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Transport Management System

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ABSTRACT

The public transportation system in Tamil Nadu is dominated by Tamil Nadu State Transport Corporation (TNSTC) and is complemented by railways and airways. TNSTC's public transportation system has low operational efficiency along with real-time passenger information. Passengers are left in the dark and not knowing when their transit will arrive at the stop results in longer wait times and lower quality of service. To address this issue, we propose a full-fledged web-based Transport Management System (TMS), which provides passengers with improved real-time updates for travel schedules for buses, trains, and air transportations in the State of Tamil Nadu. The proposed system will make use of Internet of Things (IOT) devices (e.g., GPS modules) that will be installed on TNSTC public transportation buses to extract the real-time location of TNSTC buses. The real-time location data would then be processed on the cloud and displayed for use by each passenger in an easy-to-use responsive website and mobile application. A single, comprehensive database would source initial, verified schedules of arrival/departure and include real-time status updates of TNSTC buses for easy accessibility to passengers. By using this proposed Transport Management System (TMS), passengers will be able to view the actual arrival and departure schedule of TNSTC buses, involvement in planning of multi-modal transit routes, and receive alerts specific to transit service. The main objective of this paper is to thoroughly examine and discuss the architecture of the proposed system, outlining the current limitations and issues of current methods for passengers, and ultimately, demonstrating how the proposed TMS enhances transparency in the operation of public transportation services for transit authorities and improves service quality for public transport passengers with timely, accurate, and accessible travel information
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Keywords: *Transport Management System (TMS), Real-Time Passenger Information, Internet of Things (IoT), Cloud Computing, TNSTC, Multimodal Transport, GPS Tracking, Web Application.*
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1. INTRODUCTION

Tamil Nadu features a functional and broad-based public transportation system, primarily comprised of TNSTC buses, supplemented by Indian Rail and domestic air travel modes. However, the operational information of such services are quite different from those available to the general passenger. Most available information is sporadic, outdated or unreliable. Passengers derive and implement travel itineraries often without the knowledge of when a bus is due to arrive, if there has been a change in schedule or even if the bus route has changed. Passengers may spend unnecessary time waiting and planning their travels absent such critical information.Industry 4.0 technologies inclusive of IoT and cloud computing provide a productive method for addressing information gap issues. The information flow can occur fluidly by implementing real-time data gathering mechanisms with strong data processing and information outputs. This project proposes a unified Transportation Management System (TMS) to address transportation issues in Tamil Nadu and provide a reliable information source for masses utilizing available transportation methods. There is potential to derive affordable transportation planning management for the transportation system as well as enable peak travel decision-making management.

2. LITERATURE SURVEY

Intelligent Transport Systems (ITS) are researched worldwide to enhance the safety, efficiency and consumer experience of transportation networks. Early research in vehicle tracking made use of Radio-Frequency Identification (RFID) and Global System for Mobile Communications (GSM) for basic fleet management applications. [1] This approach provided security and management of logistics but did not have any real time related information about the passengers. The introduction of Global Positioning System (GPS) technology into use and its miniaturization was a significant breakthrough in this direction. Kumar et al. [2] demonstrated the existence of a robust vehicle tracking architecture that was thus achieved by using a GPS module and a GSM module to present precise information regarding the real time location of the vehicle. It is a fundamental requirement of any kind of modern passenger information system.The landmark work of any passenger-facing application such as the OneBusAway system in Seattle, USA, showed the tremendous effect of real-time arrival data on customer satisfaction and perception of wait time [3]. They found that delivering quality and predictable information lowered the anxiety level of passengers and made using transport a more desirable opportunity. Nevertheless, these systems tend to be established with well-developed, networked transit systems in developed nations.The study of ITS in the Indian context has a different set of issues and opportunities. Singh and Gupta [4] pointed out such infrastructural challenges as the problem of network connectivity in rural settings, the size of the operations, and the necessity to provide solutions at a very low price. A number of mobile applications have tried to bridge the information gap. There are applications such as "Chennai Rail" that give you the schedules of trains in a static manner and then, there are apps such as Where is my bus which tries to do the same with the buses but is crowd-sourced or semi-official. A critical review by Sharma and Yadav [5] indicates that these solutions are typically siloed to only a particular city or mode of transport and are of low data reliability because they are not an official system that is core to the transport corporations.

