Part III: Accessibility

The primary concept underlying this analysis is *accessibility*. Seemingly a simple idea, accessibility has been conceptualized and operationalized in many ways and, as widely acknowledged in the literature, there is no singular definition or interpretation that can always be called upon. In this section, I will first provide my own working definition of *accessibility*—contextualized to the goals of this project—and then explore some of the ways accessibility has been operationally measured in planning and geography. Lastly, I will summarize accessibility conditions unique to Buenos Aires and Latin America, culminating in a discussion of earlier studies that looked at public transit access in specific cities from across the region.

Part III(a): Accessibility, defined

Accessibility is an important concept in transportation geography and planning and whose interpretation can vary depending on the complexity of any given context. This is reflected in the array of definitions of *accessibility* and *access* from the literature. Nevertheless, as explained by Handy and Niemeier (1997), nearly all conceptualizations acknowledge, whether explicitly or implicitly, that it is characterized by two basic, yet highly-interconnected, components: the distribution of activities (origins *and* destinations) across a territory and the ease and costs of travel, through a transportation system, between those points in space. This second component is especially critical to this study, as it acknowledges the role of cost, measured in money *or time*, in framing whether, if at all, individuals can travel between any two locations. Without the means to feasibly travel across a space, the actual distribution of those features, measured as raw distance, is substantially less important. Considering accessibility simply as a factor of physical separation does not fully capture the realities of individual mobility. This is particularly true for low-income groups, like the *asentados*, whose budgets (*fiscal and time*) are finite, restricting their ability to move about the landscape and—in the absence of cost-effective mobility services—preventing them from reaching important destinations, regardless of their proximity.

As such, I sought a definition of *accessibility* that emphasized this component, knowing the salience of travel costs to the *asentados*. In turn, I opted for a definition from Hansen (1959): "*accessibility* is a measurement of the spatial distribution of activities about a point, *adjusted for the ability and the desire of people or firms to overcome spatial separation* (pg. 78)." In other words, it is ultimately about whether people can reach the places they need to go to carry out their daily necessities. When accessibility is high, people can reach wherever they need to go in a cost-effective manner; when it is low, people struggle or fail to reach important destinations, burdened by time- or cost-ineffective means for overcoming distance. Ideally, all people will enjoy a high degree of access, regardless of their location or socioeconomic condition. Similar definitions from Guers and Van Wee (2004), "the extent to which land-use and transportation systems enable (groups of) individuals to reach activities or destinations by a means of a (combination) of transport mode(s) (pg. 128)" and Handy and Niemeier (1997), "the spatial distribution of potential destinations, the ease of reaching each destination, and the magnitude, quality, and character of activities found there (pg. 1175)" help shape this understanding of access.

I also chose this definition because of its application to this project's goals. In my case, I am looking to calculate travel time as a measure of the cost-impedance faced by AGBA's *asentados* as they travel between their homes and a series of important activity sites for their daily lives (e.g. schools, health care, employment centers, train stations, etc.). I focus on the role of public transportation services as the mechanism for overcoming spatial separation, the likely mode of travel for residents of the *asentamientos*. By considering the *time-cost* of travel, I am moving beyond any of the existing studies of access in the *asentamientos*, all of which, e.g. TECHO and INHABITAT, looked exclusively at the physical distances separating the communities and their service providers and not whether the *asentados* could cost-effectively reach those sites. If I can show that the *asentamientos'* residents require more time to reach daily activity sites than it takes those living in formal neighborhoods, I can provide an illustration of relative accessibility conditions for the residents of metropolitan Buenos Aires' many precarious settlements.

Part III(b): Why is accessibility important?

Given that accessibility is about whether people can feasibly reach locations distributed throughout space, it is to be expected that conceptualizing and operationalizing *accessibility* is of great importance to those people responsible for studying those services that help people move across space: transport geographers and planners. When accessibility levels are poor, it indicates that the current transportation system, and all its constituent modes, is failing to meet the mobility needs of its users and that it needs to be adjusted by the proper authorities. In terms of the impact of such a situation, Cervero (2011) notes, for instance, that poor accessibility makes it difficult for people to reach jobs and schools, limits economic mobility, and promulgates social isolation, unemployment, and low wages (pg. 7). Garett and Taylor (1999) reached a similar conclusion, noting that planners and policymakers, without a complete understanding of the consequences of the spatially-uneven distribution of public investments in an urban area, created a situation where "poor or mediocre public transit service in areas with high proportions of transit dependents exacerbates problems of social and economic isolation (pg. 393)."

The role of public transportation, therefore, should be to *promote* accessibility, especially for those without private means for traveling the distances requisite for finding employment, attending school, seeking healthcare, and fulfilling other basic human needs. Jaramillo, et al. (2012) believe that traditional transport planning has focused primarily on managing demand in urban systems rather than studying their socio-economic or equity impacts. Karen Lucas, who has written extensively on the social consequences of inadequate transit, adds that the tradition of over-analyzing transport's negative economic and environmental impacts had ignored some of its social impacts like social exclusion (Lucas and Jones, 2012). Defined by Bocarejo and Oviedo (2012), social exclusion, a relatively new topic of study within the social dimensions of transportation, is a process "by which, due to an insufficient or inexistence of adequate means to travel, people are prevented from participating in the economic, political, and social life of the community ... a result of reduced accessibility to opportunities (pg. 144)." By measuring and observing accessibility conditions, such a situation could be avoided.

