IS CURITIBA, BRAZIL THE MODEL CITY FOR PARKING MANAGEMENT?

Christopher Ziemann
District of Columbia Department of Transportation
Reeves Center, 7th Floor
2000 14th Street NW
Washington DC 20010
Phone: (202) 671-2555
Fax: (202) 671-0617
Email: christopher.ziemann@dc.gov

Please Include Former Affiliation:
University of North Carolina at Chapel Hill
New East Building, Campus Box # 3140
Chapel Hill, NC 27599-3140

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ABSTRACT

As cities in developing countries struggle to cope with astronomical population growth that threatens to eclipse infrastructure capacities and cripple economic and environmental sustainability, many cities are turning to Bus Rapid Transit (BRT) to provide high capacity at a low cost and attract drivers to buses. Also important to mode choice is parking. This paper examines parking supply, price, and policies in Curitiba, Brazil, the original model city for BRT. The goal of this exploratory paper is to expand the current body of literature on Curitiba's transportation and land use connections and to bring attention to how policy impacts parking, and how parking influences mode choice. This paper provides a review of parking literature, concluding that restricting parking reduces vehicle mode share, and gives examples of policies other cities have implemented such as maximum parking allowances. Then, from interviews, this paper explains the history of parking policy in Curitiba and examines five case studies to determine how this has affected supply, demand, and price. The paper also compares this data with socio-economic statistics and data on urban form. The result is that Curitiba adopted minimum parking requirements similar to most U.S. cities, even along the BRT lines. There is high supply and in all five cases, and high demand where income and density are highest. The lessons from this paper are especially relevant to poor countries battling congestion and pollution and seeking low-cost solutions and can help define what a model city for parking management would look like.

INTRODUCTION

Cities in developing countries struggle with population growth that threatens infrastructure capacities and impedes economic and environmental sustainability. Among the most severe transportation problems are traffic congestion and air pollution. Public agencies are searching for strategies to improve their transportation systems, some cities have invested in transit improvements such as Bus Rapid Transit (BRT). This has improved conditions for public transportation users and providers, but has had varying success at alleviating congestion. Parking, however, has significant influence on mode choice, and parking management can be a low-cost tool to help poorer countries reduce congestion, curb pollution and manage their transportation infrastructure.

Because of the popularity of BRT, this paper seeks to connect research on Curitiba with research on parking. Many see Curitiba as the model city for Bus Rapid Transit (BRT). The goal of this paper is to expand the body of literature on Curitiba's transportation and land use connections and to bring attention to how regulatory policies impact parking supply and price and parking's influence on mode choice. Until recently, most of the research has been around Curitiba's BRT systems, however the conversation of transportation options needs to be broadened. This paper will examine literature on parking, describing how parking supply and price affect mode choice, and alternatives that some cities are implementing. In the summer of 2005, the author traveled to Curitiba to research parking requirements and to examine the effects of parking regulations. For the case studies, five stations were chosen based on their different characteristics and data was collected on supply and price of off-street and on-street parking spaces, and regulations of on-street parking. Transportation and land use professionals were interviewed within the Curitiba municipal government to obtain an understanding of minimum parking regulations, policies and enforcement. This data was analyzed within a framework of factors that influence parking: socio-demographic, urban form, and demand. These comparisons will show that high supply (even in the CBD), low prices, and minimum parking requirements promote automobile driving and that Curitiba's parking management system does not support its BRT program. The goal then is to begin the conversation on what it means to be model city for parking management.

LITERATURE REVIEW

Curitiba is the city that most communities recognize as instituting the original BRT system. In the 1960s, Jaime Lerner and the newly-formed Urban Research and Planning Institute of Curitiba (IPPUC) created a plan (*Plano Diretor*) that prioritized transportation investments. It coordinated transportation and land use, emphasized public transportation, and stressed financial feasibility. It created four priority corridors (axes), known as trinary axes, that consist of three high capacity roads to and from the central business district (CBD). The central road has exclusive bus lanes and slow-moving vehicle traffic. The external two roads are multi-lane, one-way, auto-oriented roads, one leading into the CBD and the other leading outwards. A major land use-transportation coordination was to steer density to these axes, which came to contain the world's first BRT system. This system allowed Curitiba to build a high quality transportation system without incurring a large debt. It also helped push development outside the CBD and reduce downtown congestion.

This downtown congestion, like in most downtowns, results from a high number of vehicles compared with the capacity of the constrained roadways. In urban centers where space is at a premium, an over-reliance on personal vehicles quickly results in congestion and air pollution. As vehicle ownership rates rise with personal incomes, problems of congestion and air pollution increase. Therefore many countries have looked to the U.S. for strategies for managing automobiles. These strategies usually stress abundant parking. However, the negative effects of parking have gone practically unnoticed until the 1990s. Most of the recent research on parking comes from the United States and Europe, therefore the outcome of this review will focus on situations in these two areas; but this paper assumes that the principles discovered can be applied to many urban contexts worldwide.

