MEASURING TRANSPORTATION INEQUALITY USING

COMPOSITE INDICES OF ACCESSIBILITY

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ABSTRACT OF THE DISSERTATION

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It is argued here that transportation planners need to incorporate issues of equity into their agenda. Although recent efforts highlight the importance of establishing and utilizing new measures and standards to evaluate transportation performance on different criteria, equality and social considerations are still left out of the discussion to a great extent. Without such measures transportation agencies can hardly integrate the concepts of equality and social inclusion into their planning, programming, and project development activities.

Transportation inequality is a concept with many components and metrics developed to identify and measure it are varied. In the United States, concerns about providing equal access to social and economic opportunities has mostly centered on the issues of access to employment, healthcare, and food. In this study, however, I propose to look at transportation inequality through a social exclusion lens. Based on the academic literature on social exclusion, seven types of facilities and services are selected here as essential activities for social inclusion. These seven categories include education,

employment, healthcare, social activities, retail, government and legal offices, banks and financial institutions.

To measure the accessibility of each of these categories three accessibility measures are used including travel time to the closest facility, average travel time to the three closest facilities, and number of facilities within 20 minutes of the origin. Furthermore, to understand the relative nature of access and social exclusion, distributional representations including the Gini coefficient, Sen welfare index, and access disadvantage index, are used here. Expert interviews and Analytic Hierarchy Process (AHP) are also used to determine weights of each category and calculate the overall composite indices. These measures are calculated using Los Angeles County and the City of Commerce as case studies. The analysis is extended to future scenarios where L.A. County's transportation Measures R and M would be complete and the effect of these measures on access and inequality levels are evaluated.

Overall, what differentiates this study from the existing academic literature is that it combines several factors into its theoretical and methodological framework of measuring access inequality. The definition of accessibility here is multidimensional and covers access to multiple, essential services to support social inclusion. The study is also conducted at the household level and provides a more accurate representation of distribution of access. Basing the accessibility measurement on GIS network analysis as opposed to straight-line analysis help further this accuracy. Finally, using the Gini coefficient, access disadvantage, and the Sen welfare index helps form a new understanding of distribution of access levels throughout communities.

The analysis here is based on data mainly collected by the Southern California Association of Governments and the LA County Office of the Assessor. Similar data has been collected by other MPOs. Therefore the methodology here can be used to evaluate accessibility in other areas without the need for additional data collection and the results can be compared across regions.

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CHAPTER ONE: INTRODUCTION

Transportation planners might have to reinvent many of their most used models, methods and even dominant paradigm to stay relevant to the goal of promoting people's quality of life. Historically transportation planning in the U.S. has focused on promoting mobility as its central principle (Handy, 2002; Li, Zhang, Wang, & Zeng, 2011). Through time Americans have become increasingly mobile and also reliant on the automobile to meet their travel needs (Sánchez, Stolz, & Ma, 2003). The post-World War II period coincided with a historic watershed as the nation recovered from 15 years of economic depression and war. It was in this period when an extraordinary highway building effort was launched with authorization of the "National System of Interstate and Defense Highways" (1956). The rapidly growing network of freeways made more land available outside cities which led to extensive suburbanization. The resulting sprawl itself pushed for construction of more roads and the automobile became a necessity rather than a luxury. As a result of fast-growing suburbanization middle and upper-class housing moved to suburbs followed by the services seeking proximity to selected customers and agglomeration in big shopping centers to get the benefit of economies of scale (Sánchez & Wolf, 2005). Although experiences of American central cities vary they have in general undergone diminishing employment market share in their associated metropolitan areas with a few exceptions (Hill & Brennan, 2005). Central urban areas were left to those who could not afford or were prohibited from moving to suburbs and their quality of life started to degrade in these neighborhoods. As inner-city residents were becoming more isolated they gradually lost access to employment since employers had already followed the well-off communities to suburbs. Access to other services such as food and retail also became limited in these areas (Sánchez, Stolz, & Ma, 2003). Extensive investment in highways and roads and promoting the car as the centerpiece of the American Dream created hypermobile communities. Hypermobility is a term used by Adams (1999) to suggest that although increased mobility has been mostly viewed as an indicator of progress, it is possible to have too much of a good thing. Benefits of mobility have environmental costs as well as social costs. Adams suggests that even if the harmful environmental consequences of current and projected levels of mobility could be eliminated by technological advances, significant social problems would still remain. High mobility levels cause disadvantaged individuals who are financially, culturally or physically restrained in increasing their mobility patterns to become even more disadvantaged (Handy, 2005; Lucas, 2006).

Therefore, transportation planners need to not only focus on mobility but also take into consideration the social context of transportation. It is hard to separate transportation from other issues such as employment, education, health, housing etc. since nowadays the majority of our daily activities depend on transportation. Although the internet and other communication technologies offer a variety of substitutes, physical presence is still needed and used for most daily activities and for some the only available way to do so. Seeing transportation not as an isolated phenomenon but in light of the importance of activities it is used to attain paints a different picture. The key role of transportation is highlighted even further when evaluating it in providing access to essential activities and services through a social justice and inequality lens. Transportation systems can provide some with high levels of mobility and freedom while preventing others from accessing the main activities of society. For instance, a system mainly designed around the automobile causes hardship for households with one or no car by creating sprawling development patterns, longer distances, and insufficient public transportation provisions. Such unequal access has adverse consequences for the society as a whole.

Although the destructive social effects of inequality are indisputable, classical economics has long considered inequality the inevitable compromise to accomplish efficient economic growth (Kuznets, 1955; Kaldor, 1977). Kuznets's influential hypothesis was that income inequality follows an inverse U-shape through the development process meaning that it inevitably rises with industrialization but eventually declines as more workers join high-productivity sectors of the economy. Kuznets's ideas were developed concurrently with increasing critiques of the welfare economies of the 1930s and 1940s. As a response to such critiques as well as declining inequality in the 1950s and 1960s, economics of that era generally concentrated more on efficiency questions rather than income inequality and redistribution (Atkinson & Bourguignon, 2000). The common interpretation of the declining inequalities was that based on Kuznets's prediction we had entered the second stage of development. However, the trend was followed by a sharp reversal since the 1970s especially in the U.S. (Piketty & Saez, 2001). Previous assumptions of correlation between income inequality and growth were reexamined and questioned (Barro, 2000; Panizza, 2002; Voitchovsky, 2005) and redistribution became more of a concern. Recent studies since the 1990s back up this renewed concern and show that regions investing in equality have stronger and more resilient growth (Paul & Verdier, 1996; Benner & Pastor, 2012).

Considering the renewed interest in equality and its importance in development and growth as well as the tight relationship between transportation and socio-economic issues, it is vital for transportation planners to incorporate equitable transportation into their agenda. This is especially true for planners and policy makers in government agencies considering the extensive consequences of their decisions on the public. In fact, many of the U.S. metropolitan areas have already included social equity in their long-term transportation planning goals. However, these goals have not always been translated into clear objectives and performance measures (Bollens, 2002; Manaugh, Badami, & El-Geneidy, 2015). Now that transportation agencies consider reducing inequality as part of their main goals they need to develop new tools and measures to assess their progress in achieving these goals. Recently there has been a growing effort in the U.S. to develop new measures especially after the signing of Moving Ahead for Progress in the 21st Century Act (MAP-21) into law by President Obama in 2012. MAP-21 funded surface transportation programs at over $105 billion for fiscal years 2013 and 2014 and identified national goals in seven thematic areas. These areas included (1) safety, (2) infrastructure condition, (3) congestion reduction, (4) system reliability, (5) freight movement and economic vitality, (6) environmental sustainability, and (7) reduced project delivery delays. To implement these goals, MAP-21 required the establishment of performance measures, including social equity measures, in consultation with State DOTs, MPOs, and other stakeholders (Highway Safety Improvement Program). MAP-21 which was set to expire at the end of September 2014 was later extended to the end of July 2015.

The act was then replaced with Fixing America's Surface Transportation (FAST) Act which was signed by President Obama in December 2015. Fast Act is the first federal law in over a decade to provide long-term funding certainty for surface transportation infrastructure planning and investment. It maintains MAP-21's performance management approach and authorizes $305 billion over fiscal years 2016 through 2020 (Federal Highway Administration).

Although recent efforts highlight the importance of establishing and utilizing new measures and standards to evaluate transportation performance on different criteria, equality and social considerations are still left out of the discussion to a great extent. This is partly because transportation planning has its roots in the engineering profession, especially traffic engineering, and is historically less concerned with the social context of its work (Whitelegg, 1997; Hine & Mitchell, 2001a; Levinson, 2002; Wachs, 2010). Moreover, its most commonly used models, like the four-step travel demand model, are based on estimating trip generation, distribution, modal split and assignment based on existing patterns. In other words, they reinforce the status quo and do not leave much room for social justice approaches that try to change existing inequalities (Deka, 2004). This and other factors have to some extent alienated the practice of transportation planning from social concerns despite the fact that milestone social movements in the history of the U.S. such as the Civil Rights or Freedom Riders movements have claimed transportation systems as their main arena (Sánchez, Stolz, & Ma, 2003).

If we plan to ameliorate the social exclusion caused by transportation inequality, we will need to be able to measure and evaluate it (Tyler, 1999; Cass, Shove, & Urry, 2005; Martens, 2016). Although some concepts are extremely hard to quantify, we still need indicators and indices to be able to talk about a phenomenon, define related goals, design strategies, evaluate outcomes and also prioritize investments and mitigation efforts. While currently there is no such index that fully represents transportation inequality, there is growing interest and emerging studies on the issue (Golub, Robinson,

& Nee, 2013; Wellman, 2015; Martens & Di Ciommo, 2017). The experience of traveling in a private vehicle is clearly much different than taking a bus. It is also clear that individuals using the same transportation mode go through different experiences due to their own characteristics and circumstances. Moreover, the set of available transportation options varies across locales. For instance, it is difficult to compare the experience of individuals with constrained transportation budget in New York City to those in Los Angeles suburbs. New York City residents have many options in accessing activities since transit is available in most areas. However, in the L.A. suburbs what individuals can access is highly dependent on whether they drive. Although the existence of the above-mentioned differences is not disputable, it is not known how big the differences are. Not being equipped with appropriate inequality measures for transportation it is not possible to even discuss the issue in much detail without assuring some degree of misunderstanding the subject. We cannot plan to make opportunities more equal and have goals such as reducing transportation inequality unless we have a way of measuring it. Developing a set of suitable measures and indices to do so is what this dissertation will try to achieve.

Research Objectives and Questions

Transportation inequality is a concept with many components. This is because one can examine it from many perspectives. Transportation inequality can refer to the unfair distribution of costs and benefits of transportation systems including but not limited to governmental subsidies in favor of private vehicles versus transit or rail versus bus systems; unfair burden of transportation projects cutting through low income and minority communities; unequal participation of communities in decision making processes; and discriminatory distribution of traffic externalities such as environmental degradation, pollution and a higher rate of crashes (Sánchez, Stolz, & Ma, 2003; Deka, 2004). In this study, I propose to look at transportation inequality through a social exclusion lens. In particular, I intend to quantify unequal access and transportation opportunities that will exacerbate social exclusion across different communities and individuals.

Transport-related social exclusion is a concept that sheds light on the importance of transportation and access in a social context. Social exclusion imposes huge costs, both human and financial, on people directly affected as well as on the economy and society at large. Social exclusion is not only limited to poverty and low income. It is a broader concept that addresses some of the wider causes and consequences of poverty. It is a term for what can happen when people are excluded from participating in normal activities of a society and participating in these activities depends on physically accessing them. Social exclusion is a relative concept just like inequality and within this conceptual framework higher mobility rates in a society translates into worse relative access and inclusion for disadvantaged populations (Handy, 2005). Therefore, unequal access exacerbates social exclusion.

Before discussing inequality, I assume a definition of justice and fairness in distribution of access. As Martens et al. (2012c) argue it is impossible to achieve absolute equal distribution of access over space. Therefore, we need to answer the question of what is an alternative just distribution. There are several views on definition of justice. Barr (2012) has presented three main categories of theories of social justice: libertarian, collectivists, and liberal views. While libertarians believe in an endowment based reward system with no public intervention, collectivists aim to reach the highest possible level of equality in opportunities and outcomes. The third group, liberal views, is divided into two types: utilitarian and Rawlsian. Utilitarians define a just distribution as one that maximizes total utility for society. Rawlsians on the other hand believe social justice calls for equal basic opportunities for everyone and greatest benefits to the least advantaged groups (Barr, 2012).

As the overall framework in this research I choose Rawls's theory of justice that has previously been used to define just distribution of access in the literature (Martens, Golub, & Robinson, 2012c; Golub & Martens, 2014). Rawls (1971) has four classical principles as alternatives to the principal of equality. In his view a just distribution is one that meets one of these conditions: (1) it provides the maximum average level of what is being distributed, access in this case; or (2) it maximizes the average access level with a floor constraint for the minimum; or (3) it maximizes the average access level with a range constraint; or (4) it maximizes the lowest level of access. Of these four principles, the one that truly captures the relativeness of social exclusion is the third principle, maximizing the average access level with a range constraint. Maximizing the average level of access with a maximum range constraint can guarantee that access in general is maximized while the gap between the best and worst-off communities in terms of access does not widen. This distribution ensures that the higher level of access for some does not translate into relatively less accessibility levels for underprivileged populations and further exclusion of these groups. While agreeing on one number as the maximum range that can be used as criteria for just distribution of access throughout all communities is hard, this definition still provides a very useful framework to compare different communities in terms of inequality and also evaluate progress through time. If two communities have the same average access level but one has a narrower range then access has a more just distribution in that community.

To develop measures of transportation inequality with a social exclusion approach we also need to define a framework for transport-related exclusion based on the literature. This framework should define the interaction between social exclusion and transportation and the main components of each affecting the other one. It is clear from the outset that transportation might not be the core cause of social exclusion but it clearly interacts with most other causes since transportation is the trunk of the circulatory system for human socio-economic interaction.

The main research objective here is to develop methods to measure unequal distribution of access that leads to social exclusion. The development of such measures and indices will enable us to evaluate policies and programs such as Los Angeles transportation measures from a social perspective. Measure R and Measure M are sales tax measures for Los Angeles County to finance new transportation projects and programs, and accelerate those already in the pipeline. To answer the question of how these measures enable/disable Angelenos to participate in normal activities of their community and be socially included we need to first answer the question of how to measure transportation inequality before and after implementation of these policies. Therefore, after deriving a transport-related exclusion framework more review is necessary to study transportation inequality measures already proposed and utilized in the academic literature. We then need to answer several research questions including the following:

- What are the advantages and limitations of transportation inequality measures currently available in the literature?
- What is a feasible multi-dimensional set of indicators of transportation inequality with regard to social exclusion?
- What is the extent of transportation inequality in Los Angeles County measured by using the developed indices before and after implementation of Measures R and M?

Studies show that the U.S. socio-economic model is associated with high levels of social exclusion (Schmitt & Zipperer, 2006). Furthermore, the relative sprawl and automobile dependency in the U.S., compared to other developed countries, raises the concern for transport-related social exclusion. This concern is larger since the U.S. is far behind in studying social exclusion and introducing it in the planning and policy making dialogues. The hypothesis here is that the problem of transport-related exclusion in the U.S. is as serious as (if not more critical than) European countries while it is being discussed much less in the US. This conclusion is drawn based on the fact that searching through the academic literature at the beginning of this study I could only find five papers on the topic of transportation related social exclusion with case studies in the U.S. There are many studies on issues of transportation inequality and accessibility in this country, especially to jobs, as will be later discussed in the literature review. However, social exclusion is a multidimensional phenomenon and focusing on only one aspect of it will restrict our understanding of the issue and ability to ameliorate it.

These points highlight the need for research on social exclusion and associated transportation inequality in the U.S. This study can contribute to the body of knowledge by filling this gap in the U.S. transportation planning literature.

To succeed in developing measures for a complex issue such as transport-related exclusion it is important to keep a balance between realism and practicality. The measures of transport inequality should be multidimensional to represent the complexity of the issue while being feasible to calculate. An extensive literature review will help define the concept and its components. It also helps in finding ways to measure each component and later aggregate them to develop final indices.

The next step is to look into data available through national surveys and local studies to see if the proposed indices can be computed using existing data. This study can also identify the gap in existing information and recommend data to be incorporated in future major local/national surveys.

In the end, it is important to evaluate the proposed indices to see if meaningful conclusions can be drawn by applying them to real life cases. Through studying the County of Los Angeles as it undergoes recent transportation policies and computing the before and after inequality indices I expect to recognize strengths and weaknesses of the set of indices as well as to gain an understanding of how LA’s transportation measures will affect transportation inequality.

CHAPTER TWO: LITERATURE REVIEW

Several interrelated fields of literature are reviewed including transportation inequality, social exclusion, accessibility, and measures and metrics associated with each field. The following sections review and summarize on-going discussions in each field to identify gaps, methods, and research needs.

Transportation Inequality and Social Exclusion

Those concerned about transportation inequality seek fairness in mobility and accessibility levels across race, class, gender, and disability. The ultimate objective of transportation equity is to provide equal access to social and economic opportunity by providing equitable levels of access to all places (Sánchez, Stolz, & Ma, 2003).

Three categories of transportation equity have been defined by Bullard (2000):

- Procedural equity to assert that transportation decisions are carried out in a uniform, fair, and consistent manner with involvement of diverse public stakeholders
- Geographic equity which involves fair distributive impacts of transportation decisions across different geographies, such as rural vs. urban vs. central city.
- Social inequity and the fair distribution of transportation benefits and burdens across population groups. Intergenerational equity issues are also subsumed under this category (Bullard & Johnson, 1997; Bullard, 2000).

Litman’s framework (2002) has also been frequently used in studies dealing with transportation equity (Burris & Hannay, 2003; Delbosc & Currie, 2011c). In his framework equity can be examined in three different ways:

- Horizontal equity which is concerned with the fairness of distribution of costs and benefits among similar groups
- Vertical equity which is partly concerned with the allocation of costs among income and social classes
- Vertical equity is also concerned with measuring how well an individual's transportation needs are met compared with those of the same community (Litman, 2002)

As mentioned before, transportation inequality has many aspects and is concerned with unfair distribution of costs, benefits, opportunities, and access. Many researchers have focused on the distribution of transportation costs and benefits. A widely cited report published by the Surface Transportation Policy Project (O'Toole, 2003) argues that poor families spend a greater proportion of their expenditure on transportation relative to well-off families and the rate of increase in transportation expenditure for low-income groups and minorities is significantly higher than others. However, another study shows that low-income households have been spending slightly lower shares of their expenditures on transportation than high-income households since the early 1980s (Blumenberg & Manville, 2004). This latter finding has further been confirmed by other studies in locations such as California (Rice, 2004).

Another controversial subject has been the role of government investment in transportation. Disproportionate subsidies in favor of private vehicles have been criticized by planners since the 1970s (Rosenbloom & Altshuler, 1977; Meyer & Gomez-Ibanez, 1981). Generally, 80 cents of every dollar spent on federal surface transportation programs is designated to the Federal Highway Administration, and 20 cents is assigned to the Federal Transit Administration (National Conference of State Legislatures, 2014). However, states do not follow the same pattern in assigning their budget to transit versus highway systems. Fuel taxes are one of the major revenue sources for states to invest in transportation programs and 30 states have restrictive policies to use these revenues for highway or roadway projects only (Puentes & Prince, 2003). Therefore, states are unlikely to be devoting 20% of their overall transportation expenditures to public transportation (Sánchez, Stolz, & Ma, 2003). While the highway sector recovers 47.5% of its expenditures from its own sources, such as fuel taxes, vehicle taxes, and tolls, the remaining 52.5% comes from general fund appropriations, property taxes and assessments, investment income, bonds, and other taxes and fees (Federal Highway Administration, 2012). The situation is exacerbated since beginning in fiscal year 2015 revenues credited to the Highway Trust Fund are insufficient to meet the fund's obligations (Congressional Budget Office, 2014). In absence of any legislation to address the long-term shortfall facing the trust fund, lawmakers passed a series of measures providing temporary relief. In 2014 and 2015 Congress transferred a total of $19 billion to the trust fund from the Treasury’s general fund and other sources (Fixing the Highway Trust Fund, 2016). The Fixing America's Surface Transportation Act (FAST Act) was then enacted at the end of 2015 to transfer $70 billion of general revenue to the trust fund and enables the fund to meet spending obligations through 2020 (Federal Highway Administration, 2017).

Despite eliminating trust fund shortfalls through 2020, the fund’s long-term structural imbalance between spending and revenue remains. Several options (or combinations of those options) might be pursued to address projected shortfalls in the

Highway Trust Fund: spending on highways and transit could be reduced; revenues credited to the trust fund could be increased by raising existing taxes on motor fuels or other transportation-related products and activities; or the trust fund could continue to receive supplements from the Treasury’s general fund (Cogressional Budget Office, 2015).

The distribution of government funding within the transit sector itself is also contentious. When only bus and rail are considered, bus receives only 25.7% of the capital funds, although it carries more than 53.5% of the trips made by transit (Federal Transit Administration, 2010). Because rail transit is capital-intensive and bus transit is labor-intensive, a greater emphasis on capital subsidies favors rail over bus service. Data from the 2009 National Household Travel Survey show that persons from households earning less than $20,000 comprised 42% of bus riders, 5% of subway riders, and 10% of commuter train riders. Persons from households earning $100,000 or more comprised 41% of commuter train riders, 36% of subway riders, and only 12% of bus riders. Generally, more individuals with low incomes rely on bus service and those with high-income rely on rail service (U.S. Department of Transportation Federal Highway Administration, 2009). Therefore, the disproportionate government investment in favor of rail services has unjust consequences for bus riders who are mainly low-income individuals.

Furthermore, fare structures are often designed in such a way that shorter trips subsidize longer trips, and low-income and central-city riders generally make short trips compared with higher-income suburban users who make long trips. Also, the amount of revenue gained from passenger fares, including passes, tends to be higher on central-city transit routes than suburban routes, and more low-income transit riders tend to make trips on central-city routes (Deka, 2004).

The other aspect of funding that has been assessed as unfair is the disparity in federal funding by geographic area. Most of the nation's population is located in metropolitan areas that generate substantial revenues for highway spending, and have significant transportation infrastructure needs. However, states spend more on serving transportation needs in nonmetropolitan areas than in metropolitan areas (Puentes & Prince, 2003). MPOs, which have a better understanding of the transportation needs of metropolitan areas where many minorities and low-income individuals reside, and would be more likely to invest in public transit, only receive a small percentage of federal funds –less than 10% . Although states have the ability to provide more funding to local transportation agencies, few states actually do. One notable exception is California, which gives 75% of its federal and state transportation program funds to regional and metropolitan transportation agencies (Sánchez, Stolz, & Ma, 2003).

Low-income individuals and minorities not only benefit less from government transportation investment, they also bear disproportionate costs from transportation projects. In other words, the negative externalities of transportation are not evenly distributed throughout society. It is often the most disadvantaged groups who bear the brunt of the "disbenefits" and who pay directly through their health and their quality of life for other people's mobility (Whitelegg, 1997). Since the initiation of the Interstate Highway System, a substantial portion of it has been built within urban areas and more specifically where land values were lower, in poor neighborhoods. Upper and middle-class suburbanites were the main beneficiaries of these new freeways while minority and low-income central city residents who have fewer cars and drive shorter distances on local streets are exposed to numerous problems. Their communities were disrupted and the quality of space degraded, their health was affected by considerably higher levels of air pollutants and noise, and they were threatened by far more road accidents (Deka, 2004).

