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ROADMAP FOR DATA-DRIVEN TRANSFORMATION OF INDIAN BUS SYSTEMS

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1. ROLE OF DATA IN TRANSFORMING BUS SERVICES

Indian cities are growing rapidly - both spatially and economically, leading to overall growth in travel demand and the emergence of new growth centres due to the population influx and increasing economic activity. There is a need for public transport service providers to analyse these emerging travel demand patterns to improve their availability and accessibility such that they continue to remain the preferred choice of travel for users. However, the quantity and quality of our public transport services have not kept pace with changing user needs and are therefore losing ridership and market share to private vehicles. The lack of demand responsiveness of the Indian public transport systems is resulting in a rapid decline in their ridership despite the overall increase in population and travel activity. Increasing disposable incomes allow users to choose alternate modes of travel such as personally owned vehicles and on-demand ride-hailing services. Increased motorisation in turn has led to an increase in congestion, air pollution, traffic crashes and an overall reduction in liveability in our cities. Retaining existing public transport users and attracting users from private modes of transport is crucial for the economic progress of our cities.

Improving bus ridership requires the development of modern bus systems which can meet the everchanging travel demand and service quality requirements of users. However, public bus service design and delivery practices in India have not changed significantly over the past few decades. Indian bus agencies predominantly provide static route networks, adopt manual scheduling practices and use service volume-oriented performance metrics. Incorporating customer needs into service planning and performance monitoring isn’t yet a mainstream practice in many cities.

Cities have acknowledged the need for customer centric and demand responsive service delivery and the role of data in achieving such transformation. Many cities have invested in asset procurement and implementation of multiple new technologies over the years towards this. Intelligent Transport Systems (ITS), Management Information Systems (MIS), depot management softwares and other applications have been implemented with varying levels of success. The implementation of these technologies has led to the digitization of some of the core functions like revenue collection and performance management. However, even when the traditional service planning, scheduling and monitoring continue, many cities still view these technologies as additional activities to be managed. As a result, the data generated from these systems is not necessarily driving decision making and therefore cities are not witnessing significant efficiency improvements despite continued investments in ITS systems.

It is essential that cities view the new sources of data as a key driver of their business and integrate insights from emerging technologies into their decision-making process. Ministry of Housing and Urban Affairs (MoHUA), Government of India (GoI) has taken up various initiatives under the Smart Cities Mission to highlight the importance of digitalisation and improved data acquisition and applications in public transport[1234]. Various guidelines and specifications have also been launched by MoHUA[5] for cities to embrace such practices.

Building on the previous initiatives, this paper highlights some key strategic priorities for bus agencies, and the role of improved data management and application to achieve their desired service improvements. Areas further discussed are the various applications of ITS data, current practices across Indian cities and the way forward for their improvement. This paper implies certain recommendations based on the learnings from 'Integrated Sustainable Urban Transport Systems for Smart Cities (SMART-SUT)', an Indo-German bilateral technical cooperation project implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH[6] and its recent efforts to advance multiple data-driven decision-making tools across Indian cities. This included extensive engagement and cooperation with the bus agencies of Bhubaneswar, Trivandrum and Coimbatore over the past few years. Learnings from these city-level efforts combined with advocacy and capacity building efforts at the national level have been used to identify the issues and recommendations covered in this paper.

2. STRATEGIC PRIORITIES FOR DATA ANALYTICS TOWARDS IMPROVING BUS SERVICES

While data analytics can drive efficiency in every function of a bus agency, we recommend prioritising applications that can be implemented within the purview of the bus agency and prioritising applications from existing data systems over the ones needing new data sources. ITS systems that have already been implemented in many Indian cities provide the ideal venue for this. They typically have the following data:

i) Global Positioning Systems (GPS) based Automatic Vehicle Location (AVL) systems providing the latitude and longitude coordinates of buses, typically at a frequency of 10 seconds or better

ii) Electronic Ticketing Machines (ETM) which record the route, time, origin, destination and fare for each trip

These systems are either provided by the same vendor or through different vendors, integrated centrally through a Systems Integrator (SI). Sometimes, the city acts as a SI directly aggregating data from different vendors. Analysis of data from these sources can drive a host of innovations in bus agencies such as the following:

i. **Customer Engagement through Passenger Information and Feedback Generation**: GPS data can provide real-time information to users through smart phone based journey planning applications (apps) on the routes between their origins and destinations along with the Expected Time of Arrival (ETA) for the next bus on these routes. These apps can also be sources of user feedback on bus service improvement needs.

ii. **Performance Management**: Performance management covers the periodic evaluation of service efficiency and real time monitoring of service delivery. Periodic evaluation is typically carried out through a wide range of Key Performance Indicators (KPIs) covering the physical and financial performance of the bus system. For eg. punctuality, service-km delivered, route-wise cost recovery. Real time monitoring involves tracking deviations from the planned schedule such as traffic diversions, bus bunching etc. and

