Estimating the Route Measured Capacity using the Four-Step Model of Travel Demand Analysis

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ABSTRACT

Rationalizing existing public transportation routes has been one of the strategies employed by the Department of Transportation and various local government units in addressing the traffic congestion especially in Metro Manila. More specifically, they compute the Route Measured Capacity (RMC), to determine how many public transportation vehicles can serve a particular route. However, the issues on integrity and veracity of data used for computation affected how it is used by the regulatory board. It is still used as a guide in approving developmental routes but was already issued a moratorium for existing routes. This research explores a computational approach in determining the Route Measured Capacity of routes servicing the cities of Valenzuela and Marikina. The passenger demand was estimated through a modified Four-Step model. Trips were distributed to the itineraries retrieved from OpenTripPlanner and later consolidated for each jeepney route. The consolidated number of trips was used as the passenger demand in computing for the RMC of each route. The results were divided into two parts: one focusing on intracity routes or those that are within a city only, and the other on intercity routes, those that went beyond a city. Intracity routes had a 16.82% difference while intercity routes had a greater difference of 25.78%. In validating, the route Malinta - Bagbaguin of Valenzuela City was observed to compare the computed RMC to the actual situation on the field.

CCS CONCEPTS

•**Computing methodologies → Modeling;** *Discrete models;*

KEYWORDS

Route Measured Capacity, Road-based Transport, Travel Demand Analysis

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1 INTRODUCTION

According to the National Center for Transportation Studies (2011), more than half of the total person trips in the Philippines are done by means of public transportation. Of these, road-based modes such as jeepneys, taxis, buses, tricycles dominated the roads. While most of these modes do not have permanent stops to accommodate its passengers; they pick up and drop off them in a nonspecific manner. This kind of practice greatly contributes to traffic congestion which is a result of ineffective and insufficient transport planning according to the assessment of Asian Development Bank in 2012. Due to lack of planning, this also results to some routes not being able to accommodate the current travel demand; one jeepney route in Katipunan was found to be under-serviced by thirteen (13) units [1].

Moreover, the enforcement of traffic regulations is not strictly implemented in the country and the franchising procedures for road-based urban transport are mostly ineffective. The franchises are issued by the Land Transportation Franchising and Regulatory Board (LTFRB), which is responsible for enforcing and monitoring the laws and regulations of public land transportation services. However, the current process on approving franchises is lacking of technical basis for the reason that the approval is based on subjective arguments. This arbitrary process continued until the year 1981, where the Ministry of Transportation and Communication (MOTC) was established and a temporary ban was declared for franchise applications. It was during this time that the Road Transport Planning Division (RTPD), a division under MOTC, conducted several field surveys to estimate the demand and supply of a given route, which paved the way to the formulation of the Route Measured Capacity (RMC) method [3].

The RMC indicates the required number of public vehicles operating in a route to serve the estimated passenger demand. The RMC formula is based mainly on the passenger demand, seasonal factors, load factors, seating capacity and the number of round trips vehicles typically make during the day. The RMC was applied to buses, jeepneys and UV Express vehicles, and for few instances even to tricycles. Once determined, the Department of Transportation and Communications (DOTC), currently known as Department of Transportation, provides the RMC to LTFRB.

To obtain the estimated passenger demand, several survey methods were established by the DOTC and the process was administered by the RTPD. They sent out personnel to conduct surveys in the different regions with the cooperation of LTFRB, its field personnel, and the local government units concerned. They used various methods of assessing the data needed for the formula. Since they used surveys to collect data, the credibility of the data was questionable. Moreover, some of the variables inputted in the formula were provided by investors and therefore, resulted to biased results.

With numerous factors that led to the inconsistency of the values produced as well as a rather arbitrary approach, the RMCs were not fully implemented by LTFRB. It was stated in Department Order No. 92-587 "Defining the Policy Framework on the Regulation of Transport Service" that fithe route measured capacity test shall be used only as a guide in weighing the merits of each franchise applicationfi. They only served as a suggestion with regards to the approval of franchises [3].

