TRANSPORTATION GAP (TG) AND MODAL ADVANTAGE AREA (MAA) MODELING - A SUPPLY AND DEMAND SIDE ANALYSIS FOR METRO MANILA

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Abstract: Transport policies should ensure that a transport system satisfy at least three requirements. First, public and private modes should have sufficient physical capacity to accommodate demand. Second, public modes should do this with financially viable operations. And third, there should be sufficient demand for public modes to have profitable operations. A quick-response and integrated model is developed that evaluates the effects of transport policies on these requirements. With Metro Manila as study area, the model defines the ranges of peak-hour CBD-bound travel demand that can be accommodated by the physical capacity of public and private modes and give financial viability to public modes. It also estimates the demand for bus and car that results from transport policies; these being the dominant modes for CBD-bound trips in the study area. Results are then validated by comparing them with actual financial performance of public modes and with person trip data.

Keywords: Policy evaluation, Viability, Modal comparison, Generalized costs, TDM

1. BACKGROUND AND OBJECTIVES

Like in cities of other developing countries, economic affluence and the growing middle class have resulted in the growth of motorization in Metro Manila. Levels of car ownership and use have increased along with the buying power of people. Cities are becoming more and more dependent on the private car, and this has caused traffic congestion, excessive consumption of fossil fuel, and environmental degradation.

Transport policies should ensure that a transport system could satisfy at least three requirements. Firstly, the transport modes comprising the system, both public and private, should have sufficient physical capacity to accommodate travel demand. Secondly, public transport modes should do this with financially viable operations. And thirdly, there should be sufficient demand for the public transport mode that will sustain financially viable operations. The evaluation of transport policies in the light of these three requirements is the raison d'etre of this research.

The objective of the research is to develop a quick-response urban transportation model for developing countries that evaluates the effects of transport policies on the following:

- Physical capacity of public and private transport modes
- Financial viability of public transport mode

- Travel demand for a mode that results from such policies

The model identifies the domain of the different urban transport modes. "Domain" is defined in the study as the ranges of demand densities and trip lengths that can be accommodated by the physical capacity of modes (for all modes) and can provide financially viable operations (for public transport modes). The model also estimates demand for a mode that results from the implementation of transport policies. This travel demand is examined as to whether or not it falls within the mode's physical capacity and minimum requirement for financial viability. This resulting demand, in other words, is analyzed vis-à-vis the domain of the mode. Effects of different policy scenarios on the domains and resulting demands are examined. Policies on subsidies, fares, travel demand management (TDM), and capacity are evaluated by the model.

The study focuses on urban transportation in Metro Manila. The data used in the analysis comprise urban public transport operational and financial data, person trip data, and level of service data of different modes in the study area gathered from recent transport studies, person trip survey and original questionnaire survey conducted by the researchers.

This paper is organized as follows. Chapter 1 presents the study's background and objectives. Chapter 2 discusses the analytical framework used in the study. Chapter 3 presents the development and validation of the Transportation Gap (TG) and Modal Advantage Area (MAA) model. Chapter 4 discusses the evaluation of transport policies using the TG and MAA model. Chapter 5 presents with the research's conclusions.

2. ANALYSIS FRAMEWORK

2.1 Supply and Demand Side Analysis

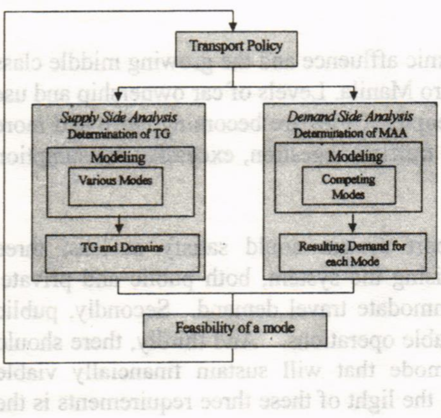


Figure 1. Supply and Demand Side Analysis

This research develops and introduces an integrated modeling approach for the analysis of urban transportation from the viewpoint of supply and demand. The model evaluates the effects of transport policy on both supply and demand side characteristics of urban transportation. Supply side analysis refers here to the determination of the domain of operation of a mode using its operational characteristics (e.g. frequency, capacity, operating speed, configuration, lay-over times, etc.) and financial characteristics (infrastructure costs, rolling stock or vehicle costs, operating costs, fares and revenues, etc.). The domains of different modes are superimposed on a cartesian coordinate system to show the resulting transportation gaps or TGs.

Demand side analysis, on the other hand, pertains to the estimation of demand for a mode that result from certain transport policies. Competing modes are analyzed and demand for each is estimated. The resulting demand is then matched with the domains of the mode. A good match means that the transport policies adopted in the analysis result in the feasibility or appropriateness of that mode to the area it serves. The lack of a match means that there is much to be desired in improving the suitability of the transport policy to the efficiency and effectiveness of the transport system. This may either mean that there is excessive demand that cannot be accommodated by the physical capacity of a mode or there is inadequate demand to meet the minimum required for viable operations of the mode.

This research uses the premise that each representative or typical transport mode has its own optimum domain of operations. The study performs a comparative analysis of supply side characteristics of different modes. A number of comparative studies on urban transport modes have been done in the past. Some notable works include that of Bouladon(1967) who identified optimum domains of modes in terms of speed and journey distance. Vuchic(1992) analyzed physical capacities of different modes in relation to maximum frequency, operating speed, and investment costs. The World Bank(1986) conducted studies on the relationship between city form and efficiency in developing countries. Newman, *et.al.*(1989) analyzed the relationship between urban form (in terms of population density and employment density) and travel demand (for private and public transport modes) for 32 major Australian, North American, European, and Asian cities. These findings explain why urban rail, for instance, is best for big cities with corridors of high travel demand. Buses suit medium size cities with relatively lower travel demand. Smaller scale and less expensive transport systems are suitable for smaller areas with smaller demand. It is therefore logical to identify the optimum domain of modes using demand density and city size as parameters.

