Rider-centric analysis of Public Utility Vehicle route modernization in the National Capital Region

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Abstract

The primary reason for traffic congestion is the sheer number of vehicles using roads. Private vehicles contribute to a significant volume of traffic, and encouraging public transport use can reduce the number of cars on roads and thus alleviate congestion. In 2020, the LTFRB proposed a new set of public transport routes with reduced route lengths. Route design for cities presents challenges, as routes should ideally improve transport coverage and trip frequency without worsening commuter experience. We evaluated public transportation in Metro Manila through a hybrid network–GIS perspective that allowed us to use a traveler-centric approach. We compared these new routes with the old routes before the route modernization and found a reduction in the number of trips completed in 2-or-less rides (92.6% vs. 96.2%), with 19.1% of trips have increased transfers and 8.14% have decreased transfers. Our analysis shows that these proposed routes inadvertently result in a degradation of the rider experience. We recommend improving walking conditions by designing pedestrian-friendly infrastructure to complement the added inconvenience of transfers.

Keywords: Computer modeling and simulation, Transportation

1 Introduction

Public transportation is not just about convenience. Access to transportation plays role in finding gainful employment [1]. Data shows that while 88% percent of Filipino households in Metro Manila do not own cars [2], private vehicles on average contribute to 49% of traffic volume in Metro Manila [3]. This disparity in access to mobility further highlights differences in social classes, where car ownership is unattainable for those of lower socioeconomic standing. Peoples' routines are highly dependent on their mode of mobility and can affect access to opportunities, living costs, and decongesting dense urban areas. With high vehicle volumes contributing the most to traffic congestion, the challenge is to shift private vehicle use to other modes like active transport (cycling, walking) and public transportation. Most traffic research use metrics like speed or delay to evaluate traffic, but fail to consider aspects that can make public transportation unattractive such as transfers and walking.

This work evaluates the public transportation system of Metro Manila by comparing personal mobility and public transportation. The COVID lockdowns in NCR provided an opportunity to implement the modernization of public transport routes for Public Utility Jeepneys (PUJs) Public Utility Buses (PUBs) across the city. These proposed new routes consolidate and modify the existing routes. We construct transportation networks that correspond to driving (direct routes from origin to destination), and a public transportation system consisting of PUJ and PUB routes. We compare the differences between driving and the public transportation network, and show how commutes can change with the implementation of new proposed routes.

2 Method

The OD surveys lack the actual route itineraries of commuters. We have to infer these itineraries ourselves to obtain an idea of the typical travel distances of commutes in an origin-destination pair. This work considers two types of transportation networks: *driving* and *public transportation.*

We represent these networks as a graph $G(V, E)$, which is defined as the set of nodes $V = \{v_1, v_2, \ldots, v_n\}$ and edges $E \subseteq V \times V$. Pairs of nodes (u, v) denote edges with $u, v \in V$. This work uses directed graphs ($(u, v) \not\equiv (v, u)$). A *driving* network represents the routes available to commuters that use personal modes of transport (e.g. cars, taxis, ride-hailing apps). In this network, commuters can use any road infrastructure that is available. We obtained this road network through OSM and (for the sake of computational efficiency) narrowed it down to these set of OSM `highway` keys: `primary`, `trunk`, `motorway`, `secondary`, `tertiary`. As a directed graph, nodes represent road intersections, while the edges represent actual roads themselves. The *public transportation* network represents routes available to commuters when they use

