Philippine Junior Data Science Challenge 2024

SAKAYAN EXPRESS: OPTIMIZING URBAN MOBILITY THROUGH DYNAMIC BUS FLEET REASSIGNMENT

OPTIMA PRIME
Foryasen, Blix D.
Lim, Jerico C.
Mapanao, Jessy Cassandra M.

EXECUTIVE SUMMARY

Metro Manila faces a critical transportation crisis characterized by severe traffic congestion, inefficient public transport, and limited mobility options. Current systems, such as the EDSA Bus Carousel, have made strides in alleviating some issues but fall short of addressing the broader systemic problems. Sakayan Express aims to optimize the public transportation system in Metro Manila by using real-time data to dynamically adjust bus routes, frequencies, and vehicle allocations based on commuter demand and traffic conditions.

This project proposes a framework for a dynamic bus fleet reassignment system. This system integrates advanced data analytics and real-time feedback to improve fleet utilization, reduce overcrowding, and enhance the overall efficiency of public transportation. The system leverages GPS-enabled buses and traffic data, supported by artificial intelligence (AI) and machine learning (ML) techniques, to predict demand and optimize real-time route planning.

Key objectives include improving bus utilization on low-demand routes, reducing passenger wait times, and increasing collaboration between transport authorities to ensure consistent data collection. The system also anticipates challenges, such as stakeholder resistance and data availability, and proposes mitigation strategies to ensure successful implementation.

KEYWORDS

Dynamic Bus Fleet Reassignment, Public Transportation, Traffic Congestion, Real-Time Data, Machine Learning, Urban Mobility, Metro Manila.

BACKGROUND

In contemporary urban environments, cities prioritizing efficient transportation built from an effective transportation network and mobility tend to have a more desirable quality of life and thriving economies. However, Metro Manila, like many rapidly urbanized cities in the Philippines, has fallen short of achieving such standards due to its car-centric system, which contributes to traffic congestion, inadequate public transportation, and limited mobility options for its citizens (Kahil & Perez, 2024).

According to the 2023 TomTom Traffic Index, Manila has ranked the worst traffic congestion among 387 metro areas worldwide, with 117 hours lost annually from everyday commuters and motorists due to extreme traffic conditions. Additionally, a report by Zaldarriaga (2024) cited from the Management Association of the Philippines revealed that more than Php 3.5 billion pesos are lost in the country's economy, acknowledging the need to address the ongoing transportation crisis.

Alternatively, the EDSA Bus Carousel system represents a promising step towards improving public transportation in the Philippines. Since its inauguration in July 2020, it has demonstrated its effectiveness in reducing traffic congestion, decreasing travel times, and making public transport a more attractive option for commuters. Expanding the coverage of this system is crucial for enhancing accessibility and reducing congestion at bus stops.

While recent efforts have been made to improve public transportation, Metro Manila still lags behind other cities worldwide in accessibility and efficiency. To achieve greater urban mobility, Metro Manila should prioritize investments in infrastructure, expand its bus system, and increase bus frequency in congested areas.

By addressing these challenges and building a more efficient transportation network, Metro Manila can create a more accessible and reliable city for its citizens. The Dynamic Bus Fleet Reassignment System can play a significant role in optimizing bus operations and improving the overall efficiency of the city's public transportation system. Technology, such as intelligent traffic management systems and real-time information for commuters, can also play a crucial role in addressing these challenges and improving the transportation experience for residents.

THE PROBLEM

The Philippines, particularly Metro Manila, is grappling with a severe transportation crisis characterized by persistent traffic congestion, inadequate public transportation options, and the fragmentation of transportation systems. These challenges significantly impact commuters' quality of life and hinder economic development. While the EDSA Bus Carousel system is a positive step towards improving public transportation, more is needed to address the systemic issues Metro Manila's residents face. There is an urgent need to integrate this system with the broader transportation network, expand its coverage, and enhance accessibility to provide a more comprehensive and efficient solution to the city's transportation woes.

LITERATURE

Metro Manila's increasing population and rapid urbanization have significantly strained its public transportation system. Congestion, overcrowding, and inefficient service have become pressing issues affecting residents' quality of life. Dynamic Reassignment Systems (DRS) offer a promising solution to address these challenges by optimizing bus deployment in real-time. DRS dynamically adjusts bus routes, frequencies, and vehicle allocations to meet fluctuating passenger demand.

Wang et al. (2023) found that DRS can significantly improve dispatching efficiency and passenger satisfaction by

learning travel patterns and adjusting vehicle reassignment moments using reinforcement learning and bilateral matching models. Furthermore, western cities like Curitiba, Brazil, and Bogota, Colombia, employed Bus Rapid Transit (BRT) to connect underserved areas with large employment centers and other key destinations (C40 Knowledge Community, 2023). In a city like Manila, this concept can be used to expand public transport to underserved areas and integrate informal bus services with the formal network and even with the Bus Carousel System.