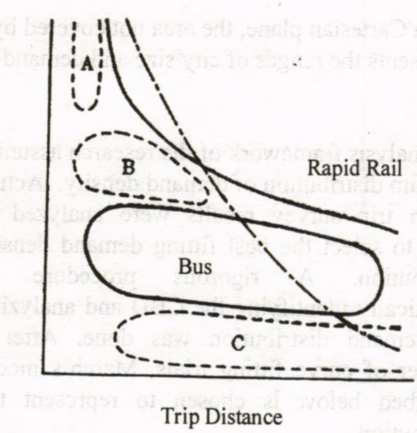


Figure 2. Domain of Rapid Rail and Bus

Yasoshima(1972), whose seminal work forms a major foundation of this research, proposed the concept that each transport mode has its optimum domain of operations in terms of trip length and demand density for that mode. He identified 'transport gaps' or ranges of demand densities and trip lengths that are not covered by the domains of high-speed rail and bus. Figure 2 shows this where the regions A, B, and C represent the 'transport gaps'. The Urban Transportation Research Group (Niitani, 1993) of Japan's Ministry of Construction drew inspiration from Yasohima's research and proposed, in conceptual terms, the domains of different urban transport modes in Japan. Their work, however, was strictly limited to just a conceptual image without actual and quantitative identification of the domains and TGs. Moreover, it was confined to only the concept of the TG or just the concept of supply side analysis, never threading on the territory of demand analysis. Using actual and real data, this research now quantifies the optimum domains of operations of different urban modes in Metro Manila and the demands for competing modes resulting from transport policies in the study area.

2.2 Transportation Gap Modeling

2.2.1 Basic Assumptions

The following are the assumptions used in the development of the TG model. 1.)A monocentric city is assumed and residents commute to the central business district (CBD) via the axis of a mode. All work trips are conveyed through the axis of a mode. Trip demand density is henceforth expressed in terms of the number of persons per hour per kilometer along the mode's axis. 2.) Transportation modes start from the periphery of the city to the CBD. Route length of a mode is equivalent to the city radius. 3.) Maximum trip volume is at the city center. This is because trips accumulate from the periphery of the city leading to the CBD. 4.) Urban lay-out is in terms of two variables: radius of city and demand density for trips going to the CBD at peak hour. 5.) Demand densities are expressed in equivalent 1-m wide right-of-way to make comparable results for different modes. It is necessary to do this because direct comparison of capacities of different modes (with different widths of right-of-way) is not meaningful. 6.) Focus of analysis is work trips to the CBD at peak hour.

Considering a cartesian coordinate system where the vertical axis is demand density at peak hour (in persons per hour-km) and the horizontal axis is route length or distance, the study defines the domain of a transportation mode as follows (Figure 3):

- *Upper bound*: demand densities that can be physically accommodated by the mode (Line A)
- *Lower bound*: demand densities that will result in break-even operations for the mode, in case of public transport modes (Line B).
- Line C represents the maximum reasonable distance that can be covered by certain modes such as walking or bicycle.

Superimposing the domains of different modes on a Cartesian plane, the area not covered by any domain is the transportation gap (TG). It represents the ranges of city size and demand densities that are not served by any of the modes.

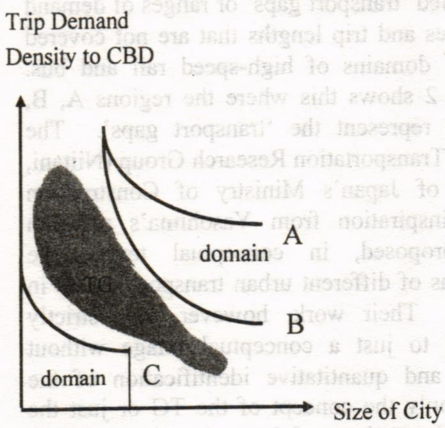


Figure 3. Domain of a Mode and Transportation Gap

The analysis framework of the research assumes a certain distribution of demand density. Actual person trip survey results were analyzed in order to select the best fitting demand density distribution. A rigorous procedure of analytically identifying the CBD and analyzing the demand distribution was done. After a number of curve fitting trials, March's model described below is chosen to represent the distribution.

$$D_x = a \times e^{-bx} \quad (1)$$

Where: D_x = demand density of commute trip to the CBD at distance x km from the CBD at peak hour. It is in persons per hour-km.

a = parameter related to the total population or number of trips and is an indication of demand density of commute trip to CBD at peak hour

b = rate of decrease of CBD-bound commute trips from city center to periphery

A high value of b means that density declines sharply with increasing distance from the CBD. This means a compact city. A low value means that density decreases more slowly, which signifies that the city is more spread out. The value of b is obtained from the empirical procedure.

