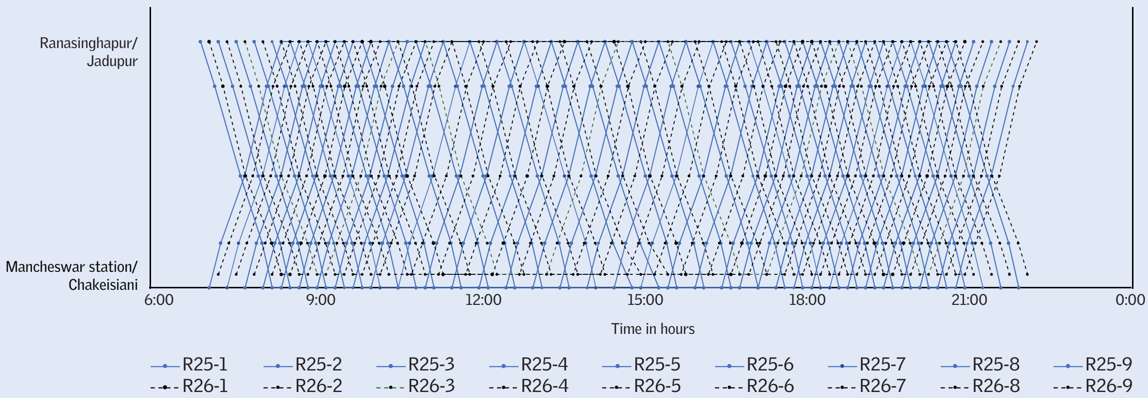
Figure 1 clearly shows that from 8.30 a.m. to 6.30 p.m., the scheduled is designed compactly to provide (headways are distrusted evenly) smooth service delivery, where 6.30 p.m. onwards services the headway gets reduced as the peak period ends.

Assessing schedules of overlapping routes

The process of scheduling of buses becomes even trickier when two or more routes have a significant overlap (see *Figure 2: Schedules of overlapping routes #25 and #26 of CRUT, Bhubaneswar*).

The figure presents a visualization of schedule of buses plying on two different routes but with some common stops along the routes 25 and 26 of Capital Region Urban Transport (CRUT), Bhubaneswar. Both the routes followed the same road segments twice—once about 6.30 km between Rasulgarh Square (chainage 4 km) to Raj Mahal (chainage 10 km) and about 4.2 km between Jagamara (chainage 18 km) to Jadupur (chainage 22 km). In such a scenario, it is imperative that buses on route #25 and #26 are planned such that they do not bunch in the overlapping route segment. Visualization tools become extremely important when trying to assess the quality of the schedule that is being prepared.

Figure 2: Schedules of overlapping routes #25 and #26 of CRUT, Bhubaneswar



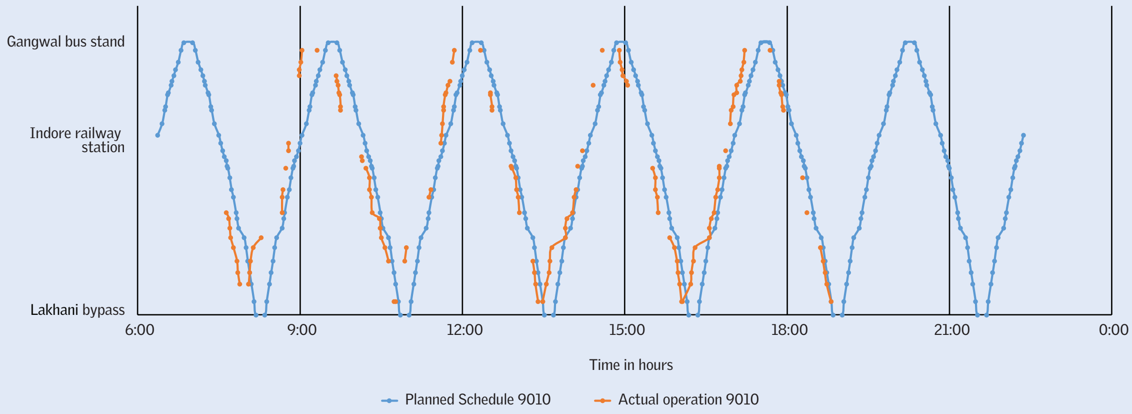
In the absence of such visualization tools, it is entirely possible that the timetables of the overlapping routes are not synced and even if the bus crew adhere to the schedule, there may be bunching of buses. Having such visualization tools make the timetabling exercise less error prone.

Assessing the schedule adherence of transit services

Once a timetable is rolled out for operations, it is necessary to monitor the service to ensure that the crew adhere to the planned timetable so that there is no gap between what is intended and what gets delivered. Transit agencies depend on the AVL system to track the buses and inform the transit supervisors on deviations.

A sample of the schedule adherence report that is generated by the ITS deployed in STUs is presented under *Item # IV in Annexure B* of this report, which is very hard to decipher. However, schedule adherence can be better monitored by way of a time-space graph (see *Figure 3: Schedule adherence of bus #9010 on route M-22 [Indore]*).

Figure 3: Schedule adherence of bus #9010 on Route M-22 (Indore)



Just by transforming a large table with hundreds of rows into a simple visualization makes it easy for the transit supervisor to assess the deviations. The following are the immediate observations that can be made from the Figure 3:

a) The bus started operations from 7.40 a.m. instead of 6.20 a.m., thereby skipping the first trip.
b) Similarly, the crew also truncated the schedule and skipped a complete round-trip after 6.50 p.m.
c) There are various times in the day that the AVLS was unable to capture the location data, which is either indicative of lack of satellite signal in the area, or of a faulty GPS unit, or a malfunctioning data processing software.
d) The bus seems to have avoided the origin stop at chainage 0.00 km on all the trips and instead turned back at the second stop at chainage 0.70 km.
e) This could be for any of the reasons in #c or because the passenger terminal may be very big, but the geo-fence in the AVLS is not covering the entire area of the passenger terminal.

With these quick observations, the supervising authority can quickly investigate, identify the root cause, and issue instructions for corrective action and penalties as per Service Level Agreement (SLA).

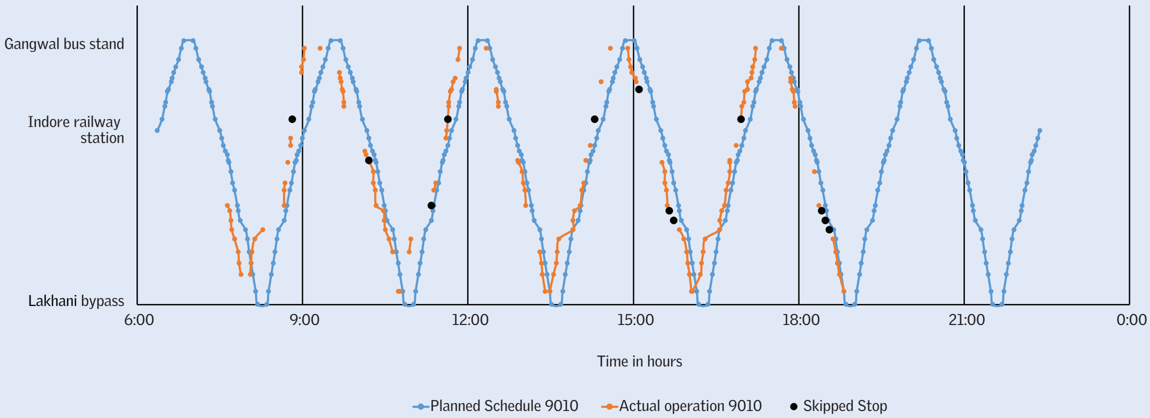
Assessing skipped stop services

Another common issue of concern, especially in Gross Cost Contracts (GCC) is that of the bus crew skipping halting at the bus stops to pick up passengers. The current most common format of the "Skipped Bus Stop Report" is shown under *Item # V in Annexure B*. However, this data can also be visualized as presented in *Figure 4: Skipped stops overlaid with schedule adherence*.

Once again, this visualization enables some quick observations that are otherwise not easy when looking a tabular report with too many cells.

a) The crew of this bus skipped stops multiple times during the day. This is sometimes possible because there are no boarding or alighting passengers at the stop at that time, or if the bus is too crowded to take passengers. Visualising this data makes it much easier and amenable to investigation.
b) Further, the visual indicates that the driver missed the "Regal Square" stop at chainage 9.90 km in the "Up" direction on all the trips. This can be because the stop has been coded incorrectly in the system or if the driver is unaware of the stop at that location. If the stop is missed by all the drivers on the route, it is most likely an issue with the system. Else the problem is with the driver.

Figure 4: Skipped stops overlaid with schedule adherence

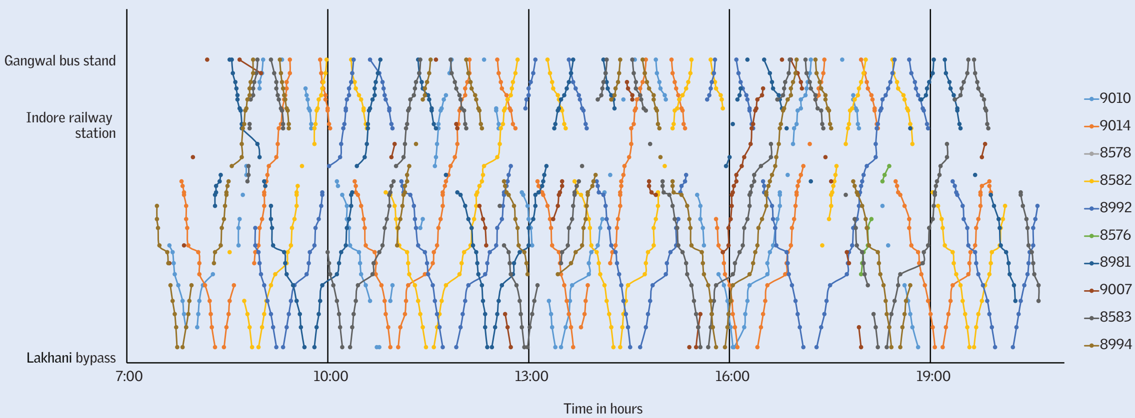


Assessing the actual service delivery

Similar to the visualization for a single bus is the overall service delivery of all fleets (see *Figure 5: Actual service delivery of all the buses on route M-22*). It can be clearly seen that the actual delivery of service on route M-22 is quite different from the plan depicted in *Figure 1*.

Another immediate observation is that the actual services ended by 20:30 hours while the planned services were up to 23:00 hours. Analysis of this variation, along with some of which are presented in the next subsections, can lead to corrective actions.

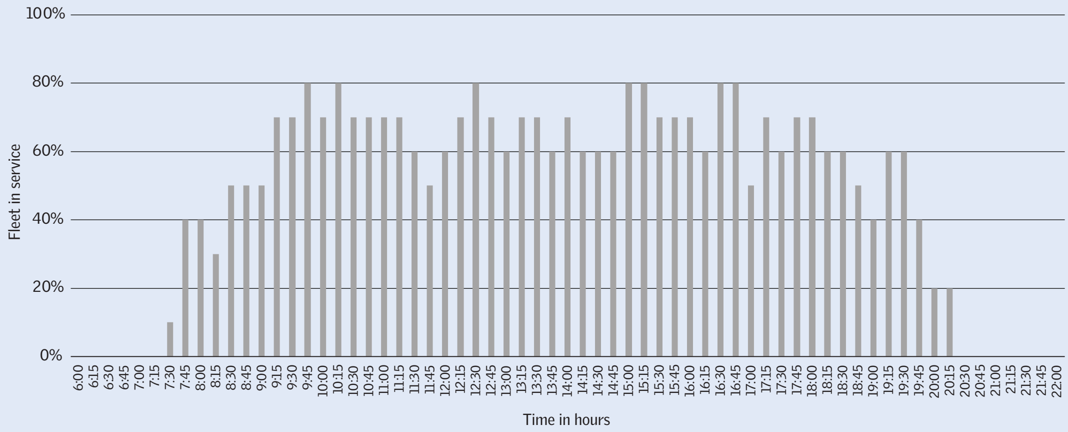
Figure 5: Actual service delivery of all the buses on route M-22



Assessing fleet deployment plan

Another method to visualize the same data is in terms of the operational fleet by the time of day (see *Figure 6: Temporal distribution of operational fleets on M-22*). It is evident that all 100 per cent of the fleet was not in operation at any point in the day, including the peak hours. This could either be because two of the total ten fleet planned were not in operation or their tracking unit was not functional. A look at the fare collection system data can enable this investigation.

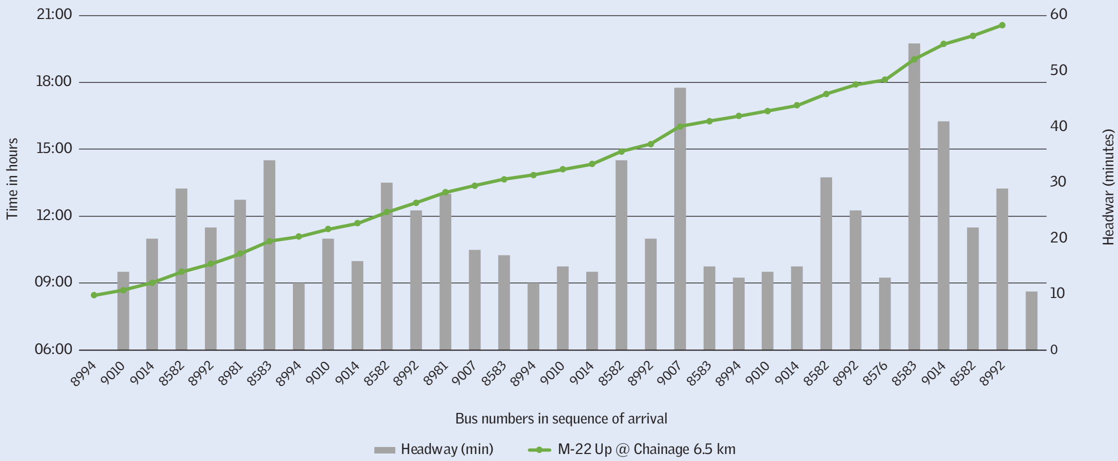
Figure 6: Temporal distribution of operational fleets on route M-22 (on March 13, 2023)



Assessing the reliability of transit services

From a passenger point of view, it is less important that the bus is exactly on schedule than the uniformity in headway at which the bus arrives at a stop. The reliability of service can be assessed by looking at the regularity of arrival of buses at a given stop.