There are also other inequality concerns with the process of planning and implementing transportation projects. The main discussions here are about the underrepresentation of minority and low-income communities in transportation planning and decision-making processes as well as their unequal access to opportunities in the transportation construction industry (Sánchez, Stolz, & Ma, 2003).

While researchers in the U.S. have mainly focused on transportation inequality and issues of mobility and accessibility, international research has extended its scope to include various issues in transport-related social exclusion. At the turn of the 21st century some international developments, mainly in Europe, brought the discussion of social exclusion to the foreground. The establishment of the Social Exclusion Unit in the United Kingdom (U.K.) in 1997 was undoubtedly most influential in dedicating more study to the subject. The unit was established following the election of the Labor government in the U.K. with renewed interest in ameliorating consequences of social exclusion. The UK Department of the Environment, Transport and the Regions (DETR) in 2000 published Indices of Multiple Deprivation which updated the previously published Index of Local Deprivation (1998). The importance of the 2000 Indices was in including accessibility as one of the main indicators. Indicators in this domain measure distance to post offices (which provide many banking services in Britain), doctor’s offices, and food shops. Other domains include income, employment, health, housing, education/skills, crime/social order, and physical environment (Department of the Environment, Transport and the Regions, 2000). In the next step, the Social Exclusion Unit recognized lack of transport and access to be influential in the reproduction of social exclusion in its 2002 report "Making the Connections: Transport and Social Exclusion" (Social Exclusion Unit, 2002).

Although social exclusion has been the subject of discussion among the transport research and policy making community internationally, many still believe it is quite hard to define social exclusion and a commonly accepted definition does not yet exist (Hine & Mitchell, 2001b; Cass, Shove, & Urry, 2005; Lucas, 2012). This is due to the fact that the phenomena dealt with under the heading of social exclusion are too varied and complex. Littlewood & Herkammer (1999) suggest that on issues like social exclusion researchers must first of all recognize the impossibility of finding exhaustive definitions since the concept is relative and varies over time with social norms. They add that a definition distinct from social debate, leads to the trap of putting unclearly defined populations into arbitrarily defined categories. Social exclusion is a relative concept that covers social processes and concentrates on relationships of power between individuals, institutions and others (Hodgson & Turner, 2003).

In spite of the above-mentioned issues some major definitions have been repeatedly used as working definitions to guide research. Walker & Walker (1997) defined social exclusion as a "dynamic process of being shut out, fully or partially, from any of the social, economic, political and cultural systems that determine the social integration of a person in society". Burchardt et al. (1999) define social exclusion as a process that causes individuals or groups, who are geographically resident in a society, not to participate in the normal activities of citizens in that society for reasons beyond their control. Areas of normal activities of citizens include production, consumption, saving, political and social activities.

Lee & Murie (1999) have also suggested eight areas under which social exclusion could be discussed. These areas have some concordance with those put forward by Burchardt et al. (1999) and include labor markets and employment, welfare markets and poverty traps, exclusion from financial circuits and public utilities, education, health, housing markets, neighborhoods, and social networks. These three definitions have been used as frameworks for more recent research. Factors that affect individuals' ability to participate in these activities can be divided into an individual's own characteristics, life events, neighborhood characteristics, and the set of social, civil, and political institutions available from the greater society (Hine & Mitchell, 2001b).

On measuring social exclusion Burchardt's five-dimensional framework was the first of its kind (Burchardt, Le Grand, & Piachaud, 1999; Burchardt, 2000). She proposed the following fields to be the basis of identifying social exclusion:

- Consumption: the inability to consume at least a minimum level of goods and services, indicated by a low income.
- Savings: having low wealth indicated by not being a property owner, not contributing to or receiving an occupational or personal pension, or very low savings.
- Production: not being engaged in a socially valued activity such as paid work, education, or retirement.

- Political engagement: not voting or taking part in any civic organization or activity.
- Social interaction: lacking the ability to engage in social interaction with family, friends or community; lacking emotional support.

Burchardt's work was developed further by others including Delbosc and Currie (2011b) who redefined the categories as income, employment, political engagement, participation in activities such as sports or hobbies, and social support. They proceeded with introducing cut-off points for each category and using surveys to identify socially excluded individuals on each dimension. People were classified as excluded using cut-off criteria from the above variables. Those with an income below $500 per week (the "poverty line") were considered excluded on one dimension as were people who were unemployed. Those who participated in no political or social activities were considered excluded and so were people with very low scores on the social support scale. Further evaluations can also be done to identify individuals excluded on more than one dimension.

Interest in access and transportation's role has risen since the publication of "Making the Connections: Transport and Social Exclusion" (Social Exclusion Unit, 2002). Transport appears to have a peripheral effect in socially excluding individuals when compared to non-transport factors like unemployment or disability (Hine & Mitchell, 2001b). Yet, it is intertwined with all other domains in life. That is transport disadvantage can in fact exacerbate social exclusion through barriers to employment, exclusion from services, fear and perceptions of safety, reduced educational attainment, and health service inequalities (Hine & Mitchell, 2003; Clifton & Lucas, 2004).

Therefore, it may be a core process to be used to ameliorate other forms of social exclusion. Adopting a social exclusion approach to transport disadvantage helps policy makers and planners to recognize the multidimensional, relational and dynamic nature of the problem (Lucas, 2012). Also, inclusive transportation policies may be less costly to implement than means-tested economic programs or non-transportation infrastructure to facilitate the mobility of disabled populations.

While social exclusion is a more general term, transport-related exclusion is defined as the process by which people are prevented from participating in the economic, political and social life of the community because of reduced accessibility to opportunities, services and social networks, due in whole or part to insufficient mobility in a society and environment built around the assumption of high mobility (Kenyon, Lyons, & Rafferty, 2003). Church et al. (2000) identify three processes as probable causes of transport-related exclusion:(1) the nature of time space organization in households, (2) the nature of the transport system, and (3) the nature of time-space organization of the facilities and opportunities individuals are seeking to access. They also proposed a conceptual framework with seven dimensions:

- *Physical exclusion:* physical nature of the transport system may create physical and psychological barriers to access by people with disabilities
- *Geographical exclusion:* dispersed locations may limit the ability to carry out activities in the immediate area
- *Exclusion from facilities:* residents in areas with high levels of social exclusion often lack access to good shopping, financial, leisure, health and

education facilities because of time and income constraints and the flight of some of these facilities from problem areas

- *Economic exclusion:* high monetary or temporal costs of travel can prevent or limit access to facilities or jobs and thus income
- *Time-based exclusion:* other demands on time, such as combined work, household and child-care duties, reduces the time available for travel, a phenomenon often referred to as time-poverty
- *Fear-based exclusion:* where fear of crime preclude the use of public spaces and/or transport services
- *Space exclusion:* where security and space management strategies can discourage excluded groups, especially the young, from using public transport spaces

This framework has been repeatedly utilized in studying the conceptual relationship between transportation and social exclusion as well as in developing measures and indicators for transport disadvantage (Church, Frost, & Sullivan, 2000).

Lucas (2012) has also categorized three specific perspectives in analyzing transport-related exclusion as a result of her comprehensive review of a decade of discussion on transport and social exclusion. The first category is an accessibility perspective. Halden (2002) is an example of research adopting this perspective; he suggested that defining links between land use and transport is a crucial task in taking forward the sustainable development agenda and accessibility measures explicitly do this. According to Halden, definitions of accessibility generally include three key elements:

- *Category of people under consideration:* each section of the population has specific needs and desires to be involved in defined activities
- *Activity supply point:* opportunities are defined in terms of the land use supply which would allow any individual to satisfy their desire to participate in the activity under consideration
- *Availability of transportation:* this defines how an individual could travel to reach the relevant facility

Greico (2006) is another example of the accessibility perspective. He includes three main dimensions for the analysis of transport-related social exclusion including: person-based measure, place-based measures, and social-category based measures.

The second group in Lucas's review is concerned with social capital and capability perspectives. Studies in this category generally emphasize the importance of social networks, social stratification, and values and norms in exclusion (Cass, Shove, & Urry, 2005; Urry, 2007). Finally, Lucas's last category deals with the time geography perspective. Here the focus is on time poverty based exclusion and how fundamental societal changes in the spatial organization of society have created new inequalities in the opportunities that are available to different people within given timeframes (Priya Uteng, 2009; Currie & Delbosc, 2010).

Parallel to discussions on transport-related social exclusion there is a body of literature on the nature of the relationship between transport disadvantage and social exclusion pioneered by Delbosc & Currie (Currie & Delbosc, 2010; Delbosc & Currie, 2011a; Delbosc & Currie, 2011b). They studied the issue through subjective, self-reported measures of transport disadvantage and personal well-being using surveys in

Victoria, Australia. They suggest that social exclusion has a greater impact on well-being than transport disadvantage alone. By observing that the most common reason people reported for feeling isolated was time poverty, they concluded that one way subjective transport disadvantage can lower well-being if it causes people to become so time poor that they become cut off from society.

Metrics developed to identify and measure the concept of transportation inequality are varied. Many of the studies focusing on access to employment, health care, etc. use the gravity-based measures as will be discussed in the next section. Those studies that focus on inequality usually borrow from methods in economics since inequality is a well-studied subject in that field. For instance, the Lorenz curve and Gini coefficient can be used not only to evaluate the distribution of income but also any quantity that can be cumulated across a population including the public transport supply (Delbosc & Currie, 2011c). However, as mentioned before progress in research on transport and social exclusion has not yet translated into common activities across local planning agencies and part of the problem is poor articulation and lack of evaluation tools at different levels of governance (Lucas, 2012). As Lucas emphasizes there is a general agreement on the need for metrics to establish minimum level and standards of public transport that are necessary for social inclusion.

Accessibility

As Lucas's (2012) review shows a considerable number of studies have taken the accessibility approach to analyze transport-related exclusion. Accessibility is a general concept and open to interpretation. Hansen's (1959) definition of accessibility as "the potential for interaction" still has validity. Accessibility is commonly associated with time or cost of reaching a destination, and qualities of the potential destinations. It is generally defined as ease of travelling from an origin to a specified destination; opportunities available to individuals to reach places with activities; the freedom to participate in activities; or the utility an individual derives from participating in activities within an integrated land use-transport environment. Choice is an important element of accessibility: more choices in both destinations and modes of travel mean greater accessibility by most definitions (Handy, 2005).

Ferreira & Batey (2007) define a framework to study accessibility and suggest that there is more than one type of accessibility including transport-maintained accessibility, telecommunication-maintained accessibility and proximity-maintained accessibility. In their view, the concept of accessibility has evolved from a deterministic and simple perspective to a much more complex and integrated one and to study it thoroughly one should go through five different layers. These layers are different approaches to the understanding of accessibility and include the following:

- The transport-based approach, which defines accessibility as ‘the inherent characteristic (or advantage) of a place with respect to overcoming some form of spatial source of friction (for example, time and/or distance). This is the commonly used definition of accessibility in the literature.
- The demand-aware approach, where accessibility is seen as depending on the available transportation facilities.
- The time-aware approach, where instead of proximity or geographical location, space-time feasibility is the central aspect of accessibility.

- The perceptions-aware approach, which has two sub-layers. The first layer addresses perceptions as a process in which individuals develop a mental picture of the world. The second layer addresses how individuals impose constraints and obligations that reflect their beliefs, ethnic background, economic capacity, professional, personal and social position or aspirations, gender and age. For example, in a society that stigmatizes mental illness, individuals in need of help may not perceive treatment facilities as acceptable and consequently accessible.
- Finally, the institutionally aware approach is part of the time-space accessible to each individual when institutionally related forces and frictions are also considered. The institutionally aware approach recognizes that institutions and individuals maintain a "dialogue" that continuously influences both sides.

While the importance of accessibility has been strongly highlighted in the transport disadvantaged and social exclusion literature, it has not translated into clear policy. Very often in planning and policy making documents accessibility is assumed equivalent to mobility (Handy, 2002). Mobility, the potential for movement, is related to the impedance component of accessibility. Policies to increase mobility will generally increase accessibility as well by making it easier to reach destinations. However, good mobility is neither sufficient nor a necessary condition for good accessibility. Although policies to increase mobility can advance accessibility, the focus on mobility in transportation planning in the U.S. has over time helped to decrease accessibility. Enhanced mobility can encourage sprawling patterns of development, which in turn can ultimately limit choices for some individuals. Moreover, fast-growing mobility for part of society can mean declining relative conditions for others who do not benefit from higher mobility. The result is a decline in relative accessibility, at least for those who need or would like to travel by modes other than the automobile and those whose needs and desires are not met by the kinds of shopping, services, and other activities found in the suburbs (Handy, 2002). In other words, although mobility itself is a component of accessibility, the experience of U.S. cities indicates that a mere focus on mobility will have adverse effects on accessibility.

To identify transport-excluded populations recent studies have focused on accessibility-based measures whereas traditional approaches were based on economic inequality indices. Cumulative accessibility measures or isochronic indices are examples of recent measures that can calculate accessibility based on the number or proportion of opportunities that can be reached within specified travel distances or times from a reference location. Accessibility measures are often calculated using detailed travel diary datasets (Handy & Niemeier, 1997; Kwan & Weber, 2003; Joh, et al., 2008; Scott & Horner, 2008). A space-time accessibility prism is another tool that uses travel diary datasets to identify disadvantaged populations. Space-time accessibility measures originally introduced by Hägerstrand (1970) describe how activities are arranged in geographic space based on time constraints. These measures analyze the individual's trajectory in space and time based on a few fixed locations that are mandatory activities and the time budget available to carry out those activities. The result is what is called a space-time prism (Casas, Horner, & Weber, 2009). Basic space-time prisms have been further improved by incorporating discretionary activities that can be undertaken between mandatory activities, delay and waiting time, and income factors. Incorporating the utility associated with mandatory activities as well as discretionary activities allows for the assessment of transportation led social exclusion (Ashiru, Polak, & Noland, 2003). GIS tools with their potential for spatial analysis have proven to be very useful in developing new and complex measures.

In studying accessibility, many researchers and policy makers have focused on accessibility of certain opportunities or services. In the U.S., concern about providing equal access to social and economic opportunities has mostly centered on the issue of access to employment and more specifically the spatial mismatch hypothesis (Sánchez, Stolz, & Ma, 2003). Spatial mismatch was first identified by Kain (1968) and refers to the disconnect between locations of housing and jobs suitable for lower-income people. In other words, those who most need entry-level jobs (primarily people of color) generally live in central cities while entry-level jobs are increasingly in suburban locations that are not easily accessible from central cities. The main focus of the spatial mismatch hypothesis has historically been on the combined effect of employment decentralization and residential segregation of African Americans in inner-city neighborhoods. Early critics of this hypothesis though have argued that data from several cities across the U.S. shows race, not space, is the key explanatory determinant of employment (Ellwood, 1986; Leonard, 1987; Jencks & Mayer, 1990; Cooke, 1993). However, Kain (1992) and other researchers believe that these studies had not used appropriate spatial mismatch measures. DeRango (2001) suggested that commuting distance which had been used by many studies rejecting this hypothesis is not an appropriate proxy for spatial mismatch and commute-based methods need to be reevaluated.

In general, reviews of academic literature and empirical evidence several decades after the issue was first introduced and criticized show that spatial mismatch is in fact relevant for explaining black/white employment differences (Holzer, 1991). Serious limitations on black residential choice, particularly the exclusion of African Americans from suburban communities, combined with the steady dispersal of jobs, and especially low-skilled jobs from central cities, were responsible for the low rates of employment and low earnings of African American workers (Kain, 1992; Holzer, Ihlanfeldt, & Sjoquist, 1994; Ihlanfeldt & Sjoquist, 1998).

Academic literature on access to work, generally concerned with disadvantaged populations including minorities and immigrants, has also branched to focus on welfare recipients' access to work. One of the main challenges of the welfare system is in connecting welfare recipients to the labor market. The growing literature about transportation's relationship to welfare indicates that transportation is a barrier to employment for the poor in general and for welfare recipients in particular. In fact, welfare usage declines as geographic job access increases not only among poor African Americans, but also among whites, Asians, and Hispanics (Ong & Blumenberg, 1997). Although originating from the same concept, the literature on welfare recipients' access diverges from spatial mismatch in that it finds modal mismatch to be a more important factor. Studies show that while the conventional notion of spatial mismatch may still apply in some metropolitan areas and for some low-income residents, spatial barriers to employment are numerous. For the poor as well as non-poor, work is not often in close proximity to home. The difference is that for the non-poor, traveling between two locations is often much easier because of the transportation mode they use compared to the time constraints using public transportation imposes on poor commuters (Taylor & Ong, 1995; Blumenberg & Ong, 2001; Blumenberg & Manville, 2004).

In addition to access to work, transportation inequality has also been studied for access to healthcare. Minority and low-income populations generally have less access to healthcare services than others (Todd, Seekins, Krichbaum, & Harvey, 1991). Penchansky & Thomas (1981) have categorized barriers that impede utilizing health care services into five dimensions: availability, accessibility, affordability, acceptability and accommodation. While the first two dimensions are spatial in nature, the last three are essentially aspatial and reflect healthcare financing arrangements and cultural factors. Guagliardo (2004) argues that in urban areas, where multiple service locations are common, the two spatial dimensions should be considered simultaneously which results in a new combined aspect: "spatial accessibility". Simple measures of spatial accessibility could be travel distance or travel time of a population to the nearest health service (Dutt, Dutta, Jaiswal, & Monroe, 1986). More sophisticated methods include: the gravity model (Joseph & Bantock, 1982), the Two Step Floating Catchment Area Method (Luo & Wang, 2003), and the kernel density method (Guagliardo, 2004), as well as their variants (Luo & Qi, 2009; Wang & Roisman, 2011; Mao & Nekorchuk, 2013). These accessibility measures help identify under-served areas and provide an opportunity to address concerns about unequal access to healthcare.

Access to healthy and nutritious food is another concern not only from a social justice point of view but also from a health perspective (Coveney & O'Dwyer, 2009). In the U.S. 2.2% of all households live more than a mile from a supermarket and do not have access to a vehicle which makes it hard to access healthy food options. In the 2001

Food Security Supplement of the U.S. Census Bureau's Current Population Survey, respondents who indicated they did not have enough food or the kinds of foods they wanted were asked whether access-related factors, such as the availability of desired foods or difficulty in getting to a store, were the causes. Responses to these direct questions show that nearly 6% of all U.S. households faced access-related problems in obtaining food (Ver Ploeg, 2010). Studies show that urban core areas with limited food access are characterized by higher levels of racial segregation and greater income inequality (Beaulac, Kristjansson, & Cummins, 2009). These populated urban areas with a majority of low-income, minority residents that have poor access to healthy and affordable food are referred to as "food deserts" in the academic literature. The phrase ''food desert'' was first used in the early 1990s in Scotland by a resident of a public housing sector scheme. It later appeared in a government publication by the British government's Nutrition Task Force in 1995 (Cummins & Macintyre, 2002). In the U.S. the expansion of large chain supermarkets on the outskirts of inner-cities in more affluent areas have led to the smaller, independent, neighborhood grocery stores closing. Furthermore, between 1970 and 1988 economic segregation became more prominent with more affluent households migrating from inner-cities to suburban areas. This shift caused the median income in the inner-cities to decrease and forced nearly one-half of the supermarkets in the three largest U.S. cities to close. Other factors that make the establishment of businesses in inner-cities less desirable are inaccurate perceptions of these areas, declining demand for low-skilled workers, low-wage competition from international markets, and zoning laws (Walker, Keane, & Burke, 2010).

As a result of limited accessibility to supermarkets, inner-city and low-income populations are more dependent on smaller food shops and convenience stores which are generally more expensive. Therefore, residents lacking access to a major grocery chain often pay higher prices for less variety, and in some cases, pay more for lower quality as well (Smoyer-Tomic, Spence, & Amrhein, 2006). These residents also have increased exposure to energy-dense food ("empty calorie" food) available at convenience stores and fast-food restaurants which altogether make maintaining a healthy diet more difficult. The absence of affordable and healthy food options and the presence of unhealthy food contribute to a prevalence of diet related health problems such as obesity and diabetes in food deserts (Gordon, et al., 2011).

To reverse the food desert trend and provide access to affordable, healthy food options in cities, government started incentive programs for grocery stores and supermarkets. In 2004, Pennsylvania became the first state to create an incentive program focused on eliminating food deserts. Pennsylvania Fresh Food Financing Initiative (PAFFFI) launched with a mandate to assist grocers with access to grants, loans and favorable financing deals to open up in food deserts. The program was then imitated by many state and local governments. The federal government also launched the Healthy Food Financing Initiative in 2010 (Kinney, 2016). In addition to the government provided incentives, market conditions have also attracted supermarkets to urban centers. With suburbs and small towns saturated with grocery stores, urban areas that were still untapped at the turn of the century became promising markets for supermarkets. As affluent millennials have started moving into cities in recent years, food retailers have also followed them (Ehrenhalt, 2006; Wells, 2017). Stop & Shop and Pathmark Stores

Inc. in the East, as well as Ralphs and Food4Less in Southern California are examples of chain stores that figured how to unlock the profit potential in more densely populated lower-income neighborhoods (Fulmer, 2000). However, operation of supermarkets in inner cities requires adaptability and localized approaches and is challenging for large grocers. In fact, there are many instances of stores that had to close shortly after opening in cities because they could not make money. Yet, retailers like Target, Wal-Mart, Whole Foods, and Aldi remain determined to expand into more urban markets (Wells, 2017).

In addition to employment, healthcare, and supermarkets, unequal access to other services has also been discussed and evaluated in the literature including access to education (Sánchez, Stolz, & Ma, 2003) and recreational activities (Deka, 2004).

A review by Geurs & van Wee (2004) later used by others as well (Benenson, Martens, & Rofé, 2010; Bocarejo S & Oviedo H, 2012) identifies four main clusters for accessibility definitions and measures in the literature:

- Infrastructure-based measures, which provide insight into the performance or service level of transport infrastructure (e.g., “the average travel speed on the road network”)
- Location-based measures, which provide insight into the accessibility of locations (e.g., “the number of jobs within 30 min travel from origin locations”)
- Person-based measures, which analyze accessibility at the individual level taking into account personal possibilities and constraints (e.g., “the number of activities in which an individual can participate at a given time”)

- Utility-based measures, which analyze the (economic) benefits that people derive from access to spatially distributed activities

Hansen's work (1959) represents one of the first attempts to define and measure accessibility . This gravity measure is one of the most-used accessibility measures and has been the basis for most studies since then. The conventional Hansen equation is defined as:

$$A_i = \sum_{j=1}^{n} a_j \cdot f(d_{ij})$$

where A_i = accessibility of the zone i (origin zone), a_j = attractiveness of zone j (destiny zone) and f (d_{ij}) = function of the distance (cost) between zones i and j.

The equation has also been expanded as:

$$A_i = \sum_{j=1}^{n} a_j \cdot (d_{ij})^{-\beta}$$

where d_{ij} is the travel time or distance between locations i and j and β is a distance-decay parameter controlling the importance of distance.

Attractiveness, a_j, is usually measured using the number of opportunities at a destination such as the number of hospital beds, class of each library, acreage of each facility, etc.