2.2.2 Delineation of Domains

The following steps illustrate how the domain of a mode is delineated. The first step determines the demand densities that can be physically accommodated by the mode. The second estimates the minimum demand densities necessary for break-even or financially viable operations of public modes.

a. Upper bound of domain: *demand densities that can be physically accommodated by the mode:*

Physical capacity S_{max} at city center per corridor (for rail transport, for instance) is:

$$S_{max} = C\,O\,N\,T \tag{2}$$

Where S_{max} = maximum physical capacity per corridor per peak hour occurring at the city center; C = passenger capacity per car; O = occupancy ratio (%) or ratio of observed average number of passengers to capacity per car at peak hour; N = number of cars per train; and T = number of trains per peak hour.

But using March model (Eq. 1), the total volume of trips V going to the CBD is given as:

$$V = \int_0^r a_{upper} x e^{-bx} dx \tag{3}$$

At the CBD, maximum capacity and volume are assumed to occur so V is equal to S_{max}. Equating V and S_{max} yields:

$$a_{upper} = p(r) \tag{4}$$

This curve $a_{upper} = p(r)$ represents the upper bound of the domain or the *physical capacity curve*. The equivalent demand density for a 1-meter width of right-of-way is obtained by dividing the demand density by the width of the right-of-way.

b. Lower bound of domain: *demand densities that will result in financially viable operations of public transport modes.*

This is determined by break-even analysis of public transport modes where total costs equal total revenues:

$$\text{Total Cost} = \text{Total Revenue} \tag{5}$$

where total cost includes initial investment cost (construction costs of infrastructure and rolling stock or vehicle costs), operating costs, and other pertinent costs. Total revenue includes farebox revenue and other sources. Both total cost and total revenue are expressed on a per year basis; hence it is necessary to use the annual equivalents of the costs. Operating costs are also expressed in annual terms. Annual equivalents of initial investment costs are estimated using Capital Recovery Factor that distributes costs into annual amounts over a certain length of time:

$$M = P \times \frac{i(1+i)^n}{(1+i)^n - 1} \quad (6)$$

where M is the annual amount, P is the total amount of investment, i is the interest rate, and n is the project design life in years over which the total amount is distributed.

Annual revenue is expressed as follows:

$$TR = \int_0^r \{a_{lower}\, xe^{-bx}\} \times 2 \times F \times x \times Edx \quad (7)$$

where TR = total annual revenue;

F = the unit fare per passenger-km

E = expansion factor to convert peak hour revenue to annual revenue. This converts peak hour volume to daily volume (by dividing by peak hour ratio obtained from person trip surveys) and then converting to annual volume (by multiplying by the effective number of days of operation per year).

x = distance from the CBD

Equating the annual total cost with annual total revenue yields an expression for a_{lower} in terms of r or

$$a_{lower} = f(r) \quad (8)$$

This curve represents the lower bound of the domain or the *financial capacity curve*. This demand density is also divided by the width of right-of-way to get the equivalent density for 1-meter right-of-way.

2.3 Modal Advantage Area Modeling

2.3.1 Basic Assumptions

The characteristics of a mode influence its utility to users. Travel time and costs incurred in using a certain mode affect its attractiveness over other modes. Traveling to the CBD is usually a choice between taking public transportation (train, bus) or private car. The choice largely depends on which mode will require lower generalized travel cost (time cost and fare for public modes and time cost, fuel cost, and parking cost for private car). It is possible to identify the area in real geographic space where taking one mode entails lower generalized costs than taking another mode. Such area is called in this study as the Modal Advantage Area or MAA of that mode. This research analyses the MAA of competing modes for CBD-bound trips in the study area: bus and car.

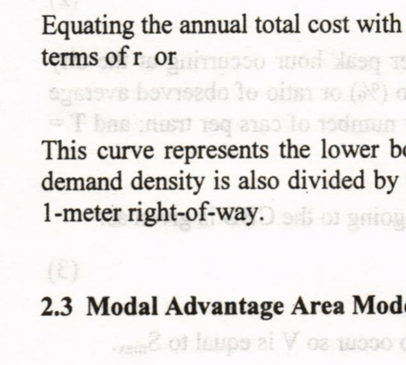


Figure 4. Concept of MAA

The following are the assumptions made for MAA modeling. 1.) A monocentric and radial urban form is assumed. 2.) Radially oriented transportation facilities start from the city's periphery and lead to the CBD. The number of radial routes is equal to the actual number of public transport corridors going to the CBD determined by examination of the study area. 3.) Station spacing of public transportation affects access time to the station. 4.) For the current analysis, competing transport modes for CBD-bound trips are bus and car. 5.) Travel distance by car is represented by rectilinear distance (sum of distance parallel and perpendicular to the axis of the bus route). Speeds on local and arterial roads are assumed to be equal. 6.) Urban lay-out is in terms of two variables: radius of city and demand density for trips going to the CBD at peak hour. 7.) Demand densities are expressed in equivalent 1-m wide right-of-way to make comparable results for different modes. 8.) Focus of analysis is CBD-bound trips at peak hour. These are shown in Figure 4.

2.3.2 Delineation of Modal Advantage Areas

Generalized costs for the competing modes bus and private car are expressed as follows:
Bus:

$$GC_B = C_B x + C_A y + w\left\{\frac{x}{V_B} + \frac{y}{V_A} + T_w + \frac{D/2}{V_A}\right\} \quad (9)$$

Where GC_B= generalized cost for bus; C_B = bus fare per passenger-km; x = horizontal distance traveled by bus; C_A = access mode fare per passenger-km; y = vertical distance traveled by access mode; w = value of time; V_B = average bus speed; V_A = average access speed; D = average distance between bus stops; T_w = waiting time at bus stop derived from bus frequency.