Figure 7: Assessment of service reliability on route M-22 at GPO bus stop



The visual in Figure 7 presents a clear picture of the passenger experience. It can be seen that the headway is quite varying, even during the morning and evening peak hours. In a scenario like route M-22 where the planned headway is quite high at 10 minutes, it is pertinent that the uniformity of headway should be ensured.

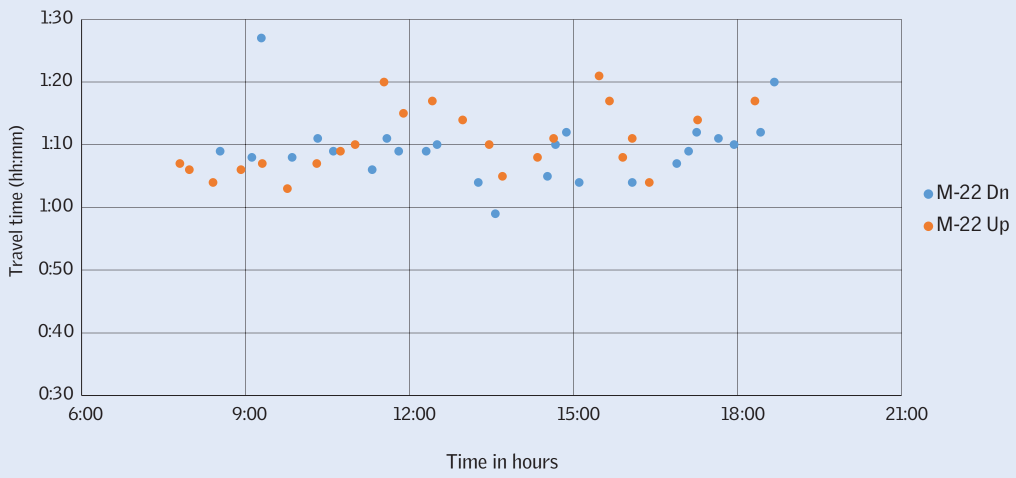
It should however be noted that the service reliability visualization may sometimes indicate excessive headway if the AVL system failed to capture a bus trip at the bus stop under examination.

Assessing the temporal variation in travel time

A common reason for the actual performance to be very different than the plan is the mismatch in the travel time in actual ground conditions. It is observed that all STUs use a fixed travel time for route during scheduling, which is not realistic (see *Figure 8: Temporal variation of travel time on route M-22*). Figure 8 shows the uniformity of travel time of both up and down services across day, which is around 70 minutes to complete one side trip. This is primarily because roads of Indore are quite congested throughout the day.

The visualization however indicates one outlier trip where the driver took about 88 minutes to complete the trip that started at about 9 a.m. Other drivers who made trips around the same time took much less time. The visualization enables the supervisor or transit manager make investigations regarding a specific driver on the causes and thus be alert to deviations.

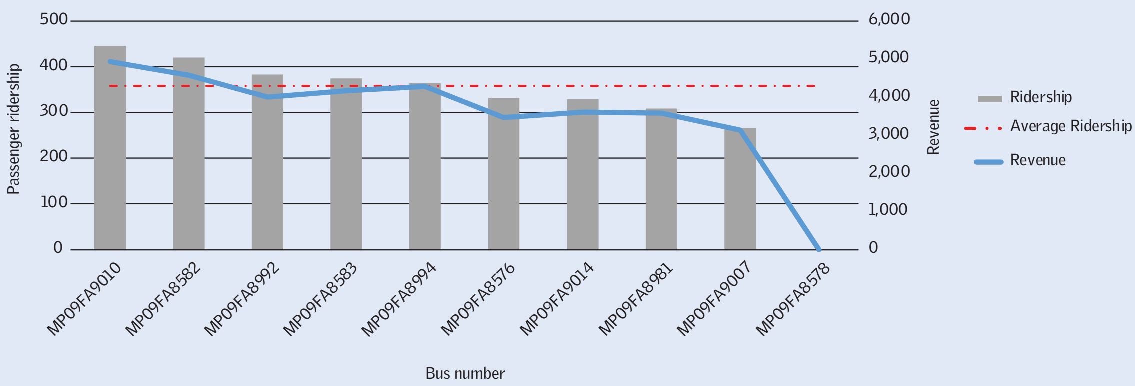
Figure 8: Temporal variation of travel time on route M-22



Assessing ticketing data to understand the performance of the system

Bus-wise analysis of ticketing data shows how each bus is performing with respect to another in terms of carrying passengers and generating revenues for the system. Accordingly, authorities can easily identify poor performers.

Figure 9: Bus-wise passenger revenue and ridership pattern



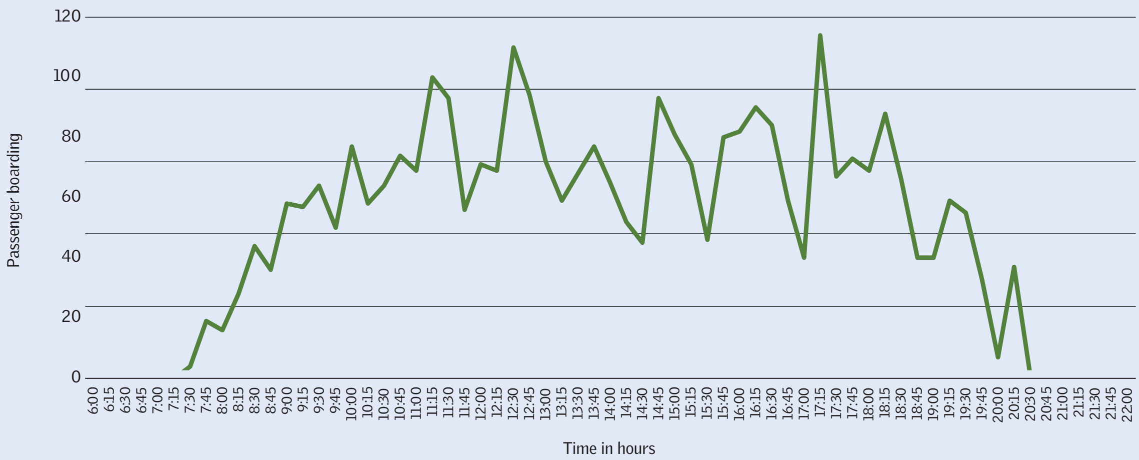
The ridership-revenue figure can quickly bring focus on the following:

- Nine of the total ten buses were operational on the day, unlike the conclusion derived in Figure 6. A quick look at the schedule adherence visualization and the bus-wise ridership is able to conclude that the GPS unit on bus #8576 was malfunctioning and needs to be fixed.
- Bus #9007 has recorded the lowest ridership, 25 per cent lower than the average, which could be a result of skipping of bus stops or even trips altogether, and needs to be investigated.
- Buses #8992 and #8576 have recorded lower average fares per passenger as compared to the other buses. This could point to the possibility of the ticket conductor issuing short-tickets (i.e. tickets to a destination nearer than the actual destination of the passenger), and syphoning off the remaining fare). If this result is consistent with the performance of the ticket conductor on other days as well, then the Revenue Assurance Team can be directed to conduct spot checks on the buses where this conductor is deployed.

Assessing the passenger demand of the system

Passenger demand distribution over time helps authorities to understand the peak and off-peak demand of the services (see *Figure 10: Temporal distribution of passenger demand on route M-22, Indore*).

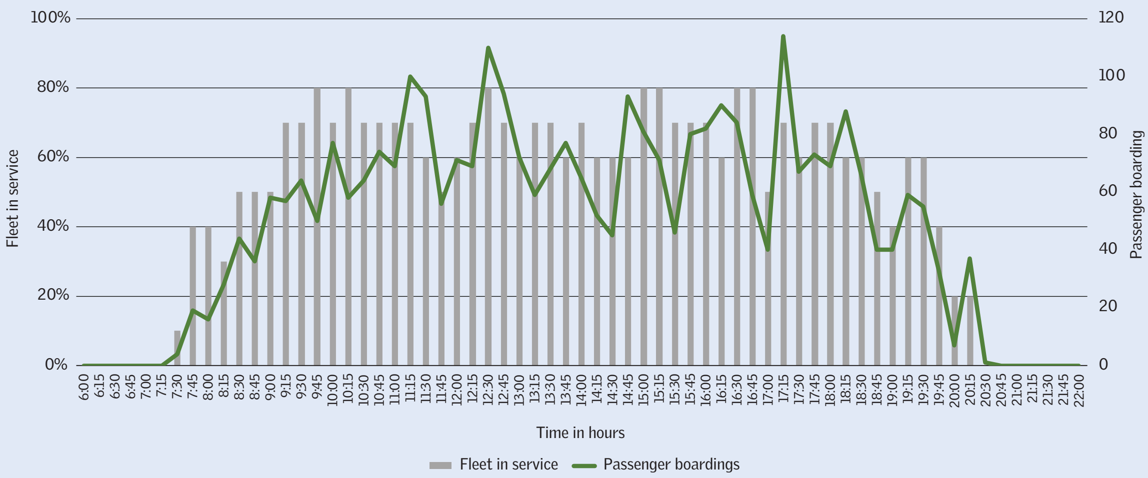
Figure 10: Temporal distribution of passenger demand on route M-22, Indore



This visualization becomes much more meaningful if we overlay the temporal variation buses within the same time period (see *Figure 6*). The combined visualization reflects how well passenger demand is well synchronised with distribution or availability of buses in that particular route (see *Figure 11: Overlay of passenger boarding over operational buses over the day on route M-22, Indore*).

The Figure 10 clearly depicts that the passenger boardings more or less proportional to the supply of buses during the day. We also know that the buses are being operated irregularly and with large headways. Hence, the conclusion can be made that there is a willingness of passengers to take the bus and there are people boarding the bus when available. This is a clear indicator that there is potential to capture more passengers along this route by improving the reliability of the buses by maintaining uniform headway (so that potential passengers wait for the bus), and by increasing the number of operational buses (shorter wait time leads to more passenger shift).

Figure 11: Overlay of passenger boarding over operational buses over the day on route M-22, Indore

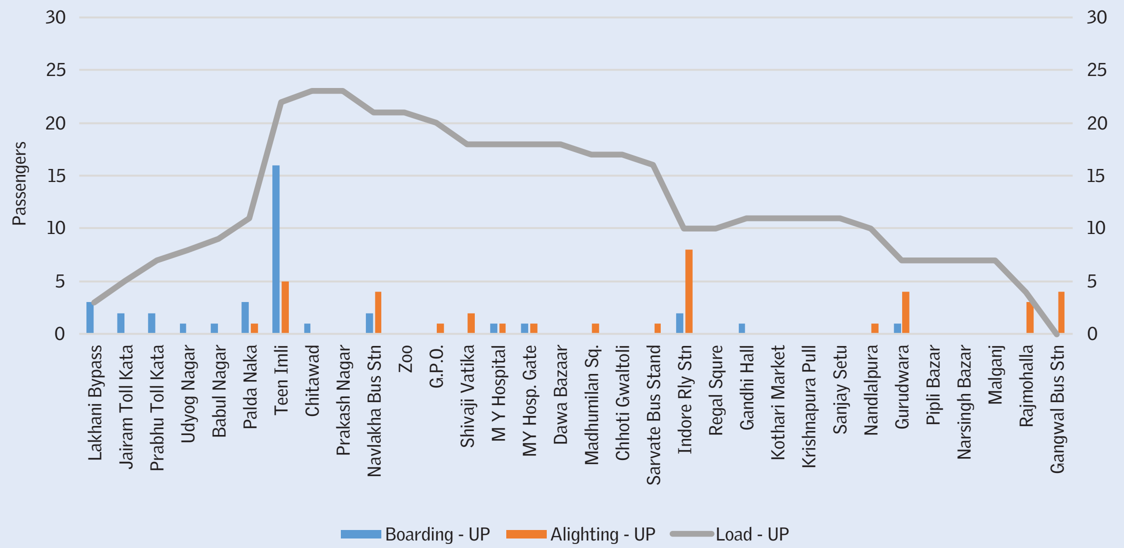


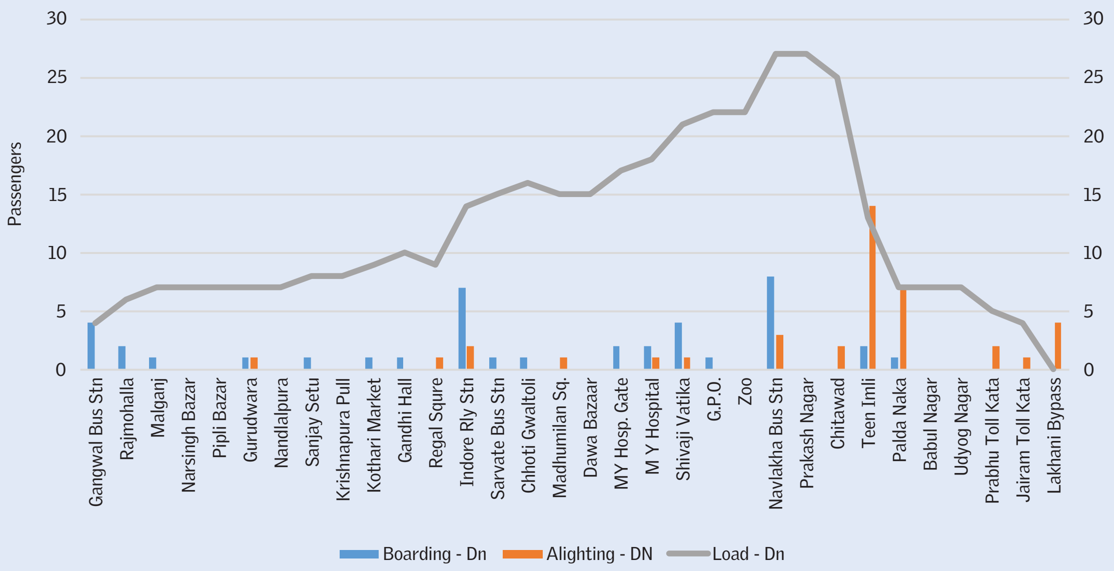
Assessing the passenger load to understand the travel pattern in the area

Apart from the simple daily summaries, ticketing data offers a wealth of information about the travel patterns of the passengers on the route (see *Figure 12: Average passenger load distribution along route M-22*). Figure 12 represents average passenger load and boarding and alighting along route M-22 in the up and down directions.