[1] https://smartnet.niua.org/transport4all/
[2] https://smartmove.niua.org/#/
[3] https://dataspace.mobi/#/
[4] https://iudx.org.in/
[5] https://mohua.gov.in/cms/escbs.php
[6] https://www.giz.de/en/worldwide/81898.html

reorganising services to mitigate passenger inconvenience. Data from GPS and ETMs can be processed using big data analytics to derive the necessary KPIs for performance management. Cities can adopt Business Intelligence (BI) dashboards that can generate these KPIs automatically and provide real-time and historic analysis for performance management.

iii. **Service Planning**: Service planning typically includes determining the route network of operations and its frequency for different time periods. Route network planning is a strategic function carried out periodically while frequency planning is a tactical function that requires regular updations for peak, off-peak, daily and weekly variations in travel demand. ETM data provides rich insights for service planning by providing historic travel demand patterns which can be used to adjust service frequency. ETM data combined with travel time data from the GPS and city level travel demand patterns can be used to review the route network performance periodically and rationalise it to meet travel demand needs optimally.

iv. **Timetabling, Vehicle and Crew Scheduling**: This involves the optimal assignment of vehicles and crew to meet service planning requirements. While service planning is typically conducted by the city bus agency, scheduling is carried out either within the same agency in case of in-house operations or by the operator contracted to provide the service. In both cases, the historic travel time data from GPS can provide rich insights towards planning for the optimal fleet to be allocated to various routes and therefore the crew needed to operate these vehicles. Crew scheduling has further complexity because of the difference in vehicle schedules which are typically developed for the 16-hour service span while crew schedules only span 8 to 12 hours according to crew shift availability.

v. **Contract Management**: Many cities outsource bus service delivery to private operators who are paid on a per-km basis subject to meeting various Service Level Agreements (SLAs). ITS can play a crucial role in efficient and transparent contract management through accurate estimation of the service-km delivered and adherence to the SLAs.

vi. **Infrastructure Development**: Data from ITS can also provide insights for long term infrastructure investment decisions. This typically includes bus stop and terminal infrastructure based on bus and passenger needs. Further, travel patterns of Vulnerable Road Users (VRUs) such as women, children, elderly, people with disabilities and others can be analysed to provide context specific infrastructure needs assessment to the concerned agencies.

3. OPPORTUNITIES FOR IMPROVING DATA MANAGEMENT AND DATA ANALYTICS IN INDIAN BUS AGENCIES

Despite the wide range of possibilities offered by ITS data in improving the core functions of bus agencies, their adoption in Indian cities has been limited. This is due to a combination of factors ranging from lack of awareness, limited technical capacity and lack of context-specific tools for data management and analytics. GIZ supported SMART-SUT project has been working with cities towards addressing these barriers. The following sections outline the key gaps in data management in Indian bus agencies and propose recommendations for addressing them.

3.1 Data Availability and Accuracy

i. **Route Network Maps**: Many cities do not maintain route network maps in machine readable formats like Geographic Information Systems (GIS). A typical route network map includes the routes, stops, terminals and depots within the bus network. These maps enable a multi-layered analysis of the accessibility of the current system, service gaps across the city, identification of locations for additional infrastructure like stops, terminals, depots and charging stations for electric buses. The lack of such network maps can lead to biases in decisions concerning route network design and service augmentation resulting in an oversupply of the available buses in some areas and undersupply in others.

ii. **Service Schedules**: The base service schedules offered by cities are not maintained in standard machine readable formats such as General Transit Feed Specifications (GTFS) in many cities. The data formats followed across cities are inconsistent and sometimes schedule formats vary even between different depots in the same city. As a result, it is difficult to inform the users on the scheduled service timetables across different routes, let alone their actual ETAs. In addition to standardisation issues, many cities adopt depot level scheduling practices with limited harmonisation centrally. This leads to overlapping services in the case of routes with buses operating from multiple depots.

iii. **ITS Bus Stop and Route Database**: The bus stop and route database in the ITS system is the basis on which the system's performance is measured. We observed that this database has gaps like inaccurate or duplicate stop locations, stop names, route alignments and even route numbers which result in inaccurate reports from the ITS system. The lack of rigorous evaluation by cities is leading to systemic perpetuation of these errors over the entire lifecycle of the ITS system.

iv. **AVL (GPS) Data Latency and Accuracy**: The GPS devices in most of the current ITS systems in Indian cities require data to be provided at a frequency of 10 sec. However, cities typically find gaps in actual data frequency with missing values due to internet connectivity issues. Whatsmore, many cities don't have any KPIs or monitoring mechanisms to test for the latency of the data and its accuracy. This will further affect key reports generated from AVL data such as service-km operated, journey speed and punctuality. In cities where bus service delivery is outsourced, poor reporting on these indicators forces cities to use manual performance evaluation methods. Even in cities with in-house operations, a lack of accurate AVL reports leads to inefficiency in performance evaluation and service planning. Therefore, improving AVL data latency and accuracy can lead to significant financial gains for the bus agency.