Car:

$$GC_C = C_C(x+y) + w\frac{(x+y)}{V_C} + P_{CBD} \quad (10)$$

Where GC_C = generalized cost for car; C_C = cost of car use per km assumed to be equal for local and arterial roads (This includes costs of fuel, tires, maintenance, and other cost items); x, y = rectilinear distance traveled by car; w = value of time; V_C = average car speed; P_{CBD} = parking fees at CBD. The term P_{CBD} may be replaced by any additional car cost such as tolls, road pricing, etc.

The boundary between bus MAA and car MAA is based on:

$$GC_{Bus} = GC_{Car} \quad (11)$$

Equating the generalized costs leads to the linear equation:

$$y = \lambda\ x + r_1 \quad (12)$$

where:

$$\lambda = \frac{\left\{C_B - C_C + w\left(\frac{V_C - V_B}{V_C V_B}\right)\right\}}{\left\{C_C - C_A + w\left(\frac{V_A - V_C}{V_C V_A}\right)\right\}} \qquad r_1 = \frac{\left\{w\left(T_w + \frac{D}{(2V_A)}\right) - P_{CBD}\right\}}{\left\{C_C - C_A + w\left(\frac{V_A - V_C}{V_C V_A}\right)\right\}} \quad (13)$$

In the above equations, λ is the slope of the MAA boundary line. It can be considered as the rate of appearance of an MAA. The expression $- r_1/\lambda$ is the distance from the CBD where an MAA starts to appear. This is the x-intercept of the MAA line. This is illustrated in Figure 11 of Section 3.6 showing actual results for Metro Manila.

After identifying the MAA of competing modes, demand densities of each of these modes is estimated using the assumed demand density distribution given by March's model. The reliability of the resulting demand for each competing mode is then verified by comparing it with demand data derived from actual person trip surveys. The resulting demand density is compared with the range of demand densities of the domains identified in TG analysis. Transport policies are conducive for the feasibility of a mode to a city when the demand densities from MAA modeling ***match*** the domains of TG modeling. If no match occurs, transport policies under consideration result in demand for a mode that is either one of the following:

- It is too high for the physical capacity of the mode to accommodate it, or
- It is too low for the mode to make financially viable operations from it.

A good match between the resulting demand density and the domain is an indication of an efficient and effective transportation system. Transport policies are explored and simulated to achieve this match.

3. MODEL RESULTS AND VALIDATION

3.1 Urban Rail

Manila's first LRT system has been operational since 1985. Being located in a high-passenger demand corridor, it has been operating beyond capacity. It carries 2.3% (JICA,1999) of all person trips in Metro Manila, a relatively high figure considering that it is only a single line.

The following data are the inputs used in delineating the LRT's domain:

Operating Speed= 35 kph; Capacity per car = 374 (7 passengers per sq. m.); # of cars per train = 2; # of trains per pk hr = 25; # of trains per off pk hr = 12; Occupancy ratio = 100%; Operating hrs per day = 18; b = 0.21; Total op cost per train-km = 221.64 Pesos /train-km; Purchase cost per car = 52,400,000 Pesos; Infra cost per km = 998,800,000 Pesos; Annual interest rate = 8 %; Life span of infra = 50 years; Life span of rolling stock = 25 years; Fare = 1.23 pesos per passenger km; Total rev to non-fare rev ratio = 1.15; Prop of peak hr rev to daily rev = 0.2; No. of effective operating days = 346 days per year; lane width = 3.8 meters

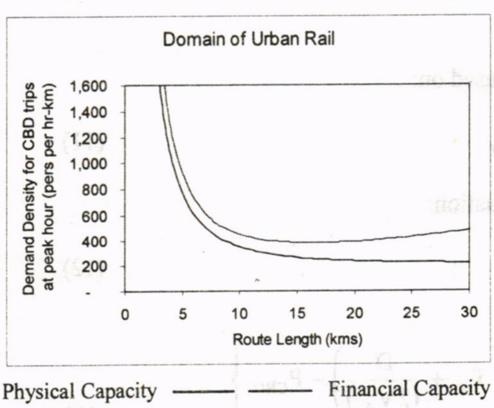
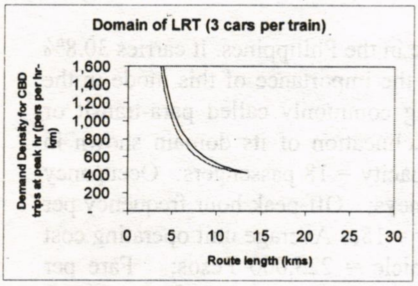


Figure 5. Domain of Urban Rail

Figure 5 reflects the LRT's current financial state. The LRT is financially successful, with revenues surpassing operating costs. However, total financial operations are not as favorable because of debt servicing and asset depreciation cost. The chart shows that there is actually *no domain* at present, a finding that is validated by the fact that operations of Manila's LRT are in deficit, in spite of its very high ridership. It is one of the few urban rail transit systems in the world that have passenger revenues exceeding operating costs. However, revenues are inadequate to cover initial investment and asset replacement costs (Valbuena, 1998).