While DRS offers potential benefits like performance optimization, enhanced decision-making, and dynamic adaptation, limitations such as consensus problems, partial flexibility due to continuous optimization to handle expected events, cost considerations, and maintenance impact may require extensive decision-making in the long run (Heydari, Silvestre, & Bessani, 2023; Hong, Jung, Kim, & Cha, 2023; Chan, Sarhangian, Taiwan, & Gogia, 2022).

Artificial intelligence (AI) and machine learning (ML) techniques have become pivotal in predicting commuter demand, traffic patterns, and route efficiency. These technologies leverage vast amounts of data from various sources to enhance the accuracy and reliability of traffic management systems, ultimately aiming to improve urban mobility and reduce congestion. Nallaperuma et al. (2019) used AI and ML techniques to integrate heterogeneous data streams from IoT devices, smart sensors, and social media to detect traffic patterns and forecast traffic flow. Thiagarajan and Prakashkumar (2021) utilized Density-Based Spatial Clustering of Applications with Noise (DBSCAN) and Seasonal Autoregressive Integrated Moving Average (SARIMA) to predict public transport demand and optimize bus schedules.

Dynamic Reassignment Systems offers a promising solution to improve the efficiency, accessibility, and sustainability of public transportation in Metro Manila. By addressing the challenges and leveraging best practices from other cities, Manila can implement DRS to enhance the quality of life for its residents and contribute to a more sustainable urban future.

OBJECTIVES

To effectively and efficiently create a Dynamic Bus Fleet Reassignment System, the following objectives must be met:

- Implement a bus reallocation system across Metro Manila based on real-time commuter demand, traffic conditions, and route efficiency.
- Increase bus utilization on low-demand routes and lower overcrowding on high-demand routes within the first six months of implementation.
- Establish cooperation with transport authorities (DOTr, LTFRB, LTO, MMDA) and bus distributors to collect real-time data from public bus systems.
- Enhance the public transportation system, reducing traffic congestion and passenger wait times.

SCOPE & DEFINITIONS

The Dynamic Bus Fleet Reassignment System aims to optimize bus operations in Manila by leveraging real-time data and advanced analytics. The system will collect and analyze passenger demand, traffic conditions, and bus performance data to adjust routes, frequencies, and vehicle allocations dynamically. Key components include a central control platform, GPS-enabled buses, real-time passenger information systems, and data analytics tools. The system will be integrated with existing transportation infrastructure and provide real-time information to commuters.

The following definitions are defined:

- Dynamic Bus Fleet Reassignment: The process of

adjusting bus routes, frequencies, and vehicle allocations in real-time to optimize service based on changing conditions.

- Real-time Data: Data is collected and processed immediately as it occurs.
- Passenger Demand: The number of passengers expected or observed on a particular route or at a specific time.
- GPS-enabled Buses: Buses equipped with GPS devices to track their location and movement.

DATASETS UTILIZED

To power the Dynamic Bus Fleet Reassignment System, the following datasets will be utilized:

Bus GPS Data

SafeTravelPH provides data on buses operating on the EDSA Busway. The dataset includes real-time location, passenger boarding, and passenger alighting.

Commuter Demand and Passenger Load Data

SafeTravelPH bus data monitors bus capacity and the locations of boarding and alighting. Real-time and historical data track high-demand areas or stops to estimate commuter mobility and bus overcrowding in real-time.

METHODOLOGY

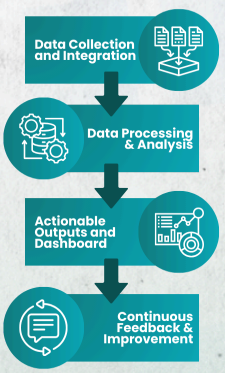

Figure 1. Sakayan Express End-to-end Methodology

Data Collection & Integration

Collect real-time bus data, tracking the GPS-enabled buses' location, routes, speeds, stop times, and passenger load to be integrated into the system.

Data Processing & Analysis

Regression models shall be used to analyze historical and real-time data to predict commuter demand at specific points on various routes. Incorporating passenger load data with traffic analysis allows the system to suggest dynamic bus reassignments and reroute buses to congested or underutilized routes through clustering models.

Actionable Outputs & Dashboard

Fleet Operators receive real-time recommendations for bus reallocations through a dashboard. The dashboard alerts fleet managers to overcrowded buses or congested routes, prompting immediate action to reallocate underutilized buses. Approving or disapproving allows flexibility and control between man and machine.

Continuous Feedback & Improvement

Continuous real-time data input allows the system to refine its predictions and demand forecasting accuracy. Fleet operators and commuters may provide feedback to improve route planning and fleet deployment. Once validated and approved, the system can be scaled to cover other modes of public transportation (e.g., Jeepneys, PUVs) and other cities and municipalities, utilizing the same technology.

