ITDP

People Near Transit:

Improving Accessibility and Rapid Transit Coverage in Large Cities

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Summary

Overview

People Near Rapid Transit (PNT) measures the number of residents in a city who live within a short walking distance (1 km) of high-quality rapid transit. This is a good way to estimate accessibility and rapid transit coverage in large cities. It is also a high-level proxy for the integration of land use and transport, and the fundamental first step toward creating inclusive transit-oriented development (TOD)—compact, higher-density, mixed-use, walkable development centered around transit stations. PNT is also the proposed indicator for the Sustainable Development Goal Target 11.2, helping to link to the SDG process and bolster action toward achieving these goals. Its simplicity and reproducibility mean the metric allows cities around the world to be quickly compared, even when data is difficult to obtain. Furthermore, visualizations of this data can highlight where new transit might be built to serve the most residents and where infill development, the development of land within an already built-up area, should be targeted to best utilize existing transit infrastructure. Finally, PNT allow cities to measure their progress over time, as new transit is built and new residents are added to the population. ITDP has assessed a number of cities around the world to compare their PNTs to one another and over time. By using PNT to understand accessibility and the integration of land use and transportation, we are able to learn what we need to do to improve our cities, making them more accessible and inclusive.

Low-density car-oriented development, often known as “sprawl,” has been the predominant urban form for cities in the past century, and the results have been disastrous for both people and the planet. This is seen in PNT, especially in metropolitan areas.

Urban population is forecasted to grow by 63% by 2050, and if trends in urban development are followed, then the total area covered by cities will triple, threatening the planet if left unguided. With the addition of 2.5 billion people, cities will have to grow. The question is how.

We need to come together to fight sprawl and create inclusive, compact, people-oriented cities. We need to disrupt urban development as we know it and create a new paradigm for growth for our cities.

The development of the PNT indicator has yielded some meaningful findings about the intersection of urban growth and transit accessibility. One of the clearest was the difference in transit accessibility between cities and metropolitan areas. Compared to cities (within municipal boundaries), metropolitan areas as a whole show a significant drop in "accessibility"—on average by half—indicating that urban expansion is occurring faster than transit investment and perhaps in ways that undermine sustainable and equitable growth. This suggests that the urban development paradigm of expansion needs to be rethought.

Introduction

Why a New Metric

For a long time, an emphasis was placed on "mobility," the ability to move freely, when discussing the role transportation plays in people's lives. The ability to move freely is only valuable if that person can reach important destinations using their mobility, though. Therefore, the transportation goal that cities should be focused on is really "access" or "proximity"—residents' ability to reach the places (work, school, shopping, etc.) they need to go to satisfy their everyday needs.

Access via rapid transit is especially important, since rapid transit is the most efficient way to transport large numbers of people around a metropolitan area. Furthermore, in addition to increasing congestion and traffic injuries and deaths, automobile-based mobility has been a leading contributor to climate change and pollution, all of which threaten the health and prosperity of city residents around the world. It is critical for cities to enable access for residents that avoids use of single-occupancy vehicles. Walking, cycling, ride-sharing, and taxis all are part of the transportation network that provides access for those without a car, and a robust public transit system with rapid transit corridors forms the backbone of that network.

For low-income residents, access to transit can mean new opportunities for jobs and less time spent commuting. Ensuring that everyone has access to transit is a critical part of making a city equitable and sustainable. ITDP is developing new and different ways to measure progress in expanding access in order to evaluate how cities around the world provide their residents with the access they require to live prosperous lives.

The concept of "accessibility" can be defined and measured in a number of different ways. Access to employment is often used as one of the most significant indicators of both economic development and effective transit. Connecting people with employment opportunities and services can be considered one of the core goals of a regional transit system. The main difficulty with this approach is acquiring location-based employment data. While accurate data is often available in high-income countries, it is much more difficult to find in low- and middle-income countries. Since the purpose of this study was to analyze transit accessibility in a variety of cities around world, we adopted the most inclusive approach possible.

This study examines a building block of overall transit accessibility: how close rapid transit is to the residents of a city. Residents of large cities need to have rapid transit options located close to where they live so they can access opportunities without using a car. Measuring the number of residents in a city or metropolitan area who are covered by rapid transit is an important barometer for the efficacy and equity of a region's transportation infrastructure. To account for differences in city size, PNT has been calculated as "percent of population living near rapid transit."

Calculating PNT can help find where city residents are served by public transit that is reliable, efficient, and fast. Thus, the decision to focus on rapid transit and not all mass transit was made because rapid transit can be consistently relied on by passengers to access destinations in a way that non-rapid service cannot. Rapid transit is essentially mid- to high-capacity transit that runs in a dedicated right-of-way and thus ensures a faster trip because it is not stuck in congestion. For example, a local bus that runs every 30 minutes in mixed traffic cannot be considered an effective means of accessing large sections of a big city. Therefore, creating rules for what is considered "rapid transit" is necessary to ensure that residents counted as proximate to rapid transit can truly enjoy the benefits that enhanced mobility via transit can provide. Access to rapid transit (defined in the next section) is critical, because slow and inefficient transit options are less competitive with other transport modes, particularly in large cities where distances are greater. This is amplified in cities in low- and middle-income countries, where the lack of reliable transit either greatly reduces economic opportunities or pushes residents toward less-sustainable modes, such as single-occupancy vehicles, as soon as they are able to afford them. As cities grow quickly in size and wealth, the commuting patterns that their residents develop today will define them for decades to come.

PNT can be an important indicator for urban policy-makers, as it is an effective proxy for how well a city provides its residents with rapid transit, thus allowing both policy-makers and residents to track the progress of their cities and urban areas.

Methodology

For the purposes of this study, we only evaluated proximity to rapid transit. ITDP defines rapid transit as any Bus Rapid Transit (BRT), light Rail (LRT), or metro line. BRT and LRT corridors must meet the BRT Basics, as defined in the BRT Standard. Metro corridors must also meet the following qualifications:

- Completely grade-separated (only applies to rail)
- Off-board fare purchase
- Operates entirely within a single built-up urban area with regular station spacing (<5km between stations, excluding geographic barriers to development, such as mountains and bodies of water)
- Operates at headways of less than 20 minutes in both directions from at least 6 a.m. to 10 p.m.
- Cars are designed to prioritize capacity over provision of seating

For metro and heavy rail, we needed to set some parameters that would exclude commuter rail that does not allow convenient intra-city travel throughout the day but instead is only useful to commuters in peak hours. The station spacing of <5 kilometers was chosen to ensure that all lines are serving a continuously urban area. Ideally, station spacing should be on average about 500 meters between stations in urban cores and less than 1.5 kilometers outside urban cores. We wanted to be inclusive to some commuter rails systems that had a greater function than just connecting suburbs to the city, so we expanded the station spacing, although it is not in line with the ideal conditions for urban transit.

To measure the percentage of people in a city who live proximate to transit, we first had to decide what a "proximate" distance is. We decided on 1 kilometer, which is generally equivalent to a 10- to 15-minute walk, depending on factors like elevation, traffic, and ease of access. The assumption, backed by research[1 2], is that people are more willing to walk to rapid transit where wait times are reduced and travel speed is greater. The conditions for walking, however, play a great role—a high correlation exists between the walking environment and access to transit. For simplicity, we created a kilometer buffer around each transit stop (as the crow flies). These buffers serve as "transit sheds." People who live within the transit shed are considered to be proximate to transit. Since walking distance is longer than the straight-line path to a station, the methodology overestimates the number of people within 1 kilometer walk of transit.

One of the most critical parts of this analysis is obtaining population data that is sufficiently disaggregated. Population data at the census tract/neighborhood level is needed at the very least to calculate the approximate number of residents within a kilometer of a rapid transit stop. If this data can be found at a smaller scale (i.e., block group), then the analysis will be even more robust. While this sort of data is easily attainable in most OECD nations through each country's respective census bureau, this is not necessarily the case in the low- and middle-income countries, where it can take additional effort to find disaggregated population data. In China, for example, we have compiled our data using Worldpop, which uses spatial imagery to estimate population data.

[1] TRB—Transportation Research Board, 2003. Transit Capacity and Quality of Service Manual, 2nd Ed.

[2] Lachapelle, U., Noland, R.B., 2012. Does the commute mode affect the frequency of walking behavior? The public transit link. *Transp. Policy* 21, 26–36. https://www.researchgate.net/publication/306091069_New_light_rail_transit_and_active_travel_A_longitudinal_study

Scope

It should be noted that rapid transit is not the only means of effective public transit. Frequent bus routes can serve large numbers of people on high-ridership corridors. In addition, not all rapid transit included in the definition should be considered a model of best practice. Some transit may provide rapid service but deliver it at a low service quality.

Also, the use of a 1 km buffer does not allow consideration of the topography, urban barriers, and specificities of the mesh of streets; therefore the actual distance and time can be greater than 1 km and the range of 10 to 15 minutes. The method of calculation considers that the population of each census tract is distributed evenly in its area (population density is constant) and accounts for demographic counts only at 10-year intervals, making the assessment of progress more difficult in smaller time intervals.