As mentioned, the data that is being used by DOTC for the RMC formula was based on surveys. Not only that conducting surveys is very tedious and time-consuming, but is costly as well. To address the aforementioned issues regarding the accuracy of the inputs provided to the RMC formula, the current method of collecting data for the passenger demand should be changed. Instead of acquiring data from surveys, geospatial data such as amenities, land use plans, population and traffic analysis zones are used in getting the passenger demand.

The previous applications of the RMC formula used many assumptions in their data. The integrity of using RMC highly depends on the integrity of the user and the data inputs, which is why as mentioned above, the LTFRB used RMCs only as a guide in approving franchises. The use of a different set of data and approach provides more credible results that can formally be used by LTFRB. Moreover, the integrity of the RMCs is evaluated through simulations. Visualizing and understanding the traffic flow is easier since simulations can be used to objectively evaluate the impact of the system on its effectiveness [2]. Simulation results will lead to making informed decisions to assess if there are routes that are currently under-serviced or over-serviced.

2 MAXIMA

The Maxima system focuses on generating the Route Measured Capacity of PUJs based on the current travel demand. Figure 1 shows the different modules of Maxima . Maxima makes use of the output generated by Via, which contains the travel demand scores per mode choice. These values are produced from the first three steps of the travel demand modeling. However, the last step which is the allocation of trips to the routes is covered by Maxima.

Figure 1: System Modules

This module is part of Plexus, a decision-support system that allows urban planners and government stakeholders assess the robustness and resiliency of current public transportation network. Planners can perform a travel demand analysis based on existing amenities and land use in order to plan future developments on the network. It provides mechanisms to manage transportation and geospatial data like routes, amenities and traffic analysis zones.

3 DETAILED DESIGN

3.1 Data Preprocessing

The model used the dataset of jeepney routes in GTFS but it contains excess information that the model does not need. Due to this, the dataset was filtered in order to fit into the model.

The routes dataset contains the following information: agency id, url, short name, long name, text color, description, route id and route type. The description contains the stops information of the jeepney routes, was used to identify the jeepney routes within Valenzuela City and Marikina City. Once the routes have been identified, the only attributes that were considered are route id and route long name. Route id serves as the unique identifier for each route, while route long name contains the full name of the route. The routes were categorized into two characteristics: intracity, which refers to a route that operates mainly on one city and intercity, which represents a route that goes far beyond the boundary of a city.

3.2 Route Filtering

Route Filtering identifies the jeepney routes that travel between zones. Figure 2 shows the step-by-step process of this module.

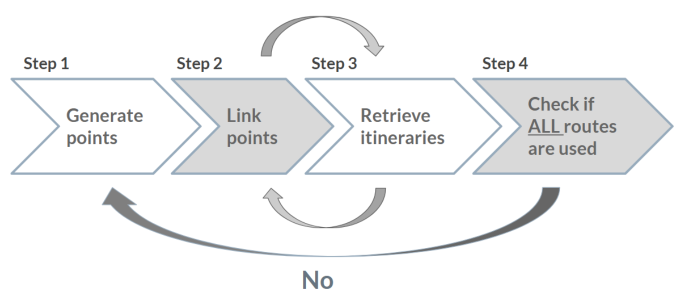

Figure 2: Process of Route Filtering

The process starts by looking at a pair of zones. First, we generate five random points in each zone. We now have a pool of ten (10) points that we paired. Linking can either be within a zone (intrazonal) as shown in Figure 3 or across the other zone (interzonal) as shown in Figure 4.

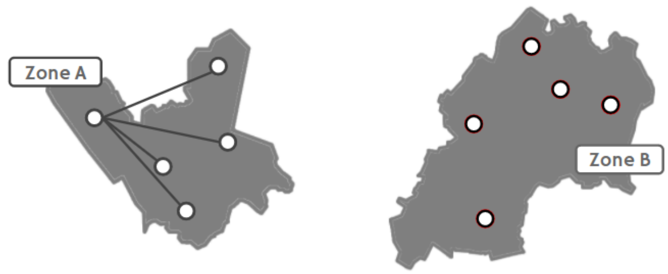

Figure 3: Linking of intrazonal points

Figure 4: Linking of interzonal points

When two points are already linked to each other, third step is to retrieve a list of itineraries from OpenTripPlanner (OTP), an open-source multi-modal planner. An itinerary consists of details on how to get from one point to another using different modes of transportation, including the routes to be used, the travel time and fare. We restricted all itineraries to use only the jeepney routes as they are the ones relevant to the study. At a time, OTP generates a maximum of three itineraries that have the least travel time.