During the early part of the 20th century in the United States, parking was never a problem, because most people did not own cars. But as the price of cars declined and ownership rose, the lack of attention to parking led to congestion specifically from double parking and parkers searching for spaces (*1*). The solution for most communities was to adopt off-street parking requirements for each land use or type of business. These were determined either by consulting various handbooks (which themselves were based on very little research), or simply to copy those of similar cities. The handbooks usually prescribed so much parking for developments to be sufficient for all but the busiest hours of the year, leading to partly or mostly empty lots for the rest of the time.

Minimum parking requirements guarantee a large supply of off-street parking, usually for free (even in many CBD's, employer-paid parking, which is free or very inexpensive to the user, is common). A vicious cycle begins of over-driving because an over-supply and under-pricing of parking creates an over-demand, and observed parking over-demand is used to set (over-)supply requirements (*2*). Abundant off-street parking has many costs, ranging from environmental to congestion to limiting access to employment. Willson and Shoup (*3*), in their study on employer-paid parking and its effect on mode choice, found that free parking encourages single-occupant vehicle (SOV) driving. Numerous studies indicate that providing parking induces driving, and usually SOV driving because parking is usually free (*2,4*).

All of this research shows that U.S.-style minimum parking requirements lead to abundant supplies that encourage higher SOV mode choice. This leads to more transportation-related pollution, and when infrastructure is constrained, this often leads to congestion. However, some cities are reducing parking supply. For example Copenhagen, Denmark, is reducing its supply by 2-3 percent per year. In Munich, Germany, parking supply reduction is used as the chief device to decrease car travel, especially to the inner city (*5*). Even cities in the United States are beginning to pick up on this trend to limit parking supply. San Francisco, New York City and Portland, Oregon have already imposed off-street parking maximum allowances in certain areas, and Washington, DC will soon too.

As a planning tool, using parking price and supply to influence mode choice has received little attention until the past decade (*6*). Oversupply of parking, which leads to a lower price (usually free) increases vehicle mode share because the marginal cost per trip is much lower than the actual cost. However, Shoup shows that when drivers pay, they drive less (*6*). This seems intuitive as an economic rule. Many cities already use parking price to reduce driving. Copenhagen has raised parking prices in areas well served by transit, and Ottawa is eliminating free parking for federal employees (*5*).

Generally, downtowns require less parking than suburban shopping centers because of good transit and pedestrian connections (*7*). Many cities have recognized this and acted upon it

with maximum parking allowances for new developments. They have found that when parking supply is limited and transit and walking are encouraged, cities can build more densely without the threat of congestion reducing mobility. Government regulation can affect prices of private supply by restricting supply itself. Privately owned parking is very expensive in Zurich, and in Munich, parking garages are forbidden (*5*). Recently, some cities have also begun variable priced on-street parking using multi-spaced meters, pricing parking differently at different times depending on demand. Washington DC has already implemented this on residential streets around the new Baseball Stadium, where four hours of parking can cost as much as $20 USD.

With regards to transit, studies show that raising the price and reducing the supply of parking has a higher impact on increasing transit ridership than improving service does (*4*). Therefore, to increase transit ridership, these examples imply that cities could regulate parking in areas well served by transit. Indeed, Copenhagen has higher parking prices in such areas and Munich is reducing parking supply around train stations and in the CBD (*5*). Downtowns in many cities around the world are known for their walkability, and public transportation is essential to provide accessibility for those outside of downtown without the negative effects of providing parking (tearing down buildings, reducing density, requiring expensive parking structures) (*8*).

The recent nature of the attention to parking may explain why Curitiba's parking management policies have been mostly ignored. However, Rabinovitch and Cervero write briefly about parking in Curitiba. Rabinovitch states that "In the *traditional center* … [n]ew parking areas are not allowed…" but that in other areas, parking requirements are necessary for building permits or new commercial activities (*9*). Two years later, Robert Cervero writes in *Transit Metropolis* "[In Curitiba, o]ff-street parking is privately owned and very expensive" (*5*). He briefly sums up the situation:

> … Within structural axes, the city imposed no parking requirements until the early 1980s… In practice, off-street parking was supplied, though at far lower levels than found elsewhere in the city. Since higher-income households owned most of the condominiums that lined the transitway, parking demands quickly outstripped supplies,… In the early 1980s, the city imposed the same parking standards as elsewhere in the city… Even retail shops within the structural axes today face the same parking standards as retail plazas on the periphery of the city. In fact, retail parking demands in outlying areas tend to be less than along transitways since poor households without cars generally reside on the outskirts and shop nearby… Incomes rather than urban densities are clearly the stronger determinant of parking demand in Curitiba.