However, the frequently used gravity-based measure suffers from some limitations. For instance, resulting values are not uniform and can vary from one study to another depending on the units of a, d, and the value of β. Therefore, comparisons cannot be made between studies; all values are relative to the particular case. Also, the measure does not consider demand for activities, just supply. To address these shortcomings modified models were later introduced which incorporated standardized values (z-scores) as well as supply and demand parameters (Delmelle & Casas, 2012; Weibull, 1976).

A gravity-based model is appropriate where units of analysis are geographical zones. However, household level accessibility is the focus of this study which will be evaluated using three other accessibility measures. These measures include travel time to the closest facility, average travel time to the three closest facilities, and number of facilities within 20 minutes of the origin. Using the first measure with a minimum cost approach together with the other two that take the element of choice into consideration allows a multidimensional evaluation of the issue.

Measuring Inequality

Inequality is related to several mathematical concepts, including dispersion, skewness, and variance. As a result, there are many ways to measure inequality. Some of the most common inequality measures include range, relative mean deviation, variance, coefficient of variation, Gini coefficient, and log variance (Cowell, 2011). The Gini coefficient is a very popular and well-known measure in economics. In the economic context, the Gini coefficient is defined as the average difference between all possible pairs of incomes in the population, expressed as a proportion of total income. However, income can be replaced with the previously calculated accessibility indices to provide inequality indices for transportation. Such indices will allow direct comparison between units with different size populations. The downside of the Gini coefficient is that calculating it requires comprehensive individual level data and it is not an appropriate measure when the data available has some degree of aggregation or an underlying hierarchy. An example of such cases is when income data is collected and presented in categories and all individuals within each category are assumed to have income equal to the average of that category (Hale, 2003).

Directly associated with inequality indices are welfare functions. In economics, a social welfare function expresses the aversion of a society for inequality and is defined as:

$$W(x) = \mu(x)\,(1-I(x))$$

where W is the welfare function, μ is the mean income, and I is the inequality measure (Lubrano, 2013). Welfare functions measure welfare as a mix between population's income mean and overall inequality. The function works in a way that if there is an increase in both poor and rich individuals' income the overall welfare is only improved if μ rises more than I. This definition of welfare is in line with Rawls's principles of justice discussed in Chapter 1. The welfare function captures the essence of Rawls' third principle which defines a just distribution as one that maximizes the average with a range constraint. If the average value increases without increased inequality the welfare index increases and the distribution is more just according to Rawls's third principle.

The inequality measure, I, in the welfare function can be replaced with various functions. If the Gini coefficient is used as the inequality measure, the social welfare index equation can be rewritten as:

$$W = \mu\,(1-G)$$

where G is the Gini coefficient. This function was first used by Sen (1976) and, hence, is called the Sen welfare index. As the Gini coefficient can be calculated for the distribution of any non-negative variable besides income through communities, welfare function can also be calculated for variables such as accessibility. This study will use both the Gini coefficient and the Sen welfare index in the following chapters.

Summary

The purpose of this research is to examine existing measures of transportation inequality and develop new composite indices that better represent unequal access leading to social exclusion. Equality issues in transportation have been gradually incorporated into federal law and agency guidance since Title VI of the Civil Rights Act of 1964 and later acts such as Intermodal Surface Transportation Equity Act (ISTEA), 1994 Executive Order - Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations, and the Moving Ahead for Progress in the 21st Century Act bill (MAP-21). Title VI mandates nondiscrimination on the basis of race, color, and national origin in programs that receive federal funds. Recipients of federal funds are prohibited from discriminating in their distribution of that funding and must demonstrate compliance with Title VI. Preparation of equity analysis for regional transportation plans is an example of MPOs' effort to fulfill this requirement (Karner & Niemeier, 2013; Karner, 2015). A policy or plan can be subject to revision or even rejection if analysis finds its impact to be discriminatory against protected populations, including low-income people, people of color, transit-dependent individuals, etc. However, agency assessments often find no evidence of transportation inequality (Rowangould, Karner, & London, 2015). This contradiction between agency analysis and the academic literature reviewed here reflect methodological shortcomings in equity assessment and absence of equality performance measures (Martens, Golub, & Robinson, 2012c; Karner, 2015). Without performance measures transportation agencies can hardly integrate the concepts of equality and social inclusion into their planning, programming, and project development activities. Transportation performance measures predict, evaluate, and monitor the degree to which the transportation system accomplishes adopted public objectives. Historically adopting performance measurement in planning and policy making has been a result of agencies' tendency to provide greater accountability and visibility to the public of their activities. Despite emphasis of the U.S. transportation laws on performance measures, there are no established standards for deciding how to measure the distribution of benefits generated by a transportation plan (Golub & Martens, 2014). In fact, other countries such as Canada and Australia are using transportation performance measures to set priorities and make planning, investment, and management decisions to a much greater extent compared to the U.S. (MacDonald, et al., 2004).

This research focuses on equal distribution of access as a performance measure since accessibility is the link between transportation and social exclusion. Access has also been suggested by other researchers as the most appropriate measure of benefits from transportation plans and investments to be considered for equity evaluations (Martens, 2012). Literature has focused on issues of access to opportunities and services such as employment, health care, grocery stores, educational institutes, and recreational facilities and provided measures of accessibility for each category independently. However, there has never been a multidimensional accessibility measure taking into consideration various components of accessibility to various activities and services necessary for social inclusion. The main components of accessibility include transportation infrastructure, land use patterns, individual constraints, and utility derived from access (Geurs & Van

Wee, 2004). Categories of activities that should be accessible to individuals in order for them to be socially included are consumption, production, saving, political engagement, and social interaction (Burchardt, Le Grand, & Piachaud, 1999). Measures of accessibility should incorporate these components and categories to equip us with tools to study and evaluate transportation related exclusion. The five categories of consumption, production, saving, political engagement, and social interaction are associated with locations of retail stores, places of employment, banks and financial institutions, government and legal offices, and places for social activities respectively. Due to the indisputable importance of education and healthcare in giving individuals the opportunity to be socially included these two categories are also added to the previous ones. Therefore, the assumption made here is that seven types of facilities and services should be accessible to eliminate transportation related social exclusion including education, employment, healthcare, social activities, retail, government and legal offices, banks and financial institutions. These will be referred to the seven essential services going forward in this dissertation. To measure the accessibility of each of these categories three accessibility measures will be used including travel time to the closest facility, average travel time to the three closest facilities, and number of facilities within 20 minutes of the origin.

Furthermore, issues of exclusion and inequality are relative concepts. Therefore, to understand them, mere measurement of access does not suffice and distributional representations such as the Gini coefficient and welfare index should be used. In absence of such metrics it is not possible for policy makers to establish objectives, evaluate transportation policies’ contribution to ameliorate/exacerbate social exclusion, or prioritize programs and projects with a social justice approach. Development of indices of transportation inequality through this research will enable transportation planners and policy makers with a social inclusion agenda to measure the phenomena they are dealing with and monitor their progress through time.

CHAPTER THREE: DATA

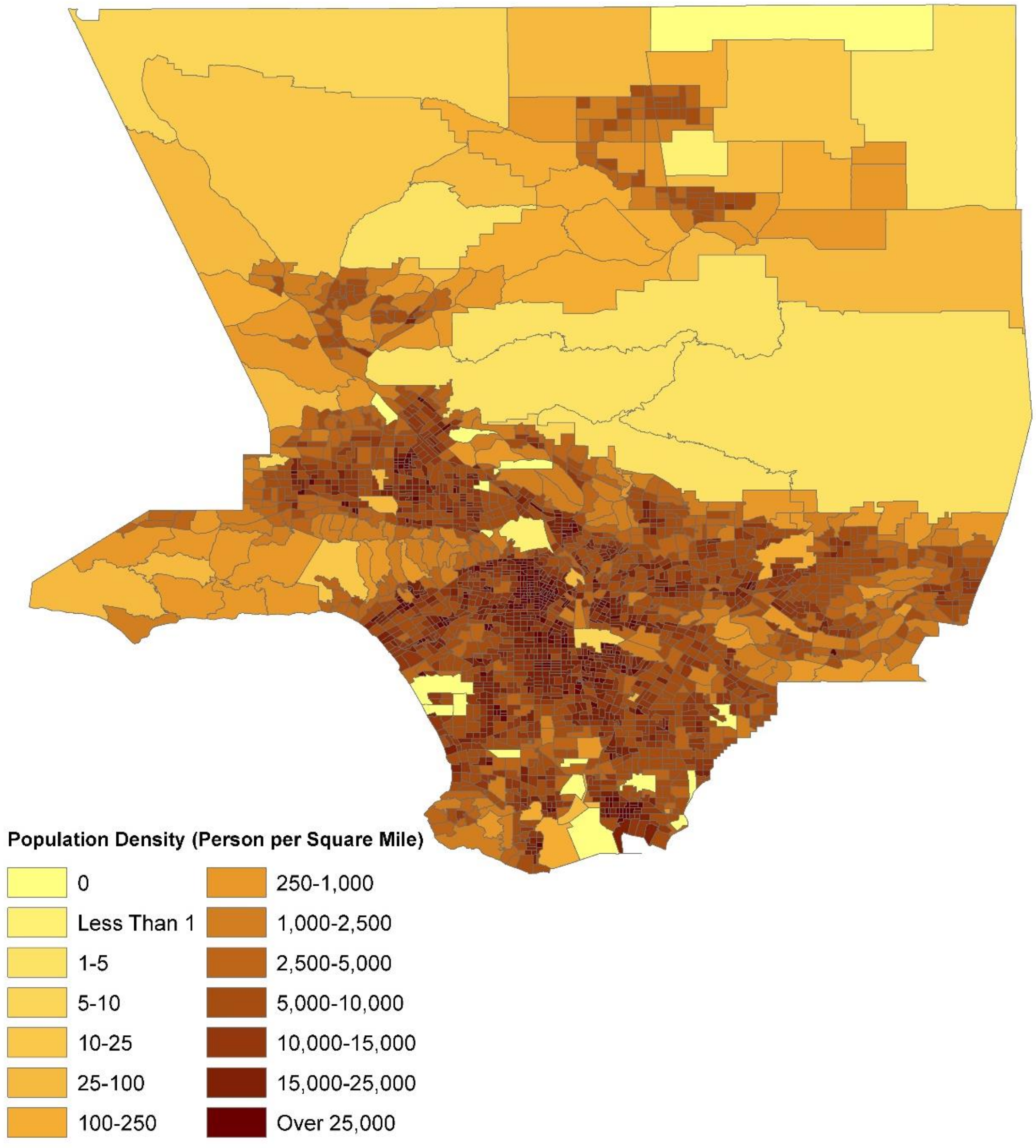
This chapter describes the study area and data sources used throughout the dissertation to develop indices of transportation inequality.

Study Area

County of Los Angeles

Los Angeles County has been the focus of much transportation related academic research and discussion. Land use patterns and high rates of driving in Los Angeles (L.A.) raise concerns for transportation inequality and social exclusion for disadvantaged populations. Despite its reputation for sprawl, Los Angeles is densely populated at the regional scale and in fact is one of the densest metropolitan areas in the country. While downtown L.A. is not as dense as some other major cities, the suburbs surrounding it are much denser in comparison. The County extends over 4,084 square miles of land and per American Community Survey 5-year estimates it was home to 10,038,388 people in 2015. Therefore, the overall County population density was 2,458 persons per square mile of land. Figure 1 shows L.A. County's population density by census tracts in 2015. It should be noted that two islands of Santa Catalina and San Clemente are part of Los Angeles County but are not shown in Figure 1.

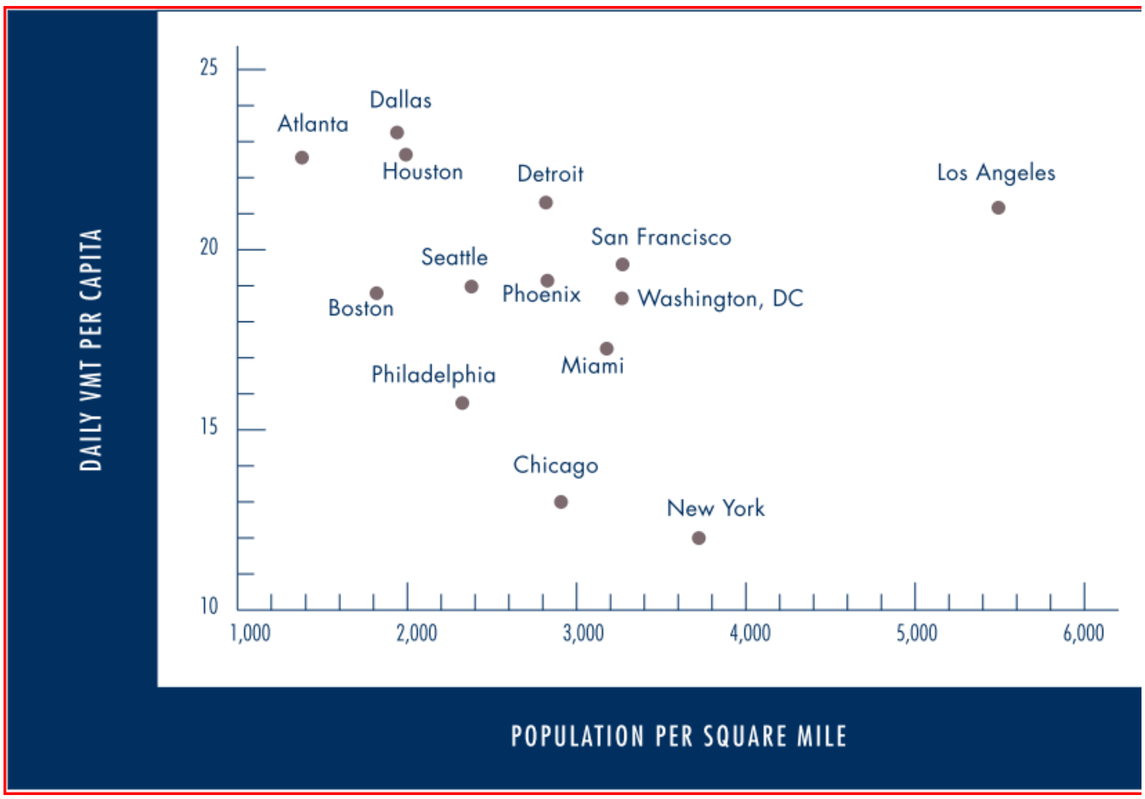
Figure 1. Los Angeles County Population Density by Census Tract, 2015



Source: Calculated based on 2015 American Community Survey 5-Year Estimates

Despite the high regional density, Angelenos do not seem to curtail their driving as much as one might expect. National trends show individuals tend to drive less on a per-capita basis as density increases. While Los Angeles residents do not drive more than residents of other large areas, they drive a lot on a per-capita basis considering the region's density. As can be seen in Figure 2, in other large metropolitan areas that have the same level of density as Los Angeles (San Francisco, Washington and New York) per capita vehicle miles of travel (VMT) is much lower (Sorensen, Wachs, Min, Kofner, & Ecola, 2008). As a result, Los Angeles is consistently ranked among the top ten urban areas in the U.S. with regard to different congestion variables (Schrank, Eisele, & Lomax, 2012).

Figure 2. Population Density vs. Daily Per-Capita VMT in Major Metropolitan Areas, 2007



Source: Sorensen, 2009

To understand the situation better it is helpful to compare Los Angeles with another metropolitan area depicted in Figure 2. In 2010 Washington had a population weighted density of 6,388, very close to the average density of all U.S. metropolitan areas, while the weighted density in Los Angeles was twice as high at 12,114. Population weighted density is defined as the average density of census tracts included in the metro area (U.S. Census Bureau, 2010). The transit share in workers commute on the other hand was 6% and 14% in Los Angeles and Washington respectively (U.S. Census Bureau, 2009).

The high rate of driving despite high density is partly associated with the polycentric land use pattern of Los Angeles which makes it hard to develop an effective transit system. The transit network will require more links in order to connect all of the dispersed population clusters and job centers with one another. If one defines metropolitan area centers as one square mile cells or two adjacent cells with more than 4,000 employees then Los Angeles with 33 centers has the highest number in the U.S. followed by Washington with 15 centers (Sarzynski, Hanson, Wolman, & McGuire, 2005). The polycentric/ dispersed land use pattern and high regional population density of Los Angeles is partly responsible for its lower share of transit and higher VMT compared to other areas (Sorensen, Wachs, Min, Kofner, & Ecola, 2008).

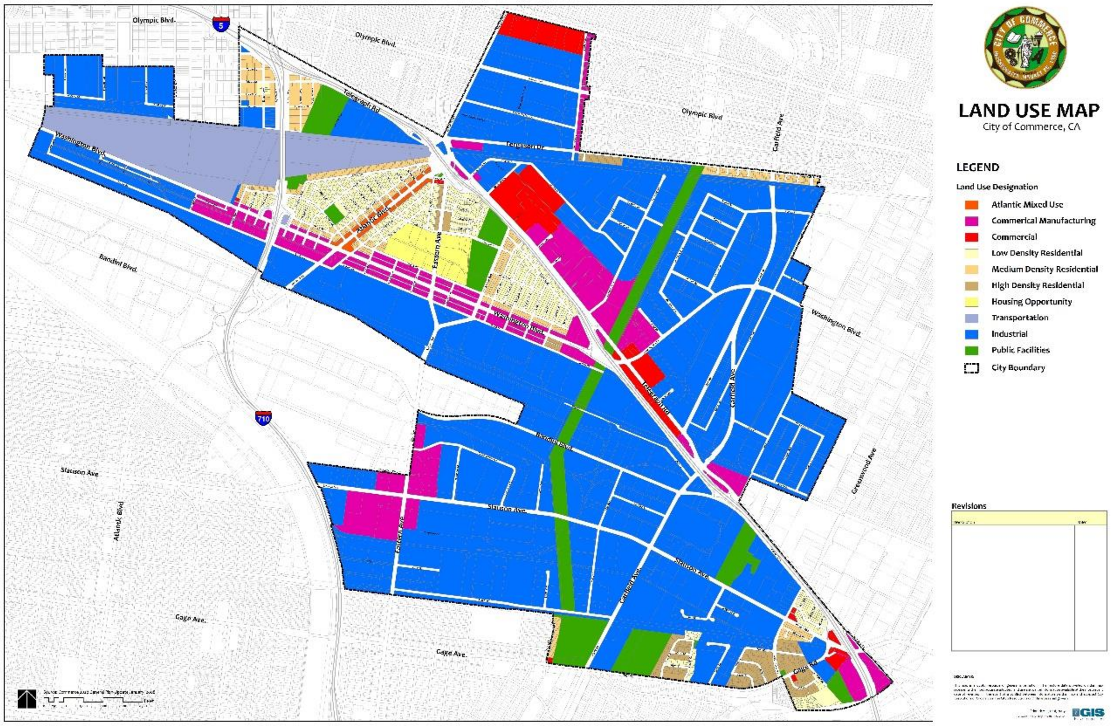
Recently L.A. has been going through major changes that are transforming its image from a sprawling suburbia dominated by car culture to what some are calling "America's next great mass-transit city" (Yglesias, 2012). The City of Los Angeles had Antonio Villaraigosa in mayor's office from 2005 to 2013 whose efforts and accomplishments in the field of transportation won him the title of LA's transportation mayor. His successor, Eric Garcetti, has also heavily campaigned for transportation policies and programs such as Measure M to expand the county's transit system. Another key player influencing the region's recent transformation is Los Angeles County Metropolitan Transportation Authority (Metro), which organizes the public transportation network for the entire agglomeration. Metro is responsible for the management and planning of the subway and exclusive bus lane networks. It also funds carpool and bike lanes as well as Metrolink, the regional rail transport service linking various counties of California (Carter, Pastor, & Wander, 2013).

The above-mentioned characteristics of L.A. County raise concerns for high levels of inequality in access. At the same time, the on-going policies and efforts to expand and invest in the transit system provide the opportunity to ameliorate the transport-related social exclusion. Because of these two aspects Los Angeles County is chosen as the case study for this research.

City of Commerce

As it will be explained in more detail in Chapter 5, GIS software is not able to perform network analysis for a dataset as large as L.A. County's. Therefore, the study's focus is on a smaller area to allow network accessibility analysis and the City of Commerce was selected. Commerce is a relatively small city, 6.6 square miles, about six miles east of downtown Los Angeles with a population of 12,823 in 2010. City population is estimated to be 12,960 in 2017 with median age of 32.8 and average household income of $56,294. About 30% of households have annual incomes less than $25,000. As Figure 3 shows, two freeways, Santa Ana I-5 and Long Beach I-710, cross the city. The city is served with its own municipal bus system as well as the Montebello Bus Line and the Metropolitan Transportation Authority (MTA). Commerce is located within ten miles from Metro's Gold Line, Silver Line, Blue Line, Green Line, Expo Line, Purple Line, Red Line, and Metrolink commuter rail. Land assigned to industrial use covers extensive areas of the city and separates residential properties and neighborhoods.

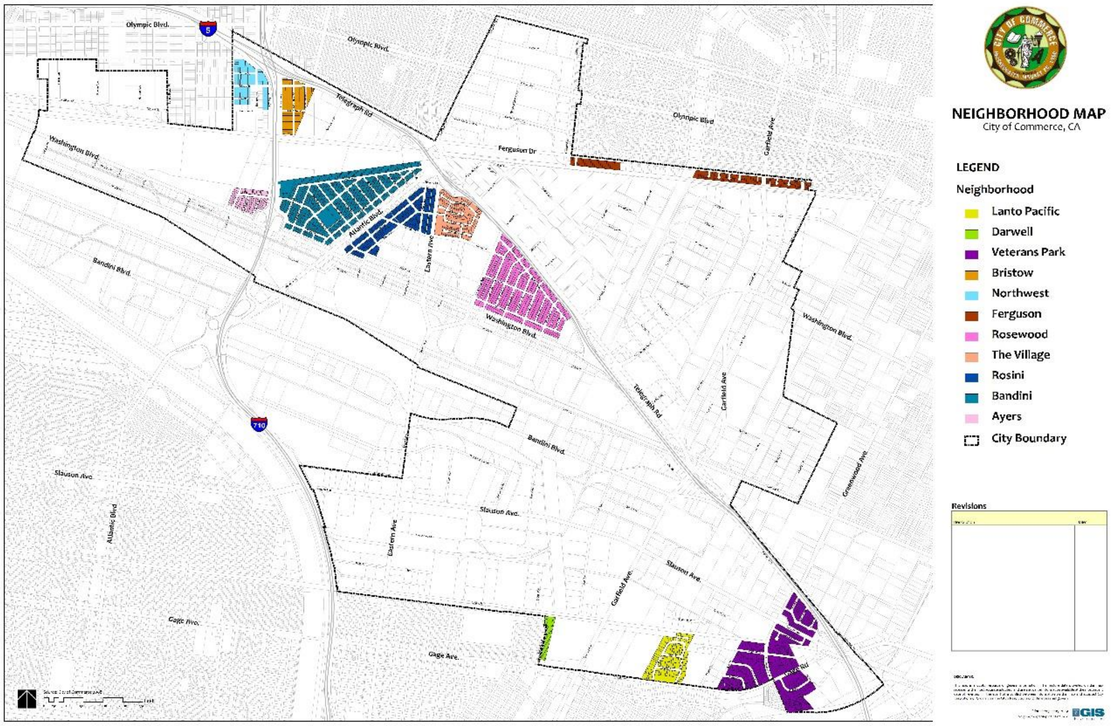
Figure 3. City of Commerce Land Use Map



Source: Planning Maps, City of Commerce. Retrieved June 25, 2017, from http://www.ci.commerce.ca.us/index.aspx?nid=360

As shown in Figure 4 the city's eleven neighborhoods are separated by freeways, railroads, and non-residential uses. Three neighborhoods of Lanto Pacific, Darwell, and Veterans Park at city's southerly boundary are separated from the rest of residential areas by railroads. Freeway I-5 which cuts through the city isolates neighborhood of Ferguson and freeway I-710 separates two more neighborhoods from the central ones. Despite the small size of the city, dispersed location of neighborhoods and various levels of access to transit and road networks make Commerce a heterogeneous city where an unequal distribution of access can be expected. Results of accessibility analysis in Commerce are presented in Chapters 5 and 6.