Steps two and three are repeated until all points have been linked to each other. However, the linkage of points from Zone A to Zone B is different from Zone B to Zone A. When there are more than two zones in the study, the first three steps of route filtering are repeated for every zone. After getting all the itineraries between zones, the last step is to check if all filtered routes have at least occurred once in the retrieved itineraries. The basis for checking this is through the route id. If otherwise, the first step is repeated, but this time increasing the number of points generated for each zone. This is done in order to retrieve more itineraries, consequently covering more routes. We tried and checked this from two, three, and five points per zone.

The itineraries are then used as the basis for splitting of the trips in the traffic assignment module.

3.3 Traffic Assignment

After we have generated trip itineraries between traffic analysis zones, the next step is to distribute the trips to these itineraries. Itineraries are used instead of routes to better observe the utility of each jeepney route.

The origin-destination matrix for the jeepney mode, was used to distribute trips. The matrix contains a balanced distribution of trips for the 17 traffic analysis zones between Valenzuela and Marikina.

We first computed for the cost of each itinerary using a multinomial logit model (Equation 3.2). It associates values for the utility of each itinerary based on the data collected from different sources such as OTP and CBMS.

The probability that an itinerary is used gets higher when its utility is higher compared to the other itineraries. However, there is also disutility in the function which is the generalized cost of each itinerary to get from one zone to another and is defined in Equation 3.1.

$$c_{ij}^{I} = t_{ij}^{I} s_i + f_{ij}^{I} \tag{3.1}$$

where

c_{ij}^{I} is the cost of itinerary I from zone i to zone j;

t_{ij}^{I} is the travel time of taking itinerary I to get from zone i to zone j;

s_i is the average hourly income of people in zone i; and

f_{ij}^{I} is the monetary cost of an itinerary I from zone i to zone j.

The hourly income is multiplied to the travel time in order to normalize the unit of measurement of the cost, which is in terms of Philippine currency.

After deriving all the costs of each itinerary going from zone to zone, the multinomial logit model defined in Equation 3.2 was used to determine the probability that trips are traveled using a specific itinerary. The computed travel cost is inversely proportional to the portion of trips to be distributed in the itineraries; the higher the cost of traveling from Zone i to Zone j, the lower probability that trips are distributed to itinerary I.

$$P_{ij}^{I} = \frac{e^{-\beta c_{ij}^{I}}}{\sum e^{-\beta c_{ij}^{I}}} \tag{3.2}$$

In the multinomial logit model (Equation 3.2), the proportion of trips by itinerary I from zone i to zone j and the costs of traveling from zone i to zone j using the itinerary I are denoted by P_{ij}^{I} and c_{ij}^{I}, respectively. Moreover, β denotes the parameter for calibration of the generaliz.

The number of trips distributed to an itinerary is derived from multiplying the trip value of an OD pair to the resulting probability of the itinerary obtained earlier. Each route that is present on that itinerary gets the same number of trips that was distributed to that itinerary.

3.4 Trip Consolidation

After distributing all the trips to the different itineraries, jeepney routes have independent number of trips depending on which itinerary/s they belong to. This module determines the total number of trips that a certain route has been distributed to, by consolidating the trip values per route based on their id. The next to be consolidated is the trips of routes that have the same name but different ids.

3.5 Route Measured Capacity

Once the number of trips have been consolidated for each route, we then used it as the passenger demand for computing the Route Measured Capacity (RMC) using Equation 3.3. The RMC is represented by the following formula:

$$RMC = \frac{PD}{UR \times VLF \times ASC \times NRT} \tag{3.3}$$

with the following notations:

RMC: the route measured capacity for a specific route

PD: the passenger demand derived from consolidating the jeepney trips for a jeepney route

UR: the utilization ratio of a jeepney route

$$UR = \frac{\text{units in operation}}{\text{actual fleet size}} \tag{3.4}$$

VLF: the viable load factor of a jeepney route

$$VLF = \frac{C_a + I_a}{S_c \times f} \tag{3.5}$$

ASC: the average seating capacity of jeepneys

NRT: the number of round trips of a jeepney route

After consolidating the values for all routes, the value of each becomes the passenger demand of the route. Originally in the RMC formula, seasonality factor is further multiplied to the passenger demand to consider certain times of the year that have much more commuters in the country. However in this study, we did not consider it.