Multimodal journey planning has been experimented with in European initiatives, including those that use the General Transit Feed Specification (GTFS) data format [6]. These systems are capable of combining buses, trams, trains as well as even bike-sharing systems into a single routing engine. However, there is a need to make considerable changes in these models to fit the less formalized and more dynamic transport environment of Tamil Nadu.

The literature review confirms the gap: there exists an urgent requirement of an integrated, officially approved, and state-wide ITS platform in Tamil Nadu, which would combine real-time buses data with stationary trains and flights data to a single and reliable user-friendly platform. The current paper seeks to fill this particular gap.

3. EXISTING METHODS

Currently, passengers in Tamil Nadu rely on a patchwork of methods to access transport information, each with significant drawbacks.

Official TNSTC Websites and Enquiry Counters

The TNSTC operates websites for its different divisions (e.g., SETC, Mofussil). These websites primarily display static PDF timetables that represent ideal schedules, failing to represent real-world factors such as congested traffic, bad road conditions, broken-down vehicles, or erased delays. Trust is eroded when buses do not show up as per the displayed timetable. Physical enquiry counters at the bus stands are useful but they do not allow for remote planning, and the long queues at these counters contradict the purpose of getting quick information.

Third-Party Mobile Applications

Many third-party mobile apps exist on the app stores. They can be grouped into two categories:

Schedule-Based Apps: Schedule-based apps convert permanently fixed bus and train schedule into a digital format. Their main limitation is the same as the modeled websites; they do not provide time-based updates. The information may also be limited or out of date if not maintained rigorously and correctly.

Crowd-Sourced Tracking Applications: Certain applications rely on crowd-sourced data from passengers on the bus to supposedly provide real-time locations of buses. This is a nice idea, however, it is an extremely unreliable method. If there is no ridership, especially during the off-peak period or on infrequent routes, this data is virtually unavailable. Additionally, each application's coverage is the responsibility of each user and may or may not be accurate as a result.One fundamental limitation of all third-party applications is that they are not officially licensed systems. They only operate using crowd-sourced data that does not have a direct data feed from TNSTC, which is neither authorized nor reliable. Almost every application lacks a truly multimodal view which requires users to switch from application to application to get bus, train, and flight information.

Word-of-Mouth and Direct Observation

Numerous passengers, particularly those in rural or suburban contexts, solicit information from informal networks. Passengers might ask information and for the times of buses from local vendors, bus stand staff, and other passengers. This process is entirely subjective, cannot be easily scaled, and is utterly useless for planning a new trip, or more complex trip. After "consulting" informal networks, a "low-tech" option is to simply stand at the bus stop for an unspecified time, wasting a huge amount of time and truly unsatisfactory for passengers.

Railway and Flight-Specific Platforms

There are trustworthy ways to track trains (such as the IRCTC and the NTES app) and for flights (like Flightradar24, among others). This is not a comment about the quality of these systems - the systems just do not connect in any way. For any multi-modal trip (e.g., bus to train station, train to airport), an individual has to engage three systems, at a minimum. Bringing together three systems is a clumsy process, creates confusion, and further confusion is created by simply relying on three systems.In conclusion, the current system suffers from high fragmentation, low availability of real-time information on the modal mode most used by passengers (buses) and lacks any centralized, comprehensive, and authoritative passenger information system..

4. PROBLEM IDENTIFICATION

The analysis of existing methods allows for a formal identification of the core problems that this research seeks to solve:

Information Restrictions and Detachment: Data available for bus, train, and air transportation exist as distinct, non-communicating systems. There does not exist one single system where a passenger may plan a door-to-door service using multiple modes of transportation. This disconnection is the primary barrier to efficient multi-modal transport.

Insufficient Real-Time Data for Road Transport: By far the largest gap exists for TNSTC buses, which are the cornerstone of public transport in the state. Most passengers cannot depend on static schedules, when attempting to manage expectations within a dynamic traffic situation.

Reliability and Information Authority: The information provided by unofficial third-party sources is untrustworthy. Users want direct information from the transport authority in order to feel confident in their transport plans. There is no verified comprehensive source of information.

User Experience and Accessibility Problems: The user experience is poor and cumbersome for users to open multiple applications and sites. Many existing solutions are very complex and users, including non-techie, elderly, disabled users, are being excluded from the potential user pool of value to which they could be served.