With substantial implications for urban poverty and economic disadvantage, those same authors believe transport authorities must work to identify geographic areas of heightened need and to prioritize strategies to spatially target and deliver mobility assets to the transport-disadvantaged. Augmenting this plea, Jaramillo, et al. (2012) believe that ensuring social inclusion can only take place through "improvements and/or implementation of a high-quality network of public transport with tariffs suitable for [disadvantaged] sectors (pg. 340)." Any solution, they say, must directly incorporate the needs of all people, not just those with the greatest demand—explicit plans should be made to incorporate transport-disadvantaged groups like the poor, the carless, the disabled, those unable to speak the local language, and children. The fact that many urban poor, especially in Latin America, are forced to live in distant locations should not stop them from being able to access and enjoy the benefits of the city through its transport system.

The impacts of improved accessibility, in turn, are many. Keeling (2008), for instance notes that "transportation enables poorer communities to [reach] basic economic activities and social services and facilitates accessibility to opportunities ... [it] reduces the friction of distance between places and regions (pg. 141)." He also extolls the virtues of high-quality transport for promoting economic competitiveness, lifting people out of poverty, and reducing inequality. Without the mobility and accessibility provided by transportation infrastructures, services, and technologies, people, places, and capital would not interact, stymieing socioeconomic development (Keeling 2002). Cervero (2011), meanwhile, notes that "for many ... the availability of good, reliable, and affordable bus and rail services can be the difference between being integrated into the economic and social life of a city or not ... a lifeline to participation in society's economic, social, cultural, and religious offerings (pg. 5)." This is particularly true in market-driven societies, where the going-price for transportation is many times above what many citizens can afford; without an affordable, accessible alternative, they are shut-off from activity sites beyond their immediate surroundings.

While this paper focuses on the mobility component of accessibility, it can be just as important to those focused on its land use component. For instance, a poorly-accessible good or service can indicate its inequitable distribution on the landscape. Related to the notion of spatial equity, or "the degree to which services are distributed in an equal way ... corresponding to the spatial variation of 'need' for that service (Taleai, et al. 2014, pg. 56)," poor accessibility can result from the under-provision of services in an area of need, even if transportation services are good. Adequate transit, on its own, does little to reduce the accessibility of schools or hospitals if they are still all located very far away from their patrons. Identifying areas of deprivation could put policy-makers and service providers in a position to open new locations or relocate offices to sites more accessible or ensure affordable housing is constructed closer to important destinations. While the distribution of all facilities will inherently produce variations in access across the landscape (there cannot be a school on every street corner), it becomes problematic when "the distance is such that access becomes impractical ... for residents (Dadashpoor, et al. 2016, pg. 159)." At the same time, accessibility to features needs to be understood relative to the characteristics of that good or service (e.g. some have higher population thresholds, naturally dispersing across space while more highly-demanded should be more concentrated) as well as the geography of that landscape (e.g. density, road network, socio-economics etc.) to ensure that there is a spatial mismatch in supply and demand and that an inequity exists. Once these considerations are made, a proper evaluation of accessibility is possible.

Blanco and Apaolaza (2018) expand on the relationship between accessibility and space, emphasizing that accessibility is a consequence of both location *and* socioeconomic conditions. While the authors acknowledge that socio-economic disadvantage and the lack of mobility assets—i.e. resources for moving about and using the city (e.g. fare-paying capacity, vehicle ownership, drivers' licenses, transit-using competencies, system knowledges, etc.)—go a long way to explain limitations in certain groups' access to urban transport services, they posit that the *territorial configuration* of these groups is equally as important. Referencing the proximity of groups to services, activities, and transport infrastructure itself, the authors contend that, "the same transport supply and territorial configuration could be advantageous to a particular social group and not for another, while the same [mobility resources] of households and individuals could be advantageous in a certain specific territorial context by not in others (pg. 2)." In other words, the accessibility conditions of a group must always be considered vis-à-vis their *socio-economic resources* ***and*** *their location*; the same system can disadvantage some groups and advantage others. This echoes an earlier conclusion from Bocarejo and Oviedo (2012) that "accessibility can be related to the time and percentage of income spent on commuting [and] the type of user, [his or her] location, and [the] mode" … "showing general higher incidents of ***time*** *in richer areas* and the important effect of ***money*** *over accessibility in low income areas* (pg. 153)." While accessibility is important in many ways, it is important to recognize that it takes different forms based on characteristics of the user.

Part III(c): Operationalizing Accessibility: *Map and Measure*

Given its importance to planners and geographers, many have tried to operationalize and measure accessibility, often with geographic information systems, to evaluate whether existing systems are adequately and appropriately serving their constituents (Litman, 2002; Manaugh and El-Geneidy, 2012; Taleai, 2014; Dadashpoor, et al. 2016). Talen, 1998, advocates GIS-mapping as a tool to "elucidate equity variation" and analyze "the spatial incongruity between resource need and … distribution" through the mapping of disadvantaged groups alongside the "local distribution of public facilities (pg. 23)." In the context of transportation, scholars have tried to determine which zones of a city or metro area have sparse transit coverage—whether by mapping route networks or stops—before comparing those gaps in service with socioeconomic to characterize the underserved, determining if they are disadvantaged or marginalized groups and judging whether supply is appropriately commensurate with demand.

