From Variability to Uniformity: Standardization of Electronic Ticketing Machines Data for Urban Transit Systems in India

Rupam Fedujwar, Nishtha Rawat, Amit Agarwal, and Rishman Jot Kaur Chahal
Indian Institute of Technology Roorkee
Correspondance: amitfce@iitr.ac.in

Abstract. This paper analyses the electronic ticketing machine (ETM) data from public transport operators of Indian cities and identifies various issues in it. The major challenges are as follows. First, the number of attributes included in the ETM data varies across cities, and the fields are inconsistent. Second, the information within each field, such as passenger categories or trip directions, varies from transit operator to operator. Third, the standardization of date/ time formats, waybill, route/ trip information, and ticket issuance is absent. Finally, the stop details are not aligned with the transit schedule (e.g., General Transit Feed Specification: GTFS) and automated vehicle location (e.g., real-time GTFS). Here's where a national electronic ticketing standard comes in; establishing standard uniform data fields across ETMs would not only benefit research but also enhance the adaptability and usability of these machines in various cities. In the context of smart cities, standardized ETM data may become a powerful tool for planning, scheduling, and managing public transport systems effectively. This study delves deeper into the variability of ETM data across Indian cities, the present challenges for the analysis, and the potential of this data for optimizing public transport operations. The paper also briefly details the data and framework to standardize the ETM data across Indian cities.

Keywords: Public transport, Smarts Cities, ETM data, Automatic Fare Collection system

Preferred citation style: Fedujwar, Rupam, Nishtha Rawat, Amit Agarwal, and Rishman Jot Kaur Chahal (2025). "From variability to uniformity: Standardization of electronic ticketing machines data for urban transit systems in India". In: *8th Conference of Transportation Research Group of India (CTRG). Guwahati, India.* See WP-108 at : https://faculty.iitr.ac.in/~amitfce/publications.html.

1 Introduction

Electronic ticketing, e-ticketing, or digital ticketing is a growing trend in transportation and related services, as evidenced by research conducted by [1]. It is being implemented in many transit services such as railway, metro, and buses in different cities worldwide [2, 3]. An E-ticket is primarily a digital document providing access to transit services, eliminating the need for a physical ticket. However, in public transport, e-ticketing systems serve as more than just payment methods. It generates a vast amount of data, which can facilitate enhanced management, control, and operations. Data collected through e-ticketing systems offers insights into public transport usage and travel behaviour. The convenience of e-ticketing has been shown to increase public transport usage. In Delhi, for instance, the introduction of the Chartr app results in a significant uptick in ticket sales and ridership, within few months of implementation [1]. E-ticketing systems provide a user-friendly experience, allowing passengers to purchase tickets from anywhere, receive instant confirmations, and avoid long queues at ticket counters. This ease of access is crucial for attracting new users to public transport systems [3]. By reducing the need for physical ticketing infrastructure and staff, e-ticketing systems can lower operational costs, increase efficiency, and improve user convenience [1]. The automation of ticket sales and validation processes streamlines operations and allows staff to focus on customer service and safety. Unlike traditional offline methods, e-ticketing systems employ cards to enhance convenience and expedite entry [4]. [5] conducted a study examining the impact of electronic ticketing systems on public transport efficiency in major southern Brazilian cities. It is observed that the implementation of e-ticketing systems has enhanced information management and control, reduced fraud, and provided more accurate ridership data. Additionally, electronic ticketing has improved security by eliminating cash handling on buses and effectively curbing the illegal trade of paper tickets. The ticketing information further be leveraged for optimizing route capacity and frequency [6]; understanding passenger flow and demand at stops [7]; analyzing ridership by different ticket type [8]; generating origin-destination matrix of passengers [9], occupancy and crowding prediction [10], etc. While metros in major cities have adopted a multiple approach, including cards, QR codes, smartphone apps, and coin-based-tokens systems for entry and exit the stops, buses predominantly rely on electronic ticketing machines (ETMs). Primarily, ticketing in buses is controlled only at entries. Although some cities like Indore have implemented closed-loop systems for bus transport (part of the Bus Rapid Transit Corridor), core payment mechanisms often rely on ETMs on most of the transit lines. Hence, it is important to delve deeper into the use of ETMs in Indian buses for ticketing purposes, which is applicable for open and closed systems.