Figure 4. City of Commerce Neighborhood Map



Source: Planning Maps, City of Commerce. Retrieved June 25, 2017, from http://www.ci.commerce.ca.us/index.aspx?nid=360

Data

To perform accessibility analysis three primary groups of data are utilized: data on residential units as origins of trips, data on location of various facilities and services as destinations, and the network through which individuals can travel from origins to destinations. The following section lists data sources for each group.

Origins

The dataset used as travel origins for accessibility analysis includes the location of residential units. Los Angeles County Office of the Assessor maintains assessment records of real and personal property in the County as well as a GIS Tax Parcel Base

Map. The 2015 parcels with associated tax roll information is available through the Assessor's Office and other websites. The 2015 Tax Roll dataset was downloaded from the L.A. County GIS Portal and parcels with residential general use were extracted from the set (Assessor Parcels – 2015 Tax Roll).

L.A. County 2015 Tax Roll data show there are 2,391,896 parcels in total in the County's 141 cities and unincorporated areas. Residential parcels comprise 91% (2,177,328 parcels) of the total and non-vacant parcels comprise 96% (2,098,581 parcels) of residential parcels. For the purpose of this study, the two islands of Santa Catalina and San Clemente are excluded from the set and the remaining non-vacant residential parcels are used. The centroid of each parcel is further located to represent the origins in accessibility analysis. Due to the large size of the dataset, GIS software could not perform analysis on it in its entirety so the set was divided to nine sub-sets by the city name in parcel's address.

The area chosen for detailed analysis, City of Commerce, has 2,198 non-vacant residential parcels. Since there can be more than one unit on each parcel, for example in case of condominium properties, the total number of residential units is different than the number of parcels. There are 3,406 units reported on non-vacant residential parcels in the City of Commerce and these units are used as the basis of analysis in this study.

Destinations

The dataset used as travel destinations for accessibility analysis includes the location of seven essential types of facilities and services identified in Chapter 2. These categories are places of employment, education, healthcare facilities, social activities, retail stores, government and legal offices, and banks and financial institutions. Any employment dataset with geocoded information on businesses can be used to extract locations of these seven categories and provide the necessary information to run the analysis. In this study, employment data collected by the Southern California Association of Governments (SCAG) is used to build the destinations dataset. SCAG functions as the Metropolitan Planning Organization (MPO) for six counties of Los Angeles, Orange, San Bernardino, Riverside, Ventura and Imperial and is the largest MPO in the nation. SCAG has been mandated by the federal government to research and draw up plans to address the region's transportation needs. To do so, the organization collects and processes comprehensive sets of data on the region.

To locate facilities and services in L.A. County, the latest employment data available, year 2011, was requested from SCAG and received via email on October 4, 2016. The employment data is recorded by North American Industry Classification System (NAICS) six-digit codes and can be separated into the seven essential types of facilities. Table 1 lists the number of locations in each category in L.A. County and Commerce based on SCAG’s data. For a complete list of selected sub-categories with their associated NAICS six-digit codes refer to Appendix F.

Table 1. Number of the Seven Essential Types of Facilities, 2011

Type of Facility	L.A. County	City of Commerce and Surroundings (Ten-Mile Buffer)
	Number of Locations	Number of Locations
Education	20,923	4,960
Employment	360,774	143,439
Healthcare	58,066	11,642
Social Activities	26,449	6,722
Retail	129,815	34,199
Govt. & Legal Offices	5,846	1,180
Banks & Financial Inst.	21,115	3,891

Source: SCAG Employment Data, 2011

Numbers presented here and used in analysis exclude the places of employment with zero or one employee. Locations such as ATM machines with zero employees and locations registered for single-person corporations with one employee offer no employment opportunities and would skew the accessibility analysis if included in destinations. Therefore, they were eliminated from this study.

Networks

To build the road network, SCAG's 2015 road data is used. This data was received on March 1, 2016 in the form of TransCAD files and was then exported to ESRI GIS shape files. It should be noted that SCAG's dataset does not include all the local roads but have been used here since it does not need any cleaning and can be directly used to build the road network. Network analysis also requires a field to be used as impedance, such as travel cost, time, etc. For this purpose, information on the posted speed on each segment of road was requested from SCAG and was received on June 16, 2016. The posted speed is used to calculate travel time based on the length of each road segment with the assumption that vehicles move at the posted speed on average. Using this information, L.A. County's 2015 road network was built with no modeled turns, no elevations, and travel time in minutes as the main attribute.

The transit network data received from SCAG could not be used since it did not include any information on the travel time. Instead, General Transit Feed Specification (GTFS) data is used to accurately model trips with public transportation. GTFS files for L.A. County were downloaded from LA Metro's website (Metro's GTFS Data). It should be noted that Metro's GTFS files do not include either regional rail lines, Metrolink, or municipal bus lines. To build the transit network using GTFS files a tool developed by Melinda Morang at ESRI was downloaded from ArcGIS website (Morang & Stevens, 2013). This tool, called "Add GTFS to a Network Dataset", processes GTFS data and generates feature classes for transit lines and stops and a SQL database of the schedules. It also creates connector features between the transit lines and stops and allows for joining the pedestrian paths to the transit network at each stop. Road shapefiles from 2015 TIGER/Line are used as the basis for pedestrian paths.

The transit network was built with 2017 bus and rail schedules assuming ten-minute wait periods before boarding and a walking speed of three miles per hour by pedestrians. The pedestrian walking speed was used for individuals getting to the first transit stop from their homes and from the last transit stop to their destinations. If walking to a destination is faster than using transit for certain origins, network analysis will disregard the transit routes and record those trips as walking trips. Since the network built in this manner is schedule-aware it caches transit schedules before solving a network analysis. The analysis then requires a specific time of day to run otherwise the transit lines will be ignored. The tool provides the option to specify a particular date or a generic day of the week. In this study, all transit network analyses were run at 8:00 am on Tuesdays. The choice of Tuesday versus other days of the week does not affect the results since transit schedules are usually the same for all weekdays. With residential parcels as origins, seven essential types of services as destinations, and road and transit networks as explained above, network analysis can be run and accessibility levels can be measured throughout the study areas. Chapter 5 summarizes the results of these analyses.

CHAPTER FOUR: INTERVIEWS

Constructing composite indices in general includes three main stages: selecting variables and components, scaling and weighting components, and aggregation of variables. After developing the framework based on my literature review and selecting access to the seven essential types of facilities as the main determinants of transportation related social exclusion in previous chapters (retail, employment, banks and financial institutions, government and legal offices, social activities, schools, and healthcare facilities) this section explains the methods used to weight and aggregate these variables.

Different methods to determine weights have been developed, including data-dependent statistical tools as well as conventional judgment-based expert opinions. Per the Handbook on Constructing Composite Indicators (OECD/EC JRC, 2008) weights based on statistical models can be assigned through principal components and factor analysis, data envelopment analysis, regression analysis, and unobserved components models. Weights based on public/expert opinion can be determined through a budget allocation method, public opinion polls, Analytic Hierarchy Process, and conjoint analysis. While statistical weighting processes aim to correct for the overlapping information of two or more correlated indicators, participatory approaches, which involve public or expert judgment, are often used for the determination of the weights with relative importance of the indicators (OECD/EC JRC, 2008). Analytic Hierarchy Process (AHP) is a judgment-based method to weight variables which has been used in various fields of decision making (Vaidya & Kumar, 2006; Ho, 2008; Saaty & Vargas, 2013) including transportation and environmental planning (Berrittella, Certa, Enea, & Zito, 2007; Dedeke, 2013). In this research AHP is used to identify potential weights for the seven essential facilities through expert interviews. The method is explained in the next section.

After variables are weighted they can then be aggregated into composite indices. Methods for aggregation include weighted arithmetic mean of sub-indicators, multiplicative geometric and nonlinear aggregations, such as multi-criteria analysis. In general, the index aggregation is either additive or functional. Additive aggregation entails the addition of weighted components to arrive at an index value and functional aggregation is based on the estimated functional relationship between variables. After identifying weights of each access category through AHP and measuring accessibility of each category through GIS analysis a simple additive method is used to aggregate the data into a composite index. The Analytical Hierarchy Process method and expert interviews utilized in this research are explained in this chapter. Chapter 5 will present results of the data analysis and the composite indices I develop.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method developed by Saaty (1977). AHP decomposes the decision hierarchy into goals, criteria, and alternatives. Then it constructs a set of pairwise comparison matrices where participants express their preference for each goal and criteria. The output of AHP analysis is quantified weights for all alternatives.

Using pairwise comparisons makes AHP an easily applicable decision-making support system which corresponds to the intuitive way that people solve problems. Psychologists argue that it is easier and more accurate to express one's opinion on only two alternatives than simultaneously on many alternatives. It also allows consistency cross checking between the different pairwise comparisons as will be explained later (Ishizaka & Labib, 2011). In each pairwise comparison, the judgement elicited from participants is taken using either relative verbal appreciation or a corresponding numerical scale of one to nine. A preference of one indicates equality between two individual activities/criteria, while a preference of nine indicates that the individual criterion is absolutely more important than the other one (Saaty, 1980; Saaty, 2008). Table 2 lists numerical values 1-9 and their associated qualitative definitions and explanations.

Table 2. Intensity of Importance Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgement slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed

Source: Saaty, 2008

All pairwise comparisons are then recorded in n by n reciprocal matrices as shown here:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & a_{ij} & \cdots \\ \cdots & a_{ji} = 1/a_{ij} & 1 & \cdots \\ a_{n1} & \cdots & \cdots & 1 \end{bmatrix}$$

where a_{ij} is the intensity of importance of comparison between element i and j (scale of 1-9). In any pairwise comparison matrix a_{ii} = 1 since a_{ii} is equally important as a_{ii}.

After developing comparison matrices, traditional AHP uses the eigenvalue method to calculate local weights, or priorities in AHP terminology, as

$A \cdot p = \lambda \cdot p,$

where A is the comparison matrix, p is the priorities vector, and λ is the maximum eigenvalue. In this method the principal eigenvector p is considered as the desired priorities vector based on perturbation theory. Saaty argues that in a positive reciprocal matrix, small perturbations in the coefficients imply small perturbations in the eigenvalues. Therefore, priorities derived through the eigenvalue are insensitive to small changes in judgment and are stable (Saaty, 1977).

Using the eigenvalue makes AHP susceptible to a problem known as rank reversal. Rank reversal happens in cases of scale inversion when comparison matrices with a dimension higher than three are inconsistent. In other words, a different formulation of the problem with big inconsistent matrices can result in reversed priorities. This problem is due to the fact that the solution of an Eigen equation depends on the formulation of the problem and is not asymmetric (Ishizaka & Labib, 2009).

In order to avoid this problem other methods of deriving priorities have been introduced. The geometric mean has been supported by a large segment of the AHP community because of its main advantage, absence of rank reversals (Ishizaka & Labib, 2011). The Row Geometric Mean Method (RGMM) is therefore used in this study to calculate weights of transportation related social exclusion indicators. As Crawford & Williams (1985) proposed in RGMM, priorities/ weights are calculated for matrix A = a_{ij} using Logarithmic Least Squares Method as:

$$r_i = \left(\prod_{i=1}^{n} a_{ij}\right)^{1/n} = exp\left[\frac{1}{n}\sum_{i=1}^{n} \ln(a_{ij})\right]$$

and normalized as:

$$p_i = r_i / \sum_{i=1}^{n} r_i$$

AHP is also susceptible to inconsistent judgment. If a comparison matrix is perfectly consistent then the transitivity rule $a_{ij} = a_{ik} . a_{kj}$ holds for all comparisons. However, human judgment is not always perfectly consistent. To ensure a minimal level of consistency and to derive meaningful priorities AHP includes a consistency test. Saaty (1977) has proposed a consistency index (CI), which is related to the eigenvalue method:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

where n = dimension of the matrix

λ_{max} = maximal eigenvalue

The consistency ratio is then calculated as:

$$CR = \frac{CI}{RI}$$

where RI is a random index (the average CI of 500 randomly filled matrices)

If CR is less than 10% , then the matrix can be considered as having an acceptable consistency (Saaty, 1977).

The consistency index as calculated per the above formula has been shown to allow contradictory judgments in matrices or to reject reasonable matrices which follow the transitivity rule. To overcome this shortcoming several other methods have been introduced, two of which are utilized in this study.

A regression of the random indices has been proposed by Alonso & Lamata (2006). The authors have calculated RI using 500,000 matrices and then obtained the least square adjustment line to estimate $\bar{\lambda}_{max}$. The resulting function is:

$$\bar{\lambda}_{max}(n) = 2.7699n - 4.3513$$

They have then estimate RI using $\bar{\lambda}_{max}$. Therefore, the consistency ratio can be calculated as:

$$CR = \frac{\lambda_{max} - n}{2.7699n - 4.3513 - n}$$

Crawford & Williams (1985) suggested the Geometric Consistency Index (GCI) which is calculated as:

$$GCI = \frac{2\ \sum_{i<j} \ln a_{ij} - \ln \frac{p_i}{p_j}}{(n-1)(n-2)}$$

Both Alonso & Lamata's CR and Crawford & Williams's CGI are used in this study to measure the consistency of participants' judgment and comparison matrices.

After each participant's comparison matrix is formed and their individual priorities, or local priorities, are calculated the next step is to aggregate those into global priorities which are the overall priorities for all participants. The traditional AHP approach uses an additive aggregation with normalization of the sum of the local priorities:

$$p_i = \sum_j w_j . l_{ij}$$

where p_i: global priority of the alternative i

l_{ij}: local priority

w_j: weight of the criterion j

This additive aggregation is subject to a different type of rank reversal due to the modification of relative values between local priorities. This type of rank reversal phenomenon is in fact not unique to AHP but to all additive models (Ishizaka & Labib, 2011). To avoid this problem, the weighted geometric mean method is used in this study to calculate the consolidated matrix C = c_{ij}. Global priorities shown as c_{ij} are calculated using:

$$c_{ij} = \exp \frac{\sum_{k=1}^{n} w_k \ln a_{ij(k)}}{\sum_{k=1}^{n} w_k}$$

Where $a_{ij(k)}$: comparison between element i and j per participant k

w_k: individual weight of participant k

Since all interviewees are given equal weights in this study the above equation can be rewritten as:

$$c_{ij} = \exp \frac{\sum_{k=1}^{n} \ln a_{ij(k)}}{n}$$

When AHP is used with multiple participants/decision makers a consensus indicator can be calculated based on Shannon alpha and beta entropy. The consensus indicator ranges from 0% (no consensus between participants) to one 100% (full consensus between participants). The AHP consensus indicator S* equals:

$$S^* = \left[\frac{1}{exp(H_\beta)} - exp(H_{\alpha\, min})/exp(H_{\gamma\, max})\right] / \left[1 - exp(H_{\alpha\, min})/exp(H_{\gamma\, max})\right]$$

where $H_{\alpha,\beta,\gamma}$ is the α, β, γ Shannon entropy for the priorities of all k participants

Shannon alpha entropy $H_\alpha = \frac{1}{k} \sum_{j=1}^{k} \sum_{i=1}^{n} -p_{ij} \ln p_{ij}$

Shannon gamma entropy $H_\gamma = \sum_{j=1}^{k} -\bar{p}_j \ln \bar{p}_j$

with $\bar{p}_j = \frac{1}{n} \sum_{i=1}^{n} p_{ij}$

Shannon beta entropy $H_\beta = H_\gamma - H_\alpha$

and $H_{\alpha\, min} = -\frac{c_{max}}{n + c_{max} - 1} \ln\left(\frac{c_{max}}{n + c_{max} - 1}\right) - (n-1)\frac{1}{n + c_{max} - 1} \ln \frac{1}{n + c_{max} - 1}$

$$H_{\gamma\, max} = (n-k)\left(-\frac{1}{c_{max} + n - 1}\right) \ln\left(\frac{1}{c_{max} + n - 1}\right) - \left(\frac{k + c_{max} - 1}{n + c_{max} - 1}\right) \ln\left(\frac{1}{k} \cdot \frac{k + c_{max} - 1}{n + c_{max} - 1}\right)$$

where n: number of criteria

k: number of participants

The following sections present the results of AHP analysis using expert interviews and the above calculations.

Interviews

Social exclusion is defined as the involuntary exclusion of individuals from participation in the normal activities of a community and it is highly relative and dependent on time and geography. In other words, normal activities vary throughout different communities and different times. Therefore, to prioritize the determinants of transportation related social exclusion in the context of Los Angeles County it is appropriate to obtain information from experts in this region. This study utilizes expert interviews to elicit data from a group of scholars and professionals who are familiar with transportation related issues in L.A. County. This data is then used as input in AHP analysis so that selected categories of variables can be weighted based on their importance in transportation related social exclusion. Interviews were mainly designed around data required to complete AHP comparison matrices but also had structured qualitative questions.

The target population for this set of expert interviews was transportation policy makers as well as activists and scholars concerned with transportation inequality and social exclusion in the City and County of Los Angeles. Interviews were conducted via telephone and fully recorded. To comply with Institutional Review Board's requirements and protect interviewees' rights a script for oral consent was prepared and submitted to the Rutgers University Arts and Sciences IRB Office. The approved copy of the script for oral consent is included in Appendix A.

Interview Process

An initial list of organizations involved in transportation decision making in the City and County of Los Angeles were selected. This list included the California Department of Transportation District 7, Southern California Association of Governments, Los Angeles County Metropolitan Transportation Authority, City of Los Angeles Department of Transportation, City of Los Angeles Great Streets Initiative, Bus Riders Union, Investing in Place, Move LA, Alliance for Community Transit-Los Angeles, Community Development Commission of the County of Los Angeles, and scholars from USC and UCLA. Within each organization the principal or an individual whose expertise was most relevant to the research subject was selected and contact information including email addresses were extracted searching each organization's website. Other scholars who have been conducting extensive research on transportation related social exclusion were also added to the initial list. This list was later extended as more interviews were conducted and each interviewee suggested more organizations/ individuals to interview. The organizations that were added later included Los Angeles County Department of Public Health, Public Health Alliance of Southern California, Los

Angeles County Bicycle Coalition, City of Los Angeles Department of Transportation Pedestrian Advisory Committee, Transportation Foundation of Los Angeles, Los Angeles Community Action Network, Multicultural Communities for Mobility, Jobs to Move America, Advancement Project, Youth Policy Institute, T.R.U.S.T. South LA, Leadership for Urban Renewal Network (LURN), Strategic Concepts in Organizing and Policy Education (SCOPE), Fixing Angelenos Stuck in Traffic (FAST), and LA THRIVES.

A total of 41 individuals were contacted, there was further communication with 24 of these individuals, and eventually 16 individuals agreed to and were interviewed (39% response rate). All individuals were first sent a recruitment email (Appendix B) briefly explaining the topic of study and asking them to participate in a phone interview. When reaching out to experts it has proven to be difficult to motivate and convince them to participate unless the main goals and context of research are clearly conveyed (Goldstein, 2002). To do so and to get a foot in the door the recruitment email also included an attachment (Appendix C) with an explanation of the objectives of the interview, AHP weighting technique to be used in the interview, and interviewee sample.

Studies show that the day and time of sending an email affect its chances of being read and responded to. Research in fields of marketing and communication finds Tuesdays to be the best day to send out emails, survey requests, etc. (Allis, 2005; Singh, Taneja, & Mangalaraj, 2009). Therefore, the majority of recruitment emails were sent on Tuesdays and 80% of the emails that were replied to, received a response within three days. In cases where a response was not received and the individual’s phone number was listed on the organization’s website a follow up phone call was made. However, these phone calls were not effective. In several cases a message was left and the call was never returned, only one of the follow up phone calls resulted in a scheduled interview. In scheduling interviews, interviewees were given complete flexibility in choosing the date and time of the interview. They were also asked to provide the best phone number to reach them, where some provided their cell phone numbers and others asked to be called at their office numbers. It was expected that some interviews would be rescheduled due to ease of rescheduling through the phone compared to face to face interviews. In face to face interviews the interviewer needs to make a journey and interviewee feels more obliged to stay committed to the time of interview. However, in phone interviews spontaneous or short notice changes in interview schedules should be expected (Christmann, 2009). In fact, several interviewees did not answer the phone when called at the scheduled interview time. A message was left and they were called back in ten minutes. Some did not answer the second call either and called back later or rescheduled via email. Eventually every individual who had originally agreed to participate was interviewed. The entire recruitment and interview process took two months, from May 2016 to July 2016.

Interview Structure

Each phone interview took approximately 30 minutes. Interviews began with reading the script for oral consent (Appendix A) to inform interviewees of their rights as research human subjects and ask permission to record the conversation. All interviewees agreed to be recorded and interviews were fully recorded and later transcribed. The interview consisted of three main sections and closing remarks. The first section asked for general information about the interviewee and their experience in the field of equitable transportation. After presenting a brief definition of social exclusion, the second section of the interview was assigned to identifying important destinations and policies that can improve access to overcome social exclusion. The third and main part of each interview included pair-wise comparison questions to build AHP comparison matrices. This section included 21 questions and all responses in this section were recorded as the intensity of importance using the scale 1-9 that was previously explained in this chapter. Finally, closing remarks gave interviewees an opportunity to add anything to their previous statements or bring up any other issues of concern. At the end, all interviewees were asked to suggest other possible interview candidates. Responses to this question were extremely helpful in extending the sample population and sending more recruitment emails. A copy of the questionnaire can be found in Appendix D.

Interview Results

The first section of each interview was assigned to a brief introduction of the interviewee and their experience in the field of equitable transportation. When asked if participants were familiar with the concept “social exclusion”, 50% responded yes (7 of 14 who answered this question).

The next section covered two questions about social exclusion: what were the normal activities of society that should be accessible to individuals so they are not socially excluded, and what policies and programs could be most effective at providing access to those activities. All except two of the activities and services that were listed by participants in response had already been included in the research framework as the seven main categories. These categories include retail, employment, banks and financial institutions, government and legal offices, social activities, schools, and healthcare facilities. Safety and affordable housing were the two reoccurring themes that were not included in the original list of this study but were brought up by several interviewees (each by five respondents, 31%). It should be noted that when interviewees discussed safety concerns they referred to issues related to both safety (crashes) and security (crimes) risks.

Of 16 interviews that were conducted, 13 were complete interviews while three interviewees chose not to respond to the pair-wise comparison questions. These participants stated that in their view all seven categories of activities and services in question are equally important and communities should not be forced to compromise on access to any one of them. Therefore, only 13 interviews were used for the AHP analysis.