In fact, questions of transportation and access have been at the forefront of a "growing scholarly interest in devising measures to assess the accessibility impacts of transport interventions," and have been employed by a wide range of studies looking at accessibility to common activity sites like health facilities, supermarkets, social services, parks, and even the transportation system itself (Tsou, et al., 2005; Chang and Liao, 2011; Delmelle and Casas, 2012; Venter, et al., 2013, Taleai, et al., 2014). All the while, most aim at "providing planners and decisionmakers with [an] assessment of the implications of potential investments for the daily lives of residents" and helping them to strategically intervene and improve accessibility conditions, taking measures like the relocation or construction of affordable housing units, employment locations, or critical services or the outright alteration of the transportation systems itself (e.g. new routes, improved schedules, comfortable vehicles, etc.) (Handy and Niemeier 1997, pg. 1176). As noted by Delmelle and Casas (2013), this process of "identifying population groups with limited access to opportunities" can be a complex task, requiring highly-specific measurements of accessibility that, over the course of the years, have taken many different shapes and forms. Thankfully, there are scholars and planners who have attempted to categorize and make sense out of these measures.

Thankfully, Handy and Niemeier, 1997, outline some common methods of measuring access and then provide strategies for calibrating the model of choice. As for the measurement types, they provide a three-pronged categorization, each of which makes different assumptions and generalizations about the two main components of *access* within a study area*:* the land uses and the travel system. The first of the three are *cumulative opportunities measures*, which reflect, as the name suggests, the iterations of a given category of activity sites that can be reached from an origin within a certain time, distance, or cost. All instances of a destination category within a certain threshold are counted, regardless of the specific travel time, distance, cost, or any other quality or characteristic of that activity site. Each origin point is assigned a number, with no other output. These measures are, on the one hand, the most simplistic but are also easy to understand and compute; this project's measure, the *travel time* from each origin to the closest school, hospital, train station, or central business district, falls into this category.

The second classification consists of *gravity-based measures*, which weight the attractiveness of potential destinations as a function of the cost, distance, or time required to reach each individual instance; with such a measure, closer locations are weighted more heavily than those that are more distant. An approach initially promoted by Hansen (1959), this method is more complex than the simplistic "cumulative opportunities" measures since it factors the human tendency to travel to the closest acceptable iteration of an activity. Along these lines, however, the gravity model is also useful for scenarios where someone is willing to travel *further* to a destination because it offers a specialized good or feature not available at other, similar sites closer to that person's origin. The function, typically an exponential equation, used to model distance-decay can be altered based on the characteristics of a given class of activity sites; some may be able to draw people from further distances than others, requiring a change in the exponent of that equation. While these may provide a more precise picture of accessibility in an area than *cumulative opportunities* measures, they require more computation, can be hard for the layperson to understand, and, as importantly noted by Delmelle and Casas (2013), can be highly subjective, depending on how certain activities are weighted. In fact, it is hard to know what exactly drives people to travel, or not travel, longer distances for a good. While I do not rely on a distance-decay function, I indirectly incorporate the elements of a *gravity model* but distinguishing between destination types, namely separating higher-order hospitals from lower-order diagnostic/treatment centers within healthcare.

The third category, meanwhile, are *utility-based measures*, which concern the probability that a person will choose to make a certain trip based on selecting, from a range of choices, the alternative that maximizes his or her utility. These are the most complex and rely on mathematical and economic models; their greatest limitations are their computational complexity, data requirements (detailed survey data on consumer preferences are warranted), and that they are difficult for the average person (or policymaker) to understand, limiting their effectiveness.

Regardless of which measure is chosen, there are some considerations that must be made. One of those is the zone of aggregation, at which accessibility is measured. For instance, access can be measured from large zones like entire cities or neighborhoods or at a small scale like an individual household or even a singular person; larger-scale projects require less data but make assumptions about the needs of entire areas, generalizing the needs of the people living there whereas small-scale, household- or individual-level studies get a fine-grained understanding of individual accessibility (as is needed with a study area like the *asentamientos*, who differ greatly from their immediate surroundings despite their small size) but are less generalizable across a region and are data-intensive.

An alternative approach to aggregation could be to apply a single measure to different socioeconomic groups or trip purposes with an area, targeting any variation between groups. These would still require separate assumptions be applied to each group before measurement: home location, travel and time budgets, available modes, and opportunity sites (i.e. different income groups start their trips from different places, select from different available modes, and have different amounts of time and money to commit to travel). If these assumptions are accurately made and can be represented with the requisite data, valuable inter-group comparisons can be made. Considering groups with alternative mobility conditions would reflect how patterns of accessibility are so strongly dependent on the complex characteristics of the travelers and capture a more nuanced understanding of access. In my case, I assume that all my travelers—those from the *asentamientos* and those from outside—are taking the same modes and traveling to the same destinations as a way of comparing outcomes; however, these groups are probably operating under different circumstances in real life.

This consideration is like another that should be made: the destinations. The set of activity sites must reflect the people under study—locations that "residences perceived to be available to them (pg. 1179)." In my case, this meant selecting activity sites that *asentados* were likely to actually need; people with such low income are more likely to attend a public school or hospital than a private university, international business center, or airport. This step also necessitates consideration of destination attractiveness, given that the size or quality of certain iterations of a feature may draw people from further away than would otherwise be assumed. While some features, like public schools, tend to draw mainly from their immediate surroundings given that the quality changes little between establishments, others, like hospitals or stores, can draw people from further away if they offer something unique. In the case of gravity models, this "attractiveness" is quantified by the exponent on the decay function, a number whose value is dependent on the characteristics of each good or service. Thought must be given to the nature of demand for each "destination" activity site and how it would manifest spatially relative to the consumers. If this consideration is important within a study area or for a particular good, some kind of decay function or product differentiation should be performed, assuming the proper data are available.