3.5.1 Sample Scenario. The utilization ratio is derived by dividing the current number of operating units to the actual fleet size based on franchise records. We extracted the data from the dataset upon consultation with an expert. Take for an example the Antipolo-Cubao (via Sumulong Hi-way) route, currently it has 146 units and a fleet size of 124 as per franchise records. By applying the formula, we get a utilization ratio of 1.18.

For the average seating capacity, we used a constant value of 22 for all the routes as the seating capacity ranges from 12-32.

The load factor expresses the ratio of the demand to the supply. It demonstrates the average load on a route throughout the day. The higher it is, the more profitable the operation. We computed for it by dividing the revenue to the product of the average seating capacity of jeepney to the fare rate per kilometer which is ₱1.50. Having a revenue of 11.32 divided by the product of 22 and 1.50, the resulting load factor is 0.34.

The number of round trips is based on the distance of the route. The route in the example has a total distance of 19.72, which is equivalent to 6.2 round trips.

$$\frac{(3441}{1.18 \times 0.34 \times 22 \times 6.2} = 63 \text{ units per day}$$

When these values are plugged into the RMC formula, the resulting RMC for the route is 63 units.

4 RESULTS AND ANALYSIS

Since most of the data used in the calculation of RMC was dated 2012, the researchers decided to validate these data through field investigation. Interviews and surveys were conducted in order to validate some of the parameters used for the RMC formula. The chosen route for observation is Malinta–Bagbaguin whose route starts at Mavanoda terminal in Valenzuela, was chosen for the following reasons:

(1) the route covers shorter distances; and
(2) the route travels within the scope of study Valenzuela.

The route Malinta – Bagbaguin was the focus of the observation of the researchers. This specific route was selected since it is an intercity route, i.e. most of the route covered are within Valenzuela.

The investigation began by riding the jeepney for a whole day. This started at 7 AM and ended at 7 PM. Although the initial plan was to follow only one jeepney for a day, the plan changed since the jeepneys typically stop operating after about 2–3 round trips. Every time the jeepney being followed stops operating, another jeepney from the terminal is chosen to be followed. Usually, the jeepey drivers stop operating during non-peak hours 10 AM to 3 PM in the afternoon and 7 PM onwards.

4.0.1 Load Capacity. The first ride departed at exactly 7:02 AM. In the first round trip, the common stops were taken note of. These common stops became the checkpoint marker at which point in time the current passenger load is recorded. In the process of recording the passenger load, the two seats occupied by the researchers were not counted. These two seats are always subtracted to the seating capacity and passenger count.

As it can be seen in Figure 5, it shows the current load factor per stop when traveling out of the terminal. The average loading factor for the jeepney going to and from Bagbaguin was 71.17%. For each stop going out of the terminal, it remained nearly above 60% all throughout until the final stop. This can be an indicator that this route has a high demand of people commuting out of Malinta area.