Given these factors, PNT can be used to provide important information about a city's transit, but it should be used in combination with other indicators when planning and assessing a city's transportation system and urban growth.

Results

In our preliminary study, we analyzed 25 different urban areas, 12 in OECD countries and 13 in non-OECD countries. Where possible, we attempted to calculate PNT for both the city (defined by municipal boundaries) and the metropolitan areas. Metropolitan areas are often defined differently depending on national or regional standards.

The rationale for analyzing cities in OECD nations separately from cities in the developing world is based upon the concept of comparing like to like. Given that the constraints on building rapid transit are quite different in the developing world than they are in OECD nations, it seemed unfair to directly compare, for example, Paris to Jakarta, given the inherent advantages that Paris receives from its position as one of the world's most affluent capitals and its historical focus on rapid transit implementation and transit-oriented growth.

Table 1. PNT in OECD Nations

Urban Area	Country	Total Population (millions)	Rapid Transit Type	Population Within 1km of Transit Stations	Percent of Population Near Rapid Transit (PNT)	Weighted Density (Residents/ km2)
Paris (City)	France	2,239,837	Metro + Tram + Suburban Rail	2,239,837	100%	29,732
Paris (Metro)	France	12,101,942	Metro + Tram + Suburban Rail	6,002,920	50%	10,474
Barcelona (City)	Spain	1,600,055	Metro + LRT	1,586,914	99%	45,161
Barcelona (Metro)	Spain	3,202,610	Metro + LRT	2,418,374	76%	38,372
Madrid (City)	Spain	3,186,620	Metro + LRT	2,930,851	92%	33,079
Madrid (Metro)	Spain	5,529,090	Metro + LRT	4,215,327	76%	29,826
London (Inner City)	United Kingdom	3,231,901	Metro + LRT + Suburban Rail	2,929,471	91%	18,636
London (Metro)	United Kingdom	10,013,257	Metro + LRT + Suburban Rail	6,130,704	61%	11,213
Rotterdam (City)	Netherlands	611,211	Metro + LRT	513,235	84%	8,735
Rotterdam (Metro)	Netherlands	1,225,154	Metro + LRT	670,130	55%	5,582
New York (City)	USA	8,354,889	Metro	6,414,768	77%	28,271
New York (Metro)	USA	19,865,045	Metro + LRT	6,913,000	35%	13,976
Boston (City)	USA	646,805	Metro + LRT	409,838	63%	11,532
Boston (Metro)	USA	4,650,726	Metro + LRT	714,506	15%	5,239
Washington, D.C. (City)	USA	633,736	Metro	361,391	57%	8,353
Washington D.C. (Metro)	USA	5,863,608	Metro	719,961	12%	3,159
Chicago (City)	USA	2,911,782	Metro	1,175,360	40%	8,517
Chicago (Metro)	USA	9,516,448	Metro	1,346,733	14%	2,606
Los Angeles (City)	USA	3,860,183	Metro + LRT + BRT	936,689	24%	7,446
Los Angeles (Metro)	USA	13,060,534	Metro + LRT + BRT	1,403,439	11%	5,413
San Francisco (City)	USA	829,072	Metro + LRT	337,064	41%	12,570
San Francisco (Metro)	USA	4,466,251	Metro + LRT	704,255	16%	5,321
Vancouver (City)	Canada	603,502	Metro	239,118	40%	8,018
Vancouver (Metro)	Canada	2,313,328	Metro	445,583	19%	4,482
Seoul (City)	South Korea	9,794,304	Metro + BRT	8,091,085	83%	24,826
Seoul (Metro)	South Korea	25,122,742	Metro + BRT	11,313,657	45%	14,845

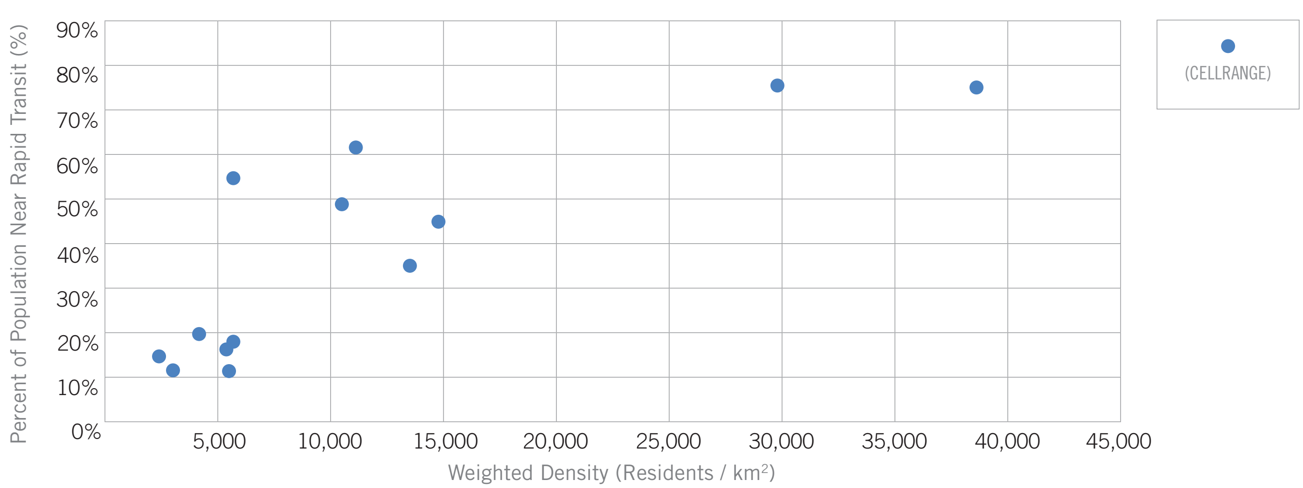
Table 2. PNT in Non-OECD Nations

Urban Area	Country	Total Population (millions)	Rapid Transit Type	Population Within 1km of Transit Stations	Percent of Population Near Rapid Transit (PNT)	Weighted Density (Residents/km2)
Rio de Janeiro (City)	Brazil	6,283,486	Rail + LRT + BRT	2,948,874	47%	30,496
Rio de Janeiro (Metro)	Brazil	11,894,423	Rail + LRT + BRT	3,348,872	28%	21,959
Mexico City (City)	Mexico	8,810,393	Metro + LRT + BRT	4,273,578	47%	18,253
Mexico City (Metro)	Mexico	19,132,979	Metro + LRT + BRT	4,795,820	31%	16,358
Jakarta (City)	Indonesia	9,991,788	BRT	4,410,442	44%	24,227
Jakarta (Metro)	Indonesia	28,019,545	BRT	4,410,442	16%	11,959
Chennai (City)	India	6,227,000	Metro	3,449,775	55%	29,055
Chennai (Metro)	India	8,653,521	Metro	3,449,775	40%	25,828
Beijing (Urban Core)	China	15,913,792	Metro + BRT	9,513,580	60%	19,538
Beijing (Municipality)	China	23,678,827	Metro + BRT	10,831,850	46%	14,440
Belo Horizonte (City)	Brazil	2,367,229	Metro + BRT	652,157	28%	15,326
Belo Horizonte (Metro)	Brazil	4,860,906	Metro + BRT	672,121	14%	11,436
Guangzhou (City)	China	12,740,270	Metro + BRT	4,913,487	39%	13,841
Guangzhou-Foshan Area	China	19,578,348	Metro + BRT	5,356,088	27%	11,050
Manila (City)	Philippines	1,636,786	Metro	694,830	46%	114,642
Manila (Metro)	Philippines	10,447,343	Metro	2,396,036	23%	83,794
Sao Paulo (City)	Brazil	11,209,673	Rail + BRT	2,792,273	25%	35,721
Sao Paulo (Metro)	Brazil	19,601,268	Rail + BRT	3,741,588	19%	29,244
Brasilia (District)	Brazil	2,556,511	Metro + BRT	441,670	17%	12,158
Brasilia (Metro)	Brazil	3,703,351	Metro + BRT	441,670	12%	9,777
Quito (City)	Ecuador	1,777,258	BRT	734,619	41%	7,390
Quito (Metro)	Ecuador	2,653,330	BRT	734,619	28%	6,043
Buenos Aires (City)	Argentina	2,758,512	Metro + LRT + BRT	1,786,388	65%	17,451
Buenos Aires (Metro)	Argentina	12,675,227	Metro + LRT + BRT	1,838,385	15%	7,621
Johannesburg (City)	South Africa	957,443	BRT	238,184	25%	12,621
Johannesburg (Metro)	South Africa	4,434,828	BRT	405,546	9%	8,396