The final consideration is the quantification of travel impedance. Traditionally, this was done as just a distance measure, whether Euclidean, Manhattan, or network-based. However, distance alone, as has been noted, is not enough to fully capture access—distances are meaningless of people have no means of crossing them. As such, time- and cost-based measures are better since they frame all travel decisions, especially for low-income *asentados*. Time-based measures, which have historically been difficult to estimate, are now possible thanks to recent innovations in geographic information systems and travel engineering models; as will be explained later, it is even possible to estimate travel times through transit alone. Assuming one has access to these data (a process made easier itself through the proliferation of open-sourced software and web-based application programming interfaces (APIs), consideration can even be given to time of data, accounting for variations in trip-length caused by restrictive transit schedules or congestion. Similarly, a cost-function can be added to capture the monetary cost of a trip, arguably one of the greatest barriers to mobility. Lastly, comparisons across modes are possible, representing the choice set available to a traveler when deciding how to reach a destination or whether the trip is feasible in the first place (i.e. transit versus driving, transit versus walking). Elaborated below, I make use of new travel-time estimation tools to improve on preexisting, distance-based estimations of accessibility within the *asentamientos*.

Making these considerations, however, is not always possible and often at the whim of data availability. Knowing the desired destinations of a target population, determining what attracts customers to individual activity sites, or having the data to estimate transit-based travel times across a network are not always possible, which forces the researcher to make assumptions. Travel surveys, when available, are helpful for understanding how individuals perceive travel and their destination choices and ensuring, in the absence of better data, that an accessibility measure is based on assumptions grounded in actual observations and perceptions. Capturing these nuances ensures, regardless of the measurement type, provides the measure with legitimacy. Endorsed by the authors, quantitative studies should be "combined with qualitative evaluations to provide a much richer understanding of the accessibility characteristics of a community … concepts of travel impedance, destination attractiveness, and choice sets … are not easily quantified depend at least partly on the perceptions of residents, rather than solely on objective criteria (pg. 1182)." As will be explored in methodology section, I called upon travel survey data (from ENMODO) and *asentamiento* interviews (from TECHO and INHABITAT) to characterize my analysis, directly informing the selection of origins, destinations, departure times, and travel modes.

When it comes to choosing a specific measurement, however, the authors provide some parting advice. They note that there is no one best approach for measuring accessibility and, instead of advocating for one over another, ask that researchers meaningfully and carefully make their choice, given that "the use of an inappropriate measure may lead to inappropriate conclusions and ineffective policy (pg. 1182)." All the while, they ask that the user consider her or his end goals for the project and its data and whether the approach and its assumptions dovetail with theory and empirical evidence on the study site. If the researcher's goal is a nuanced, complex understanding of access that does not need to be explained to a wide audience, disaggregate, individual-level measures could be better, even if they are costlier and data-intensive. If popular interpretation is key, then more simplistic, but nonetheless behaviorally- and theoretically-sound, cumulative opportunities measure could be chosen to maximize understandability. As the authors note, different methods can produce different results for the same area, especially if careful considerations are not made; what is more important is that assumptions about accessibility are "consistent with how residents perceive and evaluate their community ... a practical definition of accessibility must come from the residents themselves, rather than from researchers (1176)."

While Handy and Neiemer are not the only authors to categorize accessibility metrics, the other systems are not all that dissimilar. For instance, Geurs and van Wee (2004), offer a similar classification system that has been similarly-well cited. They believe that any good measure needs to consider four things: land-use patterns in a region (i.e. the location and quantity of trip origin and destinations as well as demand for various activity sites), transportation systems (the networks linking origins and destinations their costs and flow characteristics), temporal constraints (in terms of origins—individual people's time budgets—and destinations—hours of operation of different sites), and the various constraints and limitations that affect individual users (transport usage trends vary depending on factors like age, income, education, assets, disability, or location). An accurate model of access should incorporate all of these elements, if possible, although they acknowledge that not all of these possible to acquire.

This in mind, the authors subsequently provide a four-pronged categorization of common measures of accessibility: (1) infrastructure-based, (2) location-based, (3) person-based, and (4) utility-based. Those studies in the first category deal with service quality along a network, emphasizing travel speeds, congestion, and how well an individual transportation mode facilitates access. The second category looks at the accessibility from a given location to an assortment of activity sites scattered across a study area, often with the goal of identifying the number of locations within a reasonable travel distance or reachable under a certain cost threshold, identical to *cumulative-opportunities*. Person-based measures are the individual scale, focusing on the activity sites available to a given person considering any personal characteristics that may affect or hinder their movement across an area (e.g. income, disability, age, employment, etc.); like the gravity-based models, this begins to look at the unique characteristics of a traveler or an activity site that adds complexity to the assumption that people will only consider those activity sites closest to their origin. The last category, the same as one from Handy and Niemeier, consists of studies that take an economic approach to accessibility and consider the benefits or use-value that people derive from a given distribution of activities and how this influences mobility choices. In this system, my approach will qualify as *location-based*, although with elements of the first and third (incorporating travel times and differentiating my destination classes, respectively).