POTENTIAL CHALLENGES

In implementing a system in a real-world setting, challenges may arise that affect the performance of the design.

Data Availability

Real-time data on commuter demand and route efficiency may need to be more consistent, resulting in the system's inaccuracy. Inconsistency and inaccessibility of data from different sources may affect the system's ability to predict commuter demands across various locations.

Stakeholder Resistance

Stakeholders such as bus operators and drivers may resist changes in bus routes or schedules, and commuters may oppose the modifications implemented in traditional bus routes or schedules.

MITIGATION STRATEGIES

Formulating strategies after identifying potential challenges is essential in ensuring the system's best performance.

To guarantee data consistency and availability, constant information with transport authorities such as the Department of Transportation (DOTr), Land Transportation Office (LTO), Land Transportation Franchising and Regulatory Board (LTFRB), and Metropolitan Manila Development Authority (MMDA) is a must. Transparent and smooth communication with the transport agencies induces standardized data collection methods, ensuring real-time, reliable data.

Consistently engaging with stakeholders (e.g., bus operators and drivers) by emphasizing the system's potential benefits promotes favorability. Real-time updates about the system shall be provided to ensure its reliability.

SUCCESS METRICS AND KPI'S

Successful integration of the system in a real-world setting aims to improve operational efficiency through enhanced decision-making for fleet operators, leading to smoother and more efficient fleet deployment.

Fleet Utilization Rate

Integrating the system with daily fleet management operations should maintain a 75% fleet utilization rate, that is, the available buses actively serving passengers on the road. A significant increase denotes over-utilization of bus routes, while a substantial decrease denotes under-utilization.

Overcrowding Reduction

The system aims to reduce bus overcrowding by 30% by collecting real-time occupancy rates. An alert prompts overcrowding within the system once buses exceed 80% of their capacity.

Passenger Wait Time

GPS data will be collected to track commuters' waiting time for a bus. Reducing commuter wait times at high-demand stops by 20% correlates to improved fleet management.

REFERENCES

C40 Knowledge Community. (2023). *How cities can make public transport inclusive, equitable and accessible for everyone*. https://www.c40knowledgehub.org/s/article/How-cities-can-make-public-transport-inclusive-equitable-and-accessible-for-everyone?language=en_US

Chan, C., Sarhangian, V., Talwai, P., & Gogia, K. (2022). Utilizing partial flexibility to improve emergency department flow: Theory and implementation. *Naval Research Logistics* (NRL), 69(4), 1047-1062. https://doi.org/10.1002/nav.22073

Heydari, H., Silvestre, G., & Bessani, A. (2023). How hard is asynchronous weight reassignment? *In 2023 IEEE 43rd International Conference on Distributed*

Computing Systems (ICDCS) (pp. 523-533). IEEE. https://doi.org/10.1109/ICDCS57875.2023.00038

Hong, Y., Jung, S., Kim, S., & Cha, J. (2023). Extensions of receding horizon task assignment for area coverage in dynamic environments. *IEEE Transactions on Aerospace and Electronic Systems,* 59(9), 3114-3128. https://doi.org/10.1109/TAES.2022.3222139

INQUIRER.net. (2020, July 1). *Interim operation of busway along "new Edsa" begins*. Inquirer News. https://newsinfo.inquirer.net/1300156/interim-operation-of-busway-along-new-edsa-begins#ixzz6S3SQjbH5

Kahil, I. and Perez, A. (2024). *The urban costs of the Philippines' car obsession*. The LaSallian. https://thelasallian.com/2024/03/09/the-urban-costs-of-the-philippines-car-obsession/#:~:text=Without%20a%20comprehensive%20public%20transportation,congestion%20and%20increased%20pollution%20in

Nallaperuma, D., Nawaratne, R., Bandaragoda, T., Adikari, A., Nguyen, S., Kempitiya, T., Silva, D., Alahakoon, D., & Pothuhera, D. (2019). Online incremental machine learning platform for big data-driven smart traffic management. *IEEE Transactions on Intelligent Transportation Systems*, 20(12), 4679-4690. https://doi.org/10.1109/TITS.2019.2924883

Traffic Index ranking | TomTom Traffic Index. (2024). Traffic Index Ranking | TomTom Traffic Index. https://www.tomtom.com/traffic-index/ranking/

Thiagarajan, R., & Prakashkumar, D. (2021). Identification of passenger demand in public transport using machine learning. *Webology*. https://doi.org/10.14704/WEB/V18SI02/WEB18068.

Wang, Y., Wu, J., Sun, H., Lv, Y., & Xu, G. (2023). Reassignment algorithm of the ride-sourcing market based on reinforcement learning. *IEEE Transactions on Intelligent Transportation Systems*, 24(12), 10923-10936. https://doi.org/10.1109/TITS.2023.3274636.

Zaldarriaga, J. (2024, September 25). *Traffic*. Philstar.com. https://www.philstar.com/business/2024/09/26/2387969/traffic