Other than this brief description, the only quantitative data that exists on Curitiba's parking are minimum parking requirements.

METHODS

Because of Curitiba's preference of public transportation over the private automobile, one expects Curitiba to have a comprehensive parking plan or policy that would also support public transportation, perhaps limiting parking in areas targeted for public transportation, and that prices in these areas would be higher. Previous literature on Curitiba's transportation focuses on the BRT and land use (e.g. type, density). However, there is only the slight mention above of parking. This vagueness paints an incomplete picture of Curitiba's land use and transportation policies, and an incomplete picture of urban transportation and land use planning in general. This

paper narrows the gap of understanding on the interaction of these two aspects of urban planning. The result will be a window into the comprehensiveness of Curitiba's transportation policies, and examples of tools that other cities can use to reduce congestion and air pollution.

This paper will examine the actual outcomes of Curitiba's parking management by employing case studies of specific locations and interviews with citizens and members of the local government. Locations were chosen because they represent different types of development and demographics. As representative samples, one terminal within the CBD was chosen, along with two outer ring terminals, and two mid-route stops (each terminal and mid-route stop are along the same line). The specific sites were chosen based on their level of development, because the goal of determining Curitiba's parking management cannot be achieved in undeveloped areas. In order to show that Curitiba uses parking policies to support the development of its BRT, this paper will document parking supply, demand, pricing, socio-demographic information, and regulation and compare it to the literature reviewed.

Case Studies

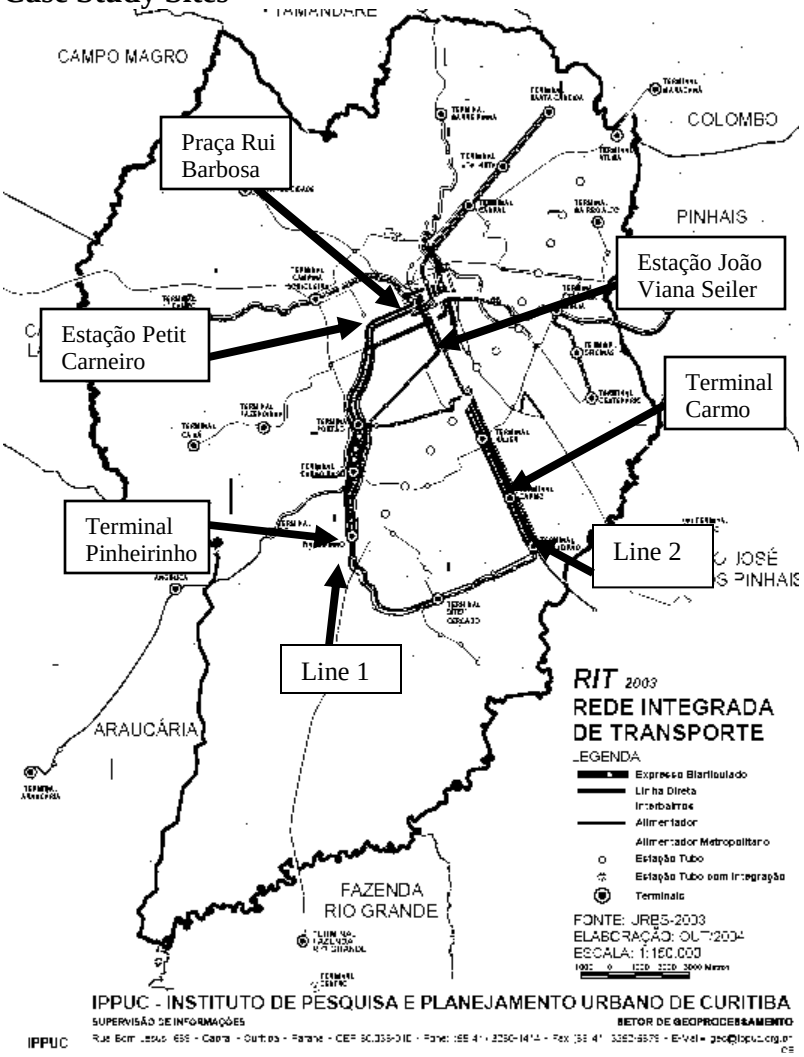
In order to assess the outcomes of Curitiba's parking management system, the area within a 400m (quarter mile) radius around five different stations of the BRT bus system was examined. These sites are shown in Figure 1.

Informally, the two lines along which the study areas lie are simply referred to by their end terminals (Pinheirinho and Boqueirão). In order to avoid confusion, the study uses the labels Line 1 for the Pinheirinho line and Line 2 for the Boqueirão line. Line 1 leads towards the southwest of the CBD through a number of wealthy neighborhoods (Est. Petit Carneiro) to the city's industrial sector (Terminal Pinheirinho). According to data, household incomes decline with distance from the CBD. Terminal Pinheirinho is the final destination for the north-south line transecting the city. Line 1 leads northwards until Praça Rui Barbosa and was planned in order to address high demand along this part of the route. Line 1 is a typical trinary axis.