This visualization quickly gives insights into average passenger load in the bus at various sections of the route. It can be seen that the passenger load is typically very low on both the ends of the route—for the first 4 km from Lakhani Bypass to Teen Imli and the last 2 km from Gurudwara to Gangwal Bus Stand. Thus, at least 6 km of the route length of 14.1 km is quite underperforming, which is fairly inefficient.

Figure 12: Average passenger load distribution along the route M-22





However, this does not mean that the trip can be truncated to run only between Teen Imli and Gurudwara as that will lose out on the few passengers boarding at those segments which will further bring down the passenger load on this bus route. This requires a more detailed analysis of the origin-destination patterns of the passengers boarding from these low demand segments. This can be done in the form of a Sankey diagram (see *Figure 13: Visualization of the passenger travel pattern long route M-22*).

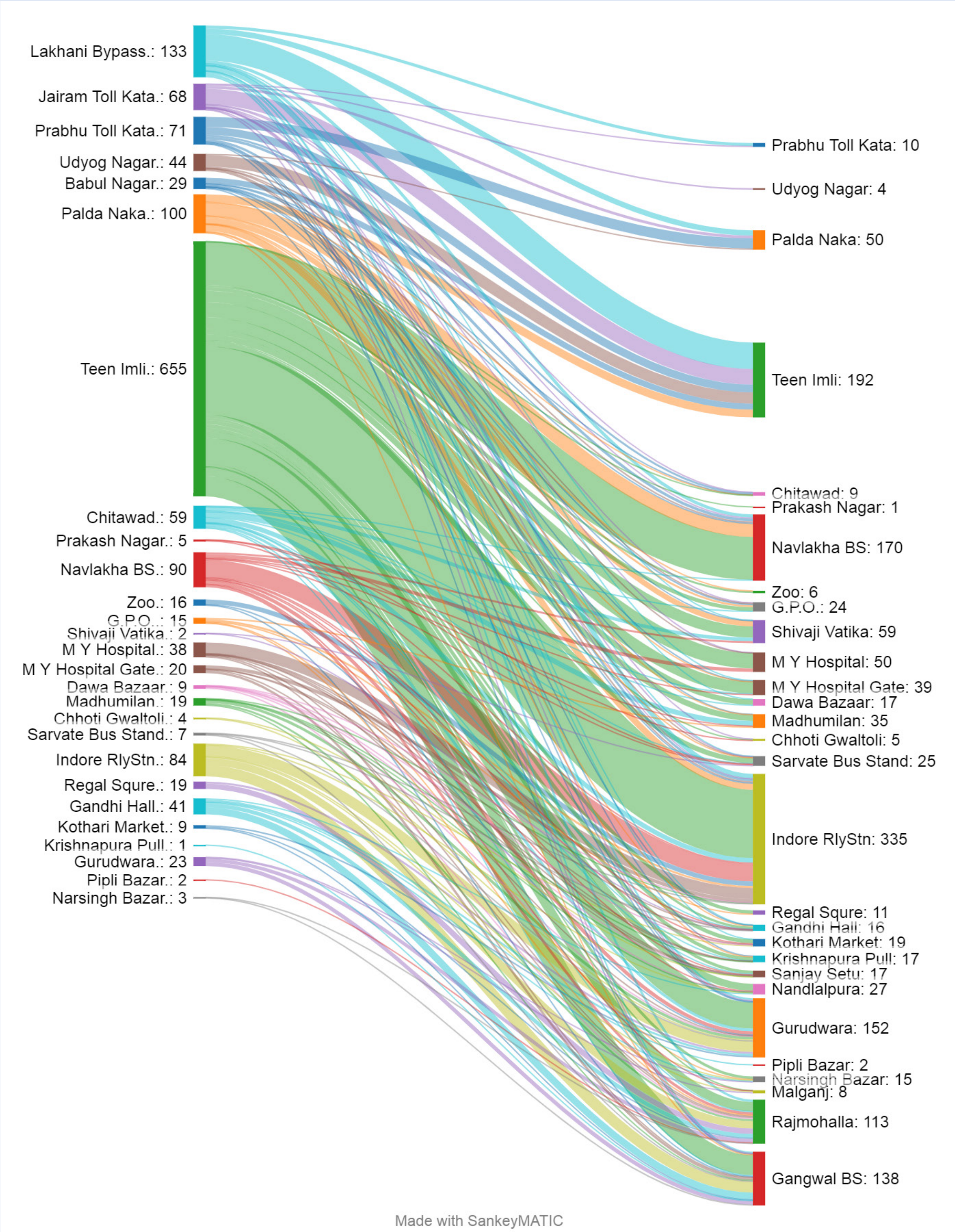
Further, the boarding and alighting patterns also point that there are about five bus stops along the route where the daily passenger activity is less than 10 over a total of 80+ bus trips. Thus, removing these stops can also help in improving the travel speed of the bus, thus improving passenger experience.

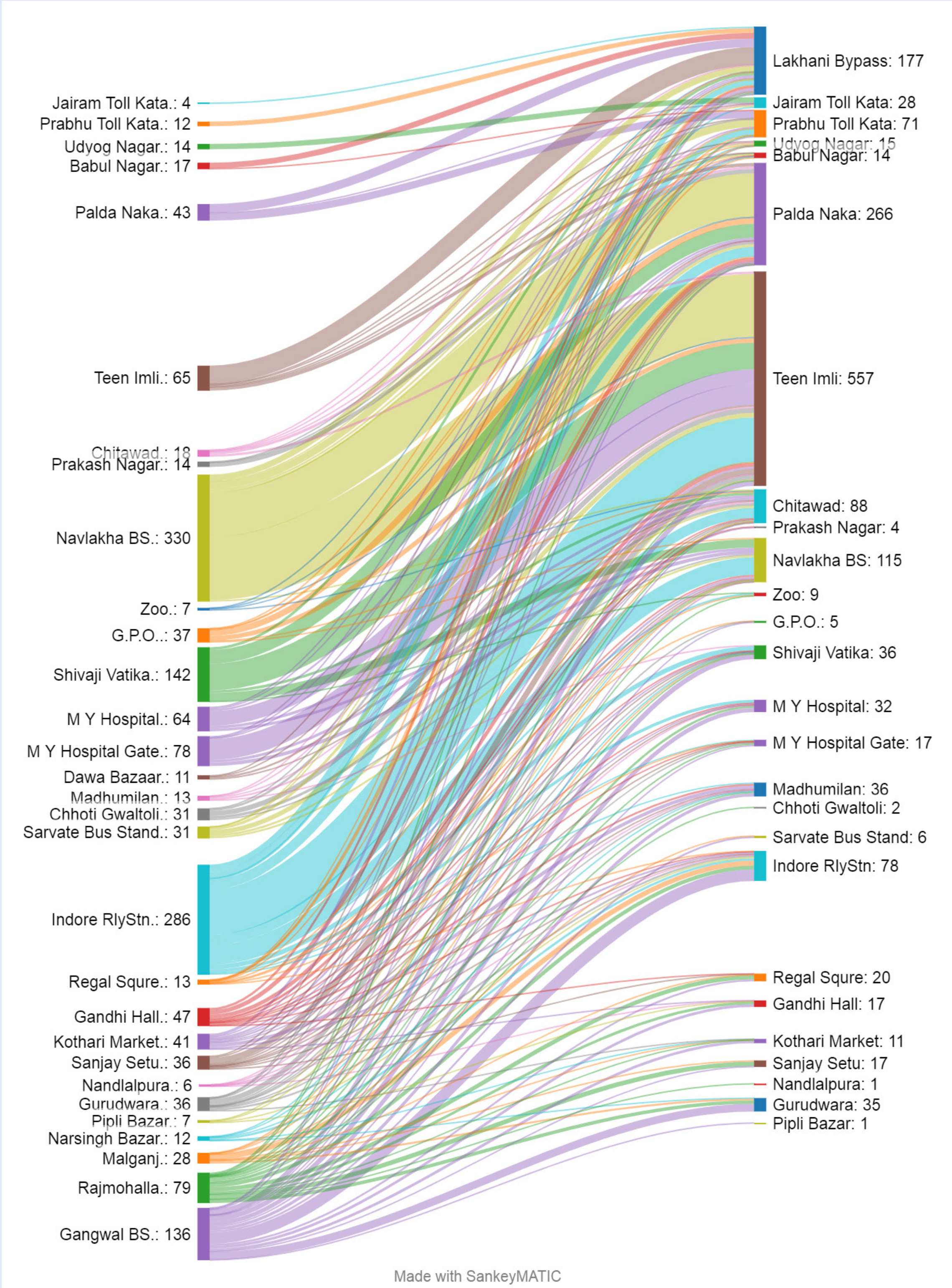
The density of the lines from the passenger origin to the destination indicates the passenger load in the bus. However, for that purpose, *Figure 12* is a much better representation. The Sankey diagram is more useful to visualize the destinations of the passengers boarding at each stop. The following are some very evident observations:

- In the "Up" direction,
    - Almost all the passengers boarding between Lakhani Bypass and Udyog Nagar stops are alighting the bus at Teen Imli.
    - A few passengers from Babul Nagar and Palda Naka are continuing beyond Teen Imli and going till Indore Railway Station.
    - Very few passengers are boarding buses from the first 4 km on Route M-22 to travel beyond Indore Railway Station.
- Similarly, in the "down" direction,
    - Passengers boarding between Gangwal Bus Stand and Pipli Bazar are alighting the bus mostly at Indore Railway Station.
    - Very few passengers boarding before Indore Railway Station are traveling beyond Teen Imli.

This visualization presents an opportunity for optimizing the route plan. Instead of operating all the 10 buses on Route M-22 from end-to-end for the 14.1 km between Lakhani Bypass and Gangwal Bus Stand, it can be restructured as the following two sub-routes:

Figure 13: Visualization of the passenger travel pattern long route M-22




Jairam Toll Kata.: 4
Prabhu Toll Kata.: 12
Udyog Nagar.: 14
Babul Nagar.: 17
Palda Naka.: 43
Teen Imli.: 65
Chitawad.: 18
Prakash Nagar.: 14
Navlakha BS.: 330
Zoo.: 7
G.P.O..: 37
Shivaji Vatika.: 142
M Y Hospital.: 64
M Y Hospital Gate.: 78
Dawa Bazaar.: 11
Madhumilan.: 13
Chhoti Gwaltoli.: 31
Sarvate Bus Stand.: 31
Indore RlyStn.: 286
Regal Squre.: 13
Gandhi Hall.: 47
Kothari Market.: 41
Sanjay Setu.: 36
Nandlalpura.: 6
Gurudwara.: 36
Pipli Bazar.: 7
Narsingh Bazar.: 12
Malganj.: 28
Rajmohalla.: 79
Gangwal BS.: 136
Lakhani Bypass: 177
Jairam Toll Kata: 28
Prabhu Toll Kata: 71
Udyog Nagar: 15
Babul Nagar: 14
Palda Naka: 266
Teen Imli: 557
Chitawad: 88
Prakash Nagar: 4
Navlakha BS: 115
Zoo: 9
G.P.O.: 5
Shivaji Vatika: 36
M Y Hospital: 32
M Y Hospital Gate: 17
Madhumilan: 36
Chhoti Gwaltoli: 2
Sarvate Bus Stand: 6
Indore RlyStn: 78
Regal Squre: 20
Gandhi Hall: 17
Kothari Market: 11
Sanjay Setu: 17
Nandlalpura: 1
Gurudwara: 35
Pipli Bazar: 1
Made with SankeyMATIC

i. Five buses operating on Route M-22 as a 12.1-km route from Lakhani Bypass to Gurudwara (subject to the possibility of turning the bus at Gurudwara), and
ii. Another five buses operating on Route M-22 as a 10.1-km route from Gangwal Bus Stand to Teen Imli.

This arrangement results in a saving of 300 km of route operation per day on Route M-22 without any practical loss in passenger ridership. This is a 21 per cent saving in travel distance that can now be utilized in operating additional six round trips on the two sub-segments, thus increasing the frequency of the route. This means lesser wait time for passengers and more passenger ridership.