Simulating the effect of increasing the train configuration from 2 cars per train to 3 cars per train will result in the domain shown in Figure 6:



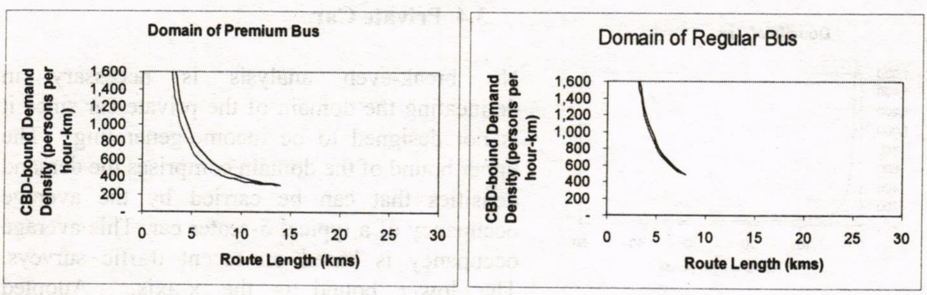
Physical Capacity ——— ——— Financial Capacity

Figure 6. Simulated Domain of LRT (Increased Configuration: 2 to 3)

3.2 Premium Bus and Regular Bus

A premium bus is defined as an air-conditioned bus with express service or limited stops. A regular bus is non-airconditioned with lower fares. Premium bus services are more expensive than those of regular bus because of liberalized fares (in contrast to the strictly regulated fares of economy buses). Only the minimum fares for Manila's premium buses are regulated. The delineation of bus' domain is similar to rail-based modes except that it does not require initial infrastructure or construction cost.

Metro Manila is where one of the busiest and highest capacity bus corridors in the world is located. This is EDSA (Epifanio de los Santos Avenue) which has 6 lanes per direction, at its widest. It is served by an estimated 12,000 to 16,000 bus trips a day carrying flows of nearly 400,000 passengers a day each way on the busier sections (JICA,1997). The following are the inputs used in delineating its domain: Ave. travel speed = 12 kph; Seating Capacity = 65; Peak hour frequency = 220 buses per lane; Off peak hour frequency = 110 buses per lane; Operating hours per day = 18 hrs; Occupancy ratio at peak hour = 125%; b = 0.21; operating cost = 16.95 P (AC), 14.19 P (nonAC) per bus-km; cost of one bus = 750,000 P (AC); 690,000 (nonAC); lifespan of vehicle = 15 years; Fare = 1.00 P (AC), 0.70 P (nonAC) per passenger-km; lane width = 3.25 meters; Farebox revenue to non-farebox revenue ratio = 1.05



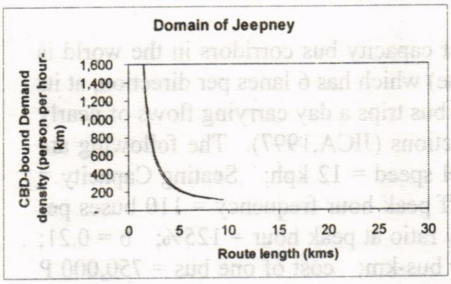
Physical Capacity ——— ——— Financial Capacity

Figure 7. Domains of Premium Bus and Regular Bus

Unlike the rail-based mode, the domains of premium bus and regular bus exist signifying profitable operations of the mode. However, premium bus domain is larger than that for regular bus as shown in Figure 7. This indicates the higher profitability of premium buses. This is consistent with trends in Manila which show more profitable operations of air-conditioned buses (JICA, 1997). This profitability is also evidenced by the high number of new applications for aircon bus franchises in Metro Manila (Montalbo, 1997). Ridership is generally sensitive to fare, but there may be other factors such as comfort that influence ridership for premium bus and regular bus.

3.3 Jeepney

The jeepney is an 18-passenger capacity para-transit mode in the Philippines. It carries 30.8% of all Manila's person-trips. (JICA,1997). This indicates the importance of this mode in the overall urban transportation system in spite of its being commonly called para-transit or informal mode. The following inputs are used in the delineation of its domain shown in Figure 8: Average speed = 9 kph; Jeepney seating capacity = 18 passengers; Occupancy ratio = 100%; Peak hour frequency per lane = 270 jeepneys; Off-peak hour frequency per lane = 135 jeepneys; Number of operating hours per day = 15; Average unit operating cost = 5.25 Pesos per jeepney-km; Purchase cost per vehicle = 225,000 Pesos; Fare per passenger-km = 0.65 Peso; Total revenue to farebox revenue ratio = 1.00; Ratio of peak hour to daily revenue = 0.15; Number of effective full days in a year = 342; Width of one lane = 3.25 meters; Gradient of demand density distribution, b = 0.21



Physical Capacity ______ ______ Financial Capacity

Figure 8. Domain of Jeepney

Like regular buses, jeepneys also have a thin line of profitability since fares are also strictly regulated and kept to a minimum. Drivers or operators who usually own one unit manage to stay afloat in the business even with a low profitability because they put off or exclude depreciation costs, perform the vehicle maintenance themselves, or underpay themselves. These practices may enable them to cope in the short run, but will eventually drive them out of business in the long run.

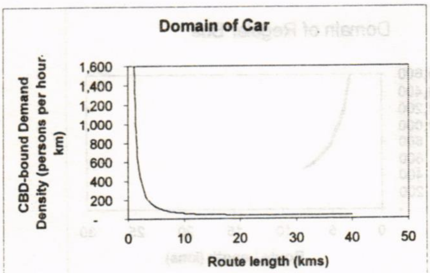


Figure 9. Domain of Car

3.4 Private Car

No break-even analysis is necessary in delineating the domain of the private car since it is not designed to be income-generating. The upper bound of the domain comprises the demand densities that can be carried by the average occupancy of a typical 5-seater car. This average occupancy is based on recent traffic surveys. The lower bound is the x-axis. Adopted parameters are: Lane capacity = 1,500 cars per hour per lane (Bang, 1995); Width of one lane = 3.25 meters; Average occupancy is 1.75 persons per car; b = 0.21

3.5 Superimposed Domains and Resulting TG

The individual domains are now superimposed to reveal the transportation gaps. Figure 10 shows the superimposed domains and the resulting TGs, including the simulated domain of the LRT (resulting from an increased train configuration). The transportation gap is the area between the domains of buses on the one hand, and the jeepney and car domains, on the other hand.