AHP Analysis

Although AHP calculations can be run manually, it is common to automate the analysis. In addition to Expert Choice (Forman, Saaty, Selly, & Waldron, 1983) which is the main software package for AHP there are many other software and tools developed to run AHP analysis. This research utilizes BPMSG's Excel template (Goepel, 2013) to organize and analyze AHP data. This template provides the option to compare use of different intensity scales (linear, logarithmic, etc.). It also calculates the consistency ratio as well as the consensus indicator based on Shannon alpha and beta entropy. Shannon entropy here is a measure of homogeneity of priorities between the respondents and can be interpreted as a measure of overlap between priorities of the group members. Its value varies between 0% and 100%, corresponding to no consensus to full consensus.

Interview responses to pair-wise comparison questions were entered into the BPMSG Excel template. This template allows for entering each interviewee's responses in one spreadsheet where individual weights and CR values are calculated. The summary sheets then reflect aggregated results and consolidated matrices based on the weighted geometric mean method. A consistency acceptance value (threshold for acceptance of inconsistency) α = 0.1 is used in this analysis. As mentioned before, BPMSG's template can be used to conduct AHP analysis based on different AHP scales including standard linear one to nine AHP scale. Other scales available for calculations in this template include logarithmic, square root, inverse linear, balanced, power, and geometric. The difference between these scales is in how intensities are transformed into elements of pairwise comparison matrices. Below is a transformation function for each scale that calculates the matrix element, c, based on the intensity, x. Intensity x is the comparison value provided by interviewees using values between 1-9.

Linear: c = x

Logarithmic: $c = \log_2(x+1)$

Root square: $c = \sqrt{x}$

Inverse linear: $c = 9/(10-x)$

Balanced: $c = \frac{0.45+0.05x}{1-(0.45+0.05x)}$

Power: $c = x^2$

Geometric: $c = 2^{x-1}$

The linear scale is the traditional AHP scale proposed by Saaty (1977). Although this scale is the most frequent used in applications, the choice of the best scale is a very heated debate (Ishizaka & Labib, 2011). To be able to compare different scales in this study all scales calculated by BPMSG's template were tested. Resulting weights for access to the seven essential facilities, EVM check (convergence of the eigenvector calculation which should be close to zero), principal Eigenvalue lambda, CR (consistency ratio), GCI (geometric consistency index), and consensus indicator for each scale is shown in Table 3. As the results show, using different scales does not change the ranking of criteria. Education is ranked as the most important service to have access to followed by employment, healthcare, social activities, retail, government, and banking. However, each criterion has different weights using different scales.

Table 3. AHP Analysis with Various Scales

		Scale						
		Linear	Logarithmic	Root Square	Inverse Linear	Balanced	Power	Geometric
Weighted Access Criterion	Education	27.3%	22.0%	20.9%	20.6%	22.5%	36.8%	36.3%
	Employment	25.4%	21.2%	20.2%	20.0%	21.5%	31.4%	31.0%
	Healthcare	21.4%	19.0%	18.4%	18.1%	19.2%	23.1%	22.7%
	Social Activities	8.2%	10.9%	11.5%	11.8%	10.9%	3.3%	3.9%
	Retail	7.6%	10.5%	11.0%	10.8%	9.8%	2.9%	3.0%
	Government	5.8%	8.9%	9.6%	10.0%	8.7%	1.7%	1.9%
	Banking	4.4%	7.6%	8.4%	8.7%	7.4%	0.9%	1.2%
EVM Check (E-09)		4.7	8.1	8.8	9.1	8.0	54.0	7.4
Eigenvalue Lambda		7.095	7.037	7.024	7.016	7.021	7.389	7.210
CR		1.2%	0.5%	0.3%	0.2%	0.3%	4.8%	2.6%
GCI		0.04	0.02	0.01	0.01	0.01	0.18	0.10
Consensus Indicator		81.8%	n/a	n/a	93.7%	90.9%	n/a	n/a

Consistency ratios and consensus indicators also vary depending on the scale used. It can be observed that the inverse linear scale tolerates inconsistency the best (smallest consistency ratios, CR = 0.2% and GCI = 0.01 %) and has the highest consensus rate of 93.7%. Power scale, on the other hand, has the lowest tolerance for inconsistency (the highest consistency ratios, CR = 4.8% and GCI = 0.18). The inverse linear scale was first introduced by Ma & Zheng (1991). High tolerance of this scale for inconsistency portrayed in Table 3 is in line with results of previous research (Dong, Xu, Li, & Dai, 2008; Franek & Kresta, 2014). This characteristic of the inverse linear scale makes it a good candidate where inconsistent responses are inevitable.

It is common in conducting AHP analysis to go back and slightly modify responses if judgments are not following the transitivity rule. BPMSG's Excel template, in fact, marks inconsistent interviewees' answers and allows for recognition of inconsistency while entering data. Six of the interviews were marked as inconsistent with CR values more than 10% when using the linear scale. However, I did not choose to contact interviewees again to ask them to modify their responses. Therefore, a scale that can tolerate inconsistencies is preferred here. Using the inverse linear scale keeps all individual CR values at an acceptable level, lower than 10% . In addition to high tolerance for inconsistency, the inverse linear scale also provides the best consensus rate among scales where the rate could be calculated. Thus, AHP analysis in this study is based on the inverse linear scale. Table 4 shows a summary of results while Appendix E presents detailed results including normalized principal Eigenvector, weighted geometric mean matrix, individual matrices, and consensus indicator calculations.

Table 4. AHP Analysis with Inverse Linear Scale

Criterion	Definition	Weight
Education	Child services and schools	20.63%
Employment	Places of employment	19.99%
Healthcare	Healthcare facilities	18.07%
Social Activities	Social services, community organizations and recreational facilities	11.83%
Retail	Supermarkets, shopping centers, and restaurants	10.78%
Government	Polling centers, government offices, and legal services	10.03%
Banking	Banks and financial institutions	8.68%
EVM Check = 9.1E-09 CR = 0.2% Consensus Indicator = 93.7%	Eigenvalue Lambda = 7.016 GCI = 0.01	

Each of the seven essential types of facilities includes subcategories as defined in Table 4

Table 4. Overall, access to education, employment, and healthcare was weighted almost twice as important as each of the other criteria. Access to banks and financial institutions, on the other hand, was ranked the least important for transport-related social exclusion. It should be noted that ranking of these criteria were not the same among all interviewees based on the pair-wise comparisons they made. Table 5 shows how each interviewee ranked the seven criteria. Since mean, median, and mode of ranks are consistent with the overall weights and ranks resulting from AHP (Table 4), it can be concluded that AHP analysis was not subject to rank reversal in this study.

Table 5. Individual AHP Rankings with Inverse Linear Scale

Participant No. / Criterion	Access Criterion Rank for Each Interview													Mean	Median	Mode
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Education	5	1	2	2	2	1	1	2	1	2	1	1	1	1.7	1	1
Employment	2	3	1	1	1	2	3	1	2	1	3	2	2	1.8	2	1&2
Healthcare	3	4	3	3	3	3	2	3	3	3	2	4	3	3.0	3	3
Social Activities	4	7	4	4	5	4	5	4	5	6	4	5	5	4.8	5	4
Retail	1	2	6	5	7	6	4	5	4	4	7	6	4	4.7	5	4
Government	6	6	5	6	6	5	6	6	6	5	6	3	6	5.5	6	6
Banking	7	5	7	7	4	7	7	7	7	7	5	7	7	6.5	7	7

To study the effect of increasing the sample size on results, Table 6 shows how the ranking of criteria changed as more interviews were conducted and added to the AHP analysis. It is observed that after seven interviews the ranking of five of the criteria does not change anymore and only the first two most important criteria, education and employment, switch ranking as the sample size grows. After eleven interviews, the ranking does not change with the increase in sample size.

Table 6. Increased Sample Size Effect on AHP Rankings with Inverse Linear Scale

Number of Interviewees	1	2	3	4	5	6	7	8	9	10	11	12	13
Education	5	4	3	3	3	3	2	2	2	2	1	1	1
Employment	2	2	1	1	1	1	1	1	1	1	2	2	2
Healthcare	3	3	2	2	2	2	3	3	3	3	3	3	3
Social Activities	4	6	5	5	5	4	4	4	4	4	4	4	4
Retail	1	1	4	4	4	5	5	5	5	5	5	5	5
Government	6	7	6	6	6	6	6	6	6	6	6	6	6
Banking	7	5	7	7	7	7	7	7	7	7	7	7	7

To further investigate the effect of enlarging the interview sample consensus indicators resulted from changing the sample size can be compared. Table 7 shows the consensus indicators calculated for different scales as the sample size grows. The results are in line with Table 6. Table 7 shows that enlarging the sample size does not improve consensus after nine interviews using linear or balanced scales whereas the inverse linear scale used in this study produces consistent consensus indicators as the sample size changes.

Table 7. Increased Sample Size Effect on AHP Consensus Indicator Using Different Scales

Number of Interviewees		1	2	3	4	5	6	7	8	9	10	11	12	13
Consensus Indicator (%)*	Linear	n/a	75	66	71	74	75	75	77	80	81	81	81	82
	Balanced	n/a	91	86	87	89	89	88	90	91	92	92	92	91
	Inverse Linear	n/a	96	91	92	93	93	92	93	94	95	95	95	94

* BPMSG Excel template only provides consensus indicator for linear, balanced, and inverse linear scales

Conclusions

To aggregate the chosen determinants of transportation related social exclusion and to develop a composite index one should weight these determinants first. Expert interviews and AHP analysis are used in this study to determine weights for access criteria. A total of 16 telephone interviews were conducted with transportation policy makers as well as activists and scholars concerned with transportation inequality and social exclusion in the City and County of Los Angeles. Half of the interviewees stated that they were familiar with the term “social exclusion”. A third of them believed that in addition to the chosen access criteria for social exclusion affordable housing and safety should also be available to everyone. Interviewees’ responses to pair-wise comparison questions were analyzed with AHP. Analysis using the inverse linear scale provides a very good consistency rate (0.2%) and high consensus indicator (93.7%). Through this analysis access to the seven essential types of facilities where weighted as follows: education 20.6%, employment 20.0%, healthcare 18.1%, social activities 11.8%, retail 10.8%, government 10.0%, and banks 8.7%. Studying the effect of enlarging the interview sample size suggests that the number of interviews was sufficient and extending the sample further would not improve the consensus indicator or affect the ranking of criteria. The resulting weights here will be used in the following chapters to measure transportation inequality in the study area. The results of data analysis are presented in the next chapter.

CHAPTER FIVE: DATA ANALYSIS

As described in Chapter 3, the primary study area in this research is the County of Los Angeles. To follow the research plan, efforts were made to run network analysis for both roads and transit networks in L.A. County. However, the size of the dataset with 2,098,581 non-vacant residential parcels in the county made it impossible for GIS to run network analysis. In fact, any command performed on this dataset would either not succeed or result in erroneous outcomes. To overcome this issue, the dataset was divided into nine sub-sets by the city name in parcel's address. The result was a total number of 2,097,399 parcels across all nine sub-sets which means 1,182 parcels were lost in the process of breaking down the dataset. This process was repeated using different methods to select and separate the sub-sets and all were too large to run a network analysis. To evaluate the feasibility of analysis, a test run was done with only one sub-set including 217,750 non-vacant residential parcels (about 10% of the entire County). GIS software was again not able to load the origins and destinations and proceed with network analysis. The first test run was done on a laptop computer with 8GB of RAM. After the failure in analysis, the same process was repeated on computers with 12GB and eventually 24GB RAMs. The increased RAM capacity did not help and all network analysis would fail after a few days of processing. The increased RAM, however, marginally decreases the process time for smaller samples.

Since accessibility analysis could not be performed as planned for the L.A. County road and transit networks, straight-line analysis was done instead. The next sections present the results of this analysis as well as a complete network analysis for the City of Commerce.

County of Los Angeles

Straight-line analysis measures the distance between origins and destinations as geographic (Euclidean) distance and can be used to measure accessibility in a simplified way. In fact, studies show that the straight-line distance is an adequate proxy for driving travel distance in absence of uncrossable physical features such as lakes, rivers, and mountains (Boscoe, Henry, & Zdeb, 2012). However, it will not be useful in studying transit users' access to essential facilities. While driving distances are in general closely associated with straight-line distances, transit routes follow a very different pattern. The distance traveled on transit routes can vary greatly, there might not be transit routes connecting certain origins and destinations, and the straight-line analysis will result in the same outcomes for both private vehicle and transit users. L.A. County straight-line analysis that is presented in this section can be interpreted within these limitations to evaluate distribution of access to seven essential services for drivers throughout the County.

As mentioned in Chapter 2, three different measures of accessibility are used in this study, travel time to the closest facility, average travel time to the three closest facilities, and number of facilities within 20 minutes of the origin. However, straight-line analysis only measures distance to facilities and not travel time. Therefore, in case of L.A. County where network analysis is not possible, time needs to be replaced with distance to approximate the accessibility measures. The resulting measures are distance to the closest facility, average distance to the three closest facilities, and number of facilities within ten miles of the origin. The ten-mile threshold is derived from sample network analyses to find how far drivers can drive on average in 20 minutes. To compare how these proxy straight-line measures compare to actual network-based measures all are calculated in the next section for the City of Commerce where the smaller dataset size allows for network analysis as well.

There is a total of 2,097,399 residential parcels in L.A. County. To find the number of residential units, each parcel entry with multiple units was copied multiple times so that the number of entries would equal the number of units using STATA command “Expand”. The result is 2,966,824 units on the residential parcels studied in L.A. County. Table 8 presents summary statistics for the two straight-line methods of measuring accessibility, distance to the closest facility and average distance to the three closest facilities, in L.A. County. The third method, number of facilities within ten miles of the origin, however, could not be calculated by GIS due to the size of the County’s dataset. The software produces an “Out of Memory” error message during analysis.

Table 8. Straight-Line Accessibility Measures for Residential Units in L.A. County

Facility Type	Distance to Closest Facility (Mile)			Average Distance to Three Closest Facilities (Mile)		
	Mean	Standard Deviation	Gini Coefficient	Mean	Standard Deviation	Gini Coefficient
Education	0.20	0.24	0.39	0.28	0.30	0.33
Employment	0.06	0.08	0.38	0.08	0.09	0.34
Healthcare	0.24	0.45	0.44	0.31	0.48	0.41
Social Activities	0.19	0.19	0.39	0.26	0.24	0.34
Retail: Food & Beverage*	0.22	0.28	0.45	0.27	0.32	0.43
Retail: All Other*	0.16	0.21	0.40	0.22	0.25	0.36
Govt. & Legal Offices	0.69	0.62	0.38	0.91	0.80	0.34
Banks & Financial Inst.	0.31	0.50	0.43	0.40	0.60	0.40

* Due to the large number of retail facilities they were separated into two categories, food and beverage and all others. For a complete list of businesses covered under each category refer to Appendix F.

As Table 8 shows, places of employment are on average the most accessible and government and legal offices the least accessible destinations in L.A. County. The table also shows that households in L.A. County are on average within less than a mile to all essential facilities. To study the distribution of accessibility throughout the County, the Gini coefficient of inequality is calculated for each accessibility measure and each facility type. STATA module developed by Jenkins (2015), “ineqdeco”, is a great tool that estimates a range of inequality and related indices including percentile ratios, Gini coefficient, Sen welfare index, Atkinson indices etc. This module is used here to calculate the Gini coefficient in L.A. County and later to calculate the Sen welfare index in the City of Commerce. A list of variables and the STATA code used for analysis is included in Appendix G.

Gini coefficients in Table 8 show that access to places of employment and government and legal offices in L.A. County are the most equally distributed categories when considering the closest facility to each household. Using the same method, access to food and beverage stores and restaurants is the most unequally distributed category in the County. If the three closest facilities are considered, educational facilities are the most equally distributed facilities immediately followed by places of employment, government and legal offices, and social activities. However, food and beverage stores and restaurants are still the most unequally distributed services throughout the county. In fact, the rank of categories does not change with the change in method of measuring accessibility except for educational facilities that takes the first place when using the three closest destinations.

Straight-line accessibility measures in L.A. County show relatively low levels of inequality with all Gini coefficients below 0.5. However, the results here do not capture the gap between accessibility levels of drivers versus transit users which can only be calculated through network analysis. The next section focuses on a smaller study area, the City of Commerce, and compares network time-based accessibility measures and resulting Gini coefficients with straight-line distance-based measures.

City of Commerce

Based on the LA County Assessor's 2015 Tax Roll, the City of Commerce has 2,198 non-vacant residential parcels with a total of 3,406 units. In order to run the network analysis, seven essential facilities were located within a ten-mile radius of the city boundary and used as the dataset for destinations. This will make the GIS analysis feasible since destinations further than ten miles will not be included in the network analysis and the dataset size remains manageable. This approach also avoids the edge effect. Edge effect in spatial accessibility analysis refers to a situation where locations close to the study area boundaries will be considered having low access to services because the facilities located outside the study area are not included in the analysis. Extending the analysis boundary for destinations ten miles beyond the city boundaries overcomes this problem.

The following sections present the results for five different scenarios: all households in Commerce using private vehicles, all households using transit, 5% of households using transit, 10% of households using transit, and households with no vehicle using transit as a proxy for actual transit use. Also, a separate set of straight-line analysis is run to compare the results with network analysis as well as county indices from previous section.

Road Network

It is expected that in a scenario where all households use private vehicles, inequality measures will be relatively low. Table 9 lists the calculated accessibility and inequality measures for access to the seven selected facilities.

Table 9. Commerce Accessibility Measures, All Households Using Private Vehicles

Facility Type	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	0.63	0.38	0.24	4,728	0.02	4,634	1.04	0.18	0.19
Employment	0.11	0.52	0.06	137,545	0.02	135,263	0.15	0.44	0.07
Healthcare	0.65	0.39	0.25	11,003	0.02	10,777	0.86	0.28	0.24
Social Activities	0.47	0.37	0.17	6,418	0.02	6,293	0.70	0.21	0.15
Retail: Food & Beverage	0.38	0.39	0.15	13,641	0.01	13,481	0.49	0.29	0.14
Retail: All Other	0.34	0.39	0.13	19,383	0.01	19,101	0.47	0.27	0.13
Govt. & Legal Offices	1.45	0.35	0.51	1,117	0.01	1,101	1.61	0.31	0.50
Banks & Financial Inst.	1.03	0.27	0.28	3,693	0.02	3,606	1.29	0.22	0.28
	Average Time to Facilities within Ten-Mile Radius								
Employment	12.79	0.04	0.51						

To interpret the results here a brief reminder of the definition for the Gini coefficient and the Sen welfare index is helpful. The Gini coefficient measures inequality in distribution of a variable and is defined as the average difference between all possible pairs of variable entries. The Gini coefficient is a unitless quantity and varies between zero and one with zero being associated with the most equal distribution and one with the most unequal distribution. In other words, the higher the Gini coefficient, the more unequal distribution of the variable in study which is accessibility here. Sen welfare index measures the overall welfare of the population, City of Commerce in this case. It is a function of both average value of accessibility and access inequality. In a perfectly equal distribution, welfare index is equal to the average value and in the most unequal distribution (G=1) welfare index is equal to 0. The Sen welfare index is calculated as:

$W = \mu \ (1-G)$

where W is the Sen welfare index, μ is the mean value, and G is the Gini coefficient.

The Sen welfare index is positively correlated with the average value and negatively correlated with the Gini coefficient. Therefore, to maximize the welfare index, the average value should be maximized and inequality should be minimized. Table 9 shows the Sen welfare indices calculated for number of facilities within 20 minutes (method B). In this calculation, the category with highest average number of facilities and lowest Gini coefficient has is associated with the welfare index. Calculating the welfare index for methods A and C, however, poses theoretical problems. When accessibility is measured as travel time (to the closest facility in method A and to the three closest facilities in method C), welfare cannot be positively correlated with the average values. In other words, welfare would not be maximized by maximizing the average travel time to facilities.

To overcome this problem, another function is used instead of the Sen welfare index in methods A and C. Access disadvantage is defined here following the same rationale of welfare functions, the difference is that it is positively correlated with both average values and the Gini coefficient. Therefore, it can be minimized by minimizing both average values (travel time in this case) and inequality levels.

$AD = \mu . G$

where AD is access disadvantage, μ is the mean value, and G is the Gini coefficient.

Since the Gini coefficient is an unitless value, access disadvantage shares the same unit as the average value. Table 9 presents the calculated access disadvantage values in minute for method A and method C where the Sen welfare index would not be meaningful.

As Table 9 shows, places of employment on average are the most accessible facilities to residents of Commerce based on all three methods. In other words, they have the lowest average time to the closest facility, the highest average number of facilities within 20 minutes, and the lowest average time to the three closest facilities. The considerably larger number of places of employment compared to other facilities is partly due to the fact that this group covers all industries including the other facilities listed here. Government and legal offices, on the other hand, are the least accessible facilities based on all three methods.

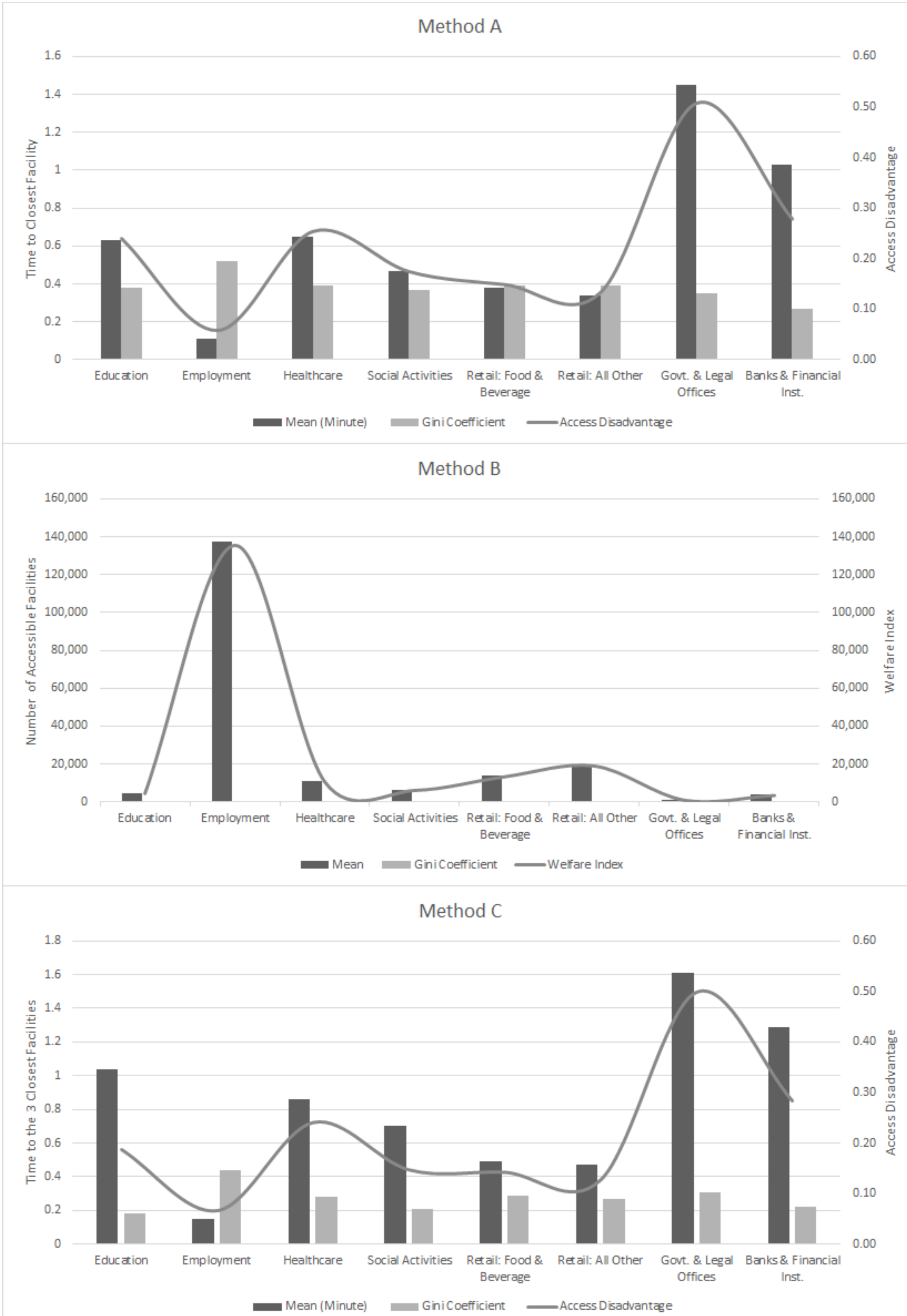
Access to employment also has the highest Gini coefficient and hence is the most unequally distributed facility. With small average travel times and high frequency of places of employment, the Gini coefficients are more sensitive to small variations in access time. Therefore, while households within residential blocks have lower access to all services compared to households living close to zone borders, the difference in their access to employment is highlighted more in the Gini coefficients. In other words, destinations such as government and legal offices that are located further from all residential parcels, both in the center and on the edges of residential zones, result in lower Gini coefficients. On the other hand, places of employment show the highest Gini coefficient with all methods.