v. **ETM Data Inaccuracies**: ETM devices are operated by conductors for issuing tickets in buses. Accurate ETM data requires their schedule of operation to be entered into the devices and the conductors entering the right origin, destination and fare information while issuing tickets. Experiences from cities show that the data entry on schedule linked to the device are generally accurate since the revenue collection is audited daily. Similarly, the fare data is generally accurate as users need to be issued tickets with the right denomination. However, few key gaps remain:

   - The origin and destination information typically has significant errors as conductors don't have adequate time to enter the details in crowded buses. Modern ETMs which automatically update the origin of the trip based on the bus location mitigate this error to some extent. Even these ETMs need some manual intervention in identifying the right route, shift and trip numbers which leads to inaccuracies
   - The issue of inaccurate stop names also adds to the inaccuracies in ETM data as the same location may be selected differently by different conductors.
   - ETMs also include several tickets where the unique ID given to each ticket is duplicated and makes it difficult to account for the exact number of tickets issued, further limiting data analysis.

vi. **Stage-wise and Stop-wise Fare Charts for ETMs**: Indian cities typically have distance-based fares determined in 'stages'. A route is typically divided into multiple stages with each stage being a combination of stops in close proximity and fares are typically set between stages and not individual stops. In urban settings, the average stage length is around 2 km and all stops within a given origin stage will have the same fare for all stops in a destination stage. The ETM software needs to take the stop and stage data into its back-end systems and use that while issuing tickets. Even if the tickets are within the same stages, knowing the exact stops of tickets are needed to understand travel demand patterns for service planning. While cities like Bhubaneswar record the exact origin and destination stop of each ticket, Trivandrum and a few other cities only record the stages in their database, thereby limiting its application for planning. Therefore, cities need to improve the ETM databases to collect stop to stop data for improved usefulness of ETM data.

vii. **Lack of Direct Tickets for Transfer between Routes**: ETMs across India are hardwired to issue tickets only corresponding to the bus on which they're operated. As a result, passengers transferring between buses need to purchase a new ticket for every leg of their journey. Given the telescopic fare system followed in Indian cities, tickets for short trips are more expensive than the longer ones. Therefore purchasing two tickets will be more expensive compared to a direct trip. This adds 'transfer penalty' on the users who are typically averse to transfer between buses due to the physical effort involved. Therefore, cities need to improve their ETM software to issue direct tickets to users' end destination rather than just the route of operation and therefore reduce users' transfer penalty.

viii. **Ticketing Data of Concessional Pass Users**: Cities typically don't capture data on concessional pass travellers like students and elderly, who form up to 50% of the overall travel demand. Therefore the service planning and scheduling activities don't incorporate the travel needs of a significant portion of their core clientele. Even though some cities mandate the issuance of 'zero' value tickets to pass users, conductors find it difficult to implement during crowded hours. Cities need to adopt recent advancements like mobile or ETM based concessional pass issuance and validation to capture pass-users' data in greater detail.

ix. **Lack of Gender Information in Ticketing Data**: The gender of the user is typically not captured in ETMs while issuing tickets. Recently, Bhubaneswar has adopted a systemic approach to capture this data and understand the gender-wise travel demand patterns. This supports the city in manifolds to appropriately assist the users. Similarly, Delhi issues pink tickets for female passengers who avail the free-bus-travel services offered by the Government.

x. **Syncing GPS and ETM Data**: The route numbers, their schedules and the corresponding unique ids are sometimes maintained separately by ETM and GPS vendors, who don't use the same nomenclature and unique ids for datasets. It is crucial for cities to ensure the two systems are integrated and therefore allow for combined analysis from the two data sets.

xi. **Data Formats across Vendors**: Cities sometimes have more than one vendor providing GPS devices or ETM devices within the same system integrator. In such cases, the data structure of different vendors is typically different thereby making it difficult to maintain consistency in reporting. It is necessary to ensure that the vendors provide data in a pre-defined format, ideally mentioned within the contract.

3.2 Data Management

i. **Database Architecture and Reporting of ITS**: The backend data of ITS systems need to follow the same hierarchy as the operators: ***Depot -> Route -> Schedule -> Trip -> Stop.*** Different datasets like schedules, GPS data, ETM data and others need to be maintained in separate tables in the same hierarchy with proper links/ keys in the database architecture. The lack of such hierarchy in the database leads to the entire city's data and reports from ITS being aggregated into a few tables, making it difficult to retrieve specific data points. This situation further impacts the KPI reports that are to be developed from these datasets. Subsequently, it results into lack of specificity in ITS reports and their ability to assist in decision making.

ii. **Data Dictionary**: A data dictionary is a centralised repository of information about the data such as an overview of all data sets (ETM, GPS, Schedules etc.), the columns in each of the data sets and their meanings. A data dictionary allows new users to quickly understand the data and use it for analysis. There was no clear data dictionary of ITS data in the cities we worked with. Developing clear data dictionaries can be a quick way to improve the possibilities of data analytics in cities. It is also critical to ensure that future upgrades to systems, for example, new ETM machines, are aligned with existing dictionaries, or allow for backward compatibility, to ensure that future upgrades do not adversely impact the existing analytics engine(s).

iii. **Data Ownership**: The data ownership clauses in bus fleet and ITS procurement are sometimes ambiguous leading to limits of access to some datasets. For eg. the Controller Area Network (CAN) data that provides valuable insights into bus performance is inaccessible by cities in many cases, if not mentioned explicitly in the contract. CAN data can help track key metrics like fuel/oil level and pressure, braking/accelerator pedal position, brake pedal condition, and fire detection/gas leakage (if any).