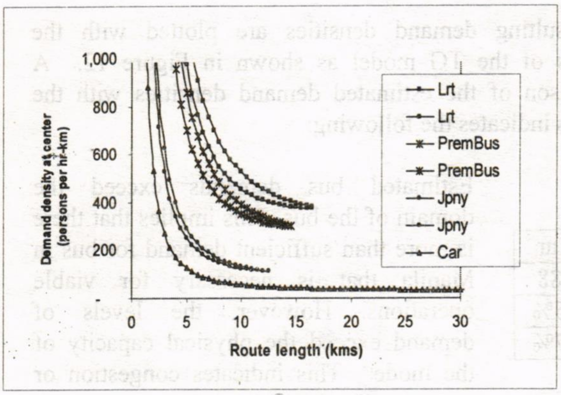


Figure 10. Superimposed Domains and TGs

The rail-based mode is not profitable (i.e., non-existent domains). In reality, it is operational because it is sustained by external subsidies or by funds other than from farebox revenue. On the other hand, bus (premium and regular) and jeepney operations are profitable, with premium buses enjoying a wider margin of profitability compared to regular buses and jeepneys.

The existence of the transportation gap indicates that with the adopted parameters, there is a wide range of demand densities that cannot be served profitably by the considered transport modes. The opportunities for transport modes to have viable operations are rather limited in the light of the parameters and conditions at hand.

The next section presents the estimation of demand for the competing modes bus and car. The resulting demand densities will be plotted later on the same coordinate system of the domains and a good match, or the lack of it, will be verified.

3.6 Results of MAA Modeling

The following level of service characteristics were used as input values in determining the properties of the MAA boundary line. These are obtained from the Metro Manila Urban Transportation Integration Study (JICA, 1999):

Bus: Ave bus speed = 12 kph; Bus fare = 1.05 Pesos per passenger-km; Value of time = 46 Pesos per hour; Distance between bus stops = 0.75 km; Waiting time at bus stops = 3 minutes; Jeepney (access) speed = 9 kph; Jeepney (access) fare = 0.65 Pesos per passenger-km; Walking speed = 3 kph; Number of bus routes = 4; City radius = 20 kms.

Car: Cost of car use = 2.13 Pesos per km; Time value = 46 Pesos per hour; Average car speed = 14 kph; Parking cost at CBD = 0

Using the expression for the slope and x-intercept of the MAA boundary line described in Chapter 2, the following results are obtained. The slope of the MAA boundary line is λ = 1.54 and the x-intercept is $-r / \lambda = 7.92$. The MAA is depicted in Figure 11.

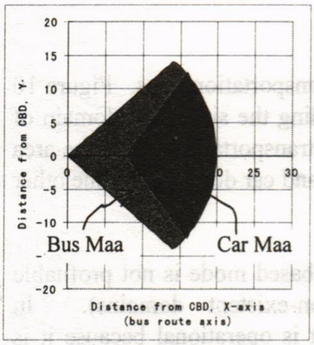


Figure 11. MAA of Bus and Car

Having determined the Modal Advantage areas, the volumes of trips by bus and car are determined using the demand density distribution of Manila. The volumes of trips are then converted to demand density and then compared with actual person trip shares by bus and car based on person trip data. Table 1 presents the results showing a general agreement between model estimates and survey data.

The resulting demand densities are plotted with the domains of the TG model as shown in Figure 12. A comparison of the estimated demand densities with the domains indicates the following:

Table 1. Validation of MAA Results

	Bus	Car
Estimated Demand Density	351	188
Estimated % share	65%	35%
PT Survey % share	53%	47%

Estimated bus demands exceed the domain of the bus. This implies that there is more than sufficient demand for bus in Manila that is necessary for viable operations. However, the levels of demand exceed the physical capacity of the mode. This indicates congestion or overcrowding in the buses.

The estimated car demand exceeds the domain of the car thus confirming the high traffic congestion observed in the city. The domain of the car may be enlarged by adopting higher values for the occupancy parameter. This may be accomplished by the suitable travel demand management measures designed to increase occupancy, such as the "3-in-1" TDM measure in another Asian city (Jakarta) which allows only those vehicles with 3 occupants to use the major thoroughfare during peak hours.

It is also interesting to explore the policies that can shift car demand to bus. Transport policies such as lower bus fares accompanied by travel demand management measures that restrain private car use have to potential to achieve this. But lower fares will further narrow down the domain of the bus mode. Hence, some policies on subsidies or some form of external funding maybe also be considered.

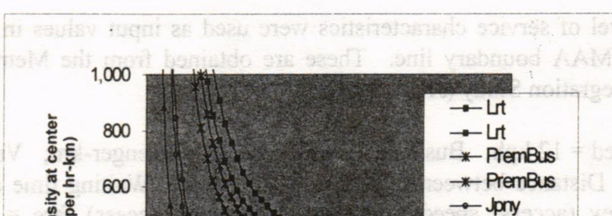


Figure 12. TG and MAA

4. TRANSPORT POLICY EVALUATION

Table 2 shows the policy variables that were evaluated in the study. Policies on subsidies, capacity expansion, fare increase, fare allowance (provided by employers), and TDM measures are evaluated. Policies to increase the domains of premium bus and private car are evaluated. The corresponding demand densities that result from such policies are also shown and compared with the domains. Policies that reduce or eliminate the transportation gap are also presented.