Implications
The visualizations presented here are by no means exhaustive. However, they present a significant improvement to the reports delivered by the ITS in the STUs. This can thus be used as a guidance document in the tender specifications to give an idea to the prospective bidders on the kind of visualization and KPIs expected from the deployment of technology for public transport.

It can also be seen that error-free data is very essential for performing analysis and business intelligence functions. Thus, having a national ITS platform would enable structured and co-relatable data that can be evaluated using artificial intelligence algorithms that can mass process this information to provide insightful recommendations at very low cost.

Although same can be translated into some beautiful graphs and charts which are self-explanatory and easy to interpret. Lack of visualizations of transit schedules, adherence, skipped stops, passenger demand among others limits transit supervisors and operators' ability to take quick actions for betterment of services.

d. Lack of data standardization

Over the past decade and a half, buses have undergone significant technological advancements. Each bus is equipped with numerous sensors that monitor the health parameters of various components, enabling the early detection of malfunctions. Under the widely adopted UBS-II specifications, buses are installed with Onboard Units (OBUs) and are required to deliver over 50 diagnostic parameters. The level of sophistication has further increased with the introduction of electric buses. However, APTS tenders have not evolved to include specifications for capturing and processing this data. Moreover, the absence of a standardized protocol for transmitting and storing VHMS data, similar to what has been established for location data (AIS 140), presents significant challenges in effectively capturing and utilizing this information. This represents a major shortfall in optimizing fleet maintenance and upkeep, especially as bus technologies continue to advance.

e. Conflict of interests of project management consultants

Transit agencies often lack specialization in technology and hence engage the services of project management consultants for the APTS procurement, which involves assessing technological needs, preparing Detailed Project Reports

(DPRs), drafting tender documents, managing the bidding process, assisting in vendor evaluation and selection, overseeing deployment, conducting acceptance tests, and ensuring successful system implementation. In some cases, Project Management Consultants also take on the responsibility of managing and utilizing the APTS infrastructure and tools post-deployment.

While this arrangement may seem appropriate, it is important to note that project management consultant payments are tied to specific milestones in the APTS procurement process outlined above. Consequently, project management consultants are only compensated if the procurement process progresses smoothly. Even in cases where project management consultants are contracted on a man-month basis, delays in tendering can lead to significant cost overruns. As a result, project management consultants often draft tenders based on what is readily available in the market, rather than what is truly necessary to enhance the transit system, in order to mitigate the risk of tendering delays. Furthermore, after the vendor selection, the interests of the project management consultant become more aligned with those of the vendor (as their payments are tied to the successful completion of deployment) rather than with the transit agency whom they represent.

f. Unreasonable timeline for project completion

Most expensive APTS deployments in India are funded by government entities or multilateral agencies, with funds allocated according to pre-defined timelines. Funds that are not being used within the stipulated time usually get forfeited after few reasonable extensions. In some cases, for quick deployment of APTS the project management consultant sides with the vendors on approving the User Acceptance Test without giving proper care to the actual requirement of the agency. In case the project management consultant is appointed by the funding agency, the transit agency comes under significant pressure to sign off the project and claim success rather than having to explain significant fund disbursement before testing the system's usefulness.

g. Deployment of rigid proprietary systems

An APTS project typically involves multiple components, making it suitable for a system integrator responsible for integrating various hardware, software, networking and storage products from different vendors into a cohesive solution. However, it has been observed that many system integrators deploy rigid proprietary systems that operate in isolation, resulting in cumbersome and ineffective system utilization. For instance, the AVLS and fare collection system both require the input of bus schedules and daily rosters. When AVLS and fare collection system are not integrated, the same roster needs to be manually

CONCERNS RELATED TO NATIONAL COMMON MOBILITY CARD (NCMC)

The concept of the national common mobility card (NCMC) was initially proposed by the Ministry of Urban Development (MoUD) in late 2010. The idea behind NCMC was to establish a unified payment system that would enable passengers to pay for public transportation across the country using a single smart card. This idea caught the attention of various city administrators who also wanted a common smart-card for all services being offered by city/state agencies. Some of the cities had also onboarded banks for the issue of common services open-loop card on the NCMC protocol. Thus, APTS tenders mandated the adoption of NCMC-enabled smart card-based payments. However, the implementation of NCMC was premature as the necessary ecosystem for its launch was not yet in place.

The introduction of NCMC involved multiple stakeholders and incurred significant costs compared to the traditional closed-loop transit cards commonly used in metro rail systems. Despite repeated failures in operationalizing NCMC, bus transit agencies never modified their directives, resulting in the failure to introduce a smart card-based cashless payment system even after more than a decade.

More recently, the Ministry of Housing and Urban Development (MoHUA), formerly known as MoUD, relaunched NCMC in March 2019. However, the relaunch has not been particularly successful. Only Delhi, Mumbai, Chennai and Bengaluru are known to have introduced smart cards intended to be interoperable between the city bus and metro rail systems. However, these systems lack integration of ticket fares for seamless travel across modes, and the smart cards are not usable outside the cities where they are issued, unless the same bank manages the NCMC-compliant card in multiple cities. Even where introduced, the percentage of use of NCMC card for ticket fare payment in bus transit is not significant. This may however change in the next few years with the recent directive of the government to the banks to issue NCMC compliant credit and debit cards going forward.

If on the other hand the closed-loop smart cards were introduced while the banks worked on enabling NCMC protocol on their credit and debit cards, bus systems across the country could have had in place a much simpler and inexpensive system enabling cashless payments, which would also foster passenger loyalty. The use of smart cards would have also allowed transit agencies to study passenger trip chaining behaviour, aiding in the design of more effective bus routes and terminal facilities. Additionally, the emergence of mobile wallet apps, near-field communication technologies, and efforts to enable credit cards on the unified payments interface make the NCMC mechanism appear complex, expensive and outdated.

Avoid one-size-fits-all approach

While the vision for the NCMC was ambitious, technological advancements have led to the transformation of digital payment options. Yet, it is evident from the most advanced transit systems in the world that transition to cashless transactions may not be possible with any single technology mode due to varying technological adoption among bus passengers in India.

Therefore, it is essential to enable multiple payment channels, such as open or closed loop contactless smartcards (e.g., Oyster card in London, Octopus card in Hong Kong and Suica card in Tokyo), integrated mobility apps (e.g., City Mapper, Moovit, and Transit app), and QR code or NFC-based mobile payment apps (e.g., Cred, Paytm, Phone pe, Apple Pay, Google Pay, etc.), with the aim to minimize cash transactions and enable user-trip chain-pattern analysis.

inserted into both systems independently, leading to inefficiencies and increased error susceptibility. Additionally, the lack of integration prevents the PIS from displaying bus occupancy alongside estimated time of arrival to passengers.

h. Insufficient internal capacity of PTAs

A major shortcoming in APTS deployments is the lack of internal capacity building within transit agencies. The control over the technology platform and the generated data is always in the hands of the system integrator or vendor. Interestingly, the entire life cycle of APTS deployment, from funding and procurement to User Acceptance Test and Annual Maintenance Contract, falls outside the purview of the transit agency, leading to a sense of disenchantment. This situation is exacerbated when the system fails to meet expectations, forcing transit staff to rely on manual record-keeping methods.

Simultaneously, it is convenient for the system integrators/vendors to retain control of the system even if it means maintaining additional manpower for day-to-day operations that could have been handled by the transit agency staff. This arrangement helps avoid drawing attention to system breakdowns.

i. Lack of transition management—end of contract

In general, the APTS tender document specifies that at the end of the contract period, the system integrators/vendors must transfer all assets to the transit agency in good working condition. However, due to the use of proprietary solutions and lack of training provided to transit agency staff, the system often becomes unusable and redundant once the contract period expires. This leads to operational disruptions until the transit agency can procure new hardware or software.

SECTION 3: The way forward

Crossing the chasm

The assessment so far has highlighted the challenges plaguing the implementation of ITS in urban bus transport. This system was anticipated to deliver and add value to bus operational performance, and increase passenger ridership. But this has become a source of expenditure and distraction without tangible gains in real terms.

While the current scenario may seem challenging, it is possible to rectify these issues with several not-so-difficult interventions.

a. Transit network digitization and use of planning and scheduling tools: To enable the effective functioning of any intelligent data analytic solutions, it is crucial to digitize and manage the transit operation plans, including stops, routes, route timetables, bus schedules, and daily roster. This data can then be input into various ITS modules in a structured manner, such as General Transit Feed Specification (GTFS). Annexure D outlines the basic scope and functional requirements of a transit network tool.

It should be noted that even with the best user interface, the creation and digitization of transit schedules, the most complex part of transit planning still remains a manual process. This challenge can be addressed through the development of a sophisticated planning and scheduling software capable of handling technical and administrative constraints to generate optimized and practical schedules with available resources. The planning and scheduling system can then have output as digitized schedules that can eliminate the need for manual digitization. Annexure D also includes some basic requirements for the Planning and Scheduling tool.

b. Making MIS reports actionable through data visualization: The existing outputs of transit ITS, as evident from the sample reports in Annexure B, are cumbersome and rudimentary, and provide limited support to decision-making. However, the same data, when presented in graphical visualizations and standardized KPIs, can become highly actionable. (See “Box: Transit Data Visualization—What Can Be Done With The Transit Data?” for sample visualizations). The importance of KPIs and the most common transit performance indicators have already been documented in various publications on public transport.

c. Decoupling hardware, software and operations during procurement: The procurement of integrated ITS systems has resulted in the deployment of components with proprietary protocols, leading to vendor lock-in and ineffective technology monitoring. Decoupling system hardware and software procurement can foster interoperability either through shared communication protocols or standardization. This approach grants transit agencies greater control over system expansion (hardware), addition of new features (software), and transition to newer technologies. Standardization of protocols also encourages competition by allowing more OEMs to enter the market.

d. Leasing of APTS components: Historically, integrated ITS deployments relied on outright system purchases due to external funding requirements. This has limited the presence of leasing-based suppliers in the public transport marketplace. However, adopting a leasing model offers advantages such as reduced capital investments, shifting performance risk to the suppliers, and ease of termination and transition in case of non-performance.

Currently, leasing is primarily limited to integrated hardware and software bundles of individual ITS components, such as GPS combined with AVL software module, etc. Often, these bundles work in silos, thus not having the benefits of system integration. There are no vendors offering comprehensive ITS solutions specifically tailored for public transport on a lease model. Transitioning to a model where ITS hardware and software are independently procured on lease can encourage greater market participation and innovation.

e. Standards/protocol for interoperability: The establishment of open data protocols and standards play a vital role in technology adoption. Standards like AIS-140 for AVLS equipment and data transmission protocol have helped to streamline technology procurement. Similarly, the creation of the General Transit Feed Specification open standard has facilitated the development of various third-party passenger information apps. It is imperative to standardize VHMS data, protocols for different transit fare instruments (stop to-stop fare, flat fare, tap-in-tap-out, daily/monthly passes, round-trip fare), and other relevant areas to eliminate vendor lock-in and reduce technology costs.

f. Creating detailed standard operating procedures (SOP): Organized and detailed SOPs play a crucial role in ensuring systematic and uniform performance of tasks, reducing ad hoc decision making, and enabling staff training. While the general ITS software modules for processing transit data are similar across the industry, the lack of standardized processes for handling uncommon scenarios (such as bus breakdown, accidents, etc.) can lead to malfunctions in ITS outputs. Developing comprehensive and detailed SOPs for all transit operations involving ITS interaction can eliminate ad hoc processes and facilitate software development for transit operations management and performance monitoring.

g. Payments—avoid one-size-fits-all approach: While the vision for the NCMC was ambitious, technological advancements have led to the transformation of digital payment options. Yet, it is evident from the most advanced transit systems in the world that transition to cashless transactions may not be possible with any single technology mode due to varying technological adoption among the bus passengers in India.

Therefore, it is essential to enable multiple payment channels, such as open or closed loop contactless smartcards (e.g., Oyster card in London, Octopus card in Hong Kong and Suica card in Tokyo), integrated mobility apps (e.g., City mapper, Moovit, and Transit app), and quick response (QR) code or NFC (near field communication) based mobile payment apps (e.g., Cred, Paytm, Phone pe, Apple Pay, Google Pay, etc.), with the aim to minimize cash transactions and enable user-trip chain-pattern analysis.

h. Extensive training of transit staff: Transit agencies have excelled in bus operations management and maintenance. But there is a significant lack of trained personnel in ITS technologies. The position of information technology head in most agencies is typically filled by senior officers specializing in bus operations or maintenance, with limited knowledge of ITS functionality. Systematic training of staff is essential not only for utilization of ITS and maximising outputs effectively, but also for understanding the technology itself. This can reduce reliance on external consultants for needs assessment and technology procurement.

i. Development of a national APTS platform:

The previous iterations of ITS procurement in India have been effective in achieving the desired objectives of service reliability and efficiency. Despite these challenges, the same procurement model continues to be followed, often with functional requirements replicated from previous tenders.

This perpetuates a limited number of vendors monopolizing the market, providing the same software that has previously failed. Yet these are issued a “go-live” approval elsewhere. Considering these challenges, it is imperative to reassess the process, learn from past experiences, and approach ITS with a new model that addresses the findings outlined in this report.