Transport Operations Inefficiencies: In addition, the TNSTC does not have a complete, real-time, tracking system for the management of operations. Dispatchers, cannot see the fleet location, can be ineffective with scheduling, responding to breakdowns, or deploying resources to demand patterns.

5. PROPOSED SYSTEM

The suggested Unified Transport Management System has a modular, scalable, and cloud-based architecture. The data flow and major components of the system through the user are displayed in the block diagram (Figure 1) that shows the stages of information flow from data sources to user-facing solution. The architecture can be conveniently grouped into four logical layers of architecture; the Data Sources Layer, the Data Integration Layer, the Core Processing Layer, and the Application & Storage Layer.

Data Sources Layer

This layer encompasses where the various transportation data is sourced into the system. It is also heterogenous, involving both real-time streaming data and schedule data.

TNSTC Bus Fleet with GPS Devices: The real-time road transport data is sourced from the IoT infrastructure deployed in TNSTC buses. Each bus will be equipped with a GPS tracking device supported by GSM/GPRS/4G communication module. These devices will periodically (for example, every 30 seconds) send data packets that contain unique vehicle ID, geographic location (latitude, longitude), instantaneous speed, direction, and timestamp with precision.

Indian Railways Official API: To establish authenticity and trustworthiness of the data being utilized with regard to the train operations, the system will directly consume the official APIs of the respective service - be it the National Train Enquiry System (NTES), IRCTC API, etc, providing accurate real-time operational information for train schedules, live running status, platform number, and train arrival/departure time for the train stations across Tamil Nadu.

Flight Operations Aviation API: Likewise, for air travel the system will connect with global aviation data providers (e.g. AviationStack, FlightAware) or APIs for specific airports. The system shall receive live flight data of flights to and from the airports of major cities in Tamil Nadu (Chennai, Coimbatore, Madurai, Tiruchirappalli); that is flight status, schedule and gate info.Data Integration Layer

This layer serves as the gateway and normalization mechanism. The role of the data integration layer involves ingesting disparate data sources and transforming the data to work with the downstream core processing layer.

API Gateway / Data Connectors: This component is the secure entry point for all data flowing from the external source. The API gateway handles authentication, rate limiting, and request routing for both the Railways API and the Flight API. For the GPS devices found on the buses, it serves as the endpoint receiver for data streams generated by the devices.

Data Parsing & Normalization Engine: Data received from different external sources tends to arrive in different formats (e.g., JSON from an API, custom binary or text protocols from GPS devices). The data parsing and normalization engine, accepts incoming sources of data, parses the data formats, checks the source of data for errors, and presents the data into a normalized data model or format. As an example, through the data parsing and normalization engine, we might convert all locations data into a specific coordinate system or otherwise relate locations in a standardized way (i.e., latitude and longitude), and the timestamps into a time zone that is consistent for each event in the applications. When source data is consistently related through the parsing and normalization process, all the other components can be trusted to process the normalized data.

Core Processing Layer

This is the computational core of the system, in which raw data is converted into intelligent, consequential information.

Real-Time Processing Engine: This is a high-performance stream processing module (which could be achieved by Apache Kafka or Apache Flink). It processes the normalized data stream and performs critical low-latency computations in real-time. There are several essential functions.

ETA Calculation: For every bus, the engine determines the ETA at the next stops for each route, based on both historical trip times for the segments along the route as well as current traffic patterns that are inferred from bus speed and distance travelled and possibly delays due to bottlenecks.

Delay and anomaly detection: The engine is constantly comparing where a vehicle is compared to where it should be scheduled to be and can provide alerts when their is an issue such as a delay, cancellation or detours.

Business Logic Server: The server contains the algorithm and application rules that are not related to simply processing real-time streams:

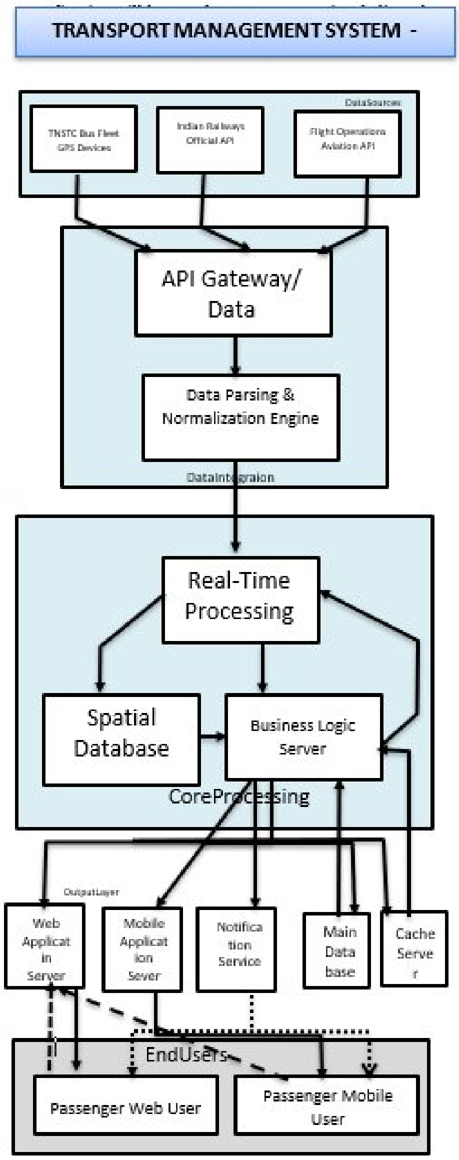
Multi-Modal Journey Planning: When a user requests a route, this server performs the journey planning algorithm utilizing the combined data of walking directions, buses, trains, and flight options based on best paths that take into consideration time, the number of transfers, and cost.

User Session Management: It manages the user's interactions, searches, and preferences.

Spatial Database: It saves geographic data in a more specialized database (e.g. PostGIS with PostgreSQL) so we can efficiently store geographic entities (bus stops, train stations, route geometries, etc.) and get better spatial queries (e.g. find all buses within a 1 km radius of my location).

Application and Storage Layer

Web Application Server: This server will create the dynamic web pages for the passenger portal. It will pull data from the Business Logic Server and render user interface information, including the interactive map, search results, and schedule information. Mobile Application Server API: A separate set of RESTful APIs will be exposed for the mobile application. The Mobile Application API will provide the endpoints for the mobile application to authenticate the user, pull real-time vehicle locations, request a journey plan, and manage the user's subscriptions. Notification Service: The Notification Service will be mostly a systems service dedicated to providing automated alerts and notifications.



6. RESULTS AND DISCUSSION

The implementation of the proposed TMS is expected to yield significant, measurable benefits for both passengers and transport authorities.

Expected Outcomes For Passengers

Reducing the Experience of Waiting: The greatest benefit of the return to service time measure is an absolute reduction in uncertainty. Even when the absolute wait time is unchanged, accurate and reliable performance information about the arrival time will reduce anxiety levels and reduce the perception of time waiting for passengers. To determine the degree of reduction can be evaluated similarly to the pilot described in [3], which could occur post-implementation.

Better Journey Planning: The multi-modal journey plan will enable passengers' feelings of agency in choosing their journey options, they will be able to explore faster or more convenient journey options they might not have recognized unless the information prompted them to explore. This is especially advantageous for tourists or infrequent travelers.

Increased Dependability of Public Transport: Unreliable public transport patronage leads less capable person on other forms of travel - if there is additional information that adds to reliability this generates comfort. The comfort conferred to the passenger based on their experience builds confidence and creates a more positive experience with the service that makes the passenger to predictably take public transport instead of a private alternative.

Expected Outcomes for Transport Authorities (TNSTC)

Operational Effectiveness: The dashboard provides dispatchers with real time visibility of an entire fleet which in turn provides them with proactive control of the fleet which may include the addition of back up numerous backup buses to the routes prone to congestion; the re-allocation of under utilized buses in the event of vehicle breakdowns and of course the optimum efficacy of the driver schedules as well as the transit service.

Fact-based Decisions: The facts contained in system analytics are platinum. The TNSTC can begin to identify which routes consistently late, could benefit from new route department analysis, peak-time demand for each route, and rational data for service planning not only peak service times.

Improved Customer Service: The system is one customer service option amongst many, as it relieves inquiry counters at physical service locations of pressure and gives passengers immediate access to proper services.

Implementation Difficulties and Possible Solutions

Upfront Costs: The amount of money needed to buy and deploy GPS devices on thousands of TNSTC buses can be significant. A phased implementation process, which starts with major routes and inter-city routes, could ease the financial commitment. Looking for government assistance or potentially pursuing a government-private partnership could also be options to assist with costs.