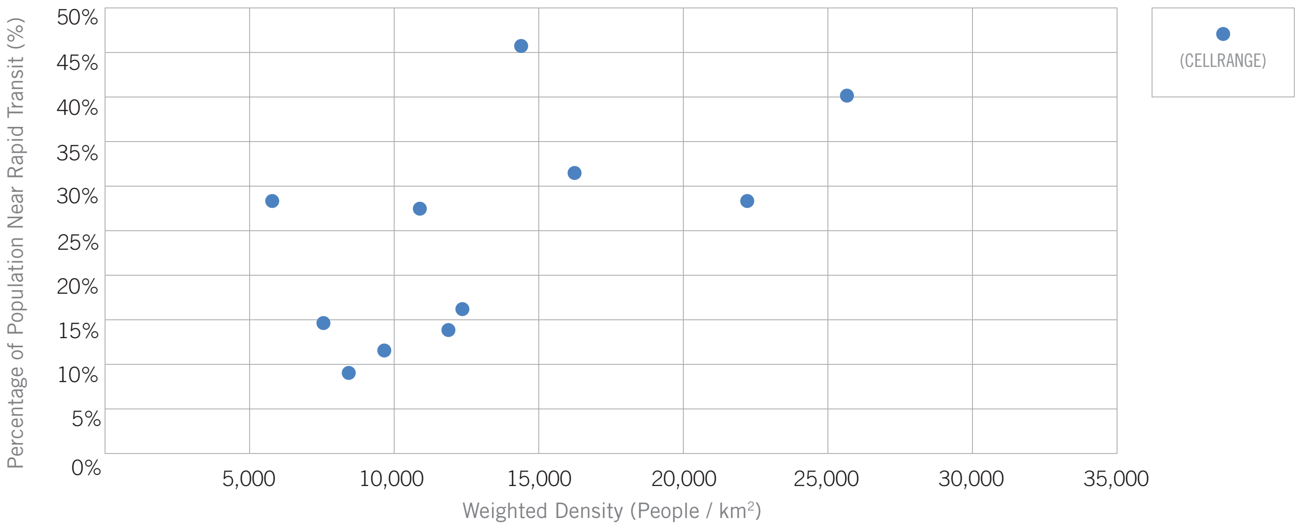
Analysis and applications

A few noticeable trends stand out on initial examination of these results. The importance of population density to these numbers is quite apparent. In general, cities with higher population density tend to have higher PNT percentages. While the trend is not completely linear, the effect of density is especially notable at the extremes. For the purposes of this study, we used population-weighted density. Traditional population density (total population/total area) can sometimes be misleading due to variable municipal areas as well as parkland and other sparsely populated areas. Population-weighted density, however, shows the average density at which a resident of the city lives. In the high-income countries, there is a clear correlation between population-weighted density and PNT, as the best three cities in terms of PNT (Paris, Barcelona, New York) all have a weighted density above 25,000 people/km². Rotterdam (city), though, shows that you can reach a high PNT with a comparatively low density. Paris has the highest PNT score of any city in this report while not having the highest weighted density. Barcelona and Madrid, both the city and metro regions, beat Paris in terms of density, but had lower PNT. Paris' population density is similar to New York City and the Madrid metro region, but while those areas had a PNT of around 75%, Paris sits at 100%. Cities with higher population density can more efficiently serve their residents with rapid transit, as fewer kilometers of infrastructure are needed to serve the same population.

PNT vs. Weighted Density in OECD Metros



PNT vs. Weighted Density in Non-OECD Metros



A similar trend can be ascertained in cities in low- and middle-income countries, although it is less linear than in developing cities. Brasilia, the least-dense city of the group, scores lowest in PNT. However, there are outlier cities like Manila, which is by far the densest city and metro area in the group but has a PNT that only falls in the middle of the pack. São Paulo is also an outlier, in that it has a high weighted density with a low PNT, showing that high population density does not automatically translate to commensurate PNT. This underscores the importance of population density and concentrating population in cities that are well served by transit.

Lower-density cities must build more kilometers of transit to provide the same level of transit access as dense cities. The two Chinese cities in this study, Guangzhou-Foshan and Beijing, both have some of the highest absolute numbers of residents within 1 km of rapid transit but still lag behind some smaller developing-world cities with less-robust transit systems in terms of PNT percentage, meaning that the city is not accessible to a larger percentage of the whole population. If these cities were denser, they might be able to achieve high PNT without as many kilometers of metro and BRT.

Across the board, the PNT for metropolitan areas as a whole lags behind the PNT for core cities. This is in line with expectations, as almost all rapid transit systems in major cities are heavily concentrated in the city core. However, the results from the PNT analysis show that in most metropolitan areas, more people live outside the city limits than within them, and these people are, in general, not able to access opportunities by rapid transit nearly as well as city residents can. Moreover, urban growth tends to happen outside the city centers, where there is lower access to transit. Unless more transit investment is made in the metropolitan regions and growth is concentrated around existing transit, PNT and accessibility are likely to decrease. These findings highlight the potential pitfalls of the existing paradigm of urban expansion, which has been car-centric sprawl.

In developed nations, the disparity between PNT in cities and metropolitan areas tends to be higher than in developing countries, with the exception of some of the most transit-accessible areas (Barcelona, Madrid, etc.). Paris's PNT drops about 50% when looking at the metro region. The majority of cities see an average of a 50% reduction in PNT from city to metro region. Washington, D.C., and Boston, however, have PNT reductions of 75% or more when going from the city to the region. This is another area where population density is heavily linked with PNT. Many of the metropolitan areas in developing countries have population densities that are quite low (<10,000/ km² in weighted density) compared to their core cities, indicating that more recent development has largely been lower-density and oriented toward car travel. Also, for OECD countries in the sample, the range between the countries was greater than the range in non-OCED countries.

PNT vs. Weighted Density in Non-OECD Metros

	City		Metro	
	Average PNT	Range Between Highest and Lowest Values	Average PNT	Range Between Highest and Lowest Values
OECD	73%	60	40%	64
Non-OECD	43%	40	24%	37

Although the disparity between metropolitan areas and cities in terms of PNT tends not to be as pronounced in the developing world, it is still quite significant. On average, the difference between the city and metro region was about 40%, and as suburbanization increases in these areas, the gulf could easily widen. Even the densest metropolitan areas in the developing world see significant drop-offs outside their core cities. The one metropolitan area in the developing world that shows a high disparity between metropolitan area PNT and city PNT is Buenos Aires, which is the sole metropolitan area studied in the developing world with a weighted density under 10,000 people/km². PNT fell by over 75% between the city and the metro region. No matter how extensive a transit network is, serving populations living at lower densities will be extremely difficult. São Paulo had the least difference (20%) between the PNT for the city versus the metro region for all cities in this cohort except Madrid.

Madrid and Barcelona seem to be the clear best practices, as they both have high PNTs and low differences between city and metro regions. Beijing emerges as the best-performing from the non-OECD countries, with both a relatively high PNT and low difference between the city and metro. While Paris and Buenos Aires have the highest PNT for each region, they both experience significant drops in PNT when looking at the metro region: 48% and 78% respectively.