Lei and Church (2010), meanwhile, added yet another classification system, focusing specifically on those measures that analyze *transit* since, in their opinion, transit's "role of providing access is *one of its most important functions* (283)." They note that transit's unique characteristics—especially compared to driving and other modes of individual travel—create unique accessibility challenges; a simple shortest-path solution does not work when a network relies on fixed routes, schedules, layovers, and fares and that people must negotiate these constraints with their own schedules and budgets. In turn, transit-specific measures are classified as measuring either (1) *system accessibility* (whether people can physically access a system and that it is proximate to everyone), (2) *system-facilitated accessibility* (whether a system takes people where they need to go in a reasonable travel time), (3) *integral accessibility* (the total number of opportunities available within a given travel distance or time), (4) *space-time accessibility* (which focuses on individual limits to movement across space vis-à-vis time budgets), (5) *utility-based accessibility* (looking at how consumers weigh travel alternatives and select the one that is most useful), or (6) *relative accessibility* (how well transit compares against rival modes in offering access to the same set of destinations). They supplement this classification by lauding the role of GIS in making each of these measurement-types possible, especially vis-à-vis their shortest-path algorithms' new-found abilities to handle the time- and schedule-based measurements necessary to truly evaluate transit accessibility. My approach incorporates elements of system access (I include train stations as an activity site by themselves), system-facilitated access (using travel time as the impedance value), and integral access (instead of a cumulative value, I include only the closest opportunity).

Miller and Harvey (2001), meanwhile, provide a similar, albeit trifurcated, system: measures that (1) incorporate individual space-time constraints, (2) those that focus on the characteristics of places that make them more or less attractive or accessible (a la gravity model), or (3) those that measure the benefits and utility that different transport alternatives afford to users vis-à-vis a larger choice set. They advocate for the first category, noting that individuals' access to locations cannot be separated from their available time. In their opinion, a well-functioning system is not necessarily high-demanded but allows all people, *regardless of time budget*, to feasibly reach demanded destinations. While I would like to carry out an analysis like this, I lack information on the time- and fiscal-budgets of typical *asentados* required for this task. Couched in a desire to ensure social inclusion, Fransen, at al. (2015) alternatively find that existing accessibility metrics ultimately focus on one of four things: (1) *physical accessibility* (people's proximity—in time or distance—to a system), (2) *frequency of transit stops* (the number of trips—or number of seats—available at the stops proximate to a person), (3) *time or cost of travel to a destination*, or (4) *the temporal variability of service* (at a location or over a route during a day, week, or year) relative to people's demands. Each metric builds in complexity over the prior. My project, which captures travel time, builds on earlier incarnations, which looked only a physical accessibility and frequency of transit stops vis-à-vis Buenos Aires' *villas* and *asentamientos*.

Lastly, Salonen and Toivonen (2013)—in their quest to compare travel times across rival modes—placed transit-based measures into groups based on complexity: those that (a) *assume average speeds for entire routes and systems and/or oversimplify transfer times* and (b) *those that attempt to include actual arrival and departure times from transit schedules*. They advocate for analysts to take the latter approach—noting its increased viability with the introduction of GTFS datasets—while acknowledging that simplifications are often necessary for scholars interested in modeling door-to-door travel using public transit given the complex parameters defining transit systems (i.e. predefined routes and schedule and variations during the day and across the week). Explained in full below, the introduction of GTFS datasets for metropolitan Buenos Aires has permits a first-of-its kind analysis of transit-based travel within the conurbation, an exciting advancement over prior work.

In the end, I ultimately adopted a **cumulative-opportunities, location-based measure**. Also known as "contour" or "isochrone" accessibility measures, these are centered on the "degree to which two places or points on the same surface are connected" and measure "the number of opportunities which can be reached within a given travel time, distance, or cost, or the measure of the (average or total) time or cost required to access a fixed number of opportunities (Geurs and Van Wee 2004, 133)." The applicability of this measure to my study case is obvious: I want to know the travel time to the closest activity site (where it be a public school, public health center, train station, or central business district) to people living in AGBA's *asentamientos*. Given the data limitations of the Google Distance Matrix API web tool, an earnest cumulative opportunities measure was not possible in the available time frame. Nonetheless, the measure's advantages remain the same: quickly operationalized, easily interpreted and communicated, and relatively undemanding of data.

All the while, I must acknowledge some of the measure's shortcoming. For one, simply identifying the nearest activity site does not incorporate people's individual perceptions or preferences—it assumes all locations are equally desirable to all people. In reality, certain sites may have characteristics or offerings that may make them more appealing than alterative sites, even if they are closer or further away. If one knows that these types of effects are in place, some modifications can be made to a standard location measure to represent these "gravitational" effects—a function can be applied that assigns higher weights to "proximate" features or those with a higher degree of service. I tried to account for this by subdividing schools and health care sites (the nearest kindergarten is much more informative than the nearest school as is the nearest hospital than the nearest generic health-related establishment). Nevertheless, the full range of choices and preferences is not fully captured and would only be possible with highly-specific qualitative ethnographic data, a near impossibility in most cases and not immediately available for Buenos Aires.

Lastly, Lei and Church (2010) note that location-based measures often do not account for daily and weekly variation in transit schedules. These metrics often assume a single frequency and speed for a given mode or route when, in fact, these values fluctuate based on time-of-day and the frequency/velocity selected by the user might only apply to a given system during certain periods. While I avoid this second pitfall by using the Google Distance Matrix API and its associated real-times schedule data and congestion information, I was unable to avoid the first, although primarily due to limitations on the API tool mandated by Google. To permit timely data processing, I made all my requests using the same times-of-day and days-of-the-week, although, with a longer timeframe, I could have replicated my requests at different hours, weekdays, or weekends to capture the variation in accessibility that naturally occurs throughout the day.