The most equally distributed groups vary depending on which method is used and are banks and financial institutions and educational facilities for methods A and C respectively. All categories of retail and government and legal offices share the lowest Gini coefficients in method B.

The Gini coefficients calculated using method B are very small highlighting the point that if accessibility is measured by the number of destinations within a certain travel time the resulting distribution will be very homogenous. However, when time to the closest, or the three closest facilities is considered, there is more variation in residents' access levels. It is also observed that the Gini coefficients for method A are higher than method C across all facility groups meaning that calculating accessibility by time to the closest facility will show the highest inequality levels.

As previously discussed, having the best accessibility measure (lowest travel time or highest number of accessible facilities) or having the most equal distribution (lowest Gini coefficient) independently does not result in a desired distribution which provides welfare for residents and promotes social inclusion. A high accessibility level can be distributed unjustly or an equal distribution can be associated with poor accessibility (as in the case of access to government and legal offices here). Therefore, it is important to evaluate the combined effect using the access disadvantage and welfare indices. The highest access disadvantage is associated with government and legal offices which also has the lowest Sen welfare index. This category is followed by banks and financial institutions with a considerable gap. Although access to employment has the highest Gini coefficients, it is associated with the lowest access disadvantage indices. In other words, while employment is unequally distributed, places of employment are highly accessible. The two retail categories follow employment and have the next highest welfare indices. Figure 5 is a visual representation of above measures.

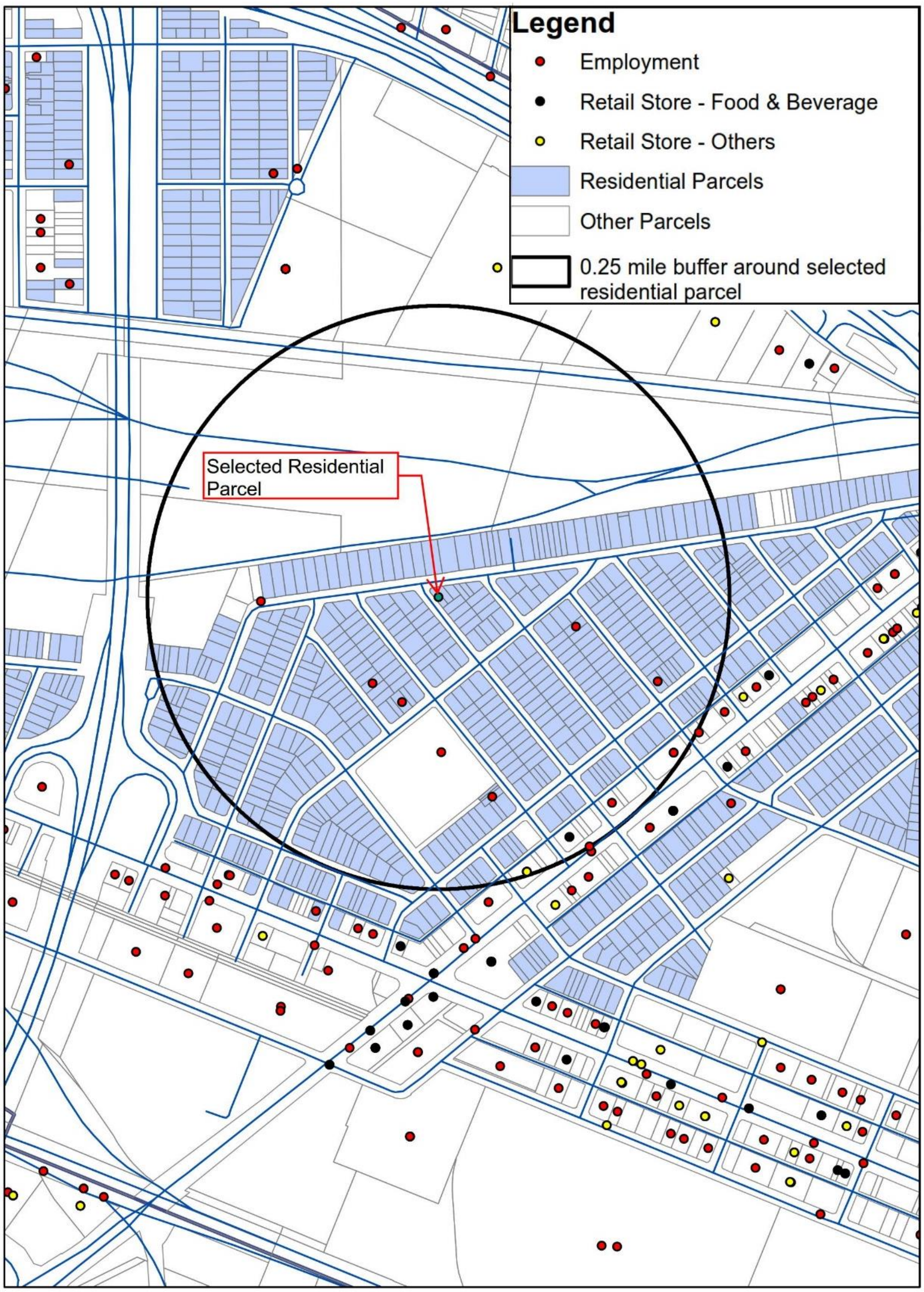
Figure 5. City of Commerce Accessibility Measures, All Households Using Private Vehicles



Access to places of employment is in nature different than access to all other facilities. While the school, grocery store, or the bank that a household uses is more likely in close proximity to its place of residence, travel surveys show that this is not the case for daily work commutes. Individuals are rarely employed at the closest employment center to their home. Therefore, time to the closest facility is a more relevant accessibility measure for categories other than employment. Although, presence of a place of employment in proximity to residential units provides an employment opportunity for the individual, there are often other barriers. For instance, the closest jobs do not necessarily match individuals' education and skill levels. To accommodate this difference between travel behavior to employment versus other facilities, an additional accessibility measure is calculated here. The last row in Table 9 shows access to employment measured by average travel time to all places of employment within the ten-mile radius of City of Commerce. If all residents of Commerce use private vehicles, they are on average 13 minutes away from all places of employment within the ten-mile radius of their city. The Gini coefficient calculated in the method is much lower than the previous number and in fact represents a very homogenous distribution of access to employment in Commerce.

Studying Table 9 reveals another interesting fact. Average values of travel time to the closest facilities are surprisingly low and are all under two minutes. However, looking at the spatial distribution of residential units and other facilities in the City of Commerce verifies that households are located very close to all services. Figure 6 is an illustration of the proximity of a selected residential unit to places of employment and retail store.

Figure 6. Proximity of Employment and Retail Stores to a Residential Parcel in the City of Commerce



As Figure 6 depicts, the closest place of employment, food and beverage store, and other retail store are all located in less than a quarter mile from the selected residential unit which explains the small travel time numbers in Table 9.

Transit Network

Relatively low inequality levels are also expected in a scenario where all households in Commerce use transit for their trips. It is also expected that inequality levels in this scenario will be higher than the previous ones associated with road networks since transit lines are not as extensive as roads. However, Table 10 shows that this is not true and Gini coefficients are lower for transit users in most groups using methods A and C. In other words, households will have more equally distributed access if they all use transit rather than private vehicles. Method B, however, results in marginal Gini coefficients for private vehicle users and the results are not comparable to the transit users.

As can be expected, access disadvantage indices are higher and welfare levels are considerably lower for transit users due to the longer travel times. Average travel time is about ten times longer for transit users compared to drivers. This gap is intensified when average travel time to all places of employment within a ten-mile radius is measured. Average time values for drivers and transit users are 13 and 184 minutes, respectively.

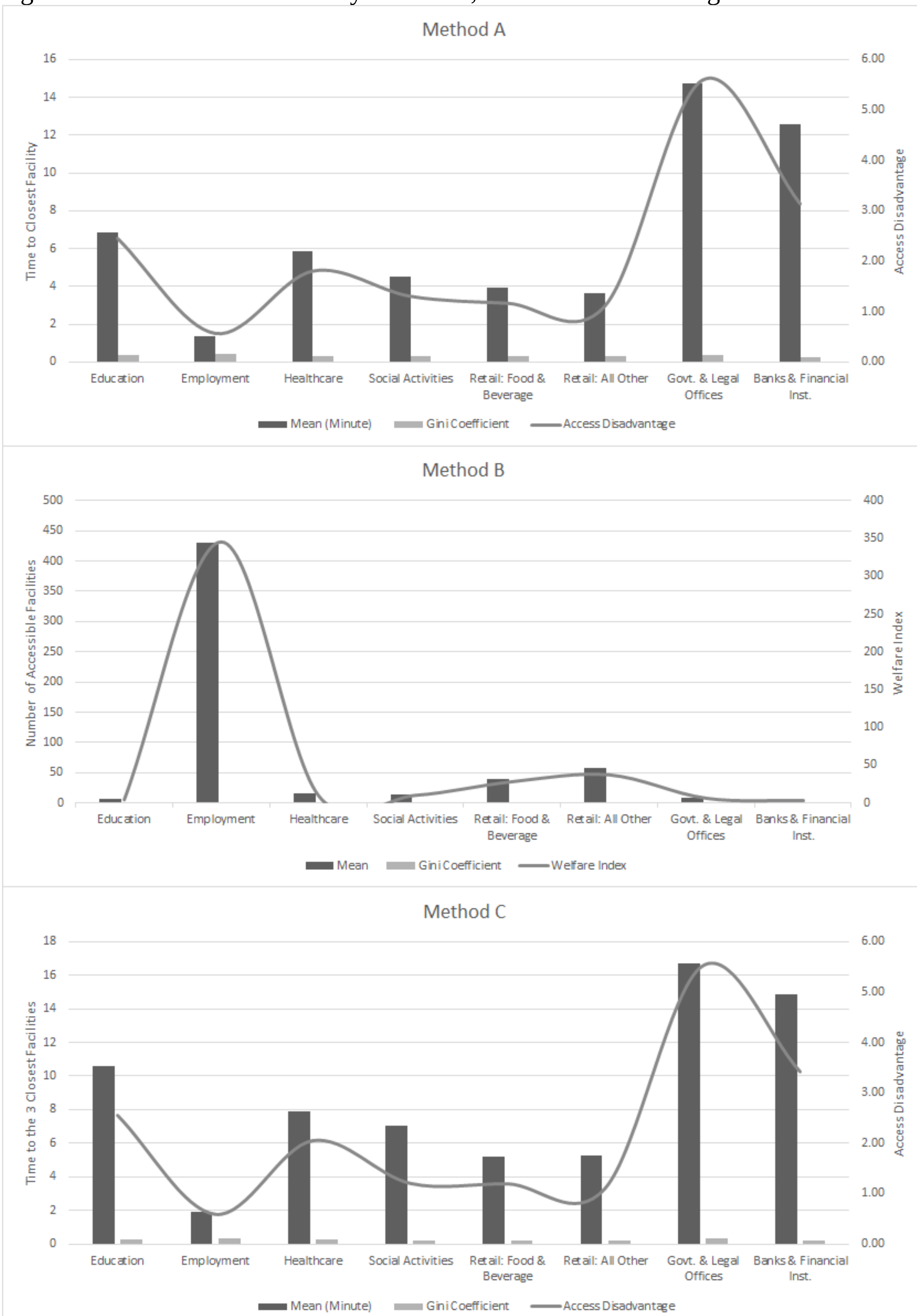
Table 10. Commerce Accessibility Measures, All Households Using Transit

Facility Type	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	6.84	0.36	2.46	6	0.33	4	10.61	0.24	2.55
Employment	1.38	0.42	0.58	431	0.20	345	1.89	0.31	0.59
Healthcare	5.85	0.31	1.81	16	0.42	10	7.87	0.26	2.05
Social Activities	4.54	0.29	1.32	14	0.29	10	7.05	0.17	1.20
Retail: Food & Beverage	3.92	0.30	1.18	39	0.28	28	5.17	0.23	1.19
Retail: All Other	3.64	0.31	1.13	58	0.37	37	5.24	0.21	1.10
Govt. & Legal Offices	14.74	0.38	5.60	9	0.30	6	16.70	0.33	5.51
Banks & Financial Inst.	12.59	0.25	3.15	6	0.42	3	14.83	0.23	3.41
	Average Time to Facilities within Ten-Mile Radius								
Employment	183.54	0.03	5.51						

As noted in Chapter 3, the network analysis for transit users is run with the assumption that there is a ten-minute wait time before boarding public transportation. Therefore, the total travel time includes walking to the transit station, ten-minute wait time, travel time on public transportation, and walking from the station to the destination. While running network analysis, if GIS detects a facility located such that walking to it takes less time than taking transit, then the travel time calculated for that facility would be the time it takes to walk there.

As represented by Table 10, employment again has the highest levels of accessibility followed by both retail groups. Government and legal offices are also still the least accessible group except by method B. When it comes to number of accessible facilities, educational and financial institutions are even less accessible than government offices to transit users. The Gini coefficients do not show any specific pattern but the coefficients associated with method B are considerably higher than the first scenario. It is also interesting to note how using different methods can present different pictures. If only time to closest facilities is used to calculate accessibility (methods A and C), employment is the least equally distributed destination for Commerce residents. However, if number of accessible facilities is used (method B), employment turns out to be the most equally distributed facility. This proves the sensibility of results to the method of measurement and the benefit of using multiple methods. When it comes to access disadvantage and welfare levels the results of all methods are consistent. Places of employment and retail stores have the lowest access disadvantage and highest welfare indices followed by healthcare facilities and social activities while government and legal offices and banks and financial institutions have the highest access disadvantage and lowest welfare indices. Figure 7 represents above measures in three graphs for the three methods used (A, B, and C).

Figure 7. Commerce Accessibility Measures, All Households Using Transit



Five Percent Transit Use

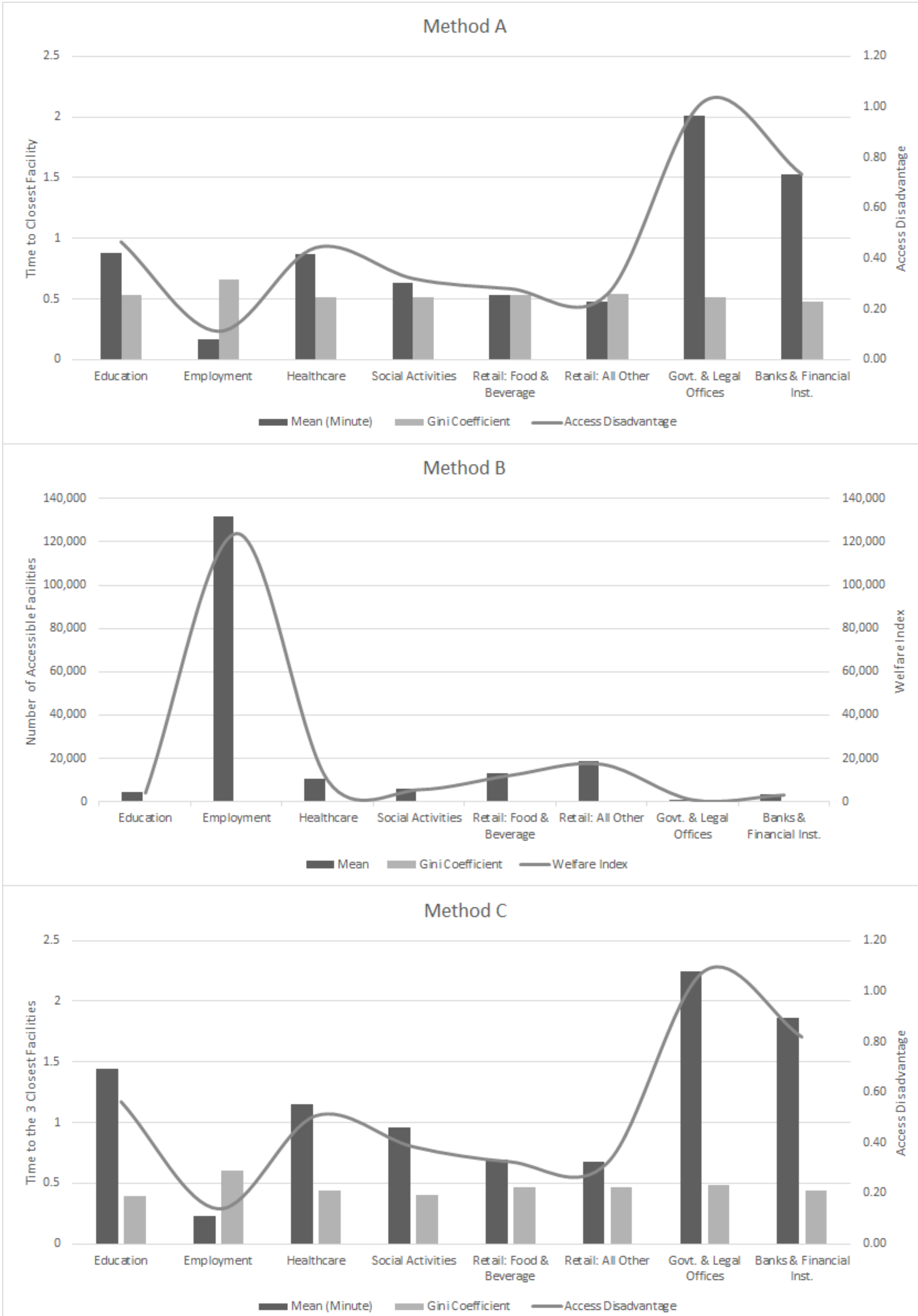
In this scenario, 5% of all households in the City of Commerce are selected using a random uniform variable. The travel time and accessible facilities for this group are calculated based on transit network analysis while all other households are assigned variables from the road network analysis. The results are presented in Table 11.

Table 11. Commerce Accessibility Measures, Five Percent of Households Using Transit

Facility Type	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	0.88	0.53	0.47	4,525	0.06	4,245	1.44	0.39	0.56
Employment	0.17	0.66	0.11	131,656	0.06	123,935	0.23	0.60	0.14
Healthcare	0.87	0.51	0.44	10,531	0.06	9,872	1.15	0.44	0.51
Social Activities	0.63	0.51	0.32	6,143	0.06	5,765	0.96	0.40	0.38
Retail: Food & Beverage	0.53	0.53	0.28	13,057	0.05	12,352	0.69	0.47	0.32
Retail: All Other	0.48	0.54	0.26	18,554	0.06	17,502	0.68	0.47	0.32
Govt. & Legal Offices	2.01	0.51	1.03	1,080	0.05	1,028	2.25	0.48	1.08
Banks & Financial Inst.	1.53	0.48	0.73	3,543	0.06	3,320	1.86	0.44	0.82
	Average Time to Facilities within Ten-Mile Radius								
Employment	20.09	0.37	7.43						

In this scenario, employment is still the most accessible and most unequally distributed destination across all three methods . Employment has the lowest access disadvantage and the highest welfare index. When access to employment is measured by average time to all places within the ten-mile radius, the Gini coefficient (0.37) implies a more equal distribution of access. Retail stores follow employment as the second most accessible and highest welfare indices. Government and legal offices and banks and financial institutions are the least accessible facilities with the lowest welfare indices throughout all three methods. In this scenario, again, method A returns higher Gini coefficients but also lower access disadvantage indices in compare to method C. Gini coefficients of methods A and C are also higher here in compare to when all residents use private vehicles or all use transit. Figure 8 illustrates the calculated accessibility measures when 5% of households in the City of Commerce use transit.

Figure 8. Commerce Accessibility Measures, Five Percent of Households Using Transit



Ten Percent Transit Use

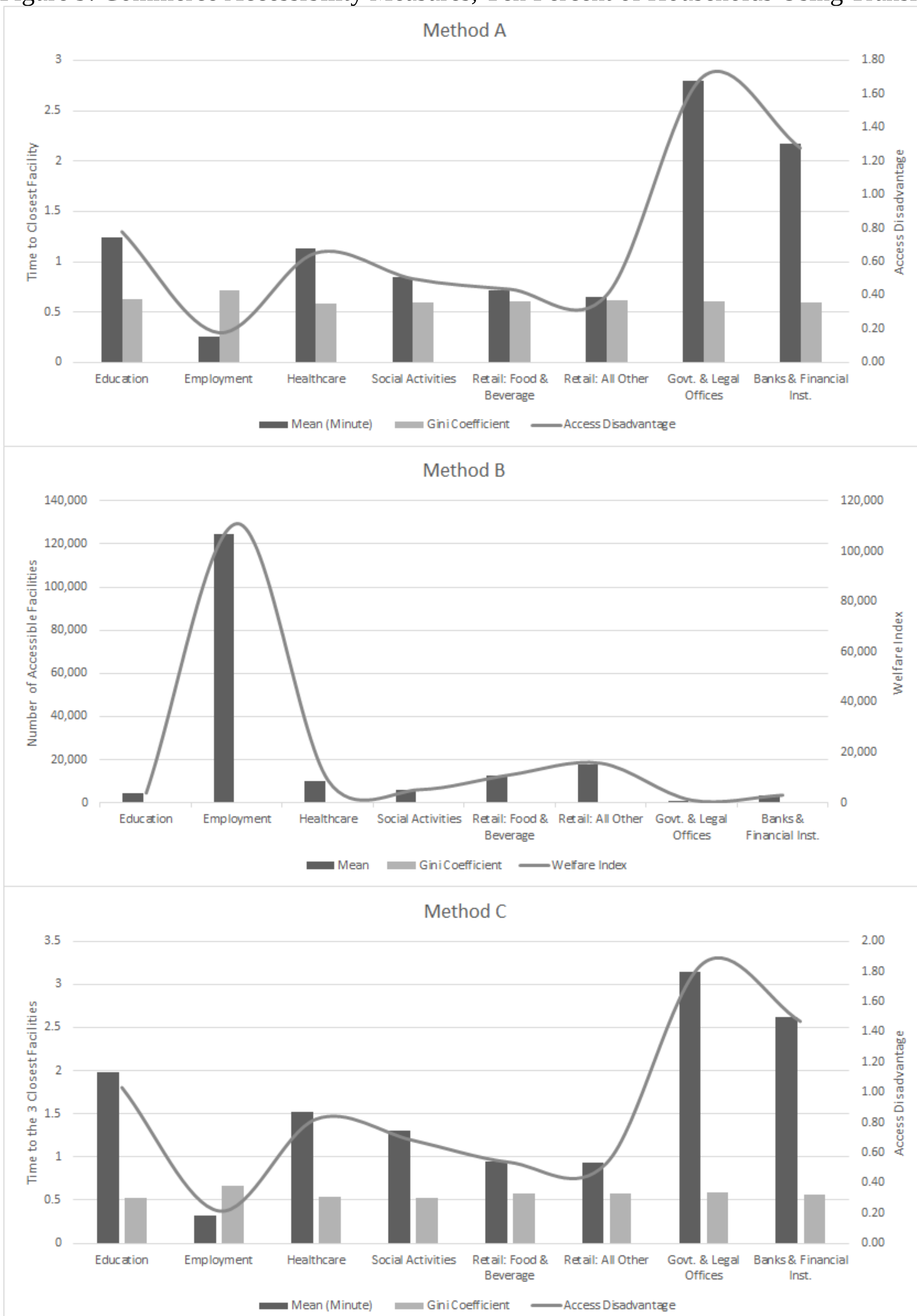
It is expected that changing the share of transit users from 5% to 10% will raise the average travel times since more households will be traveling longer on transit compared to private vehicles. It also reduces the number of accessible facilities in each group. This is confirmed by Table 12 which also shows that increasing number of transit users leads to increasing inequality and access disadvantage levels and decreasing welfare indices for accessing all different facilities.