Provision of subsidy increases a public mode's domain by pulling down the lower bound. This means that less demand densities are required for break-even operations. Fare increase has the same impact as subsidies. In addition, train configuration increase and occupancy increase enlarge the physical capacity of the mode thereby expanding the domain by pushing up the upper bound. These policies change the domains and in effect, the transportation gap. On the other hand, car parking charges make car use more expensive and thus less attractive. This affects the car modal advantage area (MAA).

Table 2. Policies for Evaluation

Mode	Policy	Simulation Values
LRT	Infrastructure Subsidy	0% to 50%
	Rolling Stock Subsidy	0% to 100%
	Configuration increase (urban rail)	2 to 3 cars per train
Bus	Vehicle Purchase Cost Subsidy	0% to 50%
	Operating Subsidy	0% to 50%
	Fare increase & Fare allowance	100% fare hike & fare allowance equivalent to fare hike
	Occupancy	125% to 165%
Car	Occupancy	1.75 persons per veh to 4 persons
	Parking Charges	0 to 1.0 US$

For the LRT, the following policies were independently evaluated: 50% infrastructure subsidy, 100% rolling stock subsidy, and train configuration increase from the current 2 cars per train to 3 cars. Results indicate that a 50% infrastructure subsidy has a greater impact than a 100% rolling stock subsidy implying that investment costs for urban rail are predominantly for infrastructure. The expansion of the train configuration (from 2 cars to 3 cars per train) also creates viability, indicating the high potential of capacity expansion measures in creating viability. This is specially favorable in Manila because of the high demand along the LRT corridor. This policy simulation was shown in an earlier section.

Figure 14 shows the evaluation of some of the several possible policies for bus and car. The plots show the effects of the policies on the domain of bus and car and on the resulting demand for these modes. The domains and estimated demand densities are plotted together, with a good match indicating favorable policies. Policies that reduce or eliminate the transportation gap are also explored.

Increasing bus occupancy ratio from the current 125% to 165% (Figure 14-a) enlarges the domain to cover the demand for bus. This means that the mode can physically accommodate demand. However, a value of 165% implies heavy passenger congestion, profitable for bus operators but a possible disincentive for passengers.

Applying the combination of several policies (Figure 14-b) such as bus occupancy ratio (165%), bus vehicle purchase subsidy (50%), and bus operating subsidy (50%) almost eliminates the transportation gap. Increasing bus fares by 100% coupled with the provision of fare allowance by employers equivalent to the fare increase shifts the lower bound of the bus domain downward (Figure 14-c). It enlarges the domain of bus and also almost eliminates the transportation gap. This policy is a TDM measure done in some developed countries to encourage workers to use public transportation. It must be noted that with this policy, the attractiveness of bus over private car is not affected since bus users end up spending the same out-of-pocket cost even with higher bus fares. Hence, the generalized cost of using bus remains the same. In effect, the estimated demand for bus (from MAA modeling) is unchanged.

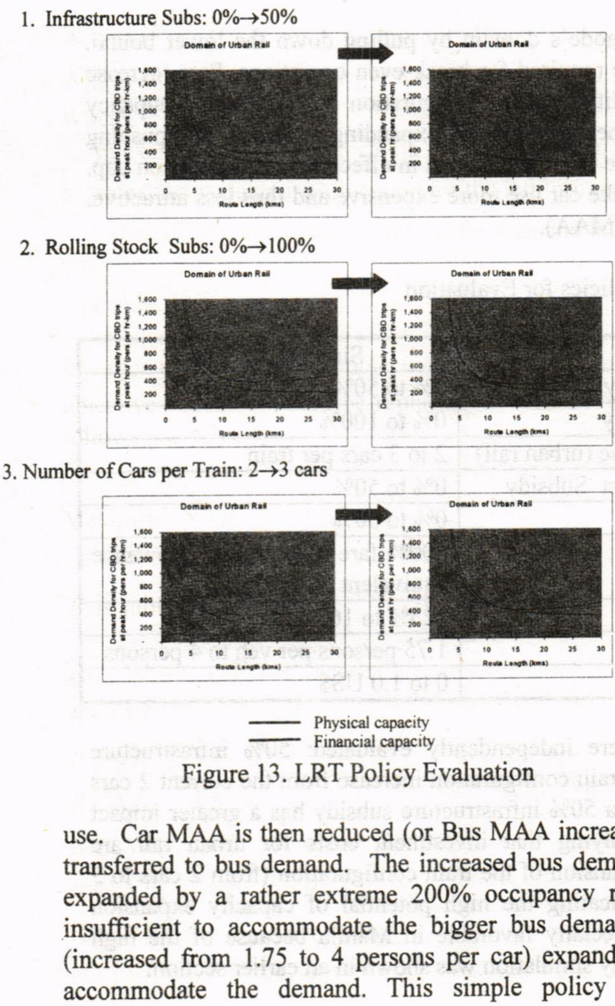
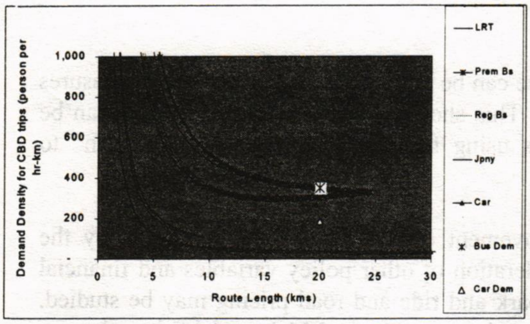