Part III(d): Accessibility in Latin America, Argentina, and the Global South

While there are hundreds, if not thousands, of papers that analyze transit-access around the world, I narrowed my search to those written about Buenos Aires and other cities in Latin

America. I made this decision because urban areas in Latin American often face similar challenges (e.g. rapid growth, extreme, income inequality, poor or nonexistent planning, and bureaucratic ineptitude) and have similar geographies (e.g. wealthy centers surrounded by an impoverished periphery, higher transit usage, lesser (but growing) car ownership, and colonial-relic monocentric morphologies) that might not be accurately captured using methods applied to cities in the Global North, where car ownership, and its associated land uses, has produced a substantially different landscape of accessibility. Since "mobility is one of the dimensions that most clearly reflects social inequities," I wanted to use the unique travel conditions of Latin America to illustrate its unique, albeit unfortunate, landscape of socioeconomic inequalities (Contested Mobilities 2018, pg. 1).

For instance, Jaramillo, et al. (2012) note that most major metropolitan areas in the region are similarly plagued with the consequences of continuous growth (people are constantly migrating into cities from underdeveloped rural areas): rampant poverty, insufficient housing, high unemployment, deficient infrastructure (whether transport, electricity, sewerage, etc.), and weak public services. In terms of geography, most, if not all, of the recent growth has taken place on cities' urban fringes, where low-income families live in sprawling slum settlements—oftentimes growing too quickly for any proper response—while the upper classes live in upscale urban neighborhoods. Illustrative of enormous "spatial inequalities in the provision of homes and work places ... brought about by rapid industrialization [and] uncontrolled population growth and migration," some of the highest rates of inequality are in Latin America, where families of stark socio-economic backgrounds can live within relative proximity to one another yet, at the same time, exist in complete isolation, walled away in either gated communities and luxury high-rise towers or sprawling slums or dense urban tenements (Camara and Banister 1993, pg. 369). The same inequalities, as it turns out, carry over to transportation and other forms of infrastructure.

As a matter of fact, there are substantial gaps "between the provision of public transport and social transport needs (Jaramillo, et al. 2012, pg. 340)" throughout the region. Service levels are typically commensurate with income, rather than population numbers, with modern, reliable services found in wealthier city centers (a regionwide socioeconomic legacy of the colonial era) and inadequate, poor-quality services (e.g. longer travel times, greater distances, sparse networks, longer waits, infrequent headways, overcrowded vehicles, etc.) in the sprawling periphery. With most jobs traditionally found in central business districts, these mobility conditions have hindered access to employment for many on the urban edge. Compounding this problem in recent years is the growth in automobile traffic, as middle- and upper-class families gain sufficient wealth to afford private vehicles; increasing congestion and air pollution, this trend has inverted urban spatial patterns, with wealthier households escaping to gated enclaves in the periphery—often not far from slums and squatter settlements—while commuting back and fort into the city. Jobs and services have started to follow the wealthy to their new homes, a shock to cities whose monocentric, radial transportation systems are unfit to handle rapidly changing geographies of housing and employment.

As discussed by Guerra, et al., (2018), this means that poor households in Latin America spend more of their relative income on travel than their wealthier counterparts, despite relying on "lower" cost transit; the long journeys between homes in distant neighborhoods and jobs in urban centers takes a fiscal toll on families. Cervero (2011), in fact, notes that "whatever savings accrue from illegally squatting on land and living in squalor (e.g. lack of piped water or indoor plumbing) often evaporate from the high expenses incurred in reaching income-earning opportunities in the city as well as essential medical, educational, and retail destinations (pg. 6)." Low-income families face a trade-off between housing and transport: cheap housing in the periphery and expensive commuting or costly central housing with less travel, an image of how "isolation from job opportunities and health care is particularly acute among those living in the urban periphery ... [where] low-cost affordable public transport ... [is] an essential lifeline to participation (pg. 5)."

In many cases, local authorities struggle to ensure spatially-equitable transit services and respond to demands for better public transport; in fact, in many cases, they are responsible for the problems themselves. For instance, policies prioritize the needs of middle- and upper-classes sectors, who have greater purchasing power and possess greater influence over policymaking. As a result, road building has received greater attention than maintaining public transit systems. Authorities have imported North American-style transportation planning methods, engineering techniques, and economic forecasting models that promote highway construction, and other projects, coaxed by influential members of the motorized middle- and upper-classes with the power to prioritize their own economic well-being. As a result, projects with greater social equity impacts, or that may benefit people of all income levels, are overlooked (Vasconcellos 2001). In turn, there are large gaps—in quality and in spatial scope—between private and public modes of travel. In many cases, public modes have been privatized, a continent-wide pattern where governments offloaded state-owned enterprises (often rail and bus companies) onto the private sector as part of neoliberal economic restructuring. Envisioned to promote innovations and infrastructure renewal, critical services have been cut, often in the poorer areas of cities, where lower-income residents do not generate sufficient revenue to warrant service (Keeling 2008).

Without strong political representation, transit-dependent, lower-income groups struggle to ensure that city planners enact and enforce policies to ensure transportation services of equal quality to those enjoyed by the automobile-savvy, cosmopolitan upper classes. Without proper planning, there is a struggle to enact "radical policies ... to alleviate the spatial inequalities in service and provision ... [through] changes in land use, development and social policies"; recommendations for equitable fare structures, bus priority lanes, intermodal coordination, mandated bus maintenance and upkeep, provision of public housing in accessible locations, and metropolitan-scale planning policies have been stymied by incompetent bureaucrats, absence of proper planning agencies, lack of political will, or economic disarray (Camara and Banister 1993, pg. 369; Vasconcellos 2001). Nevertheless, conditions seem to be improving; Bocarejo and Oviedo (2012), Jaramillo, et al. (2012), Keeling (2013), and Guzman, et al. (2017) all document how cities in the region are incorporating equity and access into their planning priorities. All the while, many cities lack the tools to properly integrate or measure access; the hope of the authors above, as well as this paper, is to provide a simplistic tool to illustrate current conditions so as to promote changes that improve access to all citizens in the future and help "populations to access and make use of economic and social opportunities (Bocarejo and Oviedo 2012, pg. 237)."