The following key learnings need to be considered:

- A fully functional planning and scheduling software, capable of generating optimized schedules while considering all constraints, is essential for an effective ITS.
- Implementing a work plan and scheduling modules will serve as a foundation for deploying various analytical and AI tools to support decision making.
- Currently, there are no readily available planning and scheduling solutions in the Indian market, and international alternatives are prohibitively expensive.
- A sample of diverse data visualizations should be developed as a reference document for specifying requirements in the MIS module of tender documents.
- A comprehensive compendium of model SOPs is necessary to guide software development and to ensure standardized practices, enabling transit staff training and eliminating ad-hoc actions.
- Standardized data protocols should be established for ITS components to facilitate interoperability and prevent vendor lock-in.
- Transit agencies are transitioning to asset-light planning and regulatory entities, but their core functions of bus operations are being outsourced to private partners. In this scenario, ownership of rapidly evolving technology systems that are outside of their core specialization, should be avoided.

Implementing these learnings may not be overly complex, but they surpass the capabilities of independent STUs or transit agencies. Given the similarities in requirements across the country and the intent to bring about standardisation of the performance evaluation, it is recommended that a national-level transit planning and scheduling platform be established as a “digital public good”.

UNIFIED PUBLIC TRANSPORT INTERFACE (UPTI)

Creating a national platform for ITS, possible named as Unified Public Transport Interface (UPTI), is crucial for standardization, innovation and efficiency in the ITS ecosystem, benefiting all transit agencies across India. This novel approach addresses the existing gaps in technology deployments and offers affordable solutions.

Components of UPTI

The software component of UPTI should encompass the following features:

a) Cloud/web-based solution;
b) Administrative module for creating user hierarchy and organizational process flow;
c) Intuitive spatial tool for transit network digitization;
d) Module for manual schedules digitization (for coding existing schedules);
e) Functions for transit timetable and schedule creation;
f) Automatic rostering based on customizable criteria and crew preferences;
g) Real-time management of rosters;
h) Validation of manual input data;
i) Publishing of routes and timetables in standardized formats (e.g., General Transit Feed Specification) to other ITS components and authorized third-party solutions; and
j) Tools for quantitative analysis (KPIs) of transit planning.

Advantages of UPTI:

a) Resolves a fundamental issue with ITS for all the transit agencies across India.
b) Significant cost reduction as the solution is to be developed only once for making available to all transit agencies.
c) Use of linear programming and operations research algorithms will optimize resource utilisation thus reducing the cost of transit operations.
d) Seamless rollout of improvements, bug fixes, and upgrades across all agencies.
e) Ability to host all forms of fixed-route public transport, including rail and IPT, whether operated by public agencies or private entities.
f) Enabling nationwide opening of transit data for multimodal transit information on third-party apps.
g) Integration with transit agency payment gateways will allowing access to passenger demand on the Open Network for Digital Commerce (ONDC) marketplace.
h) Facilitating the rollout of standardized transit data exchange protocols.
i) Encouraging innovation in transit data analytics and AI systems for monitoring and improving transit services.
j) Facilitating the development of course curricula for training practitioners and students, ensuring the availability of skilled human resources.
k) Will become an enabler for cities not having formal public transport to launch bus services using the technology platform, SOPs and other training material.

Development and ownership:

a) Custom building the optimization tool from scratch is recommended due to specific requirements and the lack of affordable off-the-shelf solutions. The software code can be open-sourced, inviting citizen contributions for improvements and wider use.
b) The ownership model can be based on the National Payments Corporation of India (NPCI). UPTI can be registered as a public unlisted company under the Association of Road Transport Undertakings (ASRTU), with major STUs as promoting shareholders. Alternatively, the solution can be owned and maintained by the Ministry of Road Transport and Highways on the model of the VAHAN portal.
c) A nominal usage fee can be charged to transit agencies, covering ongoing development and maintenance costs. Additionally, the platform can generate revenue by organizing skill development programs for transit agency staff.

Thus, development of UPTI can drive the transformation and modernization of public transit in India, contributing to sustainable development in the transport sector.

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5. Leasing: Contracting of goods and/or services for a specified time period, usually in return for a monthly/periodic payment. The term Software as a Service (SaaS) is commonly used in the case of leasing of computer software.

Annexures

Annexure A

List of functional requirements specified for scheduling software

FR 1.1. Data by division, depot, operation, route, schedule, bus type, employee type, employee, bus, etc. should be available

FR 1.2. The system shall be able to support operations for a minimum of 1000 buses.

FR 1.3. Ability to optimize the complete service delivery by developing the route and publish final timetables and rosters.

FR 1.4. Ability to Generate informative statistical summaries and MIS from the system

FR 1.5. Proposed System shall have following integrated functionalities/tools:

- Route plan and timetables
- Trips and vehicle planning
- Crew schedules
- Roster and dispatch (operations)
- Crew kiosks (optional)
- Performance monitoring
- Bus travel time data from AVL system

FR 1.6. The application shall provide feature for creating vehicles in one depot and process for transferring vehicles to other depots.

FR 1.7. Application shall have feature to capture trip/schedule wise revenue kilometre

FR 1.8. Capability to capture dead kilometres in the system.

FR 1.9. Ability to define and create charter trips into the system. Solution shall provide the entire process—quote, booking, allocation, invoicing, etc.

FR 1.10. The charter trips should be reflected into the operation module for rostering and dispatch functions.

FR 1.11. Ability to capture requirements from customer for chartered trips into the system.

FR 1.12. Ability to make quick changes in routes and bus stop locations due to traffic management (traffic police) changes (one-way streets, construction, etc.)

FR 1.13. Ability to create users in the system

FR 1.14. Ability to assign roles, access, and user permission in the system

FR 1.15. System should support user defined event definition for sending alerts and message

FR 1.16. System should be able to send alerts and email based on certain conditions/ events/transaction.

FR 1.17. Ability to produces printouts of crew schedules, duty rosters, route timetables, bus stop timetables etc.

FR 1.18. Ability to generate On-demand statistical reports and summaries

FR 1.19. The system shall ability to generate following reports, but not limited to,

- Route
- Timetable
- Crew rostering
- Statistics report - headway, running times for each trip.
- Despatch report
- Schedule cancellation report
- Crew allocation
- Schedule allocation
- Crew utilization report
- Fleet departure at depot
- Fleet dead KM per route/ fleet wise
- Revenue kilometre
- Schedule or trip cancellation
- Crew license renewal history
- Over time details per staff wise

FR 1.20. The Ability to import and export master data such as nodes details with its respective GIS data to the map, crew, vehicle, schedule, routes with stop, etc.

FR 1.21. System shall provide facility to export data/reports into pdf, excel /.csv and /XML formats

FR 1.22. Proposed system should be able to perform trip time deviation analysis to find where the critical trips

FR 1.23. System shall provide route creation and timetabling features

Annexure B

Sample MIS reports generating from existing APTS

I. ETM report

Waybill No: W1503230070						
Station Name	To Station	ETM No	Tkt No	Tkt Category	Ticket Date Time	Cond.
Belapur Rly.Stn.	Metro Bridge (Taloja)	V1E0671474	1503230P3LNX0001 - 1	General	15/03/2023 6:03:25 AM	C3059
Belapur Rly.Stn.	Raghunath Vihar (To Taloja)	V1E0671474	1503230P3LNX0002 - 1	General	15/03/2023 6:03:53 AM	C3059
Kharghar Rly. Stn. (Taloja)	Raghunath Vihar (To Taloja)	V1E0671474	1503230P3LNX0003 - 1	General	15/03/2023 6:09:02 AM	C3059
Kharghar Rly. Stn. (Taloja)	Raghunath Vihar (To Taloja)	V1E0671474	1503230P3LNX0004 - 1	General	15/03/2023 6:09:20 AM	C3059
Kharghar Rly. Stn. (Taloja)	Raghunath Vihar (To Taloja)	V1E0671474	1503230P3LNX0005 - 1	General	15/03/2023 6:09:28 AM	C3059
Kharghar Rly. Stn. (Taloja)	Ramsheth Thakur Highschool (To Taloja)	V1E0671474	1503230P3LNX0006 - 1	General	15/03/2023 6:09:54 AM	C3059
Kharghar Rly. Stn. (Taloja)	Vehicle Inspection floor (R.T.O.)	V1E0671474	1503230P3LNX0007 - 1	General	15/03/2023 6:10:10 AM	C3059
Kharghar Rly. Stn. (Taloja)	Metro Bridge (Taloja)	V1E0671474	1503230P3LNX0008 - 1	General	15/03/2023 6:10:48 AM	C3059
Kharghar Rly. Stn. (Taloja)	Vehicle Inspection floor (R.T.O.)	V1E0671474	1503230P3LNX0009 - 1	General	15/03/2023 6:11:22 AM	C3059
Vehicle Inspection floor (R.T.O.)	Kutuk Bandhan (To CBD)	V1E0671474	1503230P3LNX0010 - 1	General	15/03/2023 6:47:39 AM	C3059
Vehicle Inspection floor (R.T.O.)	Taloja gaon/ RAF (To CBD)	V1E0671474	1503230P3LNX0011 - 1	General	15/03/2023 6:48:13 AM	C3059
Vehicle Inspection floor (R.T.O.)	Belapur Rly.Stn.	V1E0671474	1503230P3LNX0012 - 1	General	15/03/2023 6:48:29 AM	C3059
Vehicle Inspection floor (R.T.O.)	Gharkul Corner (To CBD)	V1E0671474	1503230P3LNX0013 - 2	General	15/03/2023 6:48:46 AM	C3059

	Service Date	Trip No	Route No	Route Type	Route Name	Vehicle No	Cash Tkt Issued	Cash Tkt Amount	Toll Amount
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	27.00	0
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	18.00	0
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	12.00	0
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	12.00	0
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	12.00	0
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	15.00	0
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	25.00	0
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	22.00	0
	15/03/2023	2	052 AC	AC	Belapur Rly. Stn. To R.T.O. Vahantal Taloja Phase II (052AC)	MH-43-BP-5238	1	25.00	0
	15/03/2023	3	052 AC	AC	R.T.O. Vahantal Taloja To Belapur Rly. Stn. (052AC)	MH-43-BP-5238	1	15.00	0
	15/03/2023	3	052 AC	AC	R.T.O. Vahantal Taloja To Belapur Rly. Stn. (052AC)	MH-43-BP-5238	1	12.00	0
	15/03/2023	3	052 AC	AC	R.T.O. Vahantal Taloja To Belapur Rly. Stn. (052AC)	MH-43-BP-5238	1	30.00	0
	15/03/2023	3	052 AC	AC	R.T.O. Vahantal Taloja To Belapur Rly. Stn. (052AC)	MH-43-BP-5238	1	11.00	0

II. Fleet overview report

Bus Number	Updated On	speed	Last Location Name	Speed Limit	busstatus
MH-43-BG-2460	15/03/23 16:07	6	Asudgaon Depot Highway (Towards Vashi)	70	OnTrip
MH-43-BG-4138	16/03/23 11:41	33	Meenatai Thakare Chowk	70	OnTrip
MH-43-BG-4582	16/03/23 11:41	0	Panvel Rly. Stn.(W)	70	OnTrip
MH-43-BG-9862	16/03/23 0:11	0	Asudgaon Depot	70	OffTrip
MH-43-BP-0012	16/03/23 11:14	0	Asudgaon Depot	70	OffTrip
MH-43-BP-0113	15/03/23 23:37	0	Asudgaon Depot	70	OffTrip
MH-43-BP-7608	16/03/23 11:40	9	MAFCO (To Vashi)	70	OnTrip
MH-43-BP-8107	16/03/23 11:40	0	Vashi Rly.Stn.	70	OnTrip
MH-43-BP-9681	16/03/23 11:40	0	Nerul Sec.46/48/ NRI	70	OnTrip
MH-43-BP-9716	16/03/23 11:38	0	Belapur Rly.Stn. (Towards CBD)	70	OnTrip
MH-43-BP-9721	16/03/23 11:40	0	Vashi Sector 7 Bus stn.	70	OnTrip
MH-43-BP-9723	16/03/23 11:40	15	Manpada D (To KLN)	70	OnTrip
MH-43-BX-0379	16/03/23 11:31	0	Vashi Rly.Stn.	70	OnTrip
MH-43-BX-0383	16/03/23 11:38	0	Vashi Rly.Stn.	70	OnTrip
MH-43-BX-0438	16/03/23 11:31	0	Turbhe depot	70	OffTrip
MH-43-BX-0440	16/03/23 11:41	0	Vashi Rly.Stn.	70	OnTrip
MH-43-BX-0589	16/03/23 11:34	0	Vashi Rly.Stn.	70	OnTrip
MH-43-BX-0805	16/03/23 4:07	0	Turbhe depot	70	OffTrip
MH-43-H-5134	16/03/23 11:41	0	Turbhe depot	70	OffTrip
MH-43-H-5162	16/03/23 11:27	6	Turbhe depot	70	OffTrip
MH-43-H-5192	15/03/23 22:19	0	Turbhe depot	70	OffTrip
MH-43-H-5194	16/03/23 10:00	2	Turbhe depot	70	OffTrip
MH-43-H-5213	16/03/23 11:41	0	Belapur Rly.Stn.	70	OnTrip
MH-43-H-5255	16/03/23 11:39	0	Vashi Rly.Stn.	70	OnTrip
MH-43-H-5356	16/03/23 11:41	24	Turbhe Naka (Towards Vashi)	70	OnTrip
MH-43-H-5394	16/03/23 11:41	19	Yashwantrao Chavhan College Sec.14	70	OnTrip
MH-43-H-5410	16/03/23 11:41	0	Ghansoli depot	70	OffTrip
MH-43-H-5453	16/03/23 11:41	0	Koparkhairane Bus Stn.	70	OnTrip
MH-43-H-5478	15/03/23 15:01	33	Khidkali Mandir (To KLN)	70	OnTrip
MH-43-H-5485	16/03/23 9:24	7	G.D.Somani Highschool (WTC)	70	OnTrip
MH-43-H-5504	15/03/23 14:35	0	Turbhe depot	70	OnTrip
MH-43-BG-2332	16/03/23 11:21	0	Koperkhairane Sec.15 (To GNL)	70	Idle<=5KM
MH-43-BG-2334	16/03/23 7:52	0	Ghansoli depot	70	Idle<=5KM