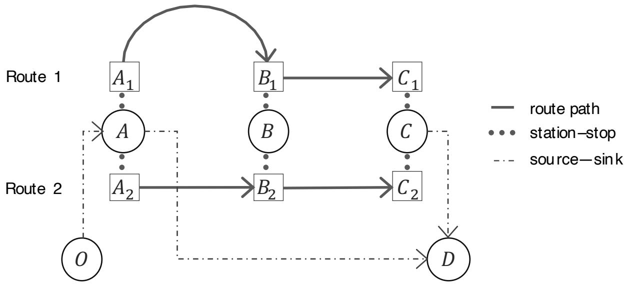

Figure 1: Sample public transportation network. Two routes pass through three stations A,B,C. There are 6 paths from O to D: $O(ABC)_1D$ and $O(ABC)_2D$ pass through the routes exclusively, $O(AB)_2(BC)_1$ and $O(AB)_2(BC)_1D$ make a transfer to the other route at station B, and finally OAD, where the pedestrian decides to travel "directly" to D without using public transportation.

public modes of transport (e.g. buses, jeepneys, trains). These modes have predetermined routes, and in most countries, designated stops. Route and stop information were obtained through General Transit Feed Specification (GTFS) feeds obtained from the Department of Transportation (DOTr).

GTFS feeds contain files that encode routes as a sequence of geolocated points that together form the shape of the route traversed by the Public Utility Vehicle (PUV). A separate file contains stop locations associated with their corresponding shape id. To insert stops into their corresponding shapes, shapes are broken up into segments represented by subsequent shape point pairs. Stops are then inserted between the endpoints of the nearest line segment to form the new shape–stop point sequence.

The LTFRB have proposed new routes[1] to overhaul the public transport system of Metro Manila. There are 309 proposed routes for PUBs, PUJs, Point-to-Point buses, and UV Express (a mix of vans and Asian Utility Vehicles (AUVs)), which consolidates the 523 PUB and PUJ routes that ply Metro Manila just before the COVID-19 pandemic. The overhauled routes are currently in a shapefile format, and lack defined stops (as in the GTFS feeds of the current PT system). As a workaround, we interpolate the route shapes to generate stops in regularly spaced intervals of 250 m; we had to exclude 26 routes that could not have the stop placements interpolated as the route was not a contiguous shape.

Unlike the *driving* network graph, which was constructed exactly as how the real physical road network is configured, we need to employ an additional layer of abstraction when constructing the directed graph representation of the *public transportation* network. In the graph representation of this network, stops are used as nodes and portions of the route between subsequent stops are used as edges. Traversing this graph is analogous to traveling along the public transport route. Route segment lengths and names were also stored as edge metadata. Some physical stops can be shared by multiple routes and we represent this link by connecting the corresponding stop nodes to an additional *station* node with a bi-directional edge to each stop; this edge represents *boarding* and *alighting* of a commuter (see Fig. 1). Stations are also connected by an edge to other stations within a distance of $R_{\text{walk}} = 2000\,\text{m}$ from each other; this represents transfers to a different route does not share a stop with the commuter's current route. A finite value of R_{walk} is chosen to avoid long computation times when all stations are connected to each other, as it is unlikely that these connections will be traversed by commuters in practice. These stations also serve as a necessary abstraction used to find the shortest transit path.

With the graph representations of the *driving* and *public transportation* road networks, we connected source (origin) and sink (destination) nodes to the graphs. Source and sink nodes were connected to the nearest node on the graph: intersections for the *driving* network and the *stations* for the *public transportation* network. Shortest paths were calculated using Dijkstra's algorithm [4] on a weighted graph, where the weights of the edges $w(u,v)$ serve as path costs. We defined three types of weights associated to the types of edges found on the network:

$$\begin{aligned} w_{\text{ride}}(u,v) &= C_{\text{ride}}\text{dist}(u,v), && (1)\\ w_{\text{walk}}(u,v) &= ||\mathbf{x}_u - \mathbf{x}_v||, && (2)\\ w_{\text{board}} &= v_{\text{walk}} \times \text{transfer time}. && (3) \end{aligned}$$

Equation 1 is used on edges that represent the shape of transport routes, and is simply the path distance of the edge weighted by a factor we set to $C_{\text{ride}} = v_{\text{walk}}/v_{\text{transit}}$, which decreases the effective distance when transit speeds are faster than walk speed. We use the euclidean distance in Eq. 2 for transfers