Table 12. Commerce Accessibility Measures, Ten Percent of Households Using Transit

Facility Type	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	1.24	0.63	0.78	4,284	0.11	3,803	1.98	0.52	1.03
Employment	0.25	0.72	0.18	124,641	0.11	111,067	0.32	0.67	0.21
Healthcare	1.13	0.58	0.66	9,970	0.11	8,847	1.52	0.54	0.82
Social Activities	0.85	0.59	0.50	5,816	0.11	5,166	1.31	0.52	0.68
Retail: Food & Beverage	0.72	0.61	0.44	12,360	0.10	11,068	0.94	0.57	0.54
Retail: All Other	0.65	0.62	0.40	17,564	0.11	15,683	0.93	0.57	0.53
Govt. & Legal Offices	2.80	0.61	1.71	1,041	0.08	956	3.14	0.59	1.85
Banks & Financial Inst.	2.17	0.59	1.28	3,369	0.11	3,000	2.62	0.56	1.47
	Average Time to Facilities within Ten-Mile Radius								
Employment	28.92	0.52	15.04						

The most and least accessible facilities remain the same in this scenario, employment and retail are associated with lowest average travel times and highest welfare indices while government and legal offices and banks and financial institutions are on the opposite end of the spectrum across all methods.

Figure 9. Commerce Accessibility Measures, Ten Percent of Households Using Transit



Proxy for Actual Transit Use

Here the number of households with no vehicles is used as a proxy for transit users. American Community Survey (ACS) collects information on the number of vehicles owned by households and the data is available by census tracts. Based on 2015 ACS five-year estimates, table B08201, the share of households with no vehicles is calculated in the three census tracts covering City of Commerce as 5%, 12%, and 17%. Respective number of residential units in each tract was randomly selected and labeled as transit users. The overall outcome is that 11.24% of households in Commerce did not own a vehicle in 2015 and are assumed to be transit users in the accessibility analysis here.

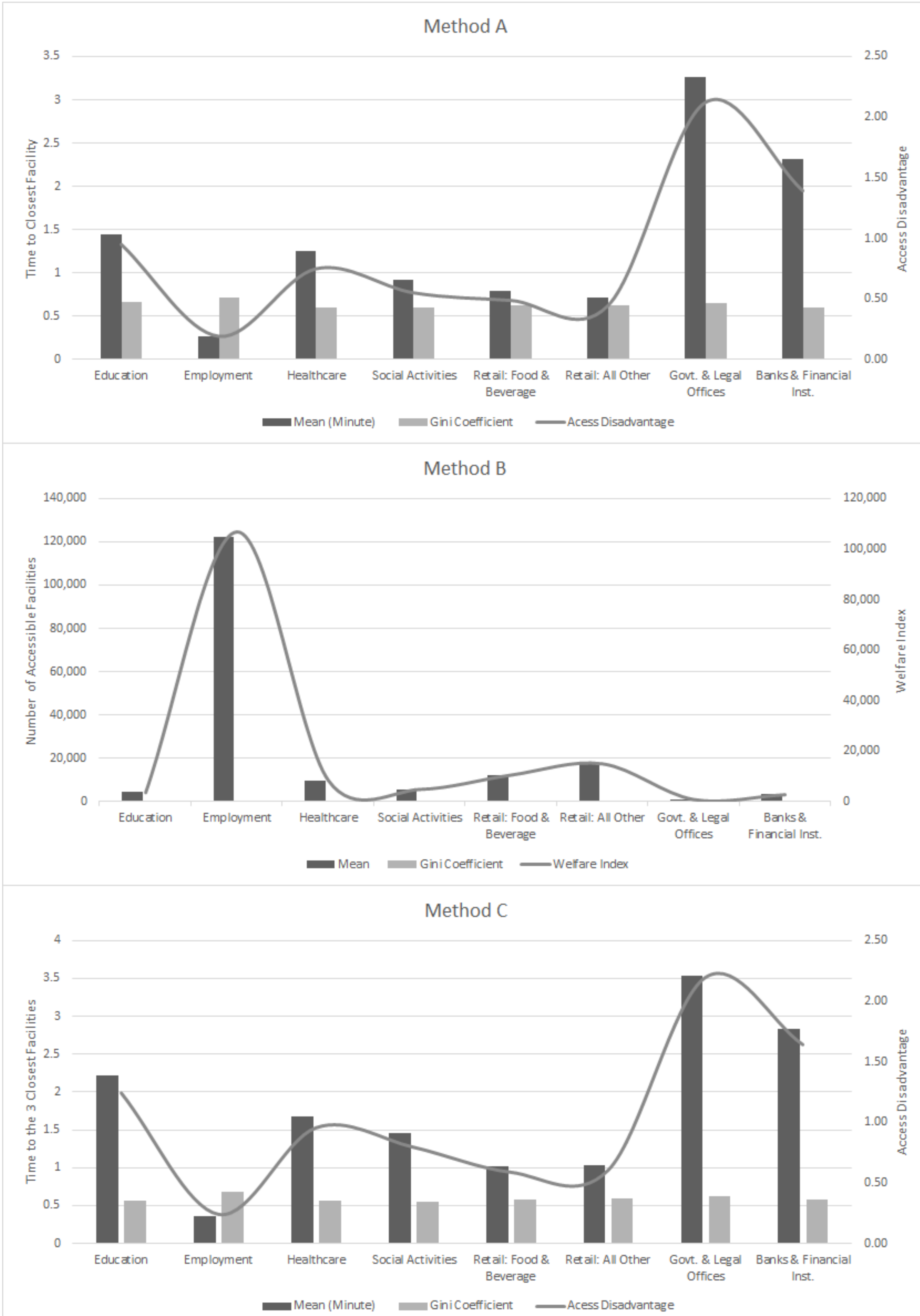
Table 13. Commerce Accessibility Measures, Households with No Vehicles Using Transit

Facility Type	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	1.44	0.66	0.95	4,204	0.13	3,659	2.22	0.56	1.24
Employment	0.27	0.72	0.19	122,291	0.13	106,836	0.36	0.68	0.24
Healthcare	1.25	0.60	0.75	9,784	0.13	8,512	1.68	0.57	0.96
Social Activities	0.92	0.60	0.55	5,707	0.13	4,970	1.45	0.55	0.80
Retail: Food & Beverage	0.79	0.62	0.49	12,122	0.12	10,640	1.02	0.58	0.59
Retail: All Other	0.71	0.63	0.45	17,230	0.12	15,082	1.03	0.59	0.61
Govt. & Legal Offices	3.26	0.65	2.12	1,041	0.08	955	3.54	0.62	2.19
Banks & Financial Inst.	2.32	0.60	1.39	3,308	0.13	2,890	2.83	0.58	1.64
	Average Time to Facilities within Ten-Mile Radius								
Employment	32.40	0.55	17.82						

The results in Table 13 show very similar patterns in average numbers, access disadvantage and welfare indices as the previous scenario since the number of households using transit is smaller in both. The Gini coefficients also show only slight increases in most cases compared to the previous section but many of the facilities have moved in rankings.

In this scenario where it is assumed households with no vehicles use transit, average travel time to places of employment within ten miles is 32 minutes with a mid-level Gini coefficient of 0.55.

Figure 10. Commerce Accessibility Measures, Households with No Vehicles Using Transit



Straight-Line Analysis

Straight-line analysis is a faster and cheaper way to conduct accessibility analysis. As described in previous sections, GIS could not run network analysis for an area as big as Los Angeles County on machines with various memory capacities. Breaking down the county into nine sub-areas did not help either. Network analysis, if at all possible, also requires long periods of time to run each step of the process. For instance, one cycle of network analysis including loading origins, destinations, solving, exporting, and processing the results for healthcare facilities within ten miles of Commerce takes five hours and 30 minutes while straight-line analysis for the same facilities only takes 15 minutes. If accessibility measures calculated by straight-line distances are comparable to those of road network analysis then it would be a preferred method to study large areas.

Table 14 displays outcomes of straight-line analysis for the City of Commerce. It should be noted that the accessibility measures have to move away from time-based to distance-based measures in this method. Therefore, distance to the closest facility, number of accessible facilities within ten miles, and average distance to the three closest facilities are calculated here. As a result, the average numbers, access disadvantage, and welfare indices for access to closest facilities cannot be directly compared with network analysis since the units are different (mile versus minute). However, since Gini coefficients are unitless measures of distribution, they can still be compared with respective numbers from previous sections. Number of accessible facilities are also unitless and can be compared. However, straight-line analysis cannot be used to represent transit routes. As opposed to roads, transit routes do not link all origins and destinations and follow irregular paths. Hence, the only meaningful comparison here would be with results of road network analysis, Table 9.

Table 14. Commerce Accessibility Measures, Straight Line Analysis

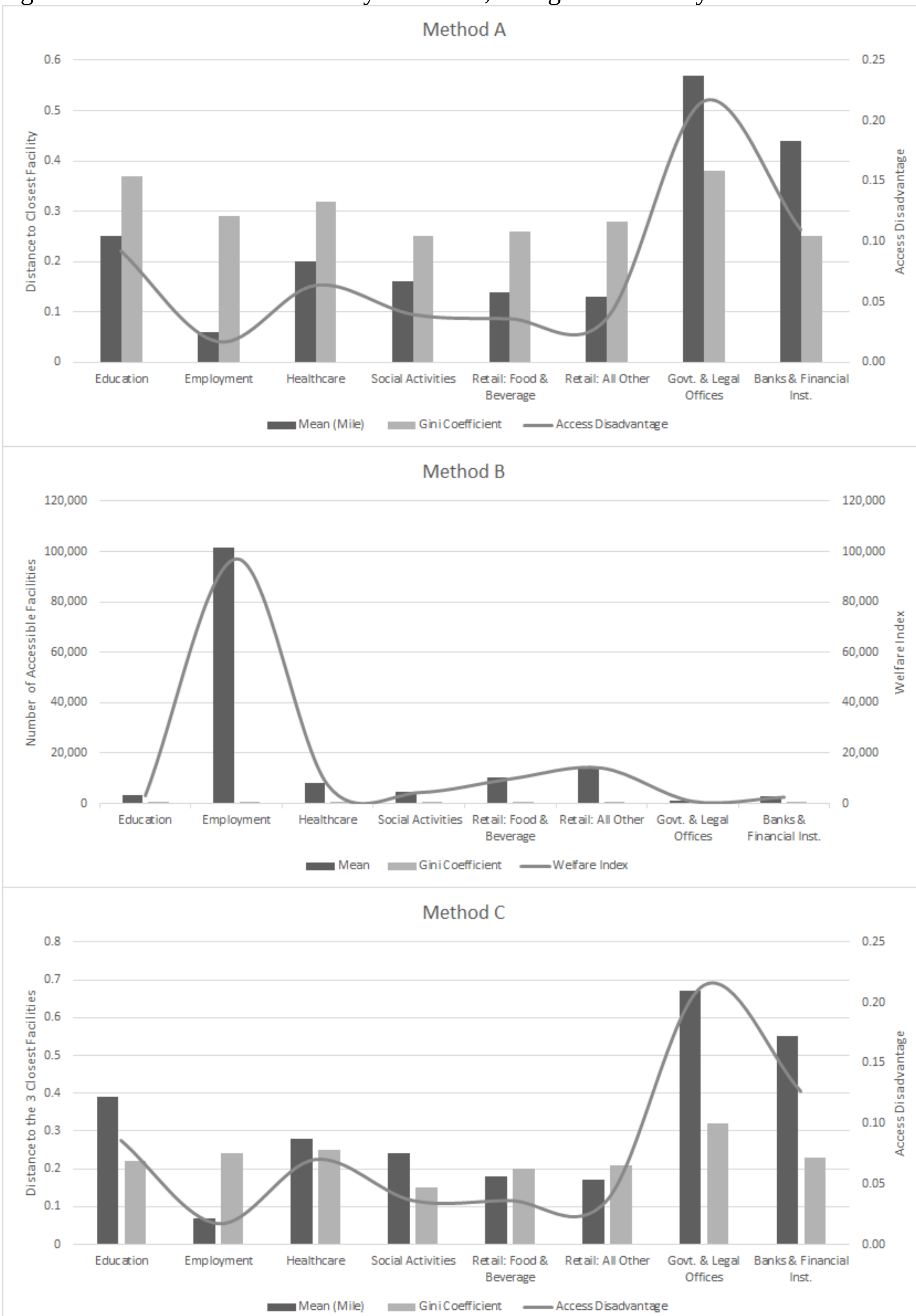
Facility Type	Distance to Closest Facility			Number of Facilities within Ten Miles			Average Distance to Three Closest Facilities		
	Mean (Mile)	Gini Coefficient	Access Disadvantage (Mile)	Mean	Gini Coefficient	Welfare Index	Mean (Mile)	Gini Coefficient	Access Disadvantage (Mile)
Education	0.25	0.37	0.09	3,380	0.06	3,187	0.39	0.22	0.09
Employment	0.06	0.29	0.02	101,396	0.04	97,238	0.07	0.24	0.02
Healthcare	0.20	0.32	0.06	7,889	0.07	7,351	0.28	0.25	0.07
Social Activities	0.16	0.25	0.04	4,703	0.06	4,433	0.24	0.15	0.04
Retail: Food & Beverage	0.14	0.26	0.04	10,233	0.04	9,838	0.18	0.20	0.04
Retail: All Other	0.13	0.28	0.04	14,632	0.03	14,156	0.17	0.21	0.04
Govt. & Legal Offices	0.57	0.38	0.22	931	0.02	913	0.67	0.32	0.21
Banks & Financial Inst.	0.44	0.25	0.11	2,701	0.05	2,566	0.55	0.23	0.13

While the mean, access disadvantage, and welfare index in this table do not have the same units as methods A and C in Table 9, ranking of facilities can still be compared. In fact, the most accessible and least accessible facilities remain the same as previous sections. Places of employment and retail are on average the closest facilities and provide highest welfare levels while government and legal offices and banks and financial institutions are the furthest with smallest welfare indices. To evaluate association between distance to closest facility in straight-line analysis in Table 14 and time to closest facility in network analysis from Table 9, respective ratios can be calculated (average distances divided by average time). These ratios will have the same unit as speed and can be converted to mile per hour. The resulting ratios vary between 18-33 miles per hour for closest facility and 19.5-28 miles per hour for the three closest facilities. This means that the calculated average distances through straight-line analysis can be converted to equivalent average times resulting in network analysis using these ratios. One mile average distance in straight line method equals 1/18 hour or three minutes average time in network analysis (assuming a ratio of 18 miles).

Access and welfare follow the same pattern in the network analysis. Gini coefficients of the first and third columns do not. Straight-line analysis mostly underestimates the Gini coefficient for access to the closest facility between 3%-33% with one exception, government and legal offices, which have a smaller Gini coefficient in the road network analysis. The Gini coefficient for employment is an outlier and is not included in this comparison. Gini coefficients for access to the three closest facilities are underestimated for some groups and overestimated for others using straight-line analysis. The largest error in the Gini coefficients, when using straight-line analysis instead of network analysis, is observed in access to employment with a 44%-45% difference between the two methods.

The average number of facilities within ten miles (straight-line) of Commerce residents are 17%-29% lower than number of facilities within 20-minute drive on road networks for all groups with most having 25%-29% lower numbers. To make the straight-line analysis a more appropriate proxy for networks the ten-mile threshold can be extended so more facilities are counted as accessible and the average numbers get closer to those calculated through network analysis. However, these thresholds might be case specific so the numbers based on comparing straight-line versus network results cannot be generalized. In general, comparison of the two groups of results here suggests that straight-line analysis cannot be a reliable proxy for network analysis in measuring inequality and welfare of access to services. Figure 11 is a visual representation of above measures.

Figure 11. Commerce Accessibility Measures, Straight Line Analysis



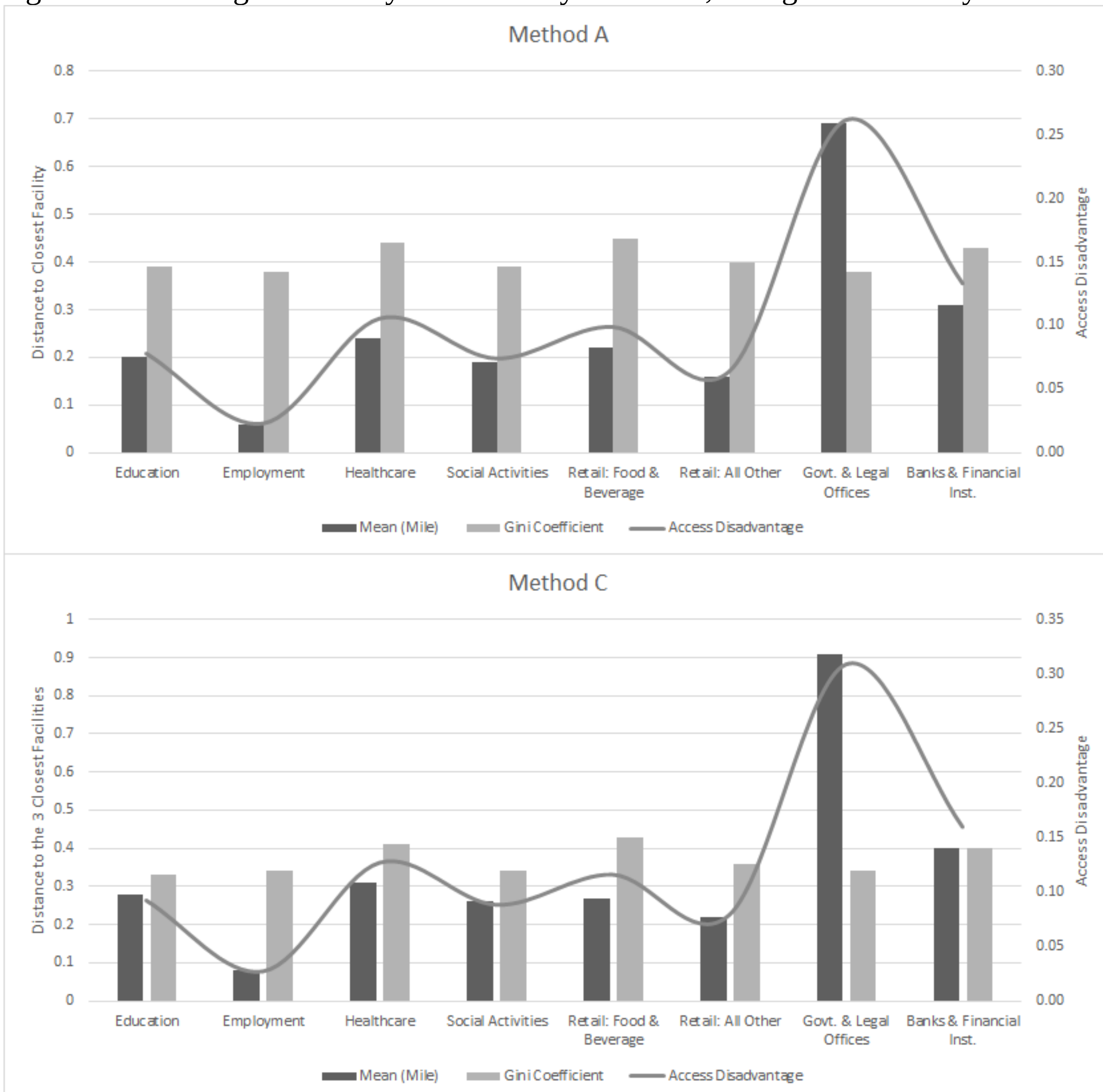
To be able to better compare results of straight-line versus network accessibility measures, a correlation analysis is conducted. Pearson correlation coefficients presented in Table 15 show that average travel distances in straight-line analysis are mostly highly correlated with average travel times in network analysis with all correlation coefficients statistically significant at 0% level.

Table 15. Pearson Correlation Coefficients between Straight-Line and Network Accessibility Measures in City of Commerce

Facility Type	Time/Distance to Closest Facility (Method A)	Number of Facilities within 20 Minutes/ 10 Miles (Method B)	Average Time/Distance to the Three Closest Facilities (Method C)
Education	0.8027	0.9298	0.7025
Employment	0.3057	0.9144	0.3157
Healthcare	0.5509	0.9096	0.4789
Social Activities	0.5274	0.9286	0.4347
Retail: Food & Beverage	0.5821	0.9213	0.5633
Retail: All Other	0.6002	0.8962	0.5338
Govt. & Legal Offices	0.8801	0.6145	0.9102
Banks & Financial Inst.	0.8044	0.9143	0.8463

The straight-line analysis here can also be compared with the one conducted for Los Angeles County in Table 8. When compared to the county as a whole, Commerce has a more equal distribution in access to all services. The average distance to the closest facilities for both City of Commerce and the county are very similar with no difference greater than a quarter mile. The access disadvantage indices imply that Commerce residents are better off in accessing all facilities compared to L.A. County. Figure 12 shows L.A. County's straight-line accessibility measures.

Figure 12. Los Angeles County Accessibility Measures, Straight-Line Analysis



Conclusions

A comparison between L.A. County and the City of Commerce straight-line analysis shows that residents of Commerce are located closer to all facilities and are slightly better off when compared to L.A. County's averages. The inequality level in Commerce is also lower than those of the county's across all facilities.

Although the average travel time and distance are highly correlated, the straight-line analysis done for L.A. County cannot be used as a proxy for network analysis. Comparison of straight-line measures in Commerce with network results shows that the relationship between Gini coefficient and access disadvantage for the two methods is not consistent and one cannot be predicted using the other. The only exception is number of accessible facilities which can be a close estimate in straight-line analysis if the distance threshold is selected appropriately. Here with a ten-mile threshold the average numbers were underestimated about 25% for accessible facilities. It can be concluded that repeating the process with a higher threshold, 12 miles for instance, will result in higher number of accessible facilities and make straight-line method a better proxy for network analysis. Nevertheless, more study is required to establish such a threshold and evaluate its ability to be generalized for different geographies.