Aside from looking for papers that explicitly handle the geographies of cities with extreme socio-territorial inequalities and that have such large transit-dependent populations, I am also seeking papers on Latin America for a much more practical reason. I need to know how to study regions without a large amount of publicly-available data, whether on income distributions, census variables and demographics, transit schedules, activity sites, or geographic information system-specific shapefiles or geo-databases (perhaps one of the biggest difference between United States-specific case studies and those from Latin America and other parts of the Global South). In fact, Gutierrez (2012) attributes some of the planning issues in greater Buenos Aires to the lack of high-quality data on commuting patterns, modal preferences, and revenue, indicating this is a problem not just for researchers but also for professional planners and policymakers in the region as well.

Part III(e): Case Studies from Buenos Aires

After reviewing the types of accessibility metrics, I began searching for papers specifically on Buenos Aires, with its massive population growth and urban sprawl, stark territorial manifestations of socioeconomic inequalities, rapid motorization, abundance of precarious settlements in its periphery, transportation system deteriorated by decades of (private- and public-sector) mismanagement, and inequitable, profit-driven distribution of public services—and its patterns of accessibility. I aimed to see which types of measurements had been used in the past and learn about what types of data were available for the conurbation. While there were not many, the two best came from Peralta Quiros and Mehndriatta (2015) and Salerno (2012); the former looked at region-wide accessibility and mobility trends in the context of urban expansion and the latter examined the transit accessibility of urban *villas* within the City of Buenos Aires. While both were reference points for literature on the history of the metro area and Argentine transportation data, the former is focused only on regionwide trends and the latter uses overly-simplistic distance calculations and is focused on mobility trends only within CABA.

The piece by Peralta Quiros and Manhdriatta is perhaps the best (and, as far as I can tell, only) example of a cumulative opportunities, location-based accessibility study on AGBA that also utilizes network-based travel time estimates. Intending to analyze links between transit accessibility and land use in Buenos Aires' fast-growing edge settlements, the authors conclude that the peripheral areas of Buenos Aires, and all the communities in those zones, are *exceptionally transit inaccessible*. This includes both wealthy gated communities (whose residents forgo transit anyway to drive personal cars into the city) and the ever-growing *asentamientos* (whose residents are too poor to own a car and must rely on a transit system that has not expanded services in a manner commensurate with growth). In fact, they find that most of Buenos Aires' 2001-to-2010 was in areas that are public transport inaccessible; rather than growing in the region's denser, more "efficient" areas closer to the city center, social housing complexes and informal settlements expanded the most in inaccessible locations.

Methodologically, the authors used a mixture of different data sources—ENMODO commuting data, remotely-sensed satellite imagery, open-sourced GIS datasets, and GTFS—as part of an isochrone accessibility model that identified the number of "employment opportunities" (a vague measurement adopted by the authors, with no explanation of how they estimated employment since, as far as I am aware, these data are not made public by the Argentine government) available within sixty-minutes travel time (driving and transit) for all people in AGBA. Travel times were calculated using a tool called "Open Trip Planner Analyst", which "utilizes the road network (in this case, Open Street Map) and transit attributes (specifically, a road network geographic information system layer and GTFS) to calculate travel times from every origin-destination pair in the city (pg. 102)." While I cannot speak to the relative accuracy of this tool, the authors performed this analysis using self-created GTFS schedule data, rather than schedule information published by Google, suggesting their estimations could be erroneous. The authors do, however, acknowledge the limitations of an isochrone model—it cannot account for changes in travel patterns during the day and congestion—and attributing its selection to minimal computation. Another disadvantage of their methods was the unit of analysis; since their goal was estimate accessibility across the conurbation, and without reference to any one type of community or neighborhood, it is impossible to look at differences the neighborhood (or *asentamiento*) level.

The second paper, meanwhile, was one of the few to explicitly estimate accessibility for people living in Buenos Aires' precarious settlements, albeit with a focus on CABA. Salerno (2012) produced an accessibility index by tabulating the total number of lines, stops, daily services, and daily seats available on transit to people living in the *villas* within the City of Buenos Aires. Using transit frequency data acquired through a personal connection at Argentina's transit-statistical agency (CNRT), Salerno determined that over 93% of the total land area of the city—including its *asentamientos* and *villas*—had access to transit (bus, rail, or subway) within a reasonable walking distance. He also surmised that most of this access was provided by buses. Nonetheless, he relied on straight-line distances for his analysis, likely over-estimating actual accessibility. I will build on this study by performing an analysis at a similar scale—individual neighborhoods—while employing accurate network-based, cost-centric measures. All the while, he makes an important disclaimer that online schedules likely do not coincide with what happens on the ground, and that congestion and other delays should be kept in mind when processing results based only on these times tables.