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[1] available at https://gist.github.com/temetski/856a6d012e5bf0a9b6a1bb2cb17774d8

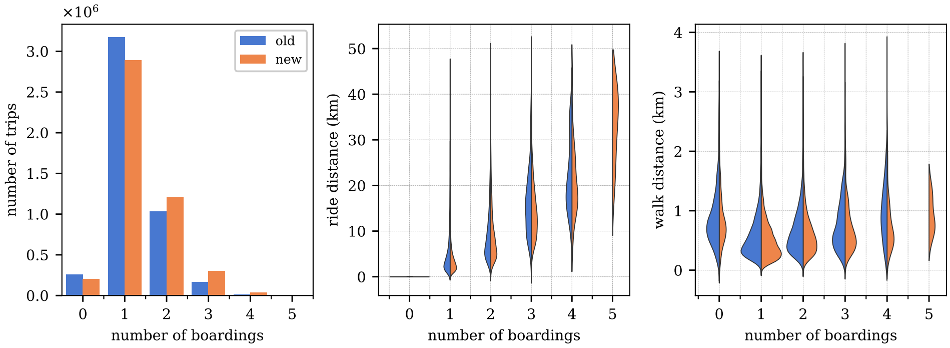

Figure 2: (A) Counts of number of passenger trips and number of boardings. Distribution of (B) ride distance and (C) walk distance , broken down by the number of boardings for the trip, between the new and old PT routes. New routes have more boardings for the longer trips.

between stations, as well as for the edges connecting sources and sinks to stations. Ideally a network that represents pedestrian paths can be used when available, and the path distance can be used in place of the euclidean distance. Finally, Eq. 3 is used to connect the stop to a station. Since the stop and station node pairs have the same coordinates, choosing $w_{\text{board}} > 0$ discourages unrealistic hopping between two routes that have a common direction (Fig. 1). If $w_{\text{board}} = 0$, routing for parallel routes (routes traversing the same road with shared stops) can contain unnecessary route transfers. This choice of Eq. 3 is interpreted as the cost of a passenger choosing to walk the rest of the way if their destination is close enough instead of waiting for another PUV to bring them closer to their destination.

This work uses $C_{\text{ride}} = 0.2$, $v_{\text{walk}} = 5\,\text{km/h}$, $v_{\text{ride}} = 25\,\text{km/h}$ and an average transfer wait time of 5 mins. We chose these values to represent pedestrian walking speeds, average vehicles speeds in congestion, and a reasonable wait time for passengers assuming adequate supply of buses. Obtaining the shortest path travel itinerary allows us to count the number of transfers in a commuting route and evaluate the efficiency of the transportation networks. Transfers are defined as an instance of a change in mode of transportation; this is measured by subtracting 1 from the number of unique route names that appear in the public transportation itinerary. Additional transfers can incur added costs, takes up time, and affects the perceived comfort and convenience of a commute.

3 Results and Discussion

We establish a baseline by comparing the existing public transport (PT) routes to an unconstrained shortest path routing on the road network of Metro Manila (*driving*). As expected, trip distance distributions of these two modes show shorter trip distances when driving as compared to using PT; however, we find that the difference is marginal, with a median trip distance of 4.75 km for PT, and 4.56 km for driving. The median difference in trip lengths between PT vs. driving is 160 m, but can go as high as 5 km. Sometimes PT use leads to shorter trips, particularly when one-way roads or obstructions (such as gated roads) forces drivers to use a longer route while a commuter can directly access the nearest station.