Line 2, containing Estação João Viana Seiler and Terminal Carmo, is not the typical trinary axis, but rather represents an axis resembling Bogotá's Transmilenio with only one roadway containing three auto lanes on each side of the exclusive bus lanes. The area is not zoned at the same high density, and this line was never considered one of the structural axes, but rather as an afterthought to connect the poor areas with the CBD. It leads past many auto-oriented businesses such as car dealerships and mechanics. Buildings are typically not more than three stories in height and big-box stores with large parking lots are not uncommon. Neighborhood retail is smaller and less frequent.

The terminals are typical; within them, passengers can transfer to different lines without paying an additional fare between the feeder lines, the express routes, and the *Interbairro* circular routes that avoid downtown. This fare integration sets Curitiba apart from most Latin American cities.

FIGURE 1 The Case Study Sites



Case study sites around which data was collected in the Summer of 2005
Source: IPPUC

Study Areas

Praça Rui Barbosa – This downtown station is the main transfer hub in the CBD for four of the five BRT routes and dozens of conventional routes. This is not an integrated fare terminal (with free transfers) because it was created before the integrated fare system existed. As one would expect, there is a high level of mixed uses, including a market, a church, a hospital, residences, pharmacies, schools, etc. Parking around this stop is either private surface lots, underground, or paid on-street. The Praça itself contains a large underground lot. There is also surface parking for employees at certain schools and the hospital.

Estação Petit Carneiro – This stop along Line 1 straddles the border between the Água Verde and Vila Isabel districts. This is a middle- to upper-income area, with high car ownership and median incomes almost three times the city's median. Density is high, but similar to the CBD. Most on-street parking is unregulated, except for a few 15-minute spaces. Next to the station is an athletic and social club for upper income clients with ample off-street parking. There

are also many smaller shops, pharmacies, etc., and most lack their own off-street parking. A couple of private lots exist that provide car-washing service.

Terminal Pinheirinho. – Along Line 1, this is the closest terminal to the Industrial Sector (*Cidade Industrial*), and lies in a lower-income location. Density is low compared with other stops. Most on-street parking is informal and rarely filled to capacity. There is a small parking lot at the terminal, potentially for park and ride customers. Other parking includes a few large retail stores and several smaller stores with parking in front.

Estação João Viana Seiler – Only a few stops outside the CBD on Line 2, this station straddles the Prado Velho and Parolin districts along the BRT axis that is not considered a structural trinary axis (Line 2). Instead, high levels of automobile traffic run alongside the exclusive bus lanes, more resembling the Bogotá style BRT with the BRT between six lanes of roadway. This route is not zoned for the same density as the other four structural axes, and therefore provides an important contrast to Line 1. Nearby is a large, undeveloped plot, a supermarket with over 800 parking spaces, several auto-oriented businesses, and low-density commercial and residential development. On-street parking is free and plentiful, and off-street parking is generally surface parking. Median income is below the city's median, although vehicle ownership rates are much higher.

Terminal Carmo – Carmo lies along the non-trinary axis on Line 2 within the Boqueirão district, which is a lower-income area. Beyond this terminal, the line extends to much of the city's public housing. Automobile ownership rates are average, and all parking, both on-street and off-street, is free. The area surrounding is residential, with neighborhood retail, lunch restaurants, and shopping markets for individual vendors.

Analysis Framework

The factors that affect parking supply and pricing, such as politics and policies, urban form, price, demand and socio-demographic characteristics, are very interrelated. According to the literature, politics and policies are arguably the most important factor, influencing urban form through zoning codes and targeted investments; parking price through prices of on-street spaces and taxes (if any) on off-street spaces; and parking supply through regulation of on-street spaces and off-street supply. If policies encourage or require dense urban form, this will restrict parking supply and raise prices. This will make transit and walking more attractive, thus reducing demand for parking. However, policies that allow or require a high parking supply and promote less dense urban form reduce parking price, leading to less transit use and walking, and a higher demand for parking. Socio-demographic characteristics also play a role, in that higher income and personal vehicle ownership rates also lead to higher parking demand.

Because public policy is arguably the most important factor affecting parking supply and price, this discussion begins with the events leading to Curitiba's adoption of minimum parking requirements, how new parking supply is regulated, and enforcement of on-street parking regulations. Then this paper will explain the existing supply of parking around the five sites, broken down into three categories: on-street (both free and paid), off-street private lots, and off-street private parking for customers and residents. On-street parking spaces are not delineated, therefore supply for each study area was measured by counting either the number of cars parked or, in cases of empty parking, every six paces (according to the author's judgment of the average length for a parking space). Only commercial off-street spaces, which consist of private lots or lots that were used and owned by a specific business were counted. Residential parking was

intentionally avoided because of the interest in parking's affect on mode choice, not on auto ownership. Off-street quantities were either provided by the attendant, owner, or manager of an establishment, or counted. This can lead to issues of unreliability in employees' or owners' perception of their own lot, especially if they provide free parking. Following supply is a short description of parking demand at each of the stations.