Public transport operators in India are upgrading to handheld and portable ETMs, to enhance efficiency and convenience in bus fare collection. These machines eliminate the need for pre-printed tickets by allowing conductors to issue tickets on board with passenger trip details (e.g., origin, destination, boarding time, fare, concession, route etc.). ETM is configured daily for each transit vehicle using a personal computer (Host PC) to specify the specific route, bus service, and driver. This configuration allows ETMs for the creation of trip re-

[1] https://niua.in/c-cube/blog/content/digital-ticketing-way-forward-safer-cashless-public-transport

ports by transferring data back to the Host PC after each journey or at the end of the day. The ETMs offer long battery life, with 7-8 hours of use after a 3-hour charge.

In contrast to the cities in developed economies, where the use of smart cards across different modes of transportation is widespread, such systems are yet to mature in developing countries such as India. For street transit, Electronic Ticketing Machines (ETMs) offer a valuable tool for issuing tickets and collecting data to understand passenger travel patterns, offer insights for better capacity utilization, etc. However, there is a paucity of research on ETM implementation and utilization in India. Some research efforts have delved into leveraging ETM data for public transport demand analysis and prediction. [11] contributed to the field by applying time series modeling to predict public bus passenger demand using ETM data, exploring the effectiveness of different Holt-Winters models using data provided by Kerala State Road Transport Corporation (KSRTC) for Trivandrum city of Kerala state. [12] showcased the utility of ETM data in deriving crucial insights into passenger travel behavior. The study, conducted across four bus depots in East Bangalore, extracted key insights such as origin-destination pairs, passenger counts, and ticket amounts, demonstrating the potential of ETM data for informing data-driven public transport strategies. [13] developed a direct demand model to predict bus ridership in Bengaluru, utilizing ETM data as the primary source for the dependent variable. Their findings indicate that stop-level characteristics, competition from other transit modes, network connectivity, and service frequency significantly influence bus ridership demand. A recent study by [8] delved into the spatiotemporal travel patterns of senior citizens in Bhubaneswar, India, by analyzing ETM data. The paper uncovers the senior passengers' ridership and travel patterns, and some policy insights were suggested to improve the PT for senior citizens in the city. [10] pioneered a hybrid approach, combining affinity propagation clustering algorithm and long short-term memory techniques to forecast crowding in the buses. Whereas [14] used the ETM data to analyze the occupancy at transit stops. The proposed method uses the artificial neural network algorithm to predict the number of passengers at the stop at any 15-minute instance. The author also proposed the method to infer stop-level boarding information when aggregated fare stage level information is present in the ETM dataset. A recent study by [15] uses ETM data to estimate passenger occupancy in public transport, which is further used to develop the composite index to assess the performance of public transport routes. These studies collectively highlight the potential of ETM data for improving public transport planning and operations.

Though there are some efforts to effectively use the data from ETM, it is not yet mainstream due to various issues. Firstly, there is a lack of uniformity due to inconsistent data formats and a lack of standardization among ETMs supplied by different vendors across India. While core details like route, trip, bus information, and stops are generally included, the variability in other attributes creates problems in understanding and analyzing the data for the transit authorities and researchers. This complicates data cleaning, analysis and comparison across cities. This inconsistency introduces errors, increases processing time and hinders the development/ transferability of unified prediction models. Moreover, ETM data is not synced with the General Transit Feed Specification (GTFS) [e.g., 10], which creates issues for the scalability and transferability of the models. These issues obstruct data-driven decision-making and benchmarking efforts. Hence, the present study proposes the standardization of ETMs across India that paves the way for a data revolution by streamlining data collection, enabling scalable and transferable models and a more efficient, rider-friendly experience.