The only additional piece worth mentioning, from Arce and Mino (2017), built a similar transportation "index" to examine access to transit within one of Greater Buenos Aires' outer departments, Jose C. Paz. Using publicly-available train schedules—as well as their own estimates for bus frequencies—the authors surmised (using a Euclidean-distance measure of access) that census blocks near train stations had the greatest supply of transit. While nothing in their study explicitly targeted *asentamientos*, scores for their index were lower in census blocks located further away from rail stations, even when considering informal transit. This was explained by taxi drivers who feared venturing into neighborhoods with poor quality streets. Since this is a common characteristic of many *asentamientos*, it could explain their inadequate supply of transport services (representative of the public stigma that *asentamientos* are unsafe and crime-ridden).

Some of the most recent work on mobility and transportation within Greater Buenos Aires—papers from Guerra, et al. (2018) and Blanco and Apaolaza (2018)—were marginally helpful in terms of accessibility research (both researchers, for instance, rely almost exclusively on ENMODO data, which, as stated before, is susceptible to bias), even if their results were insightful. The first of these papers, from Guerra, et al., concludes that income is a strong predictor of travel expenditures in AGBA and that spending increases for those households with cars, that work or live in the periphery, and that live in neighborhoods that are less dense. In terms of access, they find that travel spending was higher in zones with better job access, whether via car *or transit*. The authors speculatively attribute this trend to households in poorly-accessible locations spending less on travel because the options are poorer, especially for transit, whereas the areas with good transit access may also have good car access, increasing expenditures on bot.

While these results are helpful for framing general mobility trends in the study area, they do not entirely apply to my study. For one, this paper does not consider accessibility by housing type (they disaggregate the findings to the *radio* level but offer no way to distinguish results by where in those blocks someone lives) or as a direct factor of *travel time* (only the number of jobs within an hour of a given radio, using the same the same black-boxed job access measure created by Peralta Quiros and Mehndiratta). Access to transit, meanwhile, is proxied by unrealistic straight-line distances, which obscure accessibility conditions, as distance is probably not as important as cost in predicting access, especially for the types of people who need transit services. Lastly, the paper does not distinguish the modal break-down of travel expenditures (ENMODO, the source of these data, does not differentiate), obscuring transit expenditures with those for automobiles.

A similar conclusion (that the poor in Buenos Aires often have long, costly commutes and are unable to afford private cars) is made by the authors of the second paper, which takes a socio-territorial approach to understanding the relationship between income and travel expenses in Buenos Aires. The authors show how limited mobility is correlated with economic and territorial inequalities. They find a close relationship between the two and that location was just as predictive of limited mobility as income; some of the strongest indicators of poor mobility (e.g. trip times, frequencies, distance from transit, paved roads, non-work trips, etc.) were associated with particular geographic spaces (departments furthest from CABA), not income levels alone: "due to the unequal distribution of infrastructures and the severe social fragmentation between territorial areas [of AGBA], differential mobility is closely associated with territorial structure (pg. 5)."

A pair of case studies, one in an informal settlement (not named as a *villa* or *asentamiento*) on the southwestern side of Buenos Aires and another near a gated community on the northern periphery, confirmed the poor supply of transport in these zones. The former exhibited minimal infrastructure, few non-worked-based trips, daily travel more than five hours, and little time for socialization beyond the immediate neighborhood and the latter saw low-income groups burdened by long, transit- or nonmotorized-travel times living immediately alongside wealthy day-commuters. While the study confirms that accessibility levels vary across the metro area, they don't explicitly target certain housing types and do not add any new measures of access beyond the information logged in the ENMODO survey and their interviews with residents in the two case study communities. All the while, the observed differences in mobility across income groups, results like those from Guerra, et al. (2018), bolster my hypothesis that accessibility will be worse in the *asentamientos* than in adjacent, presumably higher-income, neighbors.

Part III(f): Case Studies from Latin America

Without any other Buenos Aires-based accessibility studies to analyze, I turned my attention to other case studies from Latin America, hoping methods or data applied to cities with similar socio-territorial circumstances would offer me advice for studying AGBA. Despite examining over a dozen cases, this endeavor was only mildly-successful. In most instances, there were large discrepancies between the data available for Buenos Aires and those within the study areas, even if the objective or conclusion of the paper (i.e. spatially inequitable distributions of transit vis-à-vis activity sites is common across the continent) was like my own.

For instance, despite the fact that almost all of them adopted a location- or cumulative-opportunities measure of accessibility—*Boisjoly, et al. (2017) and Rodriguez, et al. (2017) analyzed jobs within Sao Paulo, Brazil and Bogota, Colombia (respectively); Delmelle and Casas (2012) looked at network-based access to activity sites in Cali, Colombia; Guzman, et al. (2017) and Hernandez, et al. (2017) studied work and school trips in Bogota, Colombia and Montevideo, Uruguay (respectively); and Martinez, et al. (2017) looked at transit and social housing in Santiago, Chile*—they all relied on unique, location-specific datasets that contained statistics not made public in Argentina. As noted before, employment and income data (not readily available for Buenos Aires) are included with the Colombian census and as part of Santiago's origin/destination dataset, rendering their methods inapplicable to AGBA. Bocarejo, et al. (2012), meanwhile, correlated employment access in Bogota with travel expenditures reported through a survey of travelers, a non-option given the timeframe and resources of my project. Montevideo and Bogota have their own unique network-routing tools, which proscribed the need for outside tools like ArcGIS' network analyst or Google Maps Distance Matrix API, which I had to adopt. Nevertheless, Boisjoly, et al. (2017), whose paper I describe in full below, helped spark my plan to use the Google Distance Matrix API (beforehand, I had never seen it used in Latin America) and Hernandez, et al. (2017) used, albeit for a different purpose, the WorldPop gridded population raster datasets that I used to estimate mean population centers within the *asentamientos*.