A look at demographic statistics includes median income and vehicle ownership rates. Urban form is measured in terms of density, both residential and commercial. Although only commercial parking was counted, residential density and income correlate to land values, which imply the economic strength of an area. Commercial density is important as trip attractors, which should have a stronger influence on commercial parking demand and price than residential density.

Finally, the study compares parking prices. For private parking providers, the prices were normally posted outside or provided by the attendant. For costs of monthly parking, minimum and maximum prices are provided depending on the specific hours the monthly spot is reserved, i.e., only at night, 12 hours a day, 8 hours a day, etc. The author compares Curitiba's median monthly incomes to both monthly parking rates and hourly rates (multiplied by 8 hours, 10 days a month for non-regular drivers) to determine whether it is relatively expensive.

In order to show whether Curitiba's parking management system supports the public transportation system, this paper compares the existing data with previous research that shows that less parking supply equates to more transit riders and less driving, especially in areas with high density and high transit access.

Study Limitations

This paper is not an exhaustive study, but rather meant as an exploratory look at parking management in Curitiba. One limitation of this study is that there is little representation of middle-income areas. This merits further research, and may limit the applicability of the results of this study to the entire city of Curitiba. In addition, off-street parking supply quantities that were provided by an establishment could not be verified for accuracy. Other explanations for quantities and prices of parking supply could include land values, date of development vis-à-vis minimum parking requirements, and bus passenger capacity. This data was not possible to obtain.

RESULTS

Politics and Policies

The story of Curitiba's minimum parking regulations is similar to that in most U.S. cities. Drivers looking for parking were creating congestion. Curitiba held public meetings to demonstrate the need to remove parking vehicles from public roads with minimum parking requirements per land use and on studies done by the IPPUC and the Secretary of Urbanism. These are spelled out in Decree 582 of 1990. With regards to the bus system, this was not planned with the BRT in mind, but rather only in order to reduce congestion caused by parkers searching for a space. Regulation of off-street parking is limited to the minimum requirements for number of spaces and the dimensions thereof in new developments or new businesses. Before being developed or established, the Secretary of Urbanism reviews the plans to ensure accordance with the local land use codes for various requirements. Parking quantity and geometry are thus enforced.

With regards to new private parking lots, there are no laws regulating the price or supply of private parking. There are also no regulations limiting the construction of new private lots or spaces. Few exceptions apply, i.e. streets with no automobile traffic, BRT-only streets and pedestrian malls. Even in the CBD, a building can be torn down and replaced with a parking lot (unless protected under historic regulations). Also in the CBD (as elsewhere), if the land use changes, for example from a single-family home to a restaurant, and the new use requires more parking, this new owner will have to acquire parking nearby in order to operate the new use. These policies contradict previous research (*9* and *5*) that state that parking is intentionally limited in the CBD in order to promote public transportation.

The public supply of paid on-street parking is thoroughly enforced. Individual hours are purchased as tickets either from traffic agents of Urbanisação de Curitiba S.A (URBS) (the semi-private organization that also manages the entire public transportation system), informal vendors and watchpeople, or nearby shops. The driver then displays up to two tickets with the time, date, and license number of the car. On-street parking is diligently enforced by traffic agents who are dispatched to patrol areas, writing the license plate number of each car. The fine is R$53.00 (~$22.00USD) according to the Brazilian National Traffic Code. However, before forcing violators to pay this hefty fine, Curitiba gives them the opportunity to buy a pack of ten tickets for R$7.50 (~$3.13USD) within a specific grace period. Other regulated on-street parking exists for 15 minute parking, handicapped drivers, and retail loading zones. Traffic agents most often enforce other violations based on complaints called into the local Citizen Information and Service hotline. No Parking zones are clearly marked. Agents enforce these violations based on complaints and observations.

Supply

Most on-street parking throughout Curitiba is free, along curbs and along the curbs of the express bus lanes. Paid on-street parking is found mostly in the CBD and is regulated by URBS. The Brazilian National Traffic Code of 1998, charged URBS with most traffic functions, including enforcing parking. URBS can convert free on-street parking to paid at the request of the area, however it rarely does. In areas with high and medium density, private off-street lots provide the only long-term parking option. Many offer amenities such as security (especially at night), washing, and even valet service. Many residential buildings offer parking for their dwellers. Newer large retail stores offer parking for customers as well. In some cases, businesses rent spaces from neighboring private lots. It is noteworthy that there are very few off-street public parking lots, except for BRT terminals with limited parking.