2 Associated issues with ETM data

There are many potential issues/ non-uniformity with data obtained from ETM from different cities. The current section provides a comprehensive overview of issues/ non-uniformity that are encountered while comparing ETM data from different cities.

Divergance between GTFS and ETM: This is one of the most important issues, which is lacking in ETM data for all cities. General Transit Feed Specification (GTFS)[2] is a widely used open standard format across the globe for transit schedules, which also follows the principle of the relational database. It has identifiers for stops, trips, routes, etc., names of stops, routes, locations of the stops as well as times. GTFS is not so common in India, and even if it is available for a city, there is no sync between the GTFS and ETM data. This creates confusion between the ETM and GTFS. Clearly, to reduce the efforts and resources to clean and prepare the data, the information from two sources should be synced.

Absence of unique identifiers: For most of the fields (e.g., stop, route, etc.) in ETM, regular names are used. In the absence of a standard style, various names are used to refer to a stop or route. Most of the time, there is a typo, or different abbreviations or short forms are used. This creates ambiguity in the ETM data and requires a longer time to clean the data. This limits the usage of various map services, such as transit route application programming interfaces (APIs). Similarly, the same names are used for the stops on up/ down trips of a route, which would confuse a transit router and result in ambiguous routes. Implementing standardized stop identification practices, including unique stop IDs for each direction, is crucial to improving data consistency and usability across different ETM systems. Clearly, such unique identifiers should be the same as in GTFS.

Inconsistent ticketing time: ETM data from Indore and Bhopal exhibits inconsistencies in timestamp accuracy, necessitating manual corrections. The inconsistent datetime formats across different datasets for example, `dd-mm-yyyy hh:mm` in Bangalore, Bhopal, and Bhubaneshwar, `mm dd yyyy mm:ssAM/PM` in Nagpur, `dd/mm/yyyy hh:mm` in Delhi and `mm/dd/yyyy mm:ss` in Indore pose significant challenges for data synchronization and temporal analysis. To address

[2] https://gtfs.org/

these issues/ non-uniformity, a standardized datetime format should be adopted across all data collection and processing systems; it should be synced with the internet, or an update should be mandated after turning on the machine.

Incomplete boarding and alighting information: In certain cities, like Bangalore, passenger boarding and alighting data are aggregated at a coarser level than individual stops (cf. Fig. 1). This is often due to fare structures that group consecutive stops into fare clusters. While this approach simplifies fare collection, it obscures granular insights into passenger travel patterns. In such cases, additional data is required to infer the boarding and alighting information [14]. By dis-aggregating data at the transit stop level, transit agencies can better understand passenger flows, determine maximum load section, and identify popular boarding and alighting points. Additionally, this information can be helpful in verifying the generated revenues as well as identifying the leakages, if any.

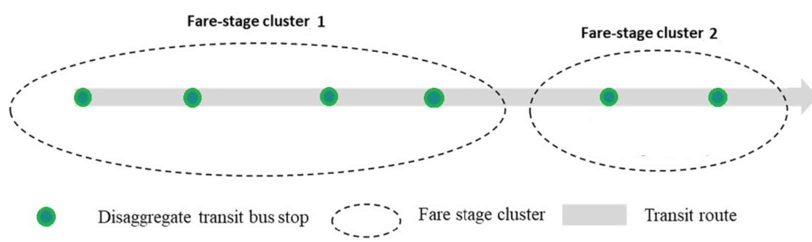

Fig. 1: Incomplete boarding and alighting info

False/ trial/ testing entries: ETM data from Bangalore reveals a trend of false entries made by conductors at the start of trips to test ETM functionality. These records introduce inaccuracies into the dataset, compromising data integrity. This kind of issue can be mitigated by providing additional information, such as terminal arrival time and departure time, that can differentiate these false records from the passenger's trip information.