Figure 1. Transit Accessibility and Population Density in Manila Bay

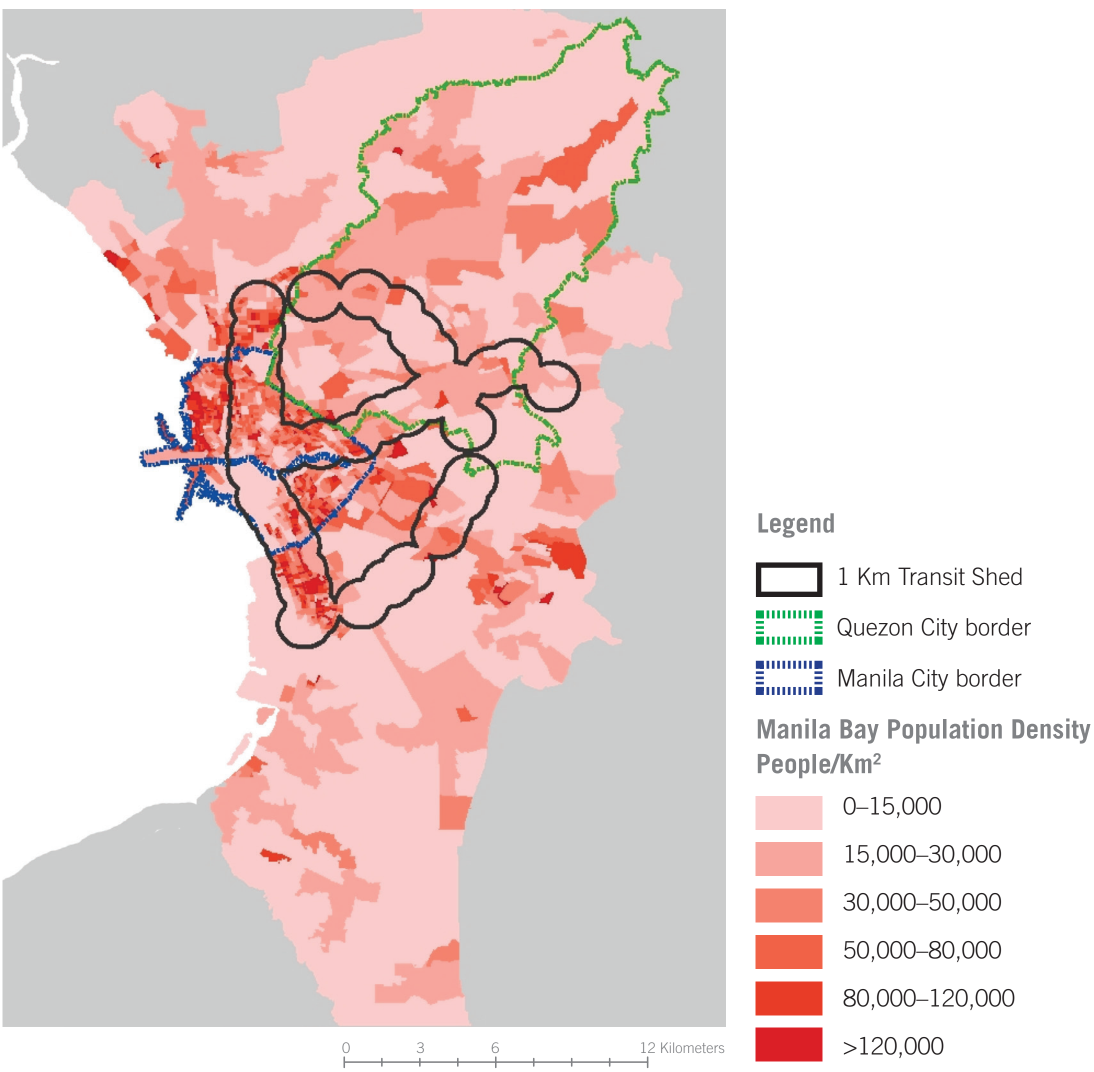


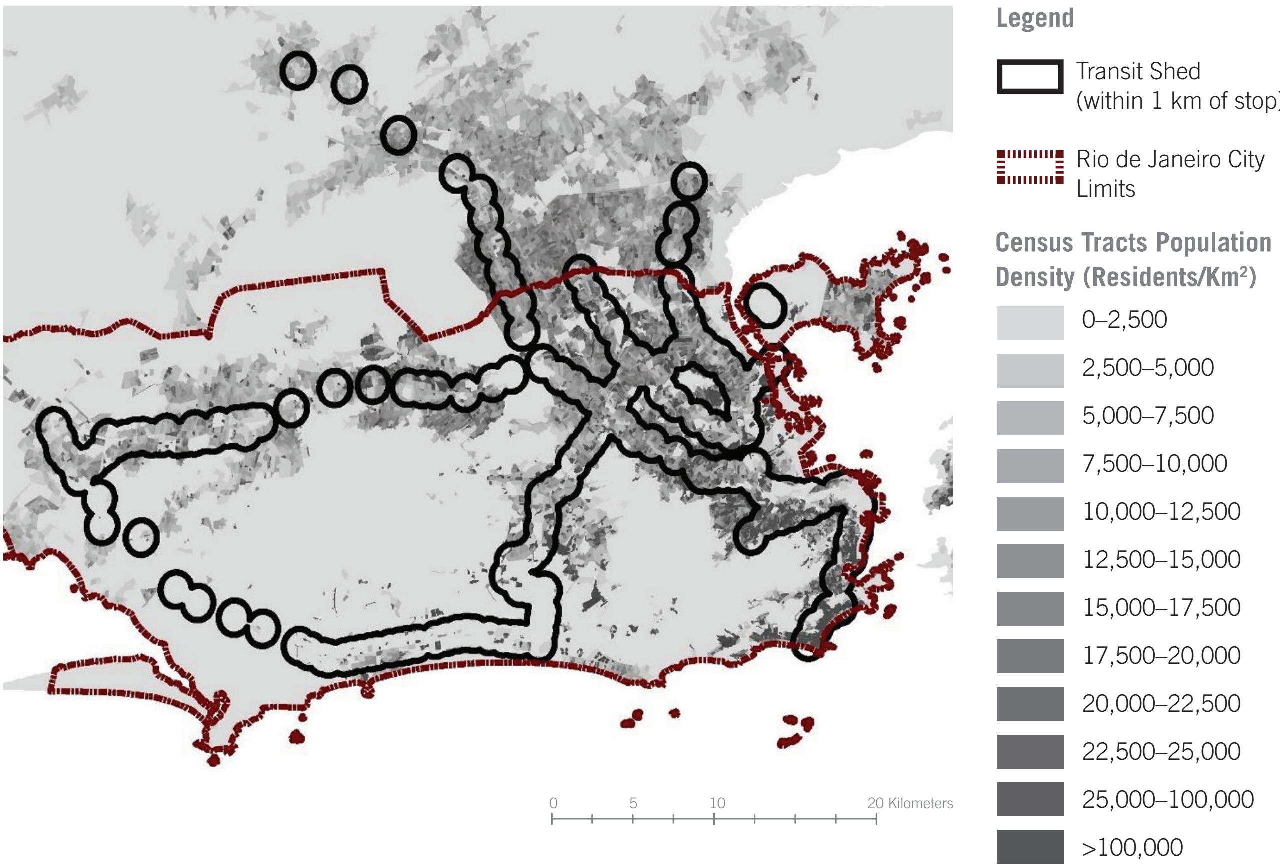
Table 3. PNT in the Manila Metropolitan Area

Urban Area	Country	Total Population	Rapid Transit Type	Population Within 1km of Transit Stations	Percent of Population Near Rapid Transit (PNT)	Population Density (Residents / Km^2)	Weighted Density
Manila (City)	Philippines	1,636,786	Metro	694,830	43%	44,634	114,642
Quezon City	Philippines	2,720,991	Metro	524,431	19%	18,395	34,061
Manila (Metro)	Philippines	10,447,343	Metro	2,396,036	23%	18,738	83,794

Of all the metropolitan areas surveyed in this study, the Manila area has the highest population density by far. Despite its high population density, though, Manila's metropolitan PNT isn't especially high, mainly because the rapid transit system (consisting of mostly elevated rail) isn't very extensive for an area of Manila's size. The City of Manila has a PNT that is relatively high for a developing-world city, in large part due to the city's relatively small land area and high population concentration. What makes the Manila area an interesting case is that the City of Manila is no longer even the most populous city in the metropolitan area. The neighboring city of Quezon City eclipsed Manila in population in 1995, and now has over a million more residents than Manila. Since 1960, Manila has only grown by about 60%, whereas Quezon City has absolutely boomed, growing by 630% during the same time. While Quezon City is still quite dense by most standards, it is notably much less dense than the City of Manila. While Quezon City is served by Manila's transit system, its larger municipal area and lower density make it more difficult to serve with transit compared to Manila. Quezon City illustrates some of the challenges that rapid urban expansion can pose for ensuring access to rapid transit for urban residents. It is important to note that Manila's high density is mainly due to the large number of informal settlements and slums within its boundaries, which suffer from overcrowding. No city should aim to be as dense as Manila. The main point is that lower-density development of any form is generally harder to serve with transit. High PNT isn't caused by high population density, but lower density makes it harder to reach a high PNT.

One of the most exciting potential applications of this data is using the maps created as part of this analysis. These maps can be used to highlight the areas of cities that stand to benefit the most from better rapid transit. For example, the maps show dense areas of a city that are not currently served by rapid transit, where new transit would serve