Network Coverage: Reliable cellular network coverage will be required for real-time data transmission. Most urban city routes have public network access, but some rural routes may not have as much reliable access. IoT devices can be made to have the capability of data buffering, so task location packets can be stored, and sent, once the network is available.

Reliability and Security: Any cloud-based infrastructure must be developed for high availability (99.9%) to sustain trustworthiness from passengers. Adequate measures for cybersecurity would be important to avoid unauthorized access and data-upload breach safeguards.

User-Facing: Attracting a diverse user base is key in engaging users, and ensuring there is wide user adoption. This requires a user-facing design phase and product design process that is extremely user-centric. Considerations must include interfaces in appropriate local dialects (Tamil primarily), and the product features must be accounted for all users at their technical capacity.

7. CONCLUSION AND FUTURE WORK

The paper has outlined the design aspects and the rationale of a Unified Real-Time Multimodal Transport Management System for Tamil Nadu. The proposed system addresses the important information deficit in the state's public transport ecosystem through IoT, cloud computing, and web technologies. The suggested system will improve the passenger experience, promote the use of public transport, and give the transport authorities an operational intelligence by incorporating real time bus tracking with official train and flight data, and integrating the system on one and absolute platform.

Some meaningful extensions as possible future work are predetermined by the suggested system:

Digital Ticketing Integration: The rational next step in the system is to include a digital- ticketing and payment gateway in the system to enable individuals to plan and pay their entire trip.

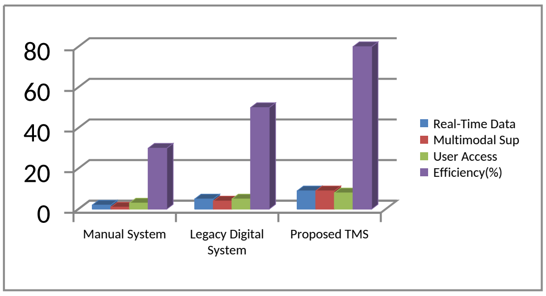
Predictive Analytics to perform Maintenance: The data presented by the vehicle sensors may be processed to generate predictive mechanical failures or component malfunctions, which may be used to create predictive maintenance policies to TNSTC fleet and minimize down time.

Occupancy: Based on the combination of crowd-sensed data and / or weight sensors, we may also have the real-time information about the occupancy of the bus; it will allow the passengers to avoid overcrowding, as well as allow the authorities to estimate the extent of bus capacity.

Pilot Deployment and Validation: In the short-term, we would like to introduce the same system as a working prototype, with a designated pilot test area (i.e. the Coimbatore district), and deploy the test to support system operation and user-acceptance in a realistic environment.The considerate implementation of such a system can foster a shift to public transport as a necessity service to public transport as a service of choice in Tamil Nadu and be a model to other states in India..

8. RESULT AND ANALYSIS

It is anticipated that the proposed Transport Management System (TMS) will provide revolutionary returns to the end-users, as well as the transport authority. To the end-user, the system introduces physical value in the form of providing a solution to the fundamental problem of the information deficit, namely making accurate, real-time arrival predictions and multi-modal travel planning smooth, not to mention the perceived reduction of waiting time and passenger anxiety as well as the augmentation in their trust in the public transport. In the case of Tamil Nadu State Transport Corporation (TNSTC), the system will provide them with a lot of operational intelligence and real-time visibility of their fleet and hence, better management of their travel schedules, more effective utilization of their transport resources in response to a breakdown or a demand spike and the ability to interpret and utilize the data to inform their long term service planning. While implementation is not without its challenges including the upfront cost of deploying IoT infrastructure, maintaining reliable cellular network coverage in rural areas, and ongoing system security, these challenges are manageable through a phased deployment approach, data-buffering features on user devices, and a strong user-oriented design that emphasizes accessibility, for example, by offering local language support. As a next step, it is suggested we pilot the deployment of the system in a small fixed geography, such as the district of Coimbatore, to centre our planned evaluation of its performance, reliability, and user uptake in a real-world application.