Fare category: Inconsistent availability of fare category or fare type (e.g., senior citizen, adult, child, female, student, etc.) and absence of records for free tickets (e.g., fare-free trips for women in Delhi) can introduce distortions in ETM data. For instance, while free tickets for women passengers (e.g., pink passes) are given, there is no recording of the trip origins/ destinations in the ETM due to pre-printed tickets, which underestimates the overall ridership. Similarly, ETM data from Bhubaneshwar shows that more than 60% of senior citizens travel on six routes out of all twenty-five routes [8]. Such kind of analysis may assist in formulating policies for older passengers. These special fare conditions should be explicitly recorded in the ETM, possibly with boarding and alighting information for accurate fare revenue analysis, passenger load profiling, and the development of effective fare policies.

Mode of payment: Payment modes for a transit ticket include cash, debit/ credit cards, UPI, smart cards, passes, etc. However, such information is mostly optional and unrecorded. Payment mode is one of the crucial information in ETM, and the absence of it limits in-depth analyses of fare revenue by mode of transport. To promote digital modes of payment, incentives may be given, which would resolve cash-handling issues, improve efficiency and attract more passengers.

Agency information: The agency information in ETM data is only available for the city of Indore, while cities like Bhopal with multiple operators lack this field. This field is very important for analyzing revenue generated and routes served by the different agencies. For example, data from Indore's ETMs highlights the revenue disparity among agencies Fig. 2. This analysis enables a comparative assessment of revenue performance and aids in identifying agencies with higher revenue generation potential.

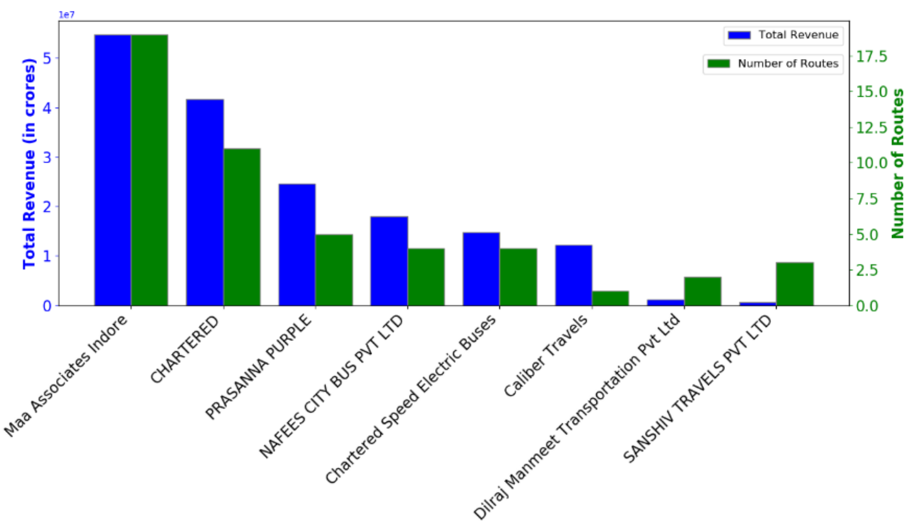

Fig. 2: Revenue generated and routes served by the different agency

Trip information: The analyses are performed at the trip level, and thus, identification of the trip is very crucial. However, in the absence of a trip ID (preferably matching with GTFS), different combinations of fields are required. For instance, in the case of Bangalore, a combination of route_no, route_id, waybill_Id, and trip_no is required. Though trip ID is present in ETM for Bhopal, it is unable to facilitate a unique trip and a combination of waybill_number, route_name, trip_number, direction, and date are required. Such approaches may introduce errors due to an analyst's bias or the unavailability of complete information. This unique trip information can further be used to estimate passenger load at different times of the day and sections on transit routes.

Unknown ETM share: Many times, multiple ticketing modes are used in a transit service; for instance, paper ticket, ETM, passes, etc. This is likely to be common during the initial phase of the system's introduction of ETM. However, continuing such practice for a longer period limits the usability of the data. In the absence of information about the share of each, a data analysis exercise cannot be performed using ETM data only. For instance, in Bangalore, together with other modes of ticketing, ETM was in use on different lines; however, there was no clarify on the share of ETM to understand the ridership patterns or crowding in the buses at different times of the day.

3 Towards uniformity of ETM data

This section presents the proposed **Relational Database for ETM** data and steps for effective implementation (Fig. 3).