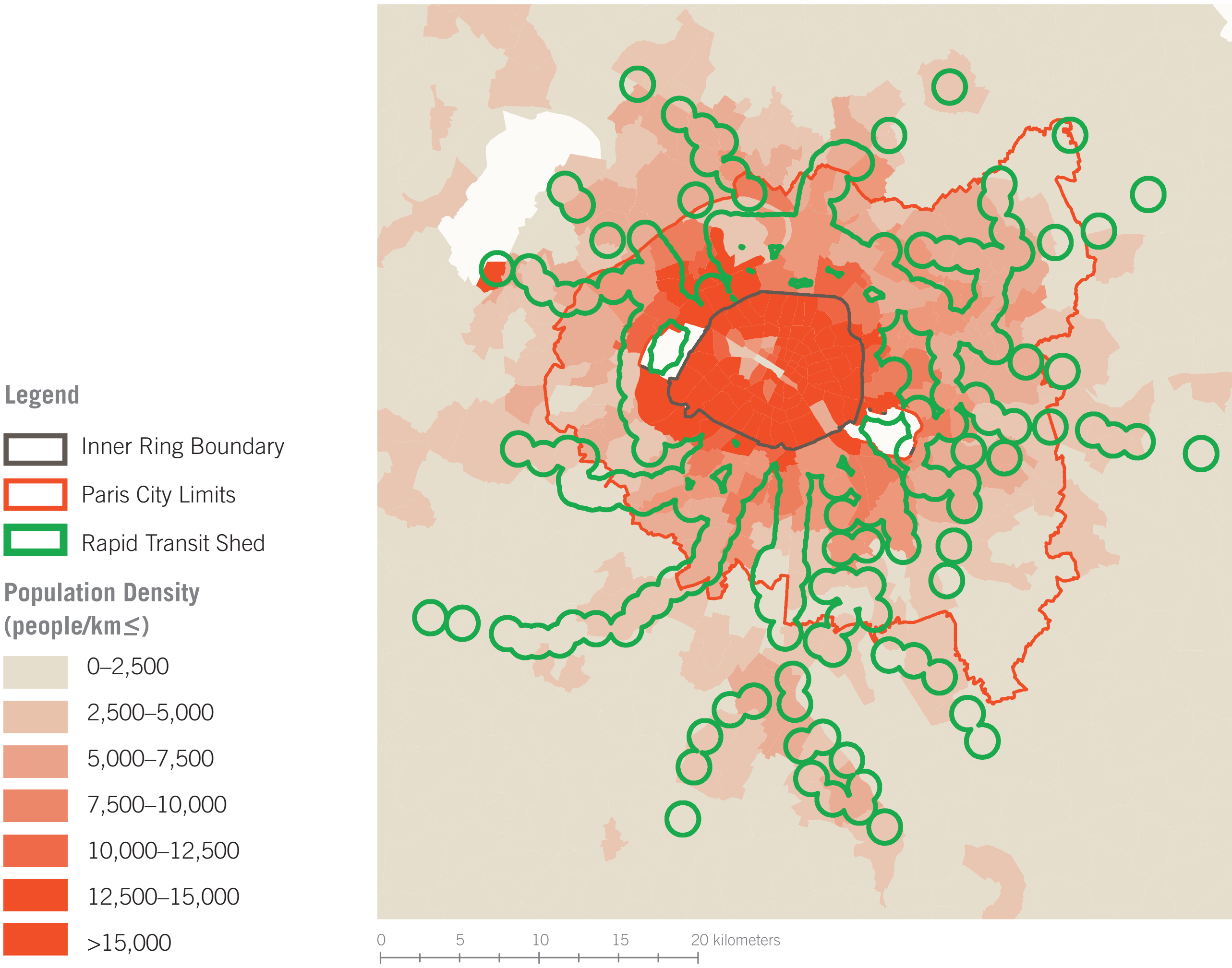
Figure 2. Transit Sheds and Population in Rio de Janeiro



many people. Additionally, the maps can help identify areas that are well served by transit but currently lacking in density: These could be targeted for additional housing, which can be an easier and less costly way to increase access to transit compared with constructing new transit corridors. However, it is important to note that these decisions should be based on deeper local analysis considering mainly the availability of urban infrastructure and possible environmental restrictions.

Pictured above is an example of this sort of map for the city of Rio de Janeiro. The areas within the black circles fall within the "transit shed." Residents who live within those areas are counted as "People near Rapid Transit." Using this map, you can see that Rio de Janeiro has done well at covering areas of high density with rapid transit. There are a few dense areas that remain unserved that should be targets for upgraded rapid transit service. There are also plenty of areas within the transit shed that are not at all dense (<1,000 people per km²), especially within the western areas of the city, but some of these contain protected environmental zones, making them unsuitable for further development. In Rio de Janeiro, it may be worthwhile focusing on increasing

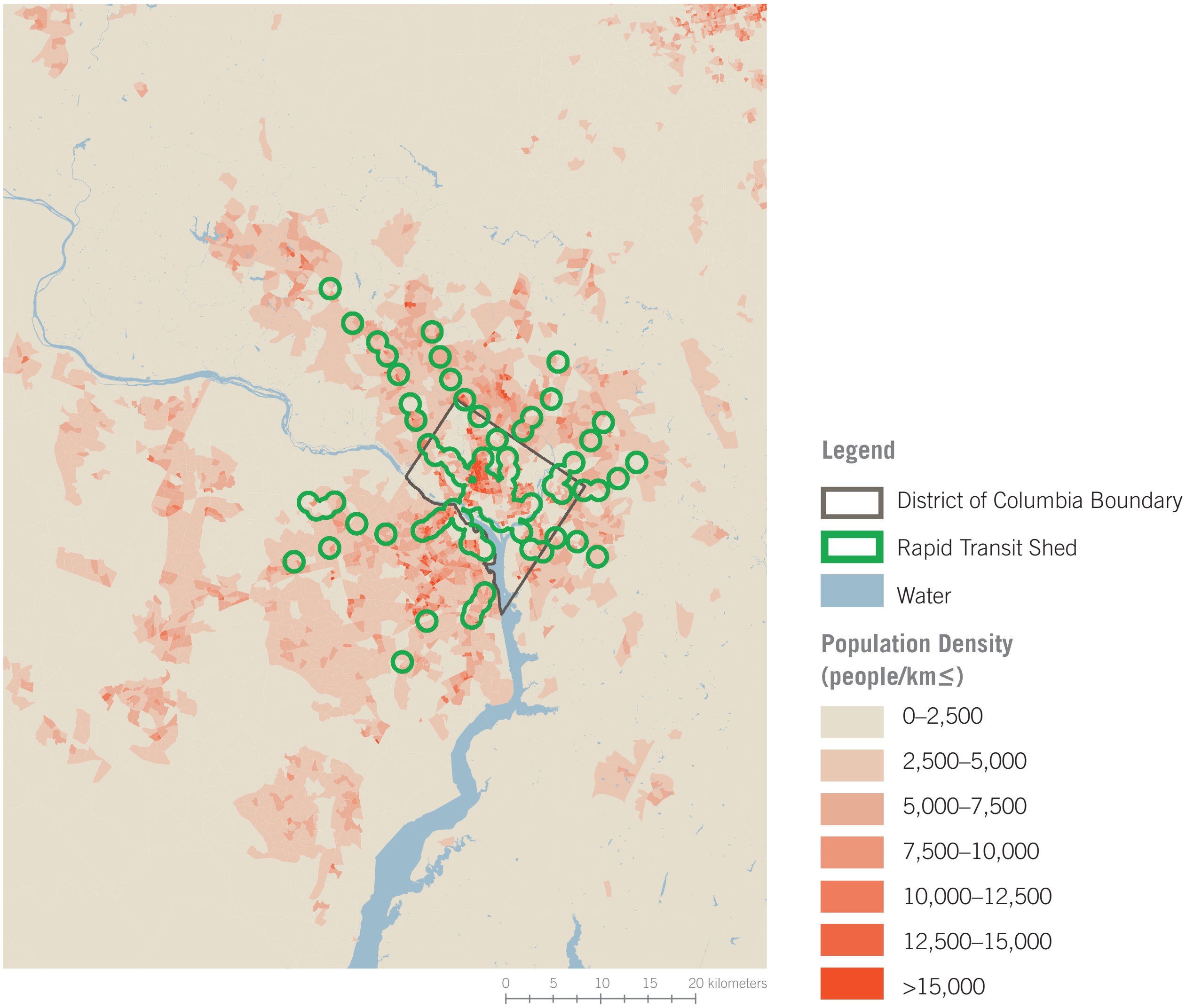
Figure 3. Transit Sheds and Population Density in the Paris Region



density in the city center and northern suburbs, which are well served by rapid transit but have actually lost population since the 1960s.