bus status device	vehicle id	division name	trip_status	total io	Depot Name	Service Type	running status
5	5914	NMMT Division	0	0	Ghansoli	Non AC	3
5	5964	NMMT Division	1	0	Ghansoli	Non AC	3
5	5975	NMMT Division	0	0	Asudgaon	Non AC	3
5	6136	NMMT Division	0	0	Asudgaon	Non AC	3
5	6140	NMMT Division	0	0	Asudgaon	Non AC	3
5	6148	NMMT Division	0	0	Asudgaon	Non AC	3
5	6125	NMMT Division	0	0	Turbhe	Non AC	3
5	6157	NMMT Division	0	0	Turbhe	Non AC	3
5	6350	NMMT Division	0	0	Turbhe	AC	3
5	6244	NMMT Division	0	0	Turbhe	AC	3
5	6325	NMMT Division	0	0	Turbhe	AC	3
5	6336	NMMT Division	1	0	Turbhe	AC	3
5	6270	NMMT Division	0	0	Turbhe	AC	3
5	6291	NMMT Division	0	0	Turbhe	AC	3
5	6209	NMMT Division	0	0	Turbhe	AC	3
5	6220	NMMT Division	0	0	Turbhe	AC	3
5	6305	NMMT Division	0	0	Turbhe	AC	3
5	6352	NMMT Division	0	0	Turbhe	AC	3
5	5948	NMMT Division	0	0	Turbhe	Non AC	3
5	5629	NMMT Division	0	0	Turbhe	Non AC	3
5	5648	NMMT Division	0	0	Turbhe	Non AC	3
5	5722	NMMT Division	0	0	Turbhe	Non AC	3
5	5555	NMMT Division	0	0	Turbhe	Non AC	3
5	5508	NMMT Division	0	0	Turbhe	Non AC	3
5	5739	NMMT Division	1	0	Asudgaon	AC	3
5	5908	NMMT Division	0	0	Ghansoli	Non AC	3
5	5838	NMMT Division	0	0	Ghansoli	Non AC	3
5	5794	NMMT Division	0	0	Ghansoli	Non AC	3
5	5787	NMMT Division	0	0	Ghansoli	AC	3
5	5941	NMMT Division	0	0	Asudgaon	AC	3
5	5894	NMMT Division	0	0	Asudgaon	Non AC	3
5	6005	NMMT Division	1	0	Ghansoli	Non AC	
5	5909	NMMT Division	0	0	Ghansoli	Non AC	

III. Bus bunching report

Bus_1_incident_Time	Depot	control point	Service Type	Route No	Route Name	Bus No 1	Bus 1 sch_start	Bus 1 actual_start	Bus 1 sch_end
3/15/2023 8:52:39 PM	Ghansoli	Ghansoli depot	AC	055 AC	Pethali Gaon/Taloja Phase 1 To Ghansoli Depot (55AC)	MH-43-BX-0387	3/15/2023 8:10:00 PM	3/15/2023 8:13:31 PM	3/15/2023 9:55:00 PM
3/15/2023 8:53:38 PM	Ghansoli	Airoli Bus Stn.	AC	131 AC	Borivali Rly.Stn. (E) To Airoli Bus Stn. Via Ghodbunder	MH-43-H-5377	3/15/2023 9:15:00 PM	3/15/2023 8:53:38 PM	3/15/2023 10:52:00 PM
3/15/2023 7:46:22 PM	Ghansoli	Airoli Bus Stn.	AC	144 AC	Aagarkar Chowk Andheri (E) To Airoli Bus Stn.(144AC)	MH-43-BP-9689	3/15/2023 7:10:00 PM	3/15/2023 7:21:26 PM	3/15/2023 8:40:00 PM
3/15/2023 7:53:27 PM	Ghansoli	Ghansoli depot	AC	018 AC	Kharkopar Rly. Stn. To Ghansoli Depot (018AC)	MH-43-BX-0490	3/15/2023 7:35:00 PM	3/15/2023 7:30:55 PM	3/15/2023 9:03:00 PM
3/15/2023 6:04:53 PM	Ghansoli	Ghansoli depot	AC	055 AC	Ghansoli depot To Pethali Gaon / Taloja Phase 1 (55AC)	MH-43-BP-9683	3/15/2023 6:00:00 PM	3/15/2023 6:01:30 PM	3/15/2023 7:45:00 PM
3/15/2023 5:01:57 PM	Ghansoli	Ghansoli depot	AC	055 AC	Ghansoli depot To Pethali Gaon / Taloja Phase 1 (55AC)	MH-43-BX-0369	3/15/2023 5:00:00 PM	3/15/2023 4:51:23 PM	3/15/2023 6:45:00 PM
3/15/2023 5:46:10 PM	Ghansoli	Ghansoli depot	AC	055 AC	Ghansoli depot To Pethali Gaon / Taloja Phase 1 (55AC)	MH-43-BX-0591	3/15/2023 4:45:00 PM	3/15/2023 4:30:31 PM	3/15/2023 6:30:00 PM
3/15/2023 6:14:54 PM	Ghansoli	Airoli Bus Stn.	AC	144 AC	Aagarkar Chowk Andheri (E) To Airoli Bus Stn.(144AC)	MH-43-BP-9736	3/15/2023 6:03:00 PM	3/15/2023 6:14:54 PM	3/15/2023 7:33:00 PM
3/15/2023 5:14:08 PM	Ghansoli	Airoli Bus Stn.	AC	144 AC	Airoli Bus Stn To Agarkar Chowk Andheri(144AC)	MH-43-BP-9736	3/15/2023 4:30:00 PM	3/15/2023 4:47:17 PM	3/15/2023 5:58:00 PM
3/15/2023 4:29:04 PM	Ghansoli	Airoli Bus Stn.	AC	144 AC	Airoli Bus Stn To Agarkar Chowk Andheri(144AC)	MH-43-BP-9582	3/15/2023 3:30:00 PM	3/15/2023 3:47:19 PM	3/15/2023 4:55:00 PM
3/15/2023 3:51:39 PM	Ghansoli	Ghansoli depot	AC	055 AC	Ghansoli depot To Pethali Gaon / Taloja Phase 1 (55AC)	MH-43-BX-0374	3/15/2023 3:25:00 PM	3/15/2023 3:07:18 PM	3/15/2023 5:10:00 PM
3/15/2023 4:35:57 PM	Ghansoli	Ghansoli depot	AC	055 AC	Ghansoli depot To Pethali Gaon / Taloja Phase 1 (55AC)	MH-43-BX-0579	3/15/2023 4:15:00 PM	3/15/2023 4:28:22 PM	3/15/2023 6:00:00 PM
3/15/2023 4:00:01 PM	Ghansoli	Ghansoli depot	AC	055 AC	Pethali Gaon/Taloja Phase 1 To Ghansoli Depot (55AC)	MH-43-BX-0386	3/15/2023 2:30:00 PM	3/15/2023 2:46:48 PM	3/15/2023 4:10:00 PM

Bus 1 actual_end	Bus No2	Bus 2 sch_start	Bus 2 actual_start	Bus 2 sch_end	Bus 2 actual_end	Bus 1 location	Bus 2 location
3/15/2023 9:50:04 PM	MH-43-BP-9683	3/15/2023 7:50:00 PM	3/15/2023 8:09:55 PM	3/15/2023 9:35:00 PM	3/15/2023 9:48:48 PM	Dr.D.Y.Patil Stadium (Towards Vashi)	Dr.D.Y.Patil Stadium (Towards Vashi)
3/15/2023 10:54:02 PM	MH-43-H-5476	3/15/2023 8:45:00 PM	3/15/2023 8:49:41 PM	3/15/2023 10:23:00 PM	3/15/2023 10:54:02 PM	7, Kasthurba Rd, Chinchpada, Borivali East, Mumbai, Maharashtra 400066, India	Borivali Rly. Stn. (E) (out)
3/15/2023 8:55:23 PM	MH-43-BP-9728	3/15/2023 6:45:00 PM	3/15/2023 7:11:22 PM	3/15/2023 8:15:00 PM	3/15/2023 8:43:57 PM	Seepz Gaon 1 (To Vashi)	Mumbai,Maharashtra
3/15/2023 9:21:06 PM	MH-43-BX-0553	3/15/2023 7:05:00 PM	3/15/2023 7:19:30 PM	3/15/2023 8:33:00 PM	3/15/2023 9:09:00 PM	Mumbai,Maharashtra	Kille Gaothan (Towards Vashi)
3/15/2023 7:55:11 PM	MH-43-BX-0591	3/15/2023 4:45:00 PM	3/15/2023 4:30:31 PM	3/15/2023 6:30:00 PM	3/15/2023 6:54:01 PM	Magh Mallhar Society	Navi Mumbai City School
3/15/2023 5:54:04 PM	MH-43-BX-0591	3/15/2023 4:45:00 PM	3/15/2023 4:30:31 PM	3/15/2023 6:30:00 PM	3/15/2023 6:54:01 PM	Panchavati	10, Prabhakar Krishanati Patil Marg, Savali, Ghansoli, Navi Mumbai, Maharashtra 400701, India
3/15/2023 6:54:01 PM	MH-43-BX-0402	3/15/2023 5:30:00 PM	3/15/2023 5:17:59 PM	3/15/2023 7:15:00 PM	3/15/2023 7:39:02 PM	Kopri Naka/ Sec.29 (Towards Ghansoli)	OES School (Towards Vashi)
3/15/2023 7:44:32 PM	MH-43-BX-0804	3/15/2023 5:42:00 PM	3/15/2023 6:11:52 PM	3/15/2023 7:12:00 PM	3/15/2023 7:40:04 PM	1, Sir Mathuradas Vasanji Rd, Sai Baba Wadi, Natwar Nagar, Jogeshwari East, Mumbai, Maharashtra 400053, India	41, Andheri - Kurla Rd, East, Mumbai, Maharashtra 400069, India
3/15/2023 6:03:05 PM	MH-43-BX-0804	3/15/2023 4:10:00 PM	3/15/2023 4:39:02 PM	3/15/2023 5:37:00 PM	3/15/2023 6:01:50 PM	Kanjurgaon	Mansukh Dyeing Company
3/15/2023 5:13:04 PM	MH-43-BX-0797	3/15/2023 3:10:00 PM	3/15/2023 3:13:52 PM	3/15/2023 4:34:00 PM	3/15/2023 4:54:03 PM	Rohit Palace, Mukteshwar Ashram Rd, Tirandaz, Powai, Mumbai, Maharashtra 400076, India	Mumbai,Maharashtra
3/15/2023 5:39:04 PM	MH-43-BX-0384	3/15/2023 3:45:00 PM	3/15/2023 3:19:46 PM	3/15/2023 5:30:00 PM	3/15/2023 5:54:04 PM	Vashi Sector 17 (To Vashi)	Vashi Bus Stn.
3/15/2023 6:27:01 PM	MH-43-BX-0384	3/15/2023 3:45:00 PM	3/15/2023 3:19:46 PM	3/15/2023 5:30:00 PM	3/15/2023 5:54:04 PM	Mumbai,Maharashtra	Rajiv Gandhi College
3/15/2023 4:31:53 PM	MH-43-BX-0402	3/15/2023 2:48:00 PM	3/15/2023 2:56:56 PM	3/15/2023 4:28:00 PM	3/15/2023 4:26:14 PM	13, Chahu Ambo Patil Marg, Savali, Ghansoli, Navi Mumbai, Maharashtra 400701, India	Ranjan Devi Chowk (To GHL)