The present study proposes a relational database to store ticket transactions and other relevant information in an efficient way to make it applicable across all cities and different transit modes. Similar to the GTFS, a relational database is proposed to manage the various fields in a table. These data tables are connected with each other using a unique identifier in each table. Each table has mandatory and optional information. These tables are briefly explained here.

Device info: This is the main table of the relational database, which connects the passenger trip and vehicle info table using unique identifiers. One row is created for each transaction, which is connected by a passenger trip table for the details of the passenger trip. Further, it has a terminal origin, terminal destination, and corresponding departure and arrival times. Importantly, this has route and trip IDs, which should match GTFS. **Depot info:** The depot info table has a unique depot ID and depot name. Since the vehicles are parked in the depot during non-operational hours and they start from the depot for the service, the vehicle info table is connected with depot info using the depot ID. **Vehicle info:** The vehicle info table contains a unique vehicle ID, vehicle registration number, depot ID, agency name, driver ID, and conductor ID. This table is related to conductor, depot, and driver tables. A vehicle will have a driver and a conductor, and thus, driver and conductor info tables are connected using their IDs. **Driver info:** The driver info table has a unique identifier, shift ID, and driver name. Similar to the conductor info table, the shift ID in the driver info table facilitates the information for persons working at different times of the day (full-time or part-time). **Conductor info:** The conductor info table has a unique identifier, shift ID, and conductor name. The shift ID facilitates the information for persons working at different times of the day (full-time or part-time). **Passenger trip info:** The passenger trip info table has many fields that provide a snapshot of various information on a trip made by one or more passengers. Every trip gets a unique identifier by which the ETM data (main) table is connected. Further, it stores the time of the payment (or ticket), which is close to the boarding time, trip origin and destination stop IDs, number of passengers, passenger category (e.g., adult, student, women, etc.), and payment ID. **Payment info:** The key information present in the payment info table includes a unique payment ID, total amount paid, and mode of payment (e.g., cash, credit card, etc.). **Smart card info:** A few users may make the payment using the smart card meant for various transit modes (e.g., metro, tram). Thus, this table consists of a unique ID and passenger trip information. This table would facilitate the extraction of the transfer information.