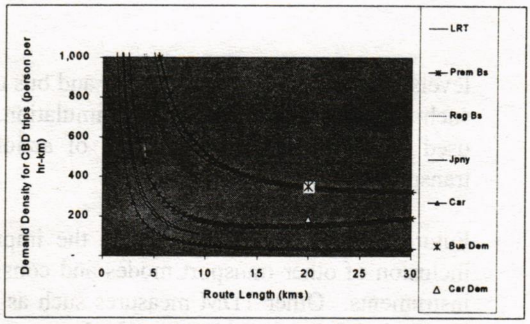
Figure 13. LRT Policy Evaluation

The result of combining bus and car measures is shown in Figure 14-d. TDM measures that aim to increase car occupancy will enlarge the domain of the car. Charging car users for parking at the CBD has a high potential to encourage a shift from car to public transport. Parking costs increase the generalized costs of car use. Car MAA is then reduced (or Bus MAA increases) and the reduction in car demand is transferred to bus demand. The increased bus demand is covered by the new bus domain expanded by a rather extreme 200% occupancy ratio (A 165% bus occupancy ratio is insufficient to accommodate the bigger bus demand). The higher car occupancy level (increased from 1.75 to 4 persons per car) expands the domain of the car enabling it to accommodate the demand. This simple policy simulation illustrates the interactive relationship between supply and demand side analysis through TG and MAA modeling.

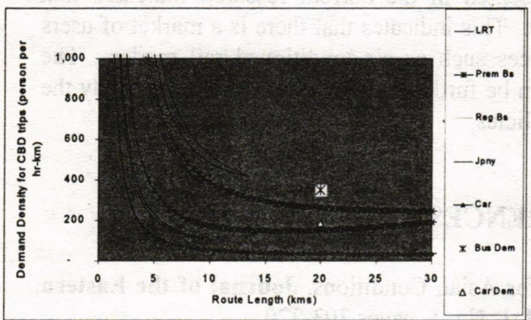
These results indicate that basically, the capacity of bus mode is rather inadequate for the high travel demand in Metro Manila. The policy simulation shows that the demand for bus that resulted from the evaluated policies can only be accommodated by extremely congested passenger conditions in buses; a rather undesirable situation that may be expected to discourage bus use and push car use to rise further. Therefore, higher-capacity transport modes such as urban rail are warranted. This is compatible with the present general policy to build new urban rail lines in the metropolis.



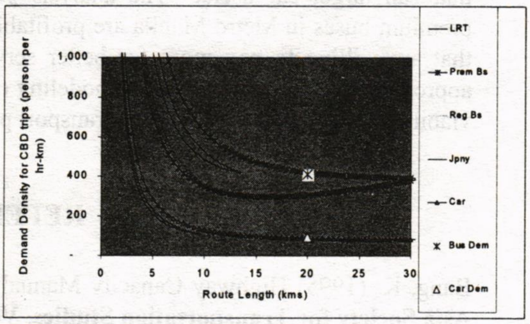
a. Bus Occupancy Ratio = 165%



b. Bus Occupancy Ratio = 165%
Bus Purchase Subsidy = 50%
Bus Operating Subsidy = 50%



c. Bus Fares = 200%
Fare Allowance = Fare Increase



d. Bus Occupancy Ratio = 200%
Car Occupancy = 1.75 $\rightarrow$ 4
Car Parking Charge = 1.0 US$

Figure 14. Bus and Car Policy Evaluation

5. CONCLUSION

This research develops an integrated model for the evaluation of transport policies for Metro Manila. The model analyzes the physical capacity, financial viability, and demand for competing modes that result from transport policies. The research demonstrates the interactive relationship between transport supply and demand.

Subsidies are indispensable for the viability of rail mode in the study area. As shown in the policy simulation, different values of infrastructure and rolling stock subsidy can create viability. Capacity expansion measures such as increasing the train configuration for urban rail are also promising measures for profitable operations. This presupposes, however, that there will be sufficient demand that can be served by the expanded rail services.

The evaluation of bus policies indicates that bus demand in the study area is too high for reasonable bus capacity. This indicates that higher-capacity modes (such as rail modes) are already necessary to serve the high demand in the study area. This is reflected in the current trends in the study area to adopt rail modes as the main urban transport modes.

The model also illustrates the effects of a combination of TDM measures to improve the performance of the transport system. Car parking charges decrease car demand and create a corresponding shift to bus use. Coupled with increases in bus occupancy and car occupancy levels, a better balance between car and bus use can be created by a combination of measures such as that shown in the policy simulation. This shows how the TG-MAA model can be used in evaluating a combination of actions using the so-called "package approach" to transport policy.

Future research directions include the improvement of the TG and MAA model by the inclusion of other transport modes and consideration of other policy variables and financial instruments. Other TDM measures such as park and ride and road pricing may be studied. Further refinement of the generalized cost expressions used in the MAA model is in order.

Another interesting direction is the viability of high-quality and high-value transport services that can target car users. The analysis presented in the current research indicated that premium buses in Metro Manila are profitable. This indicates that there is a market of users that are willing to pay more for better services such as air-conditioned rail modes. The approach developed in TG-MAA modeling can be further enhanced and applied to study the viability of such services vis-à-vis transport policies.

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