Table 1 shows us that parking supply is very different among the stops, but probably more telling is the ratio of paid parking. Praça Rui Barbosa in the CBD has the highest number of total spaces and most of the spaces are paid. The other four sites have relatively similar supply, showing that the chance of finding free parking increases with distance from the CBD. Parking supply seems to expand with higher prices, rather than limited by high density and transit access.. This points to the actual outcome of Curitiba's parking policy, that there is little, if any regulation limiting parking supply.

TABLE 1 Parking Supply Compared with Median Incomes and Vehicle Ownership

Study Area	District	Total Spaces	% of Spaces Paid	Median Income/mo (R$) - 2000	Median Income/mo ($USD) - 2000	Vehicles per Person (2000)
Curitiba	Curitiba Total	N/A	N/A	R$ 1,392.00	$580.00	0.45
Praça Rui Barbosa	Centro	5,396	84.5%	R$ 2,979.00	$1,241.25	1.07
Est. Petit Carneiro	Água Verde	3,358	16.8%	R$ 4,173.00	$1,738.75	0.68
Est. Petit Carneiro	Vila Isabel			R$ 3,576.00	$1,490.00	0.60
Terminal Pinheirinho	Capão Raso	2,521	2.5%	R$ 1,191.00	$496.25	0.50
Est. João Viana Seiler	Prado Velho	2721	0.0%	R$ 795.00	$331.25	0.73
Est. João Viana Seiler	Parolin			R$ 1,191.00	$496.25	0.70
Terminal Carmo	Boqueirão	2,588	0.0%	R$ 1,392.00	$580.00	0.40

Source for income figures: IPPUC
Source for vehicle ownership rate: Detran (PR), Demographic Census 2000; compiled by IPPUC/Data Bank
Note: Descriptions reflect data on the entire district (*bairro)* in which the stations and terminals lie.
Note: Dollar amounts were calculated using an exchange rate of R$2.40 = $1.00 USD, the approximate exchange rate at the time of data collection.
Note: Est. Petit Carneiro and Est. João Viana Seiler lie on the border of two districts. Therefore information from both districts is shown.

Socio-Demographic Influence - Income and Vehicle Ownership

Personal income plays a large role in parking demand and price. Higher personal income affects vehicle ownership rates, trip length and frequency, and a higher ability to pay the costs of driving. Low income in many areas forces people to live farther from the CBD, where transit service is not as premium. In Curitiba, many low-income bus passengers living in poorer areas would have to wait for longer headways and pay additional fares for transferring from conventional lines if they do not own a vehicle.

The collected parking data only includes commercial parking, but this can be compared with personal income levels by assuming that the target income level of a business is the income level of surrounding residents. Therefore, the assumption is that there will be more parking in areas with higher incomes. In fact, this is what Table 1 reveals. The Centro, Água Verde and Vila Isabel districts have the biggest parking supply and the most paid spaces. This data reinforces Cervero's point that wealthier areas have higher parking demand and consequently supply, despite being situated closer to the CBD. Worth noting, however, is that the poorest four districts also contain a sizable quantity of parking. Therefore other factors such as urban form must play a role.

As Table 1 shows, the two sites with the highest vehicle ownership rates (Praça Rui Barbosa, Est. Petit Carneiro) also have median incomes above the city's. This infers that income influences automobile ownership, although this certainly is not linear. It is also noteworthy that each district except one has a higher vehicle ownership rate than the entire city. Therefore proximity to the BRT lines does not equate to lower vehicle ownership rates in these examples.

Parking Demand and Urban Form - Residential and Commercial Density

Parking demand was qualitatively examined (Table 2): along Line 1 parking demand decreases with lower density. Around Est. Petit Carneiro, on-street parking was normally available, ranging

from half to three quarters filled, and mostly filled in the surrounding neighborhoods. Around Terminal Pinheirinho, Est. João Viana Seiler, and Terminal Carmo on-street parking was never filled, and empty spaces could be seen for blocks along the bus lanes and in the neighborhoods. This follows Cervero's point that poorer areas have lower parking demand.

It is expected that the highest priced parking in Curitiba would be downtown. However, with the goal from the first *Plano Diretor* of 1966 of distributing the commercial and residential activity along the structural axes, one might expect the price and supply to be somewhat uniform along the trinary axis. However, as Table 2 shows, high residential density correlates with high commercial parking supply and demand, most likely because both high density and high parking demand (and consequently supply) are the result of high land values.