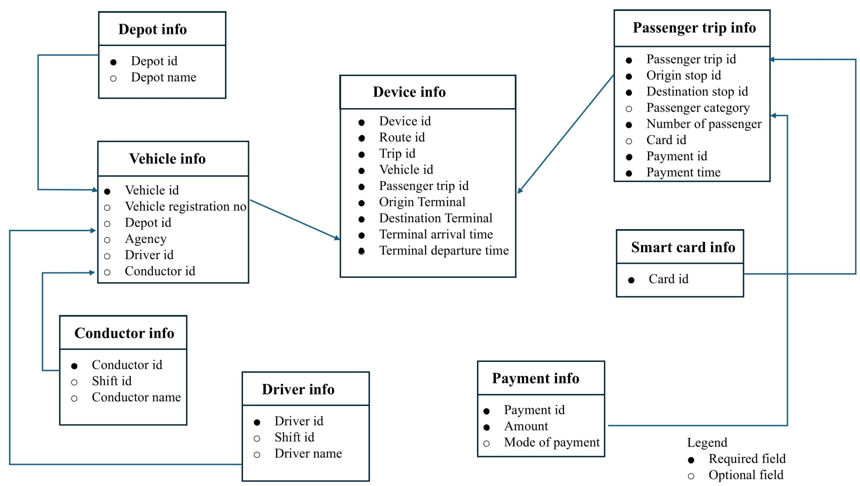

Fig. 3: Proposed database structure for electronic ticketing machine data

3.1 Recording entries in tables

The following section presents the ideal way to record the different entries in the device info table. A flow chart indicating the steps involved in recording entries for various tables is shown in Fig. 4. As soon as the vehicle leaves the depot, the associated information, like the conductor and driver, is recorded in the vehicle info table. At the same time, depot information will also be stored. This information may be saved after preparing the schedules. Then, the vehicle ID and associated device ID are stored in the device info table. The above information may be stored in the control room or also on the ETM itself by facilitating the fields. In addition, the route and trip ID on the service route are stored in the device info. From terminal start time, ticketing starts, and all the records can be stored in different tables using the single interface on ETM. Once the passenger boards the bus, information like passenger boarding, alighting, number of passengers, and category and payment ID information is associated with the passenger trip ID information. This passenger trip ID information is then stored in the device info table. In addition to all this information, some necessary information like origin and destination terminal information and arrival and departure times at this location are also stored in the device info table during departure/ arrival from/ at terminal stops.

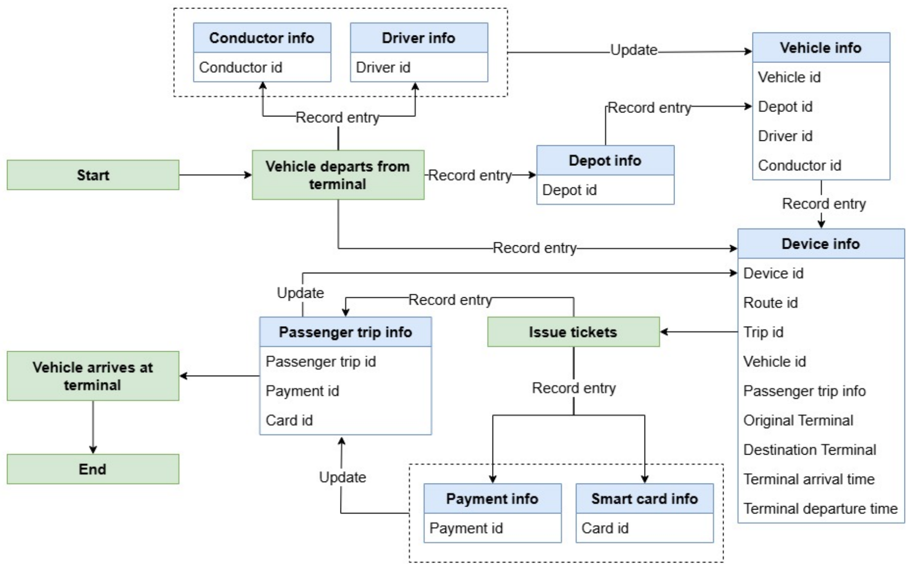

Fig. 4: ETM data recording process

3.2 Proposed standardization

The proposed standardization is based on the ETM data collected from India's six major cities (Banglore, Bhopal, Bhubaneswar, Delhi, Indore, Nagpur). This data offers a strong foundation for proposing nationwide ETM standardization.

Data types: For the proposed database structure, data type `varchar` represents variable length alphanumeric string, `int` is for integer values, `float` for precise numerical value, and `timestamp` for date and time values. The Conductor Info table has a primary key (PK) Conductor id (varchar). The Depot Info table has a PK Depot id (varchar). The Device Info table includes a PK Device id (varchar), foreign keys (FK) Vehicle id and Passenger trip id, with additional columns for terminal arrival and departure times (timestamps). The Driver Info table has a PK Driver id (varchar). The Passenger Trip Info table includes a PK Passenger trip id and FK Card id and Payment id, with additional columns for the number of passengers (int) and payment time (timestamp). The Payment Info table uses Payment id (varchar) as the PK and includes an amount column (float). The Smart Card Info table has a PK Card id (varchar). The Vehicle Info table includes a PK Vehicle id and FK Depot id, Driver id, and Conductor id (all varchar).

Time Data Standardization: Employing a uniform date and time format, such as `dd/mm/yyyy hh:mm:ss`, across all ETMs is essential for accurate data analysis and comparison. This standardized approach ensures consistency in time representation, preventing errors and facilitating efficient data processing. By adhering to the proposed standard, data from different systems can be seamlessly integrated and analyzed. This is similar to the international standard for smart card data, which specifies a date format of `ddmmyy` and a time format measured in minutes past midnight, with a format as `mmm` ranging from 0 to 1339 that ensures consistency in case of smart cards [16].