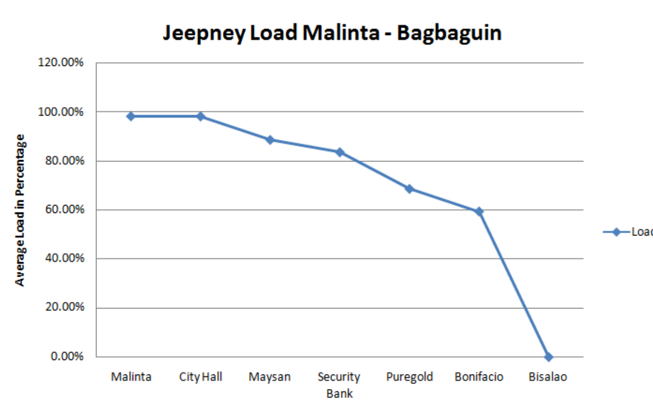

Figure 5: Average loading capacity per stop going to Bagbaguin

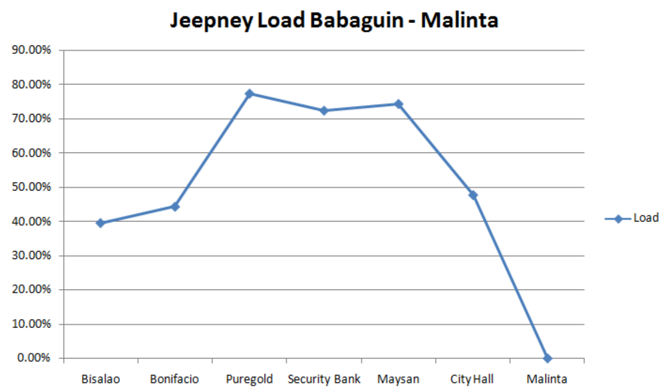

Figure 6: Average loading capacity per stop going back to the terminal

Comparing the two graphs, it can be seen that the Figure 6 has a rather lower passenger load since the starting point is not a terminal. Returning to Mavanoda terminal, the jeepneys on average still reach the threshold of 60% passenger load along their trip. These passengers are mostly coming from establishments such as shopping malls, banks and schools.

4.0.2 Passenger Demand. Another data collected from the field investigation was the total number of passengers who went up and down the jeepney. This data was also recorded since it is not possible to count the passenger demand from the current passenger load every major stop. Some passengers go up and down in between the stops since jeepneys in general do not have a designated stops and people can board and alight anywhere.

Using the passenger data from the field investigation, it was counted that there are 117 passengers in a day for a jeepney. This was further multiplied to 60 to take into account the number of jeepneys in operation. This resulted with the total of 7020 passengers in a day.

Using this value for the PD parameter in the RMC formula from Equation 5.3, we arrived at the following results. (Shown on Table 1)

Table 1: Computed RMC from Field Investigation

PD	UR	VLF	ASC	NRT	RMC
7020	1.07	0.717	22	6	69

Based from this calculation, it means that the recommended number of jeepneys for the jeepney route Malinta–Bagbaguin is approximately 69 units.

4.1 Results and Analysis of an Intercity Route

Table 2 is an example of an intercity route. It can be observed that its resulting RMC has a high discrepancy with the actual number of jeepney. Observing this in the route visualization module, it is noted that with its 19 km route distance, only a part of this route actually passes through the city of Marikina. Since the travel demand data that was distributed to this route was only from Marikina, it is possible that other zones such as Quezon, Pasig and Manila City, which this route also passes through might have been overlooked. The hypothesis is that it has failed to take into account all the passenger demand value when computing for its RMC which is why intracity routes were analyzed.

Table 2: Percent Difference of Antipolo-Cubao (via Imelda Avenue) to the current number of units and franchises

Route Name	No. of Current Units	No. of Franchises	RMC	Percent Difference (with current units)	Percent Difference (with franchises)
Antipolo-Cubao (via Imelda Avenue)	112	86	32	111.11%	91.53%

4.2 Results and Analysis of an Intracity Route

The route Parang-Marikina is an intracity route of Marikina City, it can be seen in Table 3 that the computed RMC has low discrepancies with the actual jeepney units. On average, the percent difference for intracity is better compared the results of the intercity.

Table 3: Percent Difference of Parang-Marikina to the current number of units and franchises

Route Name	No. of Current Units	No. of Franchises	RMC	Percent Difference (with current units)	Percent Difference (with franchises)
Parang-Marikina	111	97	97	13.46%	0.00%

5 CONCLUSION

For each OD pair in the matrix obtained from the Travel Demand Module, its travel demand value was further distributed to the different jeepney routes. The data obtained from OpenTripPlanner was used to incorporate weights to the distribution of the demand. After this, each value distributed to a route is consolidated to be used as the passenger demand of a jeepney route. The total demand was later on plugged in to the RMC formula.