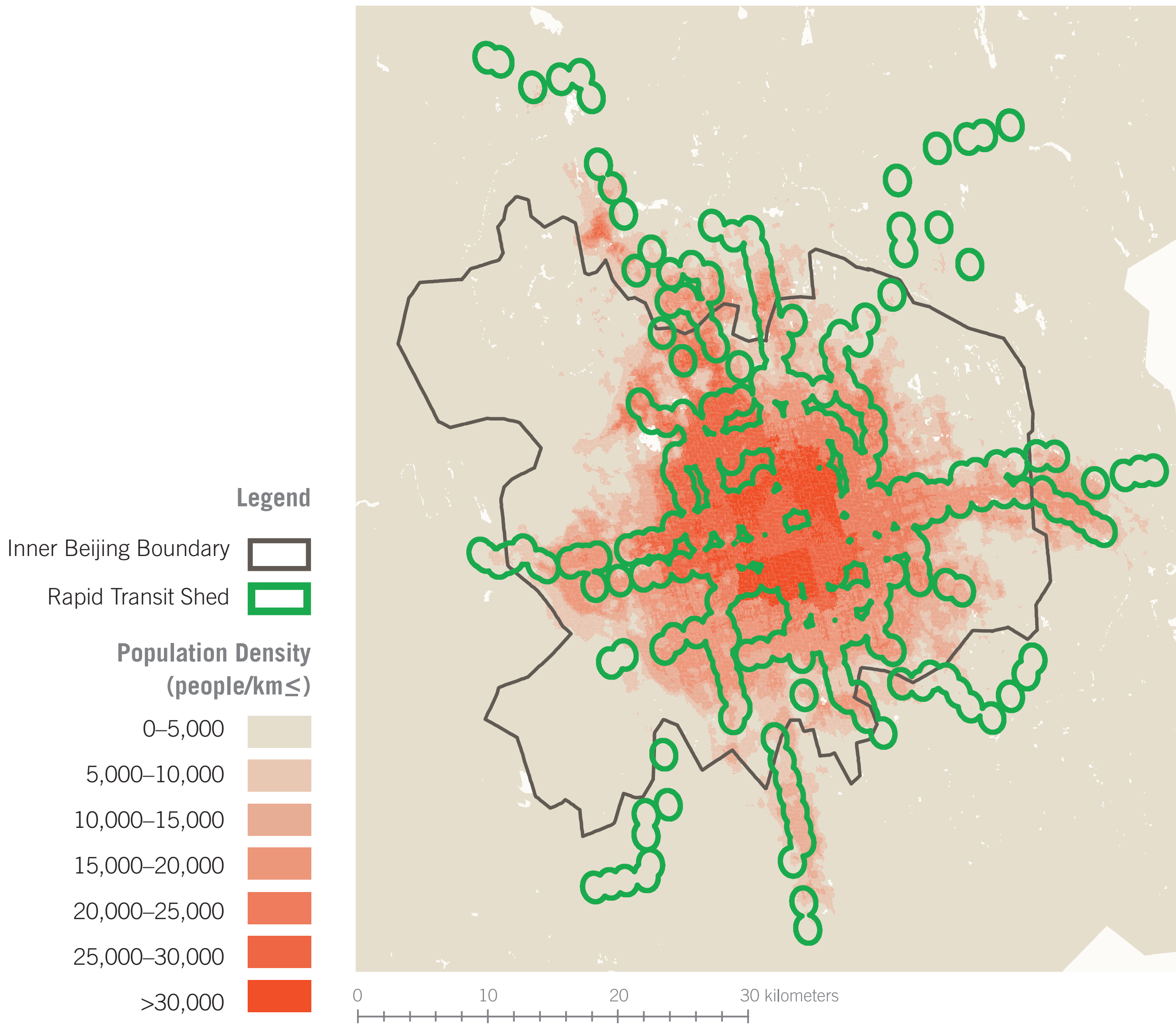
As the charts show, Rio de Janeiro is one of the leaders in PNT among developing-world cities studied. It is worth noting that in 2010, Rio de Janeiro had only reached a PNT percentage of 36%, which would put it roughly in the middle of the pack among the developing-world cities studied here. Since 2010, Rio de Janeiro's principal transit investment has been in consolidating a BRT network. The construction of the TransOeste and TransCarioca BRT lines have accounted for an approximate 14% boost in PNT percentage alone. With

Figure 4. Transit Sheds and Population Density in the Washington, D.C., Region



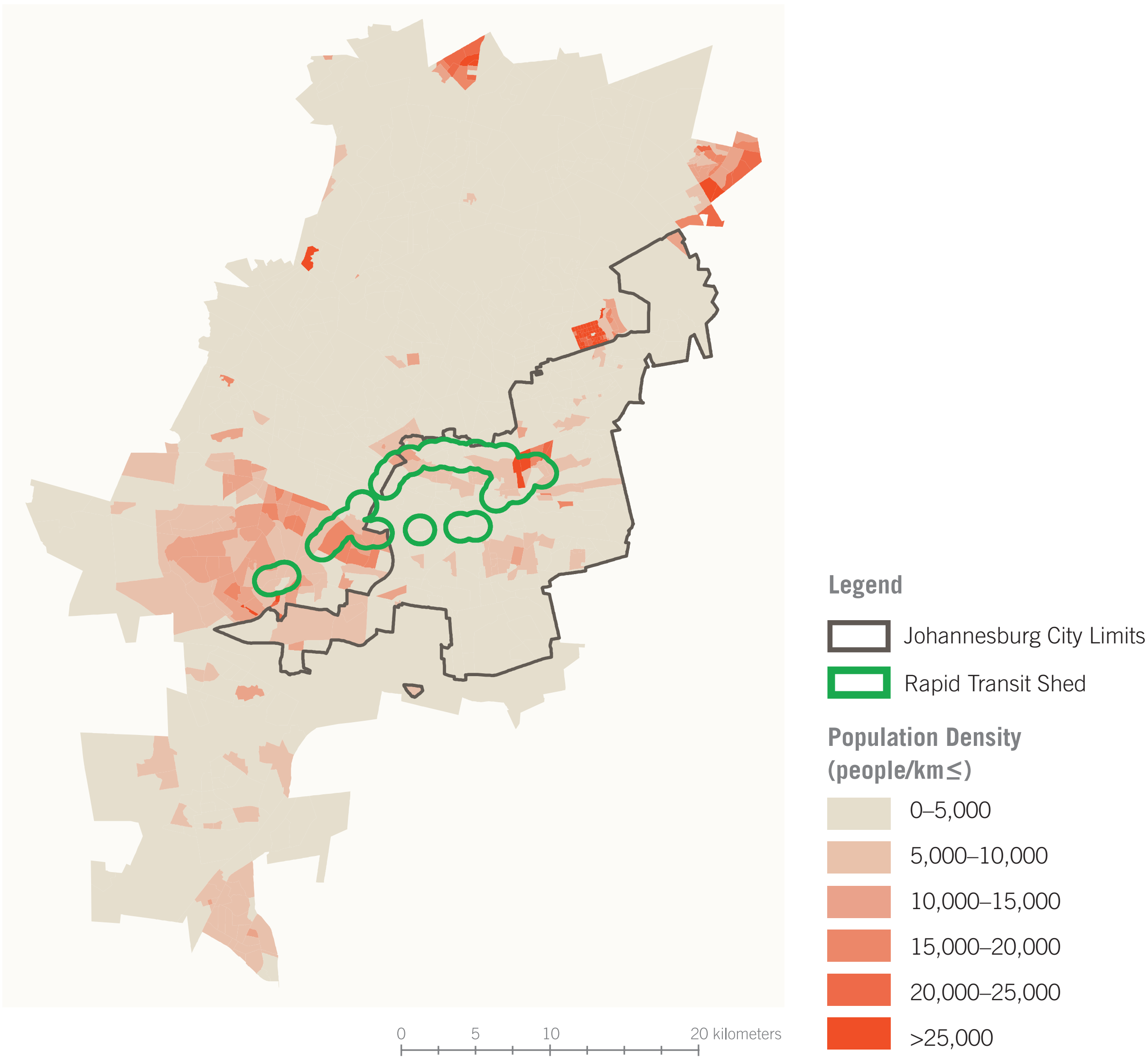
the completion of the TransBrasil and TransOlimpico BRT projects, the LRT network in Rio's downtown, and the subway Line 4, Rio de Janeiro's PNT is projected to reach 56%. Rio de Janeiro is a special case: Hosting the soccer World Cup and the Olympic Games helped it to attract sound investments for transit upgrades. While cities in the developing world often do not have enough capital to build out substantial rail transit systems like their developed-world counterparts, investing in BRT is one way they can expand the share of their population with access to transit. Jakarta, for example, has built out its entire rapid transit network with solely BRT, although there remain some issues of service quality.

Figure 5. Transit Sheds and Population Density in the Beijing Region



Paris, alongside Barcelona and Madrid, is one of the highest-achieving metropolitan areas in terms of PNT. As shown on the map (p.19), the entire city of Paris is within the Rapid Transit Shed, giving the city a PNT of 100%. However, the PNT for the metropolitan region as a whole is 50%, which while still impressive compared to the majority of cities on this list, marks a significant drop-off from the high mark set within the city limits. The primary reason for the drop-off is the growth of the outer suburbs. Paris's innermost suburbs still maintain high accessibility, with a PNT of 66%. However, despite an extensive suburban rail system, the outermost suburbs only reach a PNT of 13%, which lowers the overall PNT of the Paris region.

Figure 6. Rapid Transit and Population Density in the Johannesburg Region



Outside of New York City, Washington, D.C., has the highest-ridership rail transit system in the United States.[3] A total of 57% of residents of the District of Columbia live within an accessible distance of high-quality public transport, a very high mark among U.S. cities. However, there is once again a significant drop-off from the PNT of the city to the PNT of the metropolitan region, as the PNT of the entire D.C. metro region is only 12%. This high city–metro imbalance, while present in every area surveyed, was particularly strong in North American urban areas. The map (p.20) shows that in the D.C. region, urban development has spread out quite far from the urban core.

[3] http://www.apta.com/resources/statistics/Documents/Ridership/2015-q4-ridership-APTA.pdf

Beijing has built an impressive rapid transit system, with most construction taking place in the last 10 to 15 years. The Beijing Subway now totals 334 stations and 554 km of track. However, the city is growing so rapidly that mass transit planners are caught in the unenviable position of playing catch-up as the city continues to expand. That all of this investment still leaves 55% of Beijingers without close access to rapid transit just demonstrates how colossal the challenge is. If the city continues to expand outward, as is projected, it will take billions of dollars just to sustain the level of PNT that Beijing has reached today.