Similar issues may arise with cities increasingly adopting contactless payments via debit cards and Unified Payment Interface (UPI) based payments. Unless the contracts allow for sharing of relevant data in predefined formats, financial institutions are often reluctant to share data. This may hamper access to key data points like orgin-destination, fare paid and other insights from ticketing data that impact service and financial planning.

iv. **Open Data**: Sharing data in the public domain, preferably in machine-readable formats, helps make it more accessible for web developers and thereby the general public. The Open Transit Data efforts in Delhi[7] have demonstrated a low-cost approach to developing and sharing GTFS data (static and real-time) in the public domain. Hyderabad and Chennai are currently developing static GTFS systems which are likely to be available in the public domain.

3.3 Data Analytics and Application

Investing in good quality data and its management system can deliver multiple benefits to the city. A few key applications of data analytics towards improving system efficiency and user satisfaction are explained here, along with specific case examples of such applications. This section only provides an overview of the applications. Readers are encouraged to go through the detailed reports cited below for further information.

i. **Business Intelligence (BI) Dashboards to Visualise Performance Evaluation Metrics**: Bus agencies adopt Key Performance Indicators (KPIs) for periodic performance evaluation of their services. These KPIs cover items like productivity metrics for efficiency in service delivered, service effectiveness to measure the service uptake and cost-effectiveness to measure the financial performance. These KPIs have multiple benefits like strategic planning to improve the bus system, benchmarking different routes and depots, update service plans and manage contracts in case of outsourced operations. BI dashboards are a templatised form of KPI measurement and review where the key KPIs are identified beforehand and generated using available data sets. The dashboards would then generate and visualise these KPIs at a predefined frequency (hourly, daily, monthly, annually etc.).

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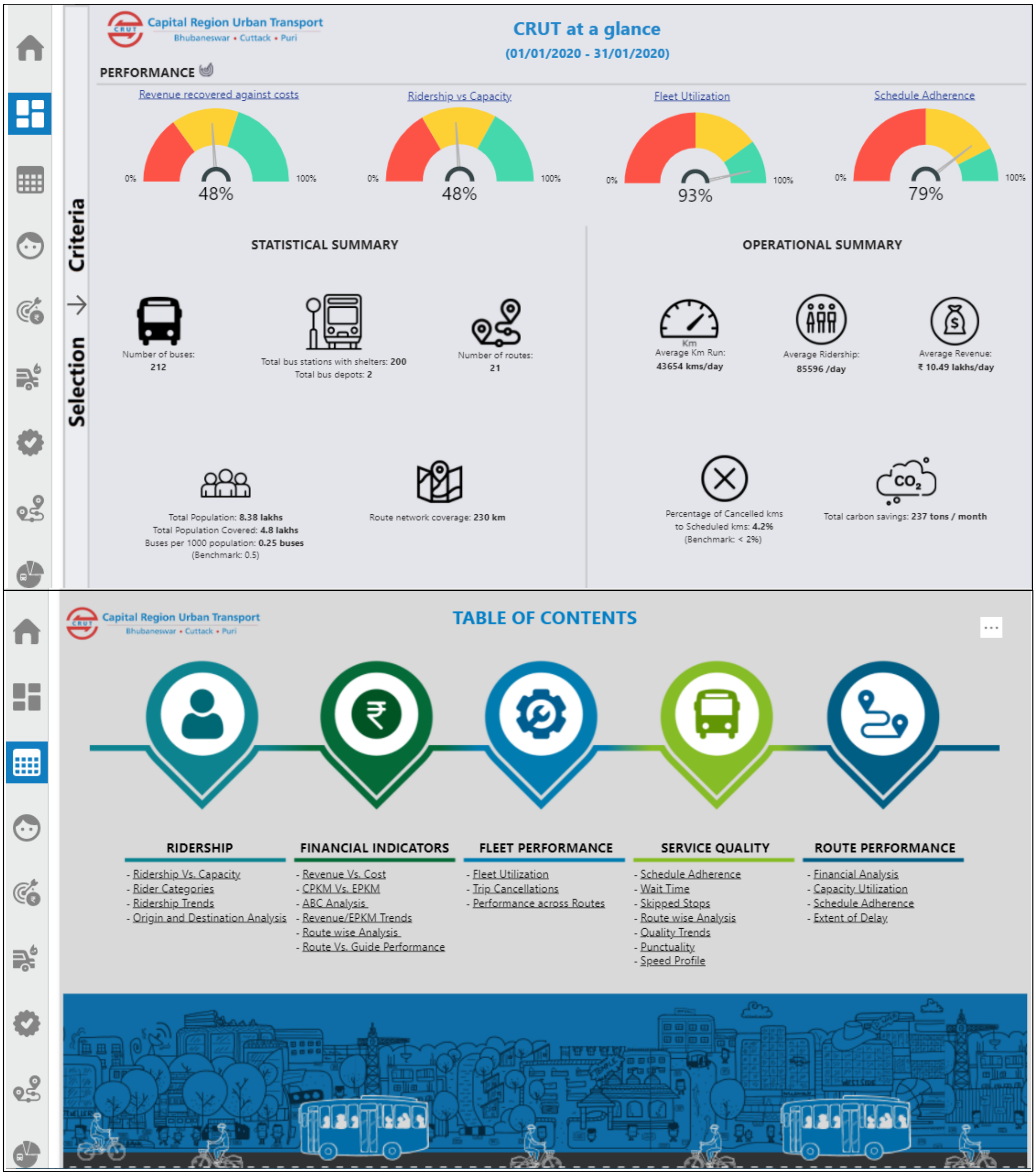
[7] https://opendata.iiitd.edu.in/