Trip distances alone are insufficient at capturing the overall commuter experience as public transport commutes may require multiple route transfers. We constructed travel itineraries for all trips in the RTRS OD matrix by choosing the path with minimum weights on the public transport network. These travel itineraries include the start and end legs of the commute (these are assumed to be via paratransit modes: walking, tricycles, pedicabs, etc.), PUB/PUJ routes taken, and transfers. However, we exclude the start and end legs from the count of number of rides, since we cannot determine which modes are available to commuters with the given data. We find that 74.0% of all trips in the RTRS survey can be achieved in 1-or-less rides, while 96.2% can be done in 2-or-less rides (again, excluding the start and end legs, see Fig. 2A). A count of zero rides means that the trip was achieved without public transport through paratransit modes. For comparison, a 2004 study on the service area of the Miami-Dade Transit Agency, which covers $777\,\text{km}^2$ (Metro Manila: $\sim 620\,\text{km}^2$) and has 83 train routes and 81 bus routes, had 14.3% trips achievable in 1-or-less rides, and 55.13% in 2-or-less rides [5].

In comparison, the modernized PT routes achieves 66.6% of trips in 1-or-less rides and 92.6% in 2-or-less rides. As a result of the consolidation of redundant routes, 7.38% of commuters have 3-or-more boardings in contrast to 3.79% under the current PT routes. Overall, transfers increased for 19.1% and decreased for 8.14% of commuters. While the overhauled routes generally increased of the number of boardings required to complete trips, trip distances are generally decreased for 61.3% of commuters (Fig. 2B). We also find that walk distance distributions appear similar for 0 to 2 boardings, and observe that the distributions shift to shorter walk distances for 3-4 boardings in favor of the modernized routes (Fig. 2C). These new routes result in commuters that will need to add additional transfers to their commutes, which costs additional fares and wait times.

The complexity of designing and modifying a PT system in large cities can make it challenging to reduce the number of transfers. If reducing the number of transfers is prohibitively difficult, another way of addressing the problem is to improve the overall commuter experience. Despite the abundance of direct routes available to commuters, anecdotal experience shows that public transport in Metro Manila has a lot of room for improvement. For example, walking on very narrow sidewalks along EDSA even for a short distance contributes to the negative perception of commuting, but walking in the wide open spaces of Ayala Triangle in Makati is a much more enjoyable experience. Evaluating the public transport system based on trip travel times (which correlates with distance as well as vehicle speeds) and number of transfers alone (which relates to cost and convenience) overlooks other factors that affect the quality of a commute. The sheer challenge of getting rides — evidenced by long lines for the MRT and LRT, and commuters that spill onto the roads while they attempt to hail rides — is part of the everyday travails commuters must endure.

Other factors such as infrastructure, personal attributes, and comfort are also key considerations in mode choice [6]. When the typical commuter is exposed to high temperatures, uneven walking surfaces, and high humidity [7], any additional inconvenience can make commutes insufferable. Although unaccounted for in our analysis, it is also important that vehicle transfers have reasonable and predictable wait times. Addressing these less than ideal conditions may help commuters consider public transport as a viable option in their daily routines, and reduce the demand for more personal modes of transport.

4 Conclusions

Our daily experience with PT still shows problems beyond route design. While on paper, our public transportation system is efficient where most trips are completed in 2-or-less rides, public opinion still favors personal car ownership. This indicates other factors such as wait times and commuting comfort must also be addressed to shift commuters to PT, reduce the volume of traffic, and alleviate congestion.

Since our analysis highlights Metro Manila's dependence on paratransit modes, the availability and convenience of these modes also play an important role in the perception of PT. And for as long as riding public transportation involves long lines and uncomfortable commutes, driving and personal modes of transport will continue to attract commuters and contribute to congestion. The LTFRB has proposed new set of routes that overhaul the PT routes in our current system; while we found that this results in shorter trips for 61.3% of commuters, 19% of commuters would bear the burden of additional transfers and wait times. The LTFRB must carefully weigh the additional inconvenience to commuters against improvements brought about by the overhaul of routes if the end goal is to convince more commuters to use public transportation.

Acknowledgments

The authors acknowledge the support provided by the Commission on Higher Education-PCARI [IIID-2016-006], and the Department of Transportation, through Varsolo Sunio, for the RTRS dataset.

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