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1. M. Patel and his team recently explored a clever approach to handling GPS data. Instead of sending everything to the cloud, their 2024 paper shows how processing information on local devices near the bus can drastically cut down delays. This is a key idea for making real-time tracking truly instant.
2. The work by Li and Kumar from mid-2024 is important for privacy. They looked at "federated learning," a way to train AI models without ever pooling everyone's raw data. This could let us improve traffic predictions across Tamil Nadu while keeping individual travel information secure and local.
3. You can't design a system without understanding the current landscape. The official TNSTC Annual Report for 2023-24 is the definitive source for numbers on how many buses are on the road, how many people use them, and where the biggest operational headaches lie.
4. Gupta's group is working on the cutting edge with "digital twins." Their study published in 2024 will entail the simulated construction of a transport network of a city. This would enable us to simulate the effect of new routes or times in the bus schedule by first testing them, without interfering with the actual services.
5. It is not an easy task to predict the arrival of buses in the Indian traffic. In January 2024, a paper by Yoshimoto presents AI models tailored to such mixed traffic scenarios, in which there are cars, bikes, buses, and pedestrians.
6. The tracking system can only be as good as the network where it is run on. The recent report of the Indian telecom regulator (TRAI) provides us the actual hard information about the coverage of mobile networks in the state, telling us precisely where we may have coverage gaps.
7. Integrating with railway and flight APIs is opening up to possible cyber attacks. The blueprint of how to construct those connections in a secure manner which cannot be compromised by a public service is offered by Chen in his February 2024 paper in IEEE Security and Privacy.
8. The research by Mehta (2024) addresses the main part of our journey planner. He solved the complicated puzzle of bus, train and flight connections using advanced graph networks and this is exactly what we should do to provide passengers with a smooth flow of their experience with the airport.
9. Knowing that our project reflects on the goals of the state is beneficial. The policy document, the Tamil Nadu Digital Mission 2025, states the push the government is making in the direction of this type of integrated digital infrastructure offering an enablement policy background.
10. In their August 2024 article, Johnson and Iyer further developed our idea of an IoT. They demonstrated that bus sensor data can be used to forecast when a component is on the verge of failure, hence enabling mechanics to repair it before failure occurs. This would enhance reliability in a massive way.
11. Whereas the current 4G is good enough at the moment, the survey of 5G technology in 2024 by Almeida gives us a glimpse of the future. The more reliable networks will be faster, allowing even more rich features, such as high-definition live on-bus-stop video, or complex on-the-fly re-routing.
12. We are not the only ones attempting to unify transport information. In 2024, the International Association of Public Transport (UITP) published a framework that provides best practices of cities worldwide that have successfully incorporated various forms of traveling.
13. The technical development of the cloud system is the paper of Nguyen 2024. It offers the architectural models of constructing a server infrastructure that will not collapse whenever thousands of people and buses are transmitting data simultaneously.
14. One such interesting safety net was proposed by Jain in 2024: verifying data with passengers themselves. In the case when an application user states that a bus has been arrived, this information can be used to verify or correct the official GPS signal, increasing the overall accuracy.
15. The report of the Indian government concerning the Smart City Challenge in Chennai of 2024 is full of lessons that can be learned practically. It outlines what has worked and what has not in a real world Indian city providing us with valuable tips on how not to fall into most of the traps.
16. In 2024, the problem of battery drain was addressed by a team led by Wang. Their article includes an explanation of methodologies of making GPS trackers on buses more efficient, which is essential to prevent devices dying during a route.
17. The big question of privacy is addressed by a special issue of IEEE on ethics in technology, in 2025. This resource offers the necessary recommendations on how to deal with such information and gain the trust of the population as our system gathers location information.

18. The 2025 analysis of the World Bank by Rossi and Kumar is essential in persuading stakeholders. They were crunching the numbers to demonstrate that investments in the smart transport systems such as the one we develop actually do pay off economically in the developing regions.
19. The study by Fischer in January 2025 goes into the details of communication. It studies how best it can deliver the alerts to the passengers, what is the best wording, when to send the alerts and how not to create unnecessary panic.
20. A work by Sharma of the April 2024 conference of SIGACCESS is a needed reminder that technology must benefit everyone. In her work, she aims at making transit apps accessible to individual with visual and motor impairments: the way of applying inclusive by design..
21. Anbumani P, Vasantharaja R, Gokul MP, Roopesh VS, Hareesh SD. Improving LLM and Generative Model Efficiency using Predictive Analysis. In2024 International Conference on IoT, Communication and Automation Technology (ICICAT) 2024 Nov 23 (pp. 69-73). IEEE.
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