Figure 1: Business Intelligence Dashboard: Summary Statistics of CRUT, Bhubaneswar



(Source: Data Analytics Study for Efficiency Improvement in City Bus Systems, Bhubaneswar, SMART-SUT, 2021)

The key to the success of a BI dashboard is identifying the right KPIs and ensuring good quality data to generate these KPIs. The traditional KPIs followed by Indian State Transport Undertakings (STUs) for many decades provide a comprehensive overview of the productivity of bus systems[8]. More recent literature emphasises the need to capture more customer satisfaction metrics like accessibility, crowdedness and excess wait time to ensure demand-responsive services.

SMART-SUT in collaboration with Deloitte and Zeliot has partnered with Capital Region Urban Transport (CRUT), the authority managing city bus services in Bhubaneswar to demonstrate a BI dashboard using ITS data. The dashboard supports CRUT in several functions including:

[8] https://morth.nic.in/performance-state-road-transport-undertakings-srtus

- Performance review of services segregated by depot, route and operator further segregated by hourly, daily, quarterly and annual performance
- Improved monitoring of the performance of the contracted bus operators against their Service Level Agreements (SLAs)
- Performance management of the system at various levels of staff, i.e., operational staff, middle and senior management
- Improved understanding of customers, their travel preferences and feedback for improvement

Figure 1 above shows a screenshot of two pages of the dashboard covering the summary statistics of the city and table of contents of the dashboard. The dashboard generates KPIs listed in the table of contents covering key categories like ridership, route and fleet-level performance, financial performance and service quality. We used historic ITS data and Power-BI, a commercially available BI software. Cities may also choose other BI platforms like Tableau (commercial), Apache Superset (Open source) or even program their own BI dashboards.

ii. **Route Network Planning and Rationalisation**: Bus route networks in cities typically grow organically based on the overall development of the city and its travel demand patterns. Over the years, this can lead to duplication of services on a few high-demand corridors and undersupply of services in recently developed areas. Analysing ticketing data from ETMs and KPIs generated from the ITS systems along with data on the overall travel demand patterns in the city can be used to review the route network performance periodically and identify venues for rationalisation. SMART-SUT has recently concluded two such efforts in the cities of Coimbatore and Trivandrum. We partnered with the Delhi Integrated Multimodal Transport Systems (DIMTS) Ltd. to review the route network in Coimbatore and with the Centre of Excellence in Urban Transport, CEPT Research and Development Foundation in Trivandrum.

In both the cities, we developed Geographic Information Systems (GIS) based route network and travel demand maps for these cities. KPIs from available ITS and manual data systems were then overlayed on the networks to review the performance of the current networks. We encountered many of the gaps in data generation and management explained in previous sections in both the cities and identified proxy sources of information to fill in for the data gaps. The analysis identified specific areas of improvement in the existing route networks and developed recommendations to reduced duplicity and improve service coverage even within available fleet resources.

Figure 2 below presents a visualisation of the current public transport accessibility levels in Coimbatore which was used to develop route rationalisation recommendations. The proposed recommendations would provide access to routes with 5 minutes or lesser headway for 21% more people in the city. This can further be extended for infrastructure recommendations like locations for bus priority lanes, new depots and terminals, etc. across the city.