Passenger Category Standardization: Establishing a standardized classification system for passenger categories across different transit agencies is crucial for data comparability and analysis. By adopting a common set of abbreviations or codes for different passenger types (e.g., adult, child, senior, student), researchers can easily identify and analyze passenger demographics and travel behaviour. This standardization enhances data utility and supports the development of targeted policies and services. Table 1 provides an overview of passenger categories employed in the ETM for different cities. The table introduces standardized abbreviations for consistent reference as category names and spellings vary across locations. The passenger categories are proposed based on the categories followed in international smart cards[3].

Table 1: Passenger category

Category	**Abbreviation**	**Description**
General	GE	All kinds of passengers, mostly adults
Senior citizen	SC	Senior passenger above 60 years
Child	CH	Children below age 14 years
Blind	BL	Passengers with visual impairment
Half orthopedically Challenge	HOC	Passengers with partial orthopedic challenge
Orthopedically challenger	OC	Passengers with full orthopedic challenge
Hearing impairment	HI	Passengers with hearuing impairment
Luggage	LG	Passengers with lots of luggage

[3] https://oyster.tfl.gov.uk/oyster/entry.do

Trip IDs: Currently, a standardized format for trip identification is absent. Consequently, authors have proposed the structure illustrated in Fig. 5 as a suitable representation. This standardized approach would facilitate unambiguous identification of trips across varying dates, times, and routes, regardless of direction. The proposed format comprises several components. The initial character designates the trip type. For example, 'T' may represent a regular scheduled trip, while other characters could be used to indicate different categories, such as 'S' for shuttle services, or 'R' for replacement trips (e.g., due to breakdowns or rerouting). It is then followed by a four-digit year indicator. Subsequently, two digits each represent the month, day, hour, minute, and second of trip initiation. The identifier concludes with the route ID and its corresponding direction.

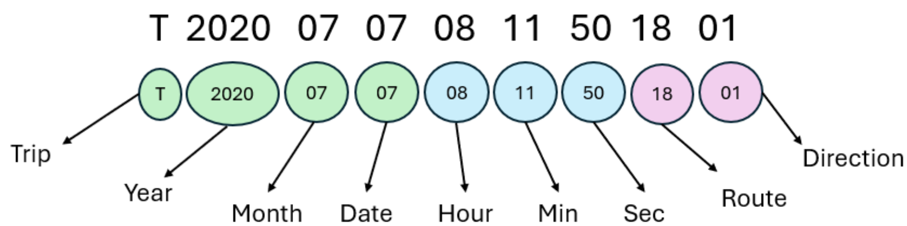

Fig. 5: Proposed Trip ID

The proposed standardizations offer the potential to improve ETM data consistency, thereby facilitating many important analyses and model development. However, local stakeholders (agencies or authorities) may require additional customizations (e.g., for regional language). For this, close collaboration between agencies and ETM providers is imperative for nationwide data harmonization. Moreover, targeted public transport staff training initiatives can reduce false entries and improve confidence in the ETM data.

4 Conclusion

The ETM data from six cities exhibits variability in attribute inclusion, format, and content, hindering comprehensive analysis, scalability, and transferability of the models. Issues include the absence of sync between GTFS and ETM, inconsistent data fields, different stop names, missing route IDs, varying date/ time formats, etc. Furthermore, the inconsistency in aggregated level boarding, alighting information, false/ testing entries, fare categories, modes of payment, and agency information in the ETM add a significant challenge in analyzing ETM data. To fully leverage the potential of ETM data, establishing a nationwide standard for data collection and formatting is imperative. The current research proposes an architecture for the establishment of relational database standards, encompassing tables for drivers, conductors, depots, vehicles, smart cards, payments, and passenger journey information, to facilitate uniform data structure for ETM across urban public transportation systems. Furthermore, standardization is also proposed for various ETM fields that will facilitate accurate data analysis, inform effective policy decisions, and support the development of data-driven strategies for improving public transport systems. In addition to its other benefits, standardized ETM data supports passenger information systems, providing travellers with tools for journey planning. Moreover, accurate ETM data with all the necessary fields can be leveraged to display multi-modal routes and real-time crowding information, assisting passengers in making informed travel decisions.