Johannesburg, the only city in Africa studied in this paper, has a very peculiar density pattern that influences its low PNT (9% for the metro area). Much of the region's population is concentrated in vast slums or "townships" on the periphery of the region, like Soweto, Alexandra, and Diepsloot. This geographic inequity automatically puts the region at a disadvantage when it comes to serving its populace with rapid transit. The Rea Vaya BRT system has expanded out of the City of Johannesburg and into Soweto, but much more work needs to be done to ensure equitable access in the Johannesburg region.

PNT as a Socioeconomic Indicator

One very exciting application of PNT is its value as a method of determining how access differs between socioeconomic strata in urban areas. Public officials often celebrate expansions of public transit networks for their ability to connect all levels of society with opportunities. However, in many cities, much of the rapid transit network is actually concentrated in areas of relative affluence. Measuring how well people with lower incomes can access rapid transit compared to people in higher income brackets can highlight disparities in access not just in a spatial sense (as highlighted in the discussion of PNT in cities vs. metro areas), but also among socioeconomic classes.

Income data is often difficult to collect and standardize, which limits the ability to study PNT among different income groups in each city we have studied. However, our colleagues in the ITDP Brazil office have been able to use income data from the Brazilian Institute of Geography and Statistics (IBGE) to examine "Social PNT" in four major Brazilian metropolitan areas among different income strata. In order to distinguish different strata, they measured household income (HI) in each metropolitan area relative to minimum wage (MW)[4], creating four different groups: households earning less than 50% of minimum wage; households earning between 50% and 100% of minimum wage; households earning between 100% and 300% of minimum wage; and households earning more than 300% of minimum wage.

[4] Minimum wage in Brazil is 10,560 Brazilian reais or $3,279 U.S. dollars annually.

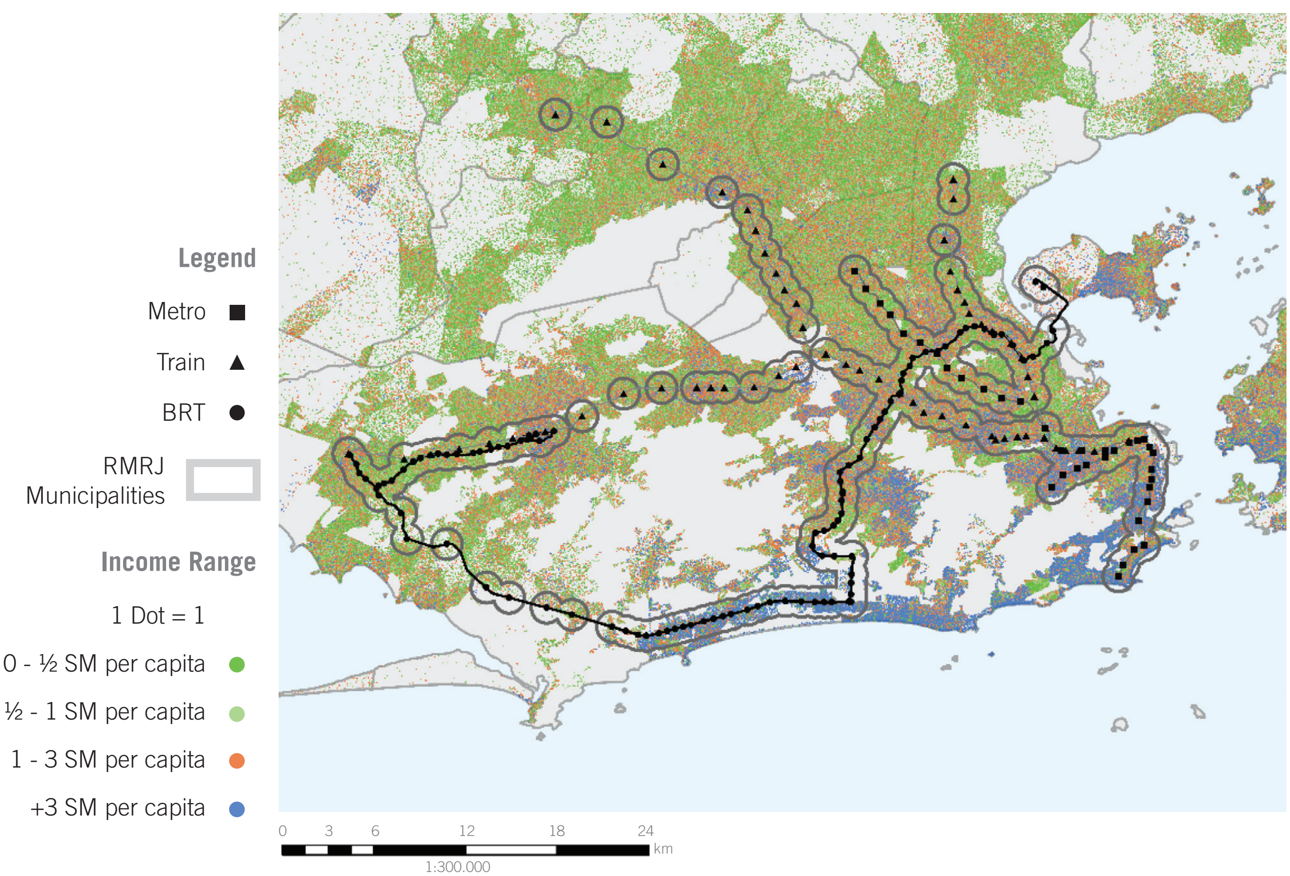
Table 4. PNT by Income Group in 2010 and 2015 for Four Brazilian Metro Areas Income Group Defined Around Minimum Wage (MW)

		PNT		PNT by Household Income (HI)			
Scope	**Year**		**Disparity (percentage points) between lowest and highest income bracket**	**<50% MW**	**50-100% MW**	**100-300% MW**	**>300% MW**
Rio de Janeiro	2010	23%	20	17%	19%	26%	38%
	2015	28%	25	22%	24%	32%	47%
	Δ 2010-2015 (%)	**+5**	**+5**	**+5**	**+5**	**+6**	**+9**
São Paulo	2010	19%	23	15%	15%	21%	38%
	2015	19%	24	15%	16%	21%	39%
	Δ 2010-2015 (%)	**0**	**+1**	**0**	**0**	**0**	**+1**
Belo Horizonte	2010	8%	12	5%	6%	11%	17%
	2015	14%	20	8%	10%	18%	28%
	Δ 2010-2015 (%)	**+6**	**+8**	**+3**	**+4**	**+7**	**+11**
Brasília	2010	11%	18	5%	8%	12%	23%
	2015	12%	18	6%	8%	13%	24%
	Δ 2010-2015 (%)	**+1**	**0**	**+1**	**+1**	**+1**	**+1**

The results of this "Social PNT" analysis for the four Brazilian metropolitan areas show that across the board, the wealthiest residents of Brazil's major metropolitan areas enjoy the best access to rapid transit. Moreover, in all four areas, the poorest residents (households earning <50% of minimum wage) have the worst access to rapid transit. As Brazilian cities expand their rapid transit networks, one might expect to see this disparity of access decrease. However, in the two areas that saw meaningful gains in overall PNT (Rio de Janeiro and Belo Horizonte), the differential between the PNT of the lowest-income groups worsened, despite absolute gains in the PNT of the lowest- and second-lowest income brackets.

The below map displays the inequity of access in the Rio de Janeiro region. Green dots represent those making minimum wage or below, and red and blue dots those making above minimum wage. In Rio de Janeiro, wealthier households seem to be concentrated near the city center or along the waterfront, and are therefore more likely to live near rapid transit. In contrast, households that are making below minimum wage are heavily concentrated in the region's northern reaches, farther from the jobs and opportunities of the city center, in neighborhoods that mostly are not served by rapid transit.

Figure 7. Rapid Transit and Household Income in the Rio de Janeiro Region



Conclusions and next steps

PNT can be used as an effective indicator for cities to quickly evaluate rapid transit access and urban growth, as it indicates how many of a city's residents are able to access opportunities using its public transit network. With limited data requirements, almost any city in the world can be assessed, and the results can be easily compared across cities. Furthermore, the spatial mapping used to calculate PNT can also be utilized to highlight where cities are succeeding in terms of providing access and where improvements can be made.

Some limitations to this approach are worth considering. The distance to transit likely overestimates the number of people who are actually within a 1 km walk of transit. In the future, this may be revised to better approximate a 1 km walk, using, for example, the street network to calculate actual walking distances. Further, PNT does not use employment locations or any sort of destinations as a factor; it only focuses on where city residents live (i.e., "origins"). For a more complete picture of transit access, it would be beneficial to also calculate the percentage of jobs that are accessible by transit. Unfortunately, while this data can often be accessed in developed countries, it is currently very difficult to find it in the developing world. Furthermore, with employment data, "Employment near Transit" (ENT) could be assessed to approximate employment accessibility in a city. This could be paired with PNT to give an even more complete picture of transit access.