TABLE 2 Demographic and Commercial Density and Total Number of Spaces

Study Area	District	On-Street Parking Demand	Total Spaces	Population (2000)	Demographic Density per KM^2 (2000)	Number of Comm. Firms	Parking Spaces per Comm. Firm
Curitiba	Curitiba Total			1,619,453	36.73	120,375	
Praça Rui Barbosa	Centro	High	5,396	31,864	98.95	17,489	0.31
Est. Petit Carneiro	Água Verde	Medium	3,358	49,867	104.67	4,769	0.64
Est. Petit Carneiro	Vila Isabel			10,949	90.41	987	
Terminal Pinheirinho	Capão Raso	Low	2,521	34,618	67.9	2,302	0.89
Est. João Viana Seiler	Prado Velho			6,911	29.15	1,093	
Est. João Viana Seiler	Parolin	Low	2,588	12,008	53.18	1,295	2.00
Terminal Carmo	Boqueirão	Low	2,721	69,013	46.27	6,157	0.44

Source: IPPUC and Municipal Secretary of Finance (SMF)/ Curitiba S.A
Note: Demographic descriptions reflect data on the entire district (*bairro)* in which the stations and terminals lie.
Note: On-street parking demand was qualitatively examined by the author: high demand indicates that spaces were difficult to find; medium demand indicates that spaces were normally available, ranging from half to three quarters filled; and low demand indicates that on-street parking is little used, if at all.
Note: Est. Petit Carneiro and Est. João Viana Seiler lie on the border of two districts. Therefore information from both districts is shown. Parking Spaces per Commercial Firm for these stations is the number of spaces around each station per the average of the two districts' number of firms.

In addition to looking at populations, the quantity economic activities can also be examined. Table 2 gives us the number of economic activities in each district. While it is understood that a corner snack shop will require far fewer parking spaces than a bank headquarters, these numbers give us an indication of the amount of activity in each district. As is to be expected, the CBD has the most economic activity, and controlled for the number of commercial firms, the CBD has the lowest ratio of parking spaces except for Boqueirão. Boqueirão has more economic activity than Água Verde, but fewer parking spaces and no paid spaces. This could be a result of businesses tailored to pedestrians because of low median income and the lower-than-average vehicle ownership rate.

Price

Despite the abundance of free parking in many areas, drivers still choose to pay. In central locations such as malls, parking is charged per hour. Many off-street and on-street spaces also have informal "watchpeople" who guard the vehicles, sell hourly parking tickets, and even wash cars. Since the price of the "watchpeople" is informal and usually dependant on a tip, the impact was not recorded. On-street parking costs R$0.75 (~$0.31 USD) per hour, however many private vendors add a price, which can in some cases double the cost. Off-street private lots that charge have various prices based on presence of a roof, the quality of the establishment, and the services they provide. Downtown, hourly prices range from about $R2.00 to about R$6.00 ($0.83-$2.50 USD) per hour depending on the provider. Also, prices vary depending on the duration of the stay. Finally, monthly prices vary based on how many hours a day the parker wishes, for example 8 hours a day vs. 12 hours a day vs. nightly.

Price is a useful tool to analyze the quantity of parking vis-à-vis the demand. Table 3 shows that the price of parking is highest in the CBD, which is expected because of high land values. In addition, a perhaps unintended consequence is that these higher prices also encourage transit and other modes. With distance from the CBD, price decreases as expected. Two phenomena are worth mentioning. First, only parking along Line 1 (the trinary axis) is priced, not along Line 2 (the atypical axis), most likely due to the automobile orientation of Line 2 despite the BRT system. Second, although pricing decreases along Line 1 relative to distance from the CBD, the average hourly price only diminishes by a maximum of 33 percent. More telling is the decrease in ratio of paid spaces from 84.5 percent around Praça Rui Barbosa to 2.5 percent around Terminal Pinheirinho (Table 1).

TABLE 3 Parking Prices

Study Area	Average Hourly Price	Average Price for 8 Hours/ Per Day	Daily Parking as % of Median Income	Average Monthly Minimum / Maximum Price	Monthly Minimum Parking as % of Median Income
Praça Rui Barbosa	R$ 2.97 ($1.24 USD)	R$ 10.30 ($4.29 USD)	7.40%	R$ 84.24 / 144.70 ($35.10 / 60.29 USD)	6.05 / 10.40%
Est. Petit Carneiro	R$ 2.28 ($0.95 USD)	R$ 9.51 ($3.96 USD)	6.83%	R$ 54.06 / 89.40 ($22.52 / 37.25 USD)	3.88 / 6.42%
Terminal Pinheirinho	R$ 2.00 ($0.83 USD)	R$ 8.65 ($3.60 USD)	6.21%	N/A / R$ 90.32 ($37.63 USD)	N/A / 6.49%
Est. João Viana Seiler	N/A	N/A	N/A	N/A	N/A
Terminal Carmo	N/A	N/A	N/A	N/A	N/A

Note: Average prices were calculated by multiplying the single hourly price at each paid parking provider by the number of spaces, and then divided by the total number of spaces.
Note: Daily parking as % of median income was calculated based on the price of parking for 8 hours, ten days a week for a regular parker, but not a parker regular enough to purchase a monthly space.
Note: The median income of Curitiba is R$ 1,392.00 ($580.00). Source: IPPUC.
Note: Dollar amounts were calculated using an exchange rate of R$2.40 = $1.00 USD, the approximate exchange rate at the time of data collection.