IV. Schedule and trips report

Division	Depot	Control Point	Trip Type	Schedule No	Schedule Name	Route	Route Type	Trip Code	Route Distance	EPKM KM	Route Travel Time	Vehicle	Driver
NMMT Division	Ghansoli	Koparkhairane Bus Stn.	Regular	31/4	31/4	031-Koparkhairne Bus Stn. To Ghansoli Depot (031)	Turn In	20230315_ 00:05:00	6.00	0.00	00:13:00		MD1276-NAVNATH MANOHAR PUJARI
NMMT Division	Ghansoli	Airoli Bus Stn.	Regular	144GAC/ 11	144GAC/ 11	144 AC-Airoli Bus Stn. To Ghansoli Depot (144AC)	Turn In	20230315_ 00:15:00	8.00	0.00	00:18:00		SD270-Vishal Mahadev Salunke
NMMT Division	Ghansoli	Ghansoli depot	Regular	50/1	50/1	050-Ghansoli Depot To Panvel Rly. Stn. (w) (050)	Turn Out	20230315_ MH43BG4134_ 04:15 AM	30.00	0.00	00:58:00	MH-43-BG-4134	MD1407-Akash Prakash Golave
NMMT Division	Ghansoli	Ghansoli depot	Regular	31/1	31/1	031-Ghansoli Depot To Uran Pentioners Park (031)	Turn Out	20230315_ MH43BG2470_ 04:27 AM	46.00	46.00	01:35:00	MH-43-BG-2470	MD1206-SANJAY SHIVAJI SHINGAN
NMMT Division	Ghansoli	Ghansoli depot	Regular	18 AC/ 12	18AC/ 12	018 AC-Ghansoli Depot To Kharkopar Rly. Stn. (018AC)	Turn Out	20230315_ MH43BX0554_ 04:35 AM	36.00	0.00	01:28:00	MH-43-BX-0554	SD271-Ravikant Satappa Sangpal
NMMT Division	Ghansoli	Ghansoli depot	Regular	50/2	50/2	050-Ghansoli Depot To Panvel Rly. Stn. (w) (050)	Turn Out	20230315_ MH43BG2458_ 04:35 AM	30.00	0.00	00:58:00	MH-43-BG-2458	MD1245-VAIBHAV BHARAT SHELAR
NMMT Division	Ghansoli	Ghansoli depot	Regular	24G/1	24G/1	024G-Ghansoli Depot To Thane (024G)	Turn Out	20230315_ MH43H5449_ 04:50 AM	18.00	0.00	00:45:00	MH-43-H-5449	MD1305-prashant bhim-rao chavan
NMMT Division	Ghansoli	Ghansoli depot	Regular	31/2	31/2	031-Ghansoli Depot To Uran Pentioners Park (031)	Turn Out	20230315_ MH43BG4135_ 04:52 AM	46.00	46.00	01:35:00	MH-43-BG-4135	MD911-SAGAR RAJARAM MOHITE
NMMT Division	Ghansoli	Ghansoli depot	Regular	50/3	50/3	050-Ghansoli Depot To Panvel Rly. Stn. (w) (050)	Turn Out	20230315_ MH43H5493_ 04:55 AM	30.00	0.00	00:58:00	MH-43-H-5493	MD1466-Avinash Goma koli
NMMT Division	Ghansoli	Ghansoli depot	Regular	20 AC/1	20AC/1	020 AC-Ghansoli Depot To Nerul Sec 46/48 (AC)	Turn Out	20230315_ MH43BP5116_ 05:00 AM	22.00	0.00	00:58:00	MH-43-BP-5116	D096148-SHIVAJI YAMAJI SONAWATE
NMMT Division	Ghansoli	Koparkhairane Bus Stn.	Regular	31/7	31/7	031-Uran Pensioner Park To Koparkhairne Bus Stn. (31)	DOWN	20230315_ 05:05:00	42.00	40.00	01:32:00		MD837-POPAT NAIKODI
NMMT Division	Ghansoli	Ghansoli depot	Regular	8/2	8/2	008-Ghansoli Depot To Vashi Rly. Stn. (008)	Turn Out	20230315_ MH43H5415_ 05:10 AM	10.00	0.00	00:35:00	MH-43-H-5415	MD977-DILIP GULABRAO SHILIMKAR
NMMT Division	Ghansoli	Ghansoli depot	Regular	66/1	66/1	066-Ghansoli Depot To Kalyan Rly. Stn. (066)	Turn Out	20230315_ MH43H5398_ 05:10 AM	26.00	0.00	01:15:00	MH-43-H-5398	MD534-JITENDRA MAHADEO SHETE
NMMT Division	Ghansoli	Ghansoli depot	Regular	55 AC/1	55AC/1	055 AC-Ghansoli depot To Pethali Gaon / Taloja Phase 1 (55AC)	Turn Out	20230315_ MH43BX0402_ 05:10 AM	34.00	0.00	01:30:00	MH-43-BX-0402	SD236-Akash N. Deshmukh
NMMT Division	Ghansoli	Ghansoli depot	Regular	50/4	50/4	050-Ghansoli Depot To Panvel Rly. Stn. (w) (050)	Turn Out	20230315_ MH43BG2455_ 05:11 AM	30.00	0.00	00:58:00	MH-43-BG-2455	MD992-SAHAJI LALASO CHOUGHLE

Conductor	Schedule Start Time	Actual Trip Start Time	Schedule End Time	Actual Trip End Time	Early Start By	Delayed Start By	Early End By	Delayed End By	Travelled Distance	Travell Duration	Trip Status	Schedule Created By	Deactivation Reason	EPKM Distance	Active/ Deactive Status
C3616-VINOD GAVRAM KAVARE	3/15/2023 12:05:00 AM		3/15/2023 12:13:00 AM								Trip Not Started	P_S_ Admin		0.00	Ok
C3792-YASHVANT MARUTI SHEMBADE	3/15/2023 12:15:00 AM		3/15/2023 12:35:00 AM								Trip Not Started	P_S_ Admin		0.00	Ok
C4089-VAIBHAV PRAKASH SONAVANE	3/15/2023 4:15:00 AM		3/15/2023 5:13:00 AM								Trip Not Started	P_S_ Admin		0.00	Ok
C3613-RAJESH SAMPAT SHINDE	3/15/2023 4:27:00 AM	3/15/2023 4:31:08 AM	3/15/2023 6:02:00 AM	3/15/2023 5:49:23 AM		00:04:08	00:12:37		44.60	01:18:15	Normal Closed	P_S_ Admin		46.00	Ok
C3554-VIJAY TUKARAM BHOSLE	3/15/2023 4:35:00 AM		3/15/2023 6:03:00 AM								Trip Not Started	P_S_ Admin		0.00	Ok
C4449-Vijay Laxman Chavan	3/15/2023 4:35:00 AM	3/15/2023 4:43:57 AM	3/15/2023 5:33:00 AM	3/15/2023 5:29:27 AM		00:08:57	00:03:33		30.60	00:45:30	Normal Closed	P_S_ Admin		0.00	Ok
C3910-ABHISHEK BALBHIM SHINDE	3/15/2023 4:50:00 AM	3/15/2023 4:53:57 AM	3/15/2023 5:25:00 AM	3/15/2023 5:29:23 AM		00:03:57		00:04:23	17.00	00:35:26	Normal Closed	P_S_ Admin		0.00	Ok
C3894-VIVEK DINKAR KHOSE	3/15/2023 4:52:00 AM		3/15/2023 6:27:00 AM								Trip Not Started	P_S_ Admin		46.00	Ok
C4451-Sudarshan Yuvraj Patil	3/15/2023 4:55:00 AM	3/15/2023 4:59:54 AM	3/15/2023 5:53:00 AM	3/15/2023 5:58:10 AM		00:04:54		00:05:10	29.60	00:58:16	Normal Closed	P_S_ Admin		0.00	Ok
C199020-PARSHURAM BHASKAR PATIL	3/15/2023 5:00:00 AM	3/15/2023 5:08:57 AM	3/15/2023 6:00:00 AM	3/15/2023 5:57:20 AM		00:08:57	00:02:40		21.50	00:48:23	Normal Closed	P_S_ Admin		0.00	Ok
C3061-SUKLAL MANGU RATHOD	3/15/2023 5:05:00 AM		3/15/2023 6:25:00 AM								Trip Not Started	P_S_ Admin		40.00	Ok
C859-MOHAN GOPAL SHELAKE	3/15/2023 5:10:00 AM	3/15/2023 5:19:15 AM	3/15/2023 5:48:00 AM	3/15/2023 5:45:42 AM		00:09:15	00:02:18		8.50	00:26:27	Normal Closed	P_S_ Admin		0.00	Ok
C3995-DINESH SHIVAJI RAJGURU	3/15/2023 5:10:00 AM	3/15/2023 5:11:28 AM	3/15/2023 6:10:00 AM	3/15/2023 6:24:01 AM		00:01:28		00:14:02	35.40	01:12:34	Trip Closed due ETA Exceed	P_S_ Admin		0.00	Ok
C3053-NITESH KANHA PATIL	3/15/2023 5:10:00 AM	3/15/2023 5:13:03 AM	3/15/2023 6:30:00 AM	3/15/2023 6:14:21 AM		00:03:03	00:15:39		33.80	01:01:18	Normal Closed	P_S_ Admin		0.00	Ok
C4243-Vijay sudhakar bavaskar	3/15/2023 5:11:00 AM		3/15/2023 6:09:00 AM								Trip Not Started	P_S_ Admin		0.00	Ok

V. Skipped bus stop report

Depot Name	Route No	Route Name	Vehicle Number	Sch Trip Timings	Act Trip Timings	Driver Name
Ghansoli	009 AC	Ghansoli Gharonda To Vashi Rly Stn (9AC)	MH-43-BX-0378	15/03/2023 23:15 - 15/03/2023 23:48	15/03/2023 23:15 - 15/03/2023 23:35	SD327 - Chetan Sambhaji Suryavanshi
Ghansoli	144 AC	Aagarkar Chowk Andheri (E) To Airoli Bus Stn. (144AC)	MH-43-BP-9689	15/03/2023 22:50 - 16/03/2023 00:12	15/03/2023 22:53 - 15/03/2023 23:40	SD270 - Vishal Mahadev Salunke
Ghansoli	050	Koparkhairne Bus Stn. To Panvel Rly. Stn. (050)	MH-43-H-5416	15/03/2023 22:30 - 15/03/2023 23:20	15/03/2023 22:44 - 15/03/2023 23:45	MD1373 - ANIL POPAT KHARAT
Ghansoli	144 AC	Aagarkar Chowk Andheri (E) To Airoli Bus Stn. (144AC)	MH-43-BP-9728	15/03/2023 22:27 - 15/03/2023 23:50	15/03/2023 22:36 - 15/03/2023 23:21	SD267 - Ravindra Sahebrav Pawar
Ghansoli	009 AC	Vashi Rly Stn To Ghansoli Gharonda (9AC)	MH-43-BX-0378	15/03/2023 22:16 - 15/03/2023 22:54	15/03/2023 22:20 - 15/03/2023 22:43	SD327 - Chetan Sambhaji Suryavanshi
Ghansoli	144 AC	Aagarkar Chowk Andheri (E) To Airoli Bus Stn. (144AC)	MH-43-BP-9685	15/03/2023 22:03 - 15/03/2023 23:28	15/03/2023 22:08 - 15/03/2023 23:08	SD311 - ANKIT SURESH MADHAVI
Ghansoli	009 AC	Ghansoli Gharonda To Vashi Rly Stn (9AC)	MH-43-BX-0378	15/03/2023 21:50 - 16/03/2023 21:28	15/03/2023 21:32 - 15/03/2023 22:09	SD327 - Chetan Sambhaji Suryavanshi
Ghansoli	004	Vashi Sec.7 Bus Stn. To Thane Via Koperkhairne (004)	MH-43-H-5433	15/03/2023 21:45 - 15/03/2023 22:50	15/03/2023 21:46 - 15/03/2023 22:51	D1475 - SHANKAR SARJERAO SALUNKHE
Ghansoli	144 AC	Aagarkar Chowk Andheri (E) To Airoli Bus Stn. (144AC)	MH-43-BP-9736	15/03/2023 21:43 - 15/03/2023 23:11	15/03/2023 21:48 - 15/03/2023 22:46	SD272 - Sagar Bajrang Ingulkar
Ghansoli	144 AC	Aagarkar Chowk Andheri (E) To Airoli Bus Stn. (144AC)	MH-43-BX-0804	15/03/2023 21:25 - 15/03/2023 22:53	15/03/2023 21:29 - 15/03/2023 22:31	MD259 - SUNIL NAGESH NAIK
Ghansoli	144 AC	Airoli Bus Stn To Agarkar Chowk Andheri(144AC)	MH-43-BP-9689	15/03/2023 21:20 - 15/03/2023 22:45	15/03/2023 21:24 - 15/03/2023 22:49	SD270 - Vishal Mahadev Salunke