In addition, PNT only considers "rapid transit," while in many cities networks of frequent transit serve large numbers of people effectively. Future iterations of the indicator could consider people near frequent transit too.

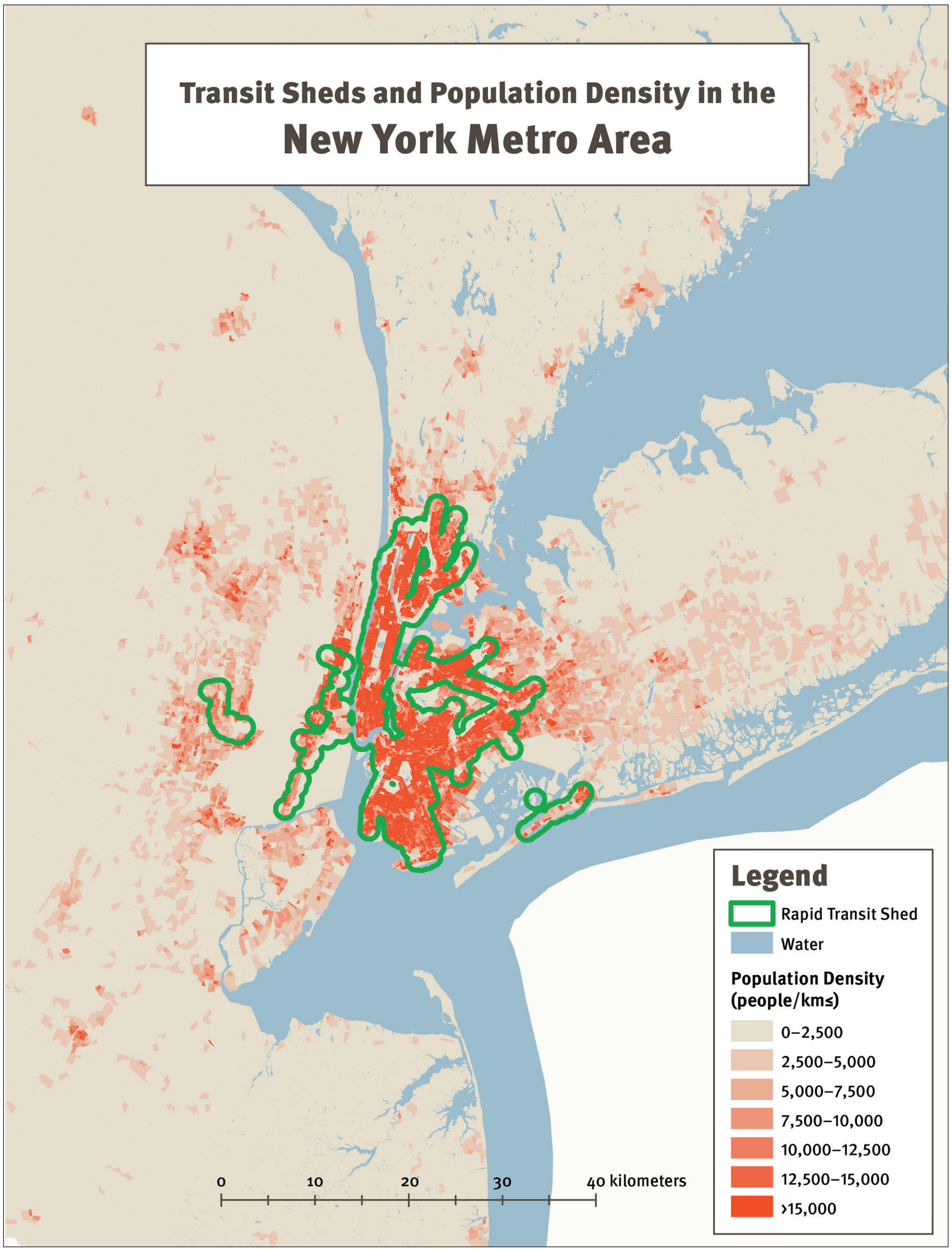
In further refinement of the indicator, we would like to expand the analysis to more cities in different developing countries. However, unlike in developed countries, where census and geographic data is easily available, obtaining this sort of information can still present a challenge. Ongoing efforts to use satellite imagery and remote sensing to estimate population density may address some of these issues in the near future. PNT data can also be used to assess how cities have progressed (or not) over time in terms of accessibility, much like the example in Rio de Janeiro.

Finally, by assessing population along demographic lines, it is possible to calculate access among various segments of the population—for example, low-income population with access to rapid transit. This could be used to show the equity of a city's transit system and development patterns, as in the Brazilian cases above. In the future, we plan to complete more income- and demographic-based assessments in more cities around the world. All of this presents an exciting opportunity to quickly assess cities that have long been difficult to evaluate due to data limitations.

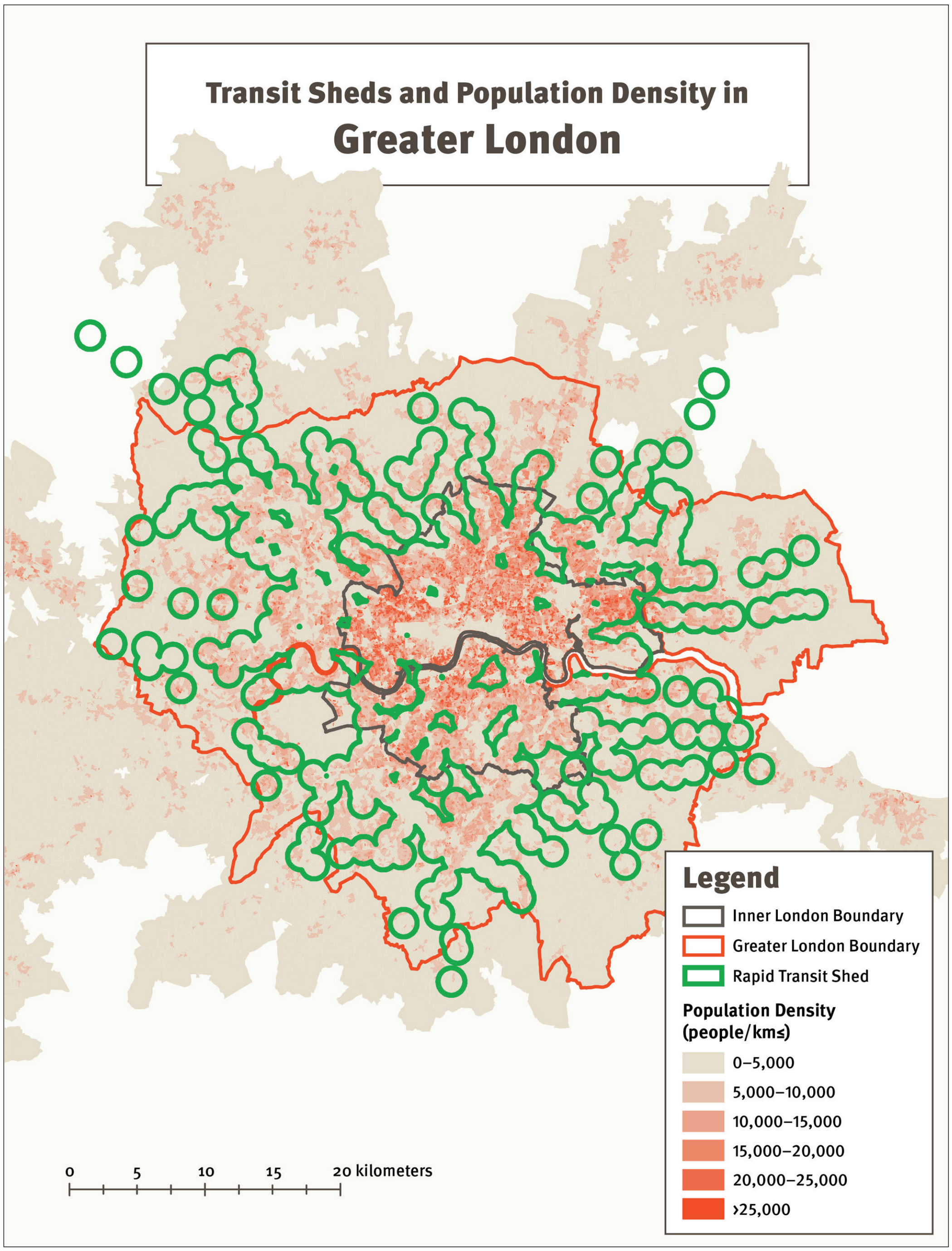
ANNEX A

Sample of cities scored with PNT

Very few cities are investing in the rapid transit systems that serve the less wealthy communities living outside of the urban core, even in Europe and especially in North America. For the 13 cities in industrialized countries that



were scored, the average PNT was 68.51%, while those cities' metropolitan regions averaged 37.28%. The metro regions of the six US cities averaged a score of 17.20%.



ANNEX B
Data Sources

U.S. Census Bureau; American Community Survey, 2014 American Community Survey 1-Year Estimates; using American FactFinder; https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

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