Also, daily parking (10 days/month) as a share of median income for a regular (but not daily) parker is highest in the CBD. Since it comprises 7-8 percent of median income, the price should dissuade the median Curitibano from driving regularly to downtown and parking all day. Two possible results should occur: either alternative modes will be more popular or drivers will choose other locations with free or less expensive parking. Monthly rates show a similar result, although assuming that monthly parkers are employees, they have little flexibility in work location.

CONCLUSION AND DISCUSSION

Curitiba, Brazil, is world-renown for its integration of land use and transportation planning. Many policies have supported the BRT system, including the trinary axis, minimum densities, and the focus on the pedestrian environment. Researchers and journalists have documented these policies and their outcomes, but the issue of parking has remained surprisingly hidden. Parking provides access to destinations for drivers, but it also carries many negative externalities. The most pertinent outcome to Curitiba is that large parking supplies caused by minimum parking requirements result in free or low-cost parking which, theoretically, promotes automobile use. This counters the intentions of the land use policies that aim to promote public transportation.

The goal of this paper is to extend the literature of Curitiba's land use and transportation planning to cover parking because policy may be one of the most influential factors in parking supply and price. In 1990, Curitiba established the Decree 582 of 1990, setting minimum parking requirements (even along the BRT routes and in the CBD) in the same spirit as many U.S. communities in the mid-20th century. However, after half a century, this has hurt public transportation ridership and increased driving in the U.S., leading to other problems such as congestion and air pollution.

Looking at five case studies along two BRT lines (a trinary axis and an axis with low density), parking price varies slightly along the trinary axis and is free along the low-density axis. The real indicator of supply versus demand, however, is the proportion of paid versus free parking. Not surprisingly, the highest rate of paid parking is in the CBD (85 percent), but the next highest rate is only 17 percent. This suggests that private parking operators are increasing the supply relative to demand. Cervero states that parking supply and price are highly correlated with income. This is true, however residential density also plays a role. Commercial density, on the other hand, is ambiguous: in the CBD, parking supply, demand, and prices are high, but around Boqueirão, with the second highest commercial density, parking supply and demand are low and parking is free. This is most likely due to the fact that in poorer areas, despite average vehicle ownership rates, most commercial activity is pedestrian based.

Two major factors may prolong the popularity of Curitiba's minimum parking requirements until congestion and/or pollution become unbearable. First, with the immigration of poor, rural migrants, Curitiba's bus ridership will remain at capacity for a very long time, so there is no push to attract more riders. In fact, without increased investments in capacity for transit, bicycles, etc., personal vehicles will have to absorb future increases in travel demand. If Curitiba's future strategy is to encourage personal vehicle travel, the minimum parking requriements will help promote this. However, this is contrary to the pro-transit policies of the model BRT city.

Second, with one car for every two persons, and this rate only increasing, automobile owners constitute an ever-growing political force, regardless of the intentions of the city to promote public transportation. Minimum parking requirements are only one sign of these changing politics. The contemporary mayor, Carlos Alberto Richa, was elected because he promised, among other things, to reduce congestion by converting two-way streets into one-way streets to form a binary ring around the CBD. Whether or not Curitiba will make similar decisions that many American cities have made which have led to an over-reliance on the private automobile remains to be seen.

The lesson is that Curitiba has many good things to teach the world regarding transit, land use, and BRT. Density requirements, land banking, a focus on inexpensive techniques and innovations are all examples of this. However, this study demonstrates that parking policy has developed apart from transit policy and promotion, and is not coordinated with goals of improving bus ridership.

Assuming that environmental sustainability and roadway efficiency are priorities of a transportation and land use policy, then a model city for parking management would encourage alternative modes such as transit, bicycles and walking. In order to reduce congestion and air pollution from transportation, cities must, among other things, reduce driving. Despite better fuel efficiency, air pollution from vehicles has not decreased. In addition to air pollution, a vehicle consumes space on the road and in parking lots, which will lead to congestion once capacities are reached. BRT and other transit improvements are essential to providing a feasible alternative to driving, but the carrot is always paired best with the stick. In other words, in addition to incentives to use public transportation, a valuable tool to reduce vehicle mode share is parking management. Reducing supply through parking maximums in the zoning code is effective if the proper governmental structures are in place; and policies that limit parking often receive a surprising amount of support from developers who are willing to build less parking as long as other developers will too. In addition, proper management of on-street spaces, including enforcement and pricing to prevent spillover parking problems, is a key part of these strategies.

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