Conductor Name	Total Stops Missed	Missed Stations
C4213 - chavan aditya babu	2	M.G.Complex (Towards Vashi),Vashi Bus Stn.(To Vashi Stn.)
C3792 - YASHVANT MARUTI SHEMBADE	15	Dr. Babasaheb Ambedkar Udyan (To Vashi),Mansukh Dyeing Company,Ankur Hospital,Kanjurgaon,Cromption Greaves Bhandup,Adarsha Vidyalaya,DAV College Bhandup (To Airoli),CGS Colony Bhandup (To Airoli),Bhandup Rly.Stn. (E) (To Airoli),Hema Park (To Airoli),Shivai Vidyalaya,Nahur Rly.Stn.,Bhandup gaon 123 (To Vashi),Divagaon Kopra (Towards Vashi),Airoli Sector-8 (Vashi)
C3442 - RAJKUMAR SHANTARAM MALASE	10	Koparkhairane Sec.2 (To Vashi),Kopri Naka/Sec.29 (Towards Vashi),Vashi Bus Stn.(To Vashi Stn.),ICL School (Towards Panvel),Shirvane Fata (Towards Panvel),Kopra Gaon (Towards Panvel),Spageti/Gharkul (Towards Panvel),Kamothe fata (Towards Panvel),Express Way / Macdonld (Towards Panvel),Asudgaon Depot Highway (Towards Panvel)
C4453 - Samadhan Suresh Patil	13	Dr. Babasaheb Ambedkar Udyan (To Vashi),Mansukh Dyeing Company,Ankur Hospital,Kanjurgaon,Cromption Greaves Bhandup,Adarsha Vidyalaya,DAV College Bhandup (To Airoli),CGS Colony Bhandup (To Airoli),Bhandup Rly.Stn. (E) (To Airoli),Hema Park (To Airoli),Shivai Vidyalaya,Nahur Rly.Stn.,Bhandup gaon 123 (To Vashi)
C4213 - chavan aditya babu	2	Vashi Bus Stn.(To GNL),Water Tank Ghansoli
C3624 - PRAKASH SHIVAJI SALUNKHE	13	Dr. Babasaheb Ambedkar Udyan (To Vashi),Mansukh Dyeing Company,Ankur Hospital,Kanjurgaon,Cromption Greaves Bhandup,Adarsha Vidyalaya,DAV College Bhandup (To Airoli),CGS Colony Bhandup (To Airoli),Bhandup Rly.Stn. (E) (To Airoli),Hema Park (To Airoli),Shivai Vidyalaya,Nahur Rly.Stn.,Bhandup gaon 123 (To Vashi)
C4213 - chavan aditya babu	4	OES School (Towards Vashi),Vashi Sec.10/15 (Towards Vashi),Vashi Bus Stn.(To Vashi Stn.),Center One Mall (To V Stn)
C3943 - DILIP MHATARDEO CHEMATE	21	Vashi Sector 8,Kamgar Hospital Vashi (Towards Thane),Vashi Sector 4 (Towards Thane),Gurudwara vashi (Towards Thane),Indira Gandhi Engineering College,Vijaya Bank/ Dyanvikas Vidyalaya,Hellen Keller (To KLN),MBP (IN),Mahape Naka (To THN),Ghansoli Rly.Stn. (To THN),Ghansoli Naka (Towards Thane),Rabale Rly. Stn.(W)/ Gothivali Gaon (To THN),Rabale Naka (To THN),Rabale Police Station (To THN),Siemens Company (To THN),Reliable Plaza (Towards Thane),Ganesh Nagar/Ambedkar Nagar (To THN),Mukand company (Towards Thane),Vitava Naka (Towards Thane),Vitava Gaon (Towards Thane),Dadoji Konddev Stadium
C3131 - ROHIDAS VITHOBA VANRE	13	Dr. Babasaheb Ambedkar Udyan (To Vashi),Mansukh Dyeing Company,Ankur Hospital,Kanjurgaon,Cromption Greaves Bhandup,Adarsha Vidyalaya,DAV College Bhandup (To Airoli),CGS Colony Bhandup (To Airoli),Bhandup Rly.Stn. (E) (To Airoli),Hema Park (To Airoli),Shivai Vidyalaya,Nahur Rly.Stn.,Bhandup gaon 123 (To Vashi)
C3653 - DIPAK RAMRAV KAMBLE	13	Dr. Babasaheb Ambedkar Udyan (To Vashi),Mansukh Dyeing Company,Ankur Hospital,Kanjurgaon,Cromption Greaves Bhandup,Adarsha Vidyalaya,DAV College Bhandup (To Airoli),CGS Colony Bhandup (To Airoli),Bhandup Rly.Stn. (E) (To Airoli),Hema Park (To Airoli),Shivai Vidyalaya,Nahur Rly.Stn.,Bhandup gaon 123 (To Vashi)
C3792 - YASHVANT MARUTI SHEMBADE	9	Bhandupgaon (To BRL),Gandhi Nagar LBS Road,IES Vidyalay (To BRL),Seepz Bus Stn.(To Andheri),MIDC Marol (To Andheri),Marol Depot (To Andheri),Chakala (To Andheri),Jumbo Darshan (To Andheri),Vishal Hall/ Teli Galli (To Andheri)

Annexure C

ITS components matrix and status

ITS Components ↓		Hyderabad	Bangaluru	
	ITS Vendor →	MapMyIndia + Payswiff	Amnex + Others	
Hardware Installed in the Bus	CAN-OBU	All BS-IV and newer bus fleet are fitted with OBUs. However, n		
	LED Displays (4)	All BS-IV and newer bus fleet are fitted with 4 LED displays a welcome message. Bus stop and route announc		
	Voice Announcement			
AVLS	CCTV + DVR	-	GPS & CCTV procured from Amnex in 2022. Mobile app launched in April 2023 and tracks over 50% of fleet. Status of CCTV not known. Ticket purchase not possible from app.	
	GPS-AVLS	GPS procured from MapMyIndia in 2022. Mobile app deployed but is not functional. Ticket purchase not possible from app.		GPS fur pur
	Passenger Information & Ticketing			
	SLA Monitoring	Manual Only	Manual Only	
AFCS	TIM/ETM	Currently transitioning to android ETMs with UPI & Credit/Debit card payments enabled.	ETMs used but only cash payment accepted.	val al
	Smart Card / NCMC Card	Transitioning to Credit/ Debit Card Enabled ETMs	None	En
	Digital/Mobile Ticketing	Transitioning to UPI Enabled ETMs	None	On
ITMS Software	Network & Schedule Digitisation	Map enabled UI for coding bus stops and routes. Bus schedules added to the system manually.	Routes and schedules added manyally or by upoading Excel tables.	Rou m
	Bus & Staff Scheduling Software	Manual Only Schedulers use fixed travel speed throughout the day.	P&S software procured from Amex but not functional, hence done manually	Trap used w ab iss
	Duty Rostering Software			
	Transit Performance Monitoring	Rudimentary data presented in large tables with t		
	Fleet Maintenance Management Software	Internal ERP software takes care of periodis maintanance and sp OBU data is not harnesssed in real-time for preventive		
	Depot & Spare Parts Management Software			
	Open Transit Data	Data not private and most often inaccessible to the transit agen		

Transit Agency City				
Mumbai	Ahmedabad	Indore	Bhubaneswar	Navi-Mumbai
Chalo + Trapeze	NEC + Others	Amnex + Chalo	Amnex + Chalo	Amnex
ver, none of the agencies have integrated them with their AVLS solution. Instead, the ITS vendors deploy a second GPS unit of their own for real-time vehicle tracking.				
lays and voice announcement systems. Generally only the outside LED displays are seen working. The LED display inside the bus usually shows generic nouncements are typically only functional at the time of initial launch but do not work once the buses are redeployed to other routes.				
-				
GPS procured from Chalo in 2022. Mobile app is functional and tracks over 70% of fleet. Ticket purchase enabled from app	GPS procured from NEC as well as another local vendor. Mobile app mostly not functional for live tracking. Ticket purchase enabled.	BRTS buses are tracked by GPS from Amnex, whereas city buses have GPS from Chalo. Chalo's bus tracking app is partially functional and also allows ticketing.	CRUT has GPS from both Amnex and Chalo. Only Chalo's mobile app is partially functional but does not allow purchase of tickets.	GPS is in use but no Mobile app for tracking buses or purchasing tickets.
Manual Only	Distance report from both AVLS systems compared and minimum of both is paid. All other SLAs are calculated manually.	City buses operate on Net Cost Contract (NCC) and hence no SLA monitoring. For the BRT, SLA mostly done manually.	Distance report from the AVLS are uses as support documents but most of SLA monitoring is manual.	Distance report from the AVLS are uses as support documents but most of SLA monitoring is manual.
Android ETMs able to validate mobile tickets and also smart-card enabled.	Android ETMs able to validate mobile tickets and also smart-card enabled.	Android ETMs allow smart-card payment.	ETMs used but only cash payment accepted.	ETMs used but only cash payment accepted.
Enabled but very megerly used.	Smartcard enabled	Smartcard enabled	None	None
Only through Chalo mobile app.	Only through BRTS-AMTS App	Only through Chalo mobile app.	None	None
Routes and schedules added manyally or by upoading Excel tables.	Map enabled UI for coding bus stops and routes. Bus schedules added to the system manually.	Routes and schedules added manyally or by upoading Excel tables.	Routes and schedules added manyally or by upoading Excel tables.	Routes and schedules added manyally or by upoading Excel tables.
Trapeze software was earlier used that initially seemed to work but later had to be abandoned due to various issues. Scheduling is now done manually.	P&S software procured from NEC/Lumiplan but not functional, hence done manually using fixed travvel speed throughout the day.	P&S software procured from Amex but not functional. Sheduling done manually using fixed travel times.	P&S software procured from Amex but not functional. Sheduling done manually using fixed travel times.	P&S software procured from Amex but not functional. Sheduling done manually using fixed travel times.
Daily rosters for buses and crew are created at the depot manually.				
vith thousands of values for each bus, thus not amenable to any decision making or optimisation. Very basic KPIs generated automatically.				
and spare parts management. ntive maintanance.	FMS part of NEC's ITS. However never got used as private operator prefers alternative cheaper SaaS solution.	FMS part of Amnex's ITS. However never got used as private operator prefers alternative cheaper SaaS solution.		Not included in ITS procurement. Private operator uses internal process/software.
agencies itself (except in Ahmedabad where Smart City Mission stores data on their servers). The data has never been harnessed internally or through third parties for identifying issues with the bus operations.				

Annexure D

Functional requirements of network digitization and planning & scheduling tool

A. Transit network and schedule digitization tool

- **Purpose:**
  A cloud hosted spatial tool that makes it easy for digitising, managing, and publishing (to third party solutions in General Transit Feed Specification, transit networks (including IPT/last-mile service), timetables, fares, etc., along with the periodic roster. The tool should further enable various analytical features including but not limited to estimate accessibility index of a place based on custom defined criterion.

- **Functional requirements:**
  Static data management functions:

  - ***Transit network digitization functions:***
    - GIS-based intuitive spatial tool;
    - Provide convenient and intuitive way of coding of bus stops and routes (by series of clicks on the map);
    - Tools to select, copy and edit existing routes;
    - Automated name suggestions while creating bus stops;
    - Ability to group multiple bus-stops by location;
    - Interface to enter (and copy/edit) timetables for each route in the network; and
    - Import/export network data from General Transit Feed Specification

  - ***Manual schedules digitization functions:*** (required only for transitioning from current manual process to the automated schedule optimization tool)
    - When digitizing manual schedules, autofill timings for intermediate stops on a route based on timings given for end stops; and
    - Ability to maintain multiple timetables for a route by date range.

  - ***System integration functions:***
    - Interface to add/edit/import/export resource information (fleet, staff, ETMs, tracking devices, validators, etc.); and
    - Ability to import various spatial datasets (socioeconomic, infrastructure, etc.) to overlay over the transit network.
    - Real-time data management functions:
    - Interface to add/edit/import/export daily or periodic roster.

- Methods to reallocate resources in real-time in case of accidents, breakdowns, or any other causes.
- The tool should have validation methods to ensure there are no conflicts in resource allocation (same resource allocated to different schedules that are temporally overlapping or spatially separated).

▪ ***Administrative functions:***
- Enable individual transit providers across the country to create and manage their accounts.
- Create a hierarchy of users in the organization who can create, modify, delete and approve changes to the transit operations data.
- Ability to create a process flow within the organization.

▪ ***Analytical tools that allow for quantitative (KPIs) and qualitative assessment of level of service, such as:***
- Total transit network length;
- Service coverage (by area, population, within specified distance of transit stop);
- Network length classification by frequency of service;
- Thematic representation of network links and stops based on various service parameters (frequency, routes, etc.);
- Accessibility index of a place in the city based on a customisable function;.
- Thematic maps of the city based on accessibility, in order to identify underserviced areas; and
- Tool to identify ideal locations for transit depots (based on fleet assignment) to reduce dead mileage.

▪ ***The tool should be able to integrate/connect with various third-party applications to publish/import static information by way of General Transit Feed Specification standard.***

B. Scheduling and rostering tool

- **Purpose:**

  The tool should support transit agencies in automatically creating route timetables, bus schedules and staff duties in an optimal manner to reduce costs by utilising resources effectively, while also ensure fairer workloads and distribution of work shifts.

- **Functional requirements:**
  - ***The P&S module should be able to consider various inputs and constraints, some of which are:***
    - Transit routes/network (input from Network Digitization Tool);
    - Intended headways (varying by time of day) either as direct input or computing based on passenger demand distribution from FCS data;
    - Travel times along the route (temporal variation from historic data);
    - Available fleet (and various attributes such as type, passenger capacity, distance range, refuelling requirements, etc.);
    - Labour laws (working hours, salary, overtime compensation, overtime limits, etc.); and
    - Staff preferences (working hours, duty days, etc.).

  - ***Considering the various constraints, the solution is expected to output:***
    - Timetable for the routes;
    - Bus schedules;
    - Staff duties;
    - Rostering of fleet and staff; and
    - Integrate with third party applications to access input parameters and export the outputs as may be necessary.

  - ***The solution should be able to create schedules based on a combination of one or more optimization criterion.***
  - ***The solution should be able to consider constraints of depot locations, need for staff to return to home depots within a specified number of hours, etc.***
  - ***Where a preferred frequency along routes is defined, the tool should be able to generate a timetable and specify the number of buses and staff that are required to operate under given constraints.***
  - ***When the number of buses is fixed, then the tool is expected to generate an optimal timetable with uniform headways in each time-period that can be operated.***
  - ***Where multiple routes have significant overlap on the same road segment, the solution should have a feature to adjust timetables of individual routes to provide near uniform headway to passengers waiting in the overlapping route segment, thus avoiding bunching of buses.***

- ***In case of electric bus fleet, the solution should additionally be able to handle the charging requirements and locations of the charging stations while creating bus schedules. [Note: Individual buses may have different constraints.]***
- ***The tool should calculate various KPIs such as daily bus utilisation, staff per bus, total cost per kilometre (based on staff salaries, overtime rates, etc.) and allow the users to select the parameter on which to optimize the results.***
- ***While rostering staff, the tool should keep track of staff leave accruals and overtime payments.***

This platform can integrate with other ITS modules in cities to facilitate information exchange, analytics, passenger information, and decision-making. Alongside the software platform, developing soft components such as a comprehensive user manual and SOPs is essential for staff training and knowledge sharing.

The massive investments in implementation of intelligent transport systems (ITS) in public transport has led to substantial advancements in electronics, communications and information technologies. This can improve the quality of public transport services significantly by advancing management of transportation and traffic and multimodal integration, and by making traveller and user information accessible. It can improve journey time, reliability and safety of services, and traffic signal efficiency; reduce accidents, traffic congestion and emissions; increase operational efficiency; and provide real-time information.

But in reality much of the anticipated operational gains have yet to be fully realized. Its application remains very narrow in scope. Urgent steps are needed to enhance this "digital public good".