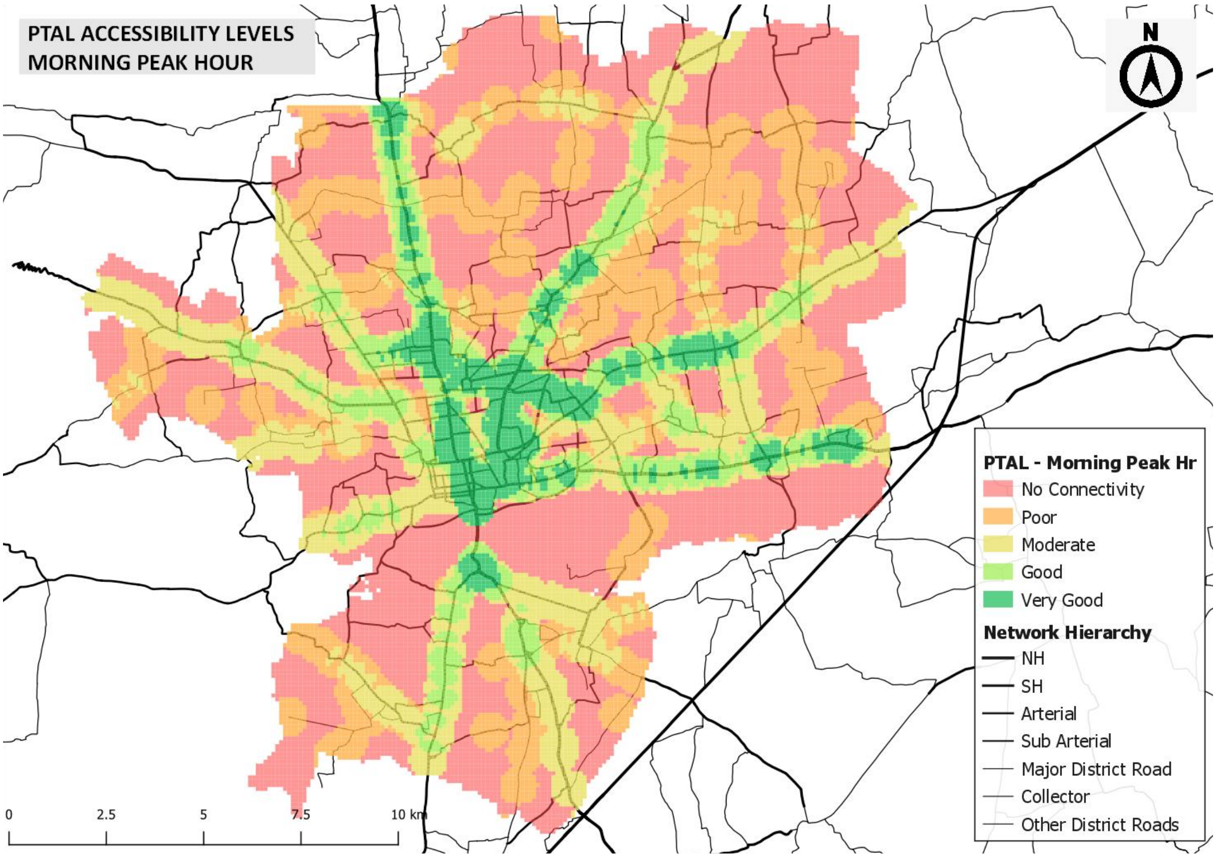
iii. **Planning for Electric Buses**: Many Indian cities are now planning and implementing electric buses as a part of their efforts to reduce emissions and the energy intensity of their public transport systems. The cost of operating electric buses is sensitive to its operating conditions as aspects like daily vehicle utilisation, speed, time available for opportunity charging etc. have a significant bearing on the specifications of electric buses, their batteries and chargers. Therefore, cities can significantly reduce their electric bus implementation costs by matching their procurement specifications with route operating conditions.

SMART-SUT partnered with DIMTS Ltd. to develop an electric bus deployment plan for Coimbatore. Detailed route level analysis was carried out for the city's bus network using available data systems to prioritise depots and routes for electric bus implementation. A combination of tools were used for this purpose: network analysis in GIS and cost optimisation analysis in Python were integrated using Knime-an open-source data analytics integration platform. The model minimizes the cost of electrification covering fixed and variable cost items in the electric bus depot and route selection, subject to constraints on the availability of buses, charging station capacity and availability of high-tension power (11 KV) to charge buses. The cost components of the objective function include the following:

- Dead-km cost, i.e., the cost of operating non-revenue trips between the depot and the route terminal location at the beginning and end of each trip
- Infrastructure development cost needed to introduce electric buses including items like depot infrastructure, charging infrastructure and power infrastructure for access to electricity