Bibliography

[1] Macià Mut-Puigserver, M. Magdalena Payeras-Capellà, Josep-Lluís Ferrer-Gomila, Arnau Vives-Guasch, and Jordi Castellà-Roca. A survey of electronic ticketing applied to transport. *Computers and Security*, 31(8):925–939, November 2012.

[2] Eddy Soeryanto Soegoto, Rudy Setiawan, and Rizky Jumansyah. Impact of e-ticketing application on bus transportation in bandung. In *Advances in Economics, Business and Management Research*, icobest-ebm-19. Atlantis Press, 2020.

[3] Sanam Kazi, Murtuza Bagasrawala, Farheen Shaikh, and Anamta Sayyed. Smart e-ticketing system for public transport bus. In *2018 International Conference on Smart City and Emerging Technology (ICSCET)*. IEEE, January 2018.

[4] Aries Susanto, Putra Rama Mahadika, Arang Subiyakto, and Nuryasin. Analysis of electronic ticketing system acceptance using an extended unified theory of acceptance and use of technology (utaut). In *2018 6th International Conference on Cyber and IT Service Management (CITSM)*. IEEE, August 2018.

[5] Rafael Mendes Lübeck, Milton Luiz Wittmann, and Luciana Flores Battistella. Electronic ticketing system as a process of innovation. *Journal of technology management and; innovation*, 7(1):17–30, March 2012.

[6] Purusharth Pathak, Kinshuk Agrawal, Hemant K. Suman, and Nomesh B. Bolia. Frequency optimization-based approach for reducing crowding discomfort in delhi bus system. *Procedia Computer Science*, 170:265–272, 2020.

[7] Anila Cyril, Varghese George, and Raviraj H. Mulangi. Electronic ticket machine data analytics for public bus transport planning. In *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)*. IEEE, August 2017.

[8] Rupam Fedujwar and Amit Agarwal. Examining the spatialtemporal travel pattern of senior citizens: An observational study in bhubaneswar. In *Accepted in 7th Conference of Transportation Research Group of India.*, 2023.

[9] Subrina Rahman, James Wong, and Candace Brakewood. Use of mobile ticketing data to estimate an origin–destination matrix for new york city ferry service. *Transportation Research Record: Journal of the Transportation Research Board*, 2544(1):1–9, January 2016.

[10] Arpit Shrivastava, Nishtha Rawat, and Amit Agarwal. Deep-learning-based model for prediction of crowding in a public transit system. *Public Transport*, May 2024.

[11] Anila Cyril, Raviraj H. Mulangi, and Varghese George. Bus passenger demand modelling using time-series techniques- big data analytics. *The Open Transportation Journal*, 13(1):41–47, May 2019.

[12] Yogalakshmi Jayabal and S. Rajagopalan. An analysis of bus ticket sales in east bangalore. 2020.

[13] L. Deepa, Abdul Rawoof Pinjari, Sangram Krishna Nirmale, Karthik K. Srinivasan, and Tarun Rambha. A direct demand model for bus transit ridership in bengaluru, india. *Transportation Research Part A: Policy and Practice*, 163:126–147, September 2022.

[14] Jatin Bhandari, Rupam Fedujwar, and Amit Agarwal. Occupancy prediction at transit stops using ann. In *2024 16th International Conference on COMmunication Systems and NETworkS (COMSNETS)*. IEEE, January 2024.

[15] Rupam Fedujwar and Amit Agarwal. Performance assessment of public transport routes: A framework using revealed data. *Research in Transportation Business and; Management*, 59:101283, March 2025.

[16] Inc Acumen Building Enterprise, United States. Federal Transit Administration, Transit Cooperative Research Program, Booz Allen Hamilton, and Transit Development Corporation. *Smartcard Interoperability Issues for the Transit Industry*, volume 115. Transportation Research Board, 2006.