So far in this chapter, all comparisons were made for accessibility and its distribution for facilities independently. It was observed that increasing share of transit users, in general, increases inequality and access disadvantage and decreases welfare for each facility. However, the overall accessibility of different scenarios has not been evaluated yet. To do so, composite indices with associated weights for each facility are calculated. As explained in Chapter 4, this study utilizes expert interviews and AHP method to calculate weights for access to each facility. To study how different weighting approaches affect the accessibility analysis, several methods are used here to calculate the composite indices of accessibility. Table 16 lists the different weighting methods used and weights associated with each method.

Table 16. Weighting Methods Used to Calculate Composite Indices of Accessibility

Weighting Method	Weights Associated with Access to Each Facility						
	Education	Employment	Healthcare	Social Activities	Retail*	Govt. & Legal Offices	Banks & Financial Inst.
Equal Weights	0.143	0.143	0.143	0.143	0.143	0.143	0.143
AHP Inverse Linear Method	0.206	0.2	0.181	0.118	0.108	0.1	0.087
AHP Linear Method	0.273	0.254	0.214	0.082	0.076	0.058	0.044
AHP Power Method	0.368	0.314	0.231	0.033	0.029	0.017	0.009
Weights Based on Trip Frequency	0.13	0.37	0.05	0.2	0.13	0.03	0.09
Extreme Scenario A	0.4	0.4	0.04	0.04	0.04	0.04	0.04
Extreme Scenario B	0.5	0.5	0	0	0	0	0

* Average of food and beverage and all other retail facilities

The first method assumes equal importance for access to all facilities and weighs all categories the same. The next three methods are results from the AHP analysis as presented in Chapter 4. The inverse linear scale in this study is associated with the best fit and highest consensus indicator among other calculated AHP scales and is used as the main weighting method. The classic linear scale is included as an alternative method too. Finally, the weights resulted from AHP analysis with power scale is also included which represents the most diverse weights.

Using judgment to assign weights based the importance of access to each category is not the only possible approach to weighting. Importance of access to each facility can also be evaluated based on the number of trips made. The next weighting method presented in Table 16 uses the National Household Travel Survey 2001 data and trip purpose statistics (Rodrigue, Comtois, & Slack, 2017). This method assigns weights to each facility equal to the share of trips made with the purpose of accessing such facilities to total trips. Two more weighting methods are introduced to examine the effect of extreme weighting scenarios on accessibility measures.

Table 17 shows the composite indices of accessibility for the City of Commerce for three methods of measuring accessibility, with a scenario when households with no vehicles use transit and everyone else uses private vehicles. In addition to methods A, B, and C, accessibility composite indices are also calculated using average time to all places of employment within the ten-mile radius concurrent with time to the other closest facilities. The results are presented under the column “method A with alternative employment accessibility measure”.

The composite indices are calculated by multiplying each variable by the weight assigned to it and adding up all resulting values.

Table 17. Composite Indices of Accessibility in Commerce, Households with No Vehicles Using Transit

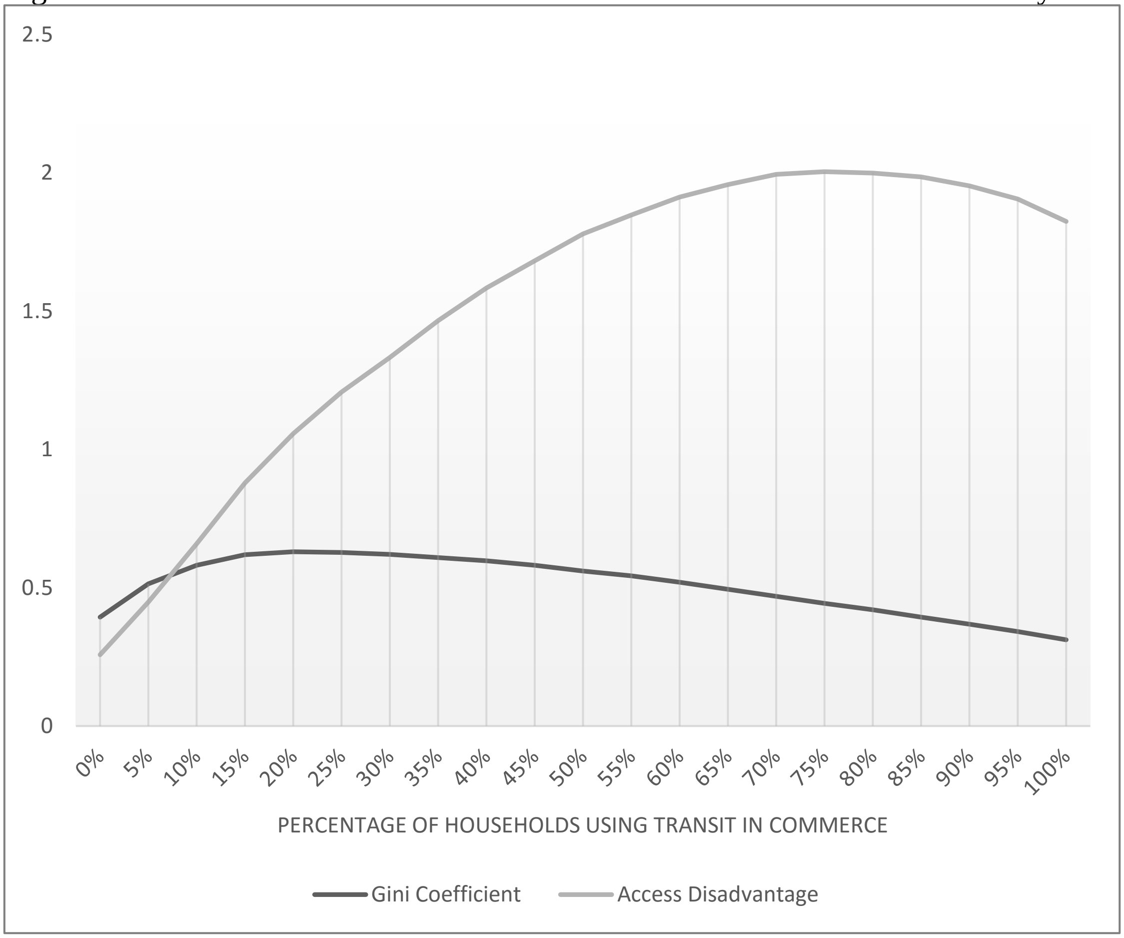
Weighting Method	Method A		Method B		Method C		Method A with Alternative Employment Accessibility Measure	
	Gini Coeff.	Access Disadvg.	Gini Coeff.	Welfare Index.	Gini Coeff.	Access Disadvg.	Gini Coeff.	Access Disadvg.
Equal Weights	0.64	0.92	0.12	20,118	0.59	1.10	0.61	3.44
AHP Inverse Linear Method	0.64	0.82	0.12	25,984	0.60	1.00	0.61	4.34
AHP Linear Method	0.65	0.73	0.13	31,524	0.60	0.92	0.61	5.21
AHP Power Method	0.66	0.66	0.13	37,439	0.60	0.85	0.61	6.20
Trip Frequency Based	0.66	0.59	0.13	43,385	0.61	0.75	0.59	7.11
Extreme Scenario A	0.68	0.67	0.13	45,406	0.61	0.84	0.61	7.72
Extreme Scenario B	0.69	0.57	0.13	55,248	0.62	0.74	0.61	9.39

Comparing the results of different weighting methods show that accessibility analysis is sensitive to the method of measurement but not so much to the weighting method used. The Gini coefficients are very similar across different weighting methods, even including the extreme weighting scenarios. The composite access disadvantage indices show more variation with various weights.

The results in this chapter suggest that as transit share increases, the overall access disadvantage calculated increases. The overall Gini coefficient also increases and represents a more unequal distribution moving from all households using private vehicles to the ones with no vehicles as transit users. Gini coefficients, however, drop again when moving to a scenario where everyone uses transit. It can be hypothesized that as the number of transit users increases the Gini coefficient of access also increases and reaches a maximum where it starts decreasing again. To investigate the relationship between Gini coefficients and transit use, access to healthcare facilities is selected as an example and accessibility measures are calculated for 5% , 10%, ... using method A. the results are shown in Figure 13.

The most unequal distribution of access is when about 20% of households use transit. When the transit users' share is less or more than this number then a smaller Gini coefficient and more equal distribution of access results. However, the access disadvantage increases with increased transit users' share and reaches its peak when 75% of households use transit. The access disadvantage then slightly declines before it gets to the point where all households use transit. While the lowest access disadvantage is associated with everyone using private vehicles, the lowest Gini coefficient occurs when all households use transit.

Figure 13. Access to Healthcare Facilities-Method A: Time to the Closest Facility



Encouraging higher rates of transit use might have great benefits for health, the environment, and maybe even inequality when more than 20% of households use transit. However, as Figure 13 indicates, increased transit use will lead to higher access disadvantage indices and worse welfare levels. Therefore, promoting more transit use as an isolated policy can reduce accessibility and welfare for residents unless it is combined with improvements in transit systems, travel times and frequency. Alternatively, land use policies can be used to provide a better distribution of locations for essential needs.

CHAPTER SIX: POLICY APPLICATION AND DISCUSSION

Applicability of the indices developed through this research can be tested by measuring transportation inequality before and after implementing a policy. In 2008, project Move LA built a powerful business-labor-environmental coalition that worked with Los Angeles mayor at the time, Antonio Villaraigosa, and Metro to get “Measure R” on the ballot and ensure its passage. Measure R was a half-cent sales tax for Los Angeles County to finance new transportation projects and programs, and accelerate those already in the pipeline. The tax took effect in July 2009 and was predicted to provide $40 billion over 30 years, 35% of which was devoted to new rail and bus rapid transit projects, 20% to carpool lanes, highways and other highway related improvements, 20% to bus operations, 3% to Metrolink projects, 5% to rail operations, 2% to Metro Rail system improvement projects, and 15% for local city sponsored improvements (Measure R).

Measure R was an ambitious expansion that would double the size of L.A. County’s rail transit system from 120 miles and 103 stations to 236 miles and 200 stations and was expected to create over 500,000 new jobs (Metro, 2009). Figure 14 is a representation of Measure R projects in rail and rapid transit as well as highway improvements. After the adoption of Measure R, mayor Villaraigosa proposed 30-10 Plan to accelerate the build-out of all twelve Measure R-funded transit projects in ten years. The 30-10 plan sought to have the federal government loan the entire amount of expected Measure R, at least the 40% dedicated to transit capital, to Metro all at once. This loan would be paid back gradually as revenues from the Measure R sales tax come in, and would provide enough money so that all the projects will be able to be completed in 10 years instead of up to 30 (by 2019). The 30-10 plan later turned into a national campaign, America Fast Forward, which in collaboration with many other cities proposed an expansion of low cost federal loans for transportation nationwide.

Figure 14. Measure R Transit and Highway Projects

Source: Measure R Fact Sheet, LA Metro. Retrieved July 9, 2017, from http://media.metro.net/measureR/images/Measure_R_fact_sheet.pdf

In November 2016 L.A. County voters passed another of Metro's transportation ballot measures with 71.15% support. Measure M is an additional half-cent sales tax titled "Los Angeles County Traffic Improvement Plan". Draft Measure M guidelines were released by Metro in March 2017 for public review and revised guidelines were eventually approved by the Metro Board in June 2017. The tax increase was effective on July 1, 2017 and is expected to generate an estimated $860 million a year in 2017 dollars.

Measure M proposed projects will be built over a 40-year period (Metro, 2016). Figure 15 show both transit and highway improvement projects included in Measure M.

Figure 15. Measure M Transit and Highway Projects

Source: Measure M Fact Sheet, LA Metro. Retrieved July 9, 2017, from http://theplan.metro.net/wp-content/uploads/2016/10/factsheet_measurem.pdf

To evaluate the outcomes of these two measures on transportation related social exclusion, the networks used to analyze accessibility in previous chapters were updated with Measure R and M projects. Then new network analysis was conducted to calculate accessibility and its associated inequality and welfare indices in the City of Commerce. The following section presents the results of this analysis.

Measure R and M Projects in the City of Commerce

The two transportation Measures R and M cover many types of projects including repaving local streets; highway lane additions, ramp/interchange improvements and other highway capacity enhancement projects; investment in rail and bus operations; bridge and other transportation infrastructure maintenance; bike path construction and extension; rail and rapid transit expansion etc. The method used to measure accessibility in this study is sensitive to new roads and transit routes that will affect travel times and not all types of improvements. In other words, Measures R and M can affect the accessibility analysis here through projects which create new routes. Therefore, only the rail and rapid transit expansion projects included in Measures R and M can affect the values calculated in this study for accessibility, Gini coefficients, access disadvantage, and welfare indices. These projects are identified in a ten-mile radius from the City of Commerce boundary and include the following:

Measure R Projects:

- Gold Line Foothill light rail transit extension (already completed)
- Exposition Blvd. light rail transit, Culver City to Santa Monica (already completed)
- Regional Connector (under construction)
- Crenshaw transit corridor (under construction)
- West Side subway extension (under construction)
- Gold Line Eastside rail extension (also included in Measure M projects)
- West Santa Ana light rail corridor: Union Station to City of Artesia (also included in Measure M projects)

Measure M Projects:

- Green Line rail extension to Norwalk Metrolink station
- Vermont BRT Corridor: Hollywood Blvd. to 120^{th} St.
- Crenshaw Line Rail Northern extension to West Hollywood
- Orange Line BRT connector to Gold Line rail

The two completed projects, Gold Line Foothill extension and Exposition Blvd. light rail extension, are in the GTFS data downloaded and already included in the transit network analysis. The remaining lines where manually added to the GIS shapefiles to create a new network that represents the transit network after both measures are completely implemented. The routes for each project were based on the maps published by Metro and in cases with more than one option being studied for a route, one of the options was selected and added to the network.

Figure 16 and Figure 17 are examples of the maps that were used to manually draw the new routes and stops for West Side subway extension and the Gold Line east side extension. There is more than one route proposed for the Gold Line east extension so one, Washington Blvd. option, was selected for the purpose of this study. Appendix H includes maps for other Measure R and M transit expansion projects that are located within a ten-mile radius of the City of Commerce and are used in this study.

In the absence of GTFS schedules for the new lines, assumptions were made about the speed of each line so travel times can be calculated accordingly. The average speed on existing BRT, Orange Line, is 22 mile per hour so the same speed is assigned to the new BRT lines as well. The maximum speed on the Gold Line and Expo Line is 55 miles per hour and the same assumption was made for the new rail lines.

Figure 16. West Side Subway Extension

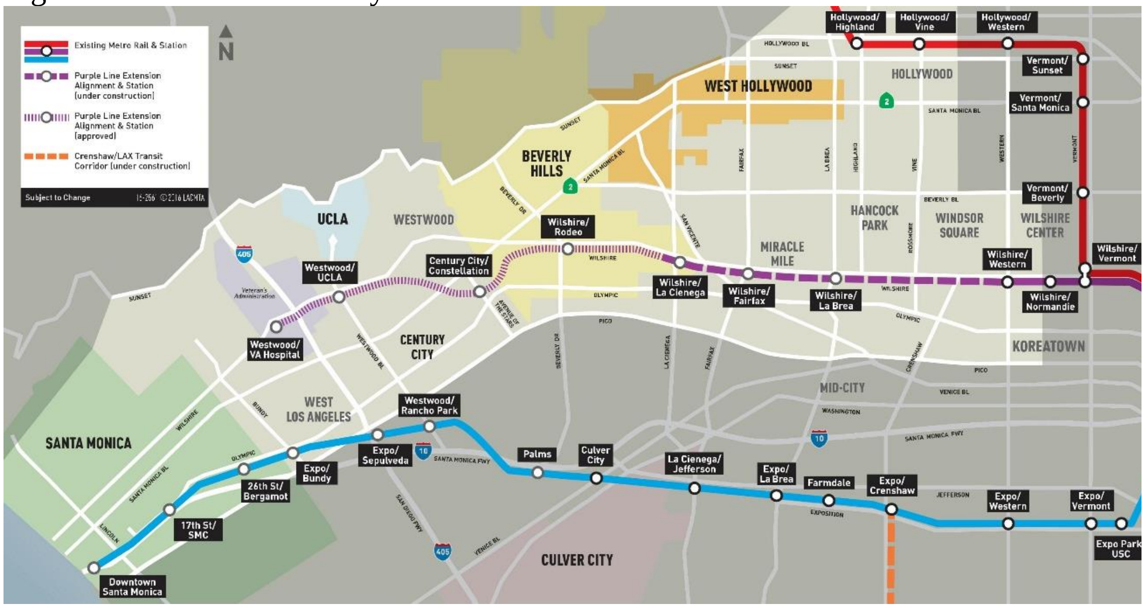
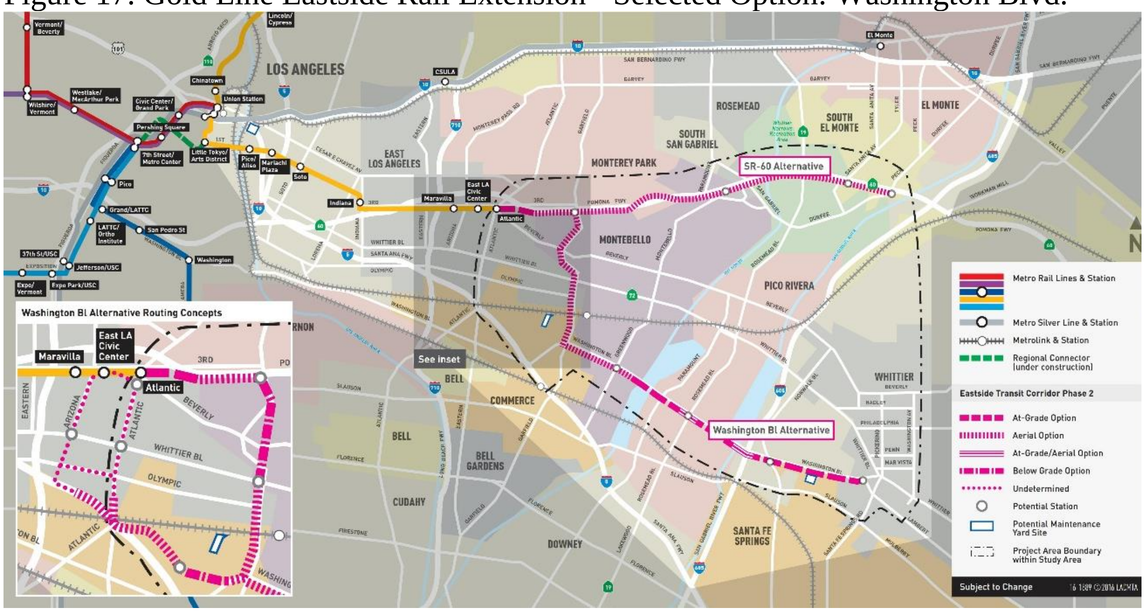


Figure 17. Gold Line Eastside Rail Extension - Selected Option: Washington Blvd.



Other Measure R and M transit expansion projects that are not located within a ten-mile radius from the City of Commerce boundary are not included in this analysis. These projects include the following:

Measure R Projects:

- Green Line Extension: Redondo Beach Station to South Bay Corridor
- Green Line Extension to Los Angeles International Airport
- San Fernando Valley North-South Rapidways: Canoga Corridor (project acceleration)
- San Fernando Valley East North-South Rapidways (project acceleration)
- San Fernando Valley I-405 Corridor Connection

Measure M Projects:

- Airport Rail Connector and Green Line Rail Extension
- East San Fernando Valley Transit Corridor
- Gold Line Rail Extension: Foothill to Claremont
- Purple Line Rail Subway Extension: Century City West to Westwood/VA Hospital
- West Santa Ana Light Rail Corridor: Union Station to City of Artesia
- Orange Line BRT Improvements
- Gold Line Eastside Rail Extension
- Green Line Rail Extension: Redondo Beach to Torrance Transit Center
- Sepulveda Pass Underground Transit Corridor
- Orange Line BRT Conversion to Light Rail
- LAX BRT Connector to Santa Monica
- Metro Rail and Express Bus Extension from Westwood to LAX Metro Connector

Accessibility after Implementation of Measures R and M Projects

To isolate and evaluate the effect of Measures R and M on accessibility, the analysis was run with the same origins and destinations of year 2015. The same road network is also used. The two measures have planned for several highway and street improvement projects but no new road construction. Therefore, the 2015 road network is used for accessibility analysis after implementation of Measures R and M as well. While keeping origins, destinations, and road network constant, a new transit network is used here that includes Measures R and M transit projects listed above. Following sections present results and comparisons with 2015 analysis.

Transit Network

Table 18 shows the results of accessibility analysis after transit expansion projects of Measures R and M are complete in a scenario where all Commerce households use transit. It also shows the change in mean, Gini coefficient, access disadvantage, and welfare index from the 2017 analysis presented in Chapter 5.

Table 18 shows there is a small improvement in access to the three closest retail stores (1%). There is a larger improvement in access to government and legal offices measured with both method A and C (2%-8% across different variables). In addition to a shorter travel time and lower access disadvantage indices, the distribution of access to this activity is also improved as shown by lower Gini coefficients. The number of accessible facilities as measured by method B does not show improvements for any destination activity.

Table 18. Commerce Accessibility Measures after Implementation of Measures R and M, All Households Using Transit

Facility Type & Change Since 2017 (%)	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	6.84	0.36	2.46	6	0.33	4	10.61	0.24	2.55
Percent Change since 17	0	0	0	0	0	0	0	0	0
Employment	1.38	0.42	0.58	432	0.20	345	1.89	0.31	0.59
Percent Change since 17	0	0	0	0	0	0	0	0	0
Healthcare	5.85	0.31	1.81	16	0.42	10	7.87	0.26	2.05
Percent Change since 17	0	0	0	0	0	0	0	0	0
Social Activities	4.54	0.29	1.32	14	0.29	10	7.05	0.17	1.20
Percent Change since 17	0	0	0	0	0	0	0	0	0
Retail: Food & Bev.	3.92	0.30	1.18	39	0.28	28	5.17	0.23	1.19
Percent Change since 17	0	0	0	0	0	0	0	0	0
Retail: All Other	3.63	0.31	1.13	58	0.37	37	5.21	0.21	1.09
Percent Change since 17	0	0	0	0	0	0	-1	0	-1
Govt. & Legal Offices	14.16	0.36	5.10	9	0.30	6	16.30	0.31	5.05
Percent Change since 17	-4	-5	-9	0	0	0	-2	-6	-8
Banks & Financial Inst.	12.59	0.25	3.15	6	0.42	3	14.79	0.23	3.40
Percent Change since 17	0	0	0	0	0	0	0	0	0
	Average Time to Facilities within Ten-Mile Radius								
Employment	92.73	0.04	3.71						
Percent Change since 17	-49	33	-33						

The additional employment access measure, average travel time to all places of employment within a ten-mile radius shows significant improvements in travel time and access disadvantage. If all households in Commerce used transit, the average travel time to employment would be cut in half, and access disadvantage by one-third, after implementation of Measure R and M projects. The Gini coefficient, however, suggests a small increase (from