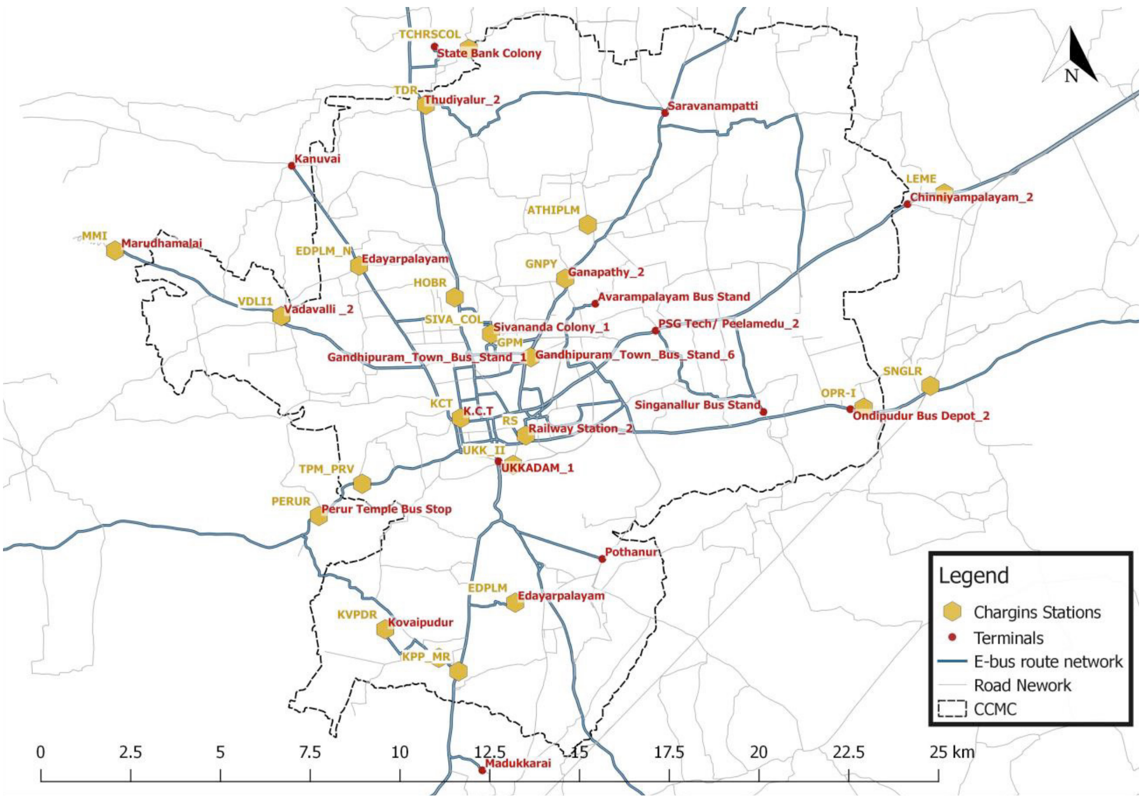
This model was used to test alternative scenarios of deployment of 70 electric buses the city planned to induct at the time of conducting this study. A total of 23 candidate charging locations including overnight

Figure 2: Public Transport Accessibility in Coimbatore



(Source: Route Rationalization and City Bus Service Improvement Study for Coimbatore, SMART- SUT, 2021)

Figure 3: Electric Bus Routes and Charging Stations Selected for Coimbatore



(Source: Route Rationalization and City Bus Service Improvement Study for Coimbatore, SMART- SUT, 2021)

charging at depots and opportunity charging at bus terminals were identified as presented in Figure 3. These locations can optimally serve the entire bus network of Coimbatore. The study also analysed the impact of deploying alternative bus technologies available in the market to assess the vehicle-km to be served, the number of chargers needed, batteries required over the lifecycle of the contract, daily energy consumption and operational personnel required.

iv. **Schedule Optimisation**: Route network planning is a strategic exercise typically undertaken once in few years according to the changing travel demand patterns of the city. Scheduling is more of a tactical activity undertaken more frequently on a daily, monthly, or quarterly basis, according to emerging operational. Scheduling can broadly be classified into the following categories:

- **Service Schedules or Timetables** include route-wise information on one or more of the following items: the planned hourly frequency (buses per hour), headway (time between successive buses) and time of arrival of buses at each stop for the entire day. These schedules are disseminated widely for passenger information and are therefore recommended to be maintained in global standards like GTFS[9] and others[10].

- **Vehicle Schedules** include the daily schedule of each bus, its start and end times at the depots, the list of trips to be performed through the day and their time of operation. Vehicle schedules also need to factor in fleet availability based on their maintenance needs and even charging needs, in the case of electric buses.

- **Crew Schedules** cover the type of crew shifts to be allocated to meet the vehicle schedules and the duty roster for the crew assigned to these shifts. Crew shifts are typically defined as day-out (8-hour shift), night out shift (two back to back 8-hour shifts followed by a rest day typically used in rural operations), general shift (12-hour shift) and night service (8-hour shift overnight) as per the Motor Transport Workers Act 1961[11]. Cities need to identify the right combination of crew shifts to meet the vehicle schedules. Crew rosters would then be prepared to account for crew hours of operations and their unavailability due to weekly offs, planned and unplanned leaves.

- **Charger Schedules**: With the emergence of electric buses, cities also need to plan for their charger schedules by matching vehicle schedules and their charging needs with the charger availability and the time needed for charging.

Scheduling is an analytically intensive exercise that needs to maximise the service and minimise cost while meeting constraints like ensuring minimum service levels, meeting travel demand, incorporating travel and rest times, availability of resources like fleet, crew and depot etc.

Indian bus agencies typically adopt manual scheduling practices using simple calculations that limit them in incorporating the constraints explained above. This leads to significant inefficiencies in timetables, vehicles and crew scheduling practices resulting in missed trips, inconvenience to passengers and dissatisfaction among the crew. A combination of transport planning, data analytics and Operations Research (OR) techniques need to be applied for cities to optimize their schedules and potentially reduce the cost of operations between 5-10%[12].