The researchers were able to extend the study on RMC by changing the method of obtaining the data on Passenger Demand. Using geospatial data, the passenger demand was able to be estimated. This method can be a good alternative since the current method used in getting the passenger demand is through conducting surveys and that will require a lot of manual processing before getting the data.

Next, the result of the RMC for the route Malinta-Bagbaguin was validated through field investigation. Comparing the actual observed passenger demand to the generated demand of Maxima, the results for the intracity routes were not very far apart. This can signify that estimating the passenger demand using the geospatial data is a possible alternative when computing for RMC of a certain route given that all zones passed through by the route has travel demand data.

The visualization of the GTFS route data was displayed on Maxima. This data was cleaned by the Plexus team upon using. This visualization is the basis of the list of jeepney routes for the OTP. After computing for the result, the calculated RMC for each jeepney route is also reflected in the visualization.

Upon validating the RMC of Malinta-Bagbaguin route, it was discovered that the computed RMC for this intracity route was close to the actual number of units. Since the study only has data for Valenzuela and Marikina City, not all jeepney routes used by the two cities were successfully given a close estimation.

Upon testing, it was discovered that changing the fare and travel time both have an effect on the forecasted output. Since fare and travel time are the parameters of the cost function, the total cost of going from one zone to another was affected. The results show that if the cost gets higher, the number of trips distributed to an itinerary gets lower. Between fare and travel time, it was also discovered that the travel time has a bigger impact to the results. This trend is true for all the modules: traffic assignment, trip consolidation and route measured capacity. In traffic assignment, this trend was clearly reflected on the distribution of trips to the itineraries going from one zone to another. Since the itineraries are observed one at a time, the increase or decrease in their forecasted output is evident. The same goes for trip consolidation, but the change in the consolidated trips was very minimal since there are a lot of itineraries involved and only one itinerary was changed on the previous module. Moreover, the results in the RMC stayed the same due to the minimal change in the consolidated trips or the passenger demand of the routes.

6 FUTURE WORK

6.0.1 Estimate for the PUJ Franchise. Researchers who wish to further continue this study can further expand the scope of the study. Since this research only focused and used the Travel Demand data from the cities of Marikina and Valenzuela. Expanding the research area may take into consideration more distribution of passenger demand from trips coming from other zones. Data from the urban regions if not for the whole Philippines should be taken into consideration since these places may are the ones that produces the most travel demand.

6.0.2 Underestimation of RMC. Based on the current implementation of solving for the RMC, some of the results are not consistent with the current number of jeepneys. Comparing the current values to the results, there are some routes with a higher RMC as compared to the original, and some with lower.

Since RMC is not strictly implemented into the franchising of current route, it is possible that urban planners might have overestimated or underestimated the demand for certain PUJ routes. While this may not be the only cause of the inconsistency of values, there is also a possibility that the lack of travel demand data from the other zones may have caused the deficiency of the passenger demand to a route. Whether it is an intracity or intercity route, there can still be a chance that these routes may be the best choice for traveling in between cities, specifically farther cities that may possibly use these PUJ routes as one of their connecting route.

6.0.3 Overestimation of RMC. On the other hand, results of overestimation of RMC may be caused by the way the jeepney routes were specifically restricted in the process of route filtering. It was observed that some route itinerary returned by the OTP were not the optimal ones. Since OTP was modified to use legs restricted to only PUJ routes and walking routes, it returns some itinerary that were unrealistic to be used. With this, it is suggested that during route filtering, all modes should have been considered. This way, PUJ routes that are not optimal will not be considered and will not be assigned with trips that should have been assigned to the ideal routes.

6.0.4 Parameters of the Generalized Cost. The parameters used in the cost function only considers the fare and travel time of each itinerary. Looking into other parameters such as the number of transfers and the walking distance between these transfers may improve the current equation in computing for the travel cost. By doing this, the distribution of trips to the itineraries may be more precise.

6.0.5 Validation of RMC. Conducting a field investigation is tedious and time-consuming since it takes up a whole day to validate a single route. An agent-based simulation can be an option in validating the computed RMC. It can help speed up the validation process since it will already show a visualization of the flow of vehicles depending on the inputted passenger demand.

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