Some bus agencies tried off-the-shelf schedule optimization softwares towards this objective. However, the success so far has been limited because such softwares were originally developed for cities where the timetable is given as input to the operator who then defines the vehicle and crew schedules. In Indian cities, operators are typically in charge of both timetabling and scheduling (of buses and crew). Therefore, the Indian bus agencies, researchers and solution providers need to come together and invest in developing context-specific solutions that serve Indian bus system needs. SMART-SUT has been supporting MoHUA in organizing a global data challenge called ‘SMART MOVE: Innovative Urban Mobility Challenge’ to support few such initiatives[13].

4. NEED FOR CAPACITY BUILDING AND DEVELOPMENT OF CONTEXT-SPECIFIC TOOLS

The previous sections highlight the need for improved data management in Indian bus agencies, the avenues for improvement and the potential applications of data towards overall service efficiency improvement of bus agencies. The envisaged results from each of these steps are only possible through improved awareness of

[9] https://developers.google.com/transit/gtfs
[10] https://data4pt-project.eu/wp-content/uploads/2021/04/3-NK_Differences-between-standards.pdf
[11] https://www.indiacode.nic.in/bitstream/123456789/16412/1/motor_transport_workers_act_1961.pdf
[12] https://shaktifoundation.in/report/roadmap-improving-city-bus-systems-india/
[13] https://smartmove.niua.org/#/

the issues and the technical capability to bring in the best practices explained in this paper. The awareness and capacity building activities need to cover a wide range of stakeholders involved in the planning, procurement and implementation of ITS systems:

i) Bus agencies - in charge of many key functions impacting data management and application such as ITS procurement, service planning, scheduling and operations

ii) Policymakers - in charge of standards and certification of ITS systems

iii) Consultants - supporting cities in the ITS procurement and management, public transport planning

iv) Academics and think tanks - researching public transport systems

v) Think tanks and civil society organizations - advocating for demand-responsive public transport

The capacity building of these stakeholders would require the development of necessary tools for data creation, management and analytics that combine the necessary transport planning, data science and Operations Research (OR) expertise for improved public transport systems. Adoption of such tools by cities would also require extensive technical assistance and training programs for the concerned stakeholders.

5. SUMMARY AND RECOMMENDATIONS

The paper provides an overview of the role and opportunities for improved data availability, management and analytics in driving service efficiency and customer responsiveness of Indian bus agencies. Data analytics from existing ITS systems such as vehicle tracking and electronic ticketing can improve several strategic priority areas for bus agencies such as customer engagement, performance management, service planning, scheduling and contract management of outsourced bus services. The paper explains the current gaps and opportunities to improve data practices in each of these strategic priority areas through specific case examples.

Data availability and its accuracy are identified as the primary area of improvement covering the following items:

i) Development of route network maps and service schedules using standard formats like GIS and GTFS

ii) Accuracy in ITS data ranging from the bus stop and route database, GPS and ETM data

iii) Improved ticketing practices to ensure stop and stage-wise fares, issue direct tickets for passengers transferring between buses and capture concessional pass and gender-segregated data

iv) Coherence in data between GPS and ETM devices and the multiple vendors issuing these devices

Management of data is another key area of improvement to enable application of the available data. The following areas of improvement are identified towards this:

i) Database architecture and reporting of the ITS systems to reflect the operational hierarchy of urban buses, i.e., ***Depot -> Route -> Schedule -> Trip -> Stop.*** The lack of which is leading to aggregated reporting practices which don't significantly assist decision making

ii) Data dictionaries need to be developed by the cities and ITS vendors to explain the various rows and columns of data maintained. This will allow accurate understating of available data and help improve its application

iii) Data ownership and openness needs to be clearly defined by the cities right from the stage of contracting for the ITS systems and to allow for the application of non-proprietary data for improved customer information and operational decision making

Data analytics of ITS and other secondary data sources has the following key areas of application:

i) BI dashboards to track service delivery efficiency, performance management, customer satisfaction and feedback

ii) Route network planning and rationalization to periodically review the route network and update it to improve bus service access within the available bus fleet. This can further be extended for infrastructure recommendations like locations for bus priority lanes, new depots and terminals, etc.

iii) Planning for electric buses through identification of priority routes and depots for deployment along with locations for charging

iv) Schedule optimization covering multiple facets of service planning and delivery including route timetables, vehicle and crew schedules and schedules of chargers for electric buses

The paper also highlights the need for capacity building of stakeholders involved at various stages of data generation, management and application including the bus agencies themselves and other supporting actors like policymakers, consultants, academics, think tanks and civil society organizations. Given the unique operating, contracting and performance characteristics of Indian bus agencies, the need for the development of context-specific tools is also identified as a key area of improvement. GIZ has been working with Indian cities to create such tools as highlighted in the paper and would continue to engage with all the key stakeholders towards improved data management and its application in Indian bus agencies. We would continue to build partnerships and take up technical cooperation and capacity-building activities towards the advancement of data-driven transformation of Indian bus services.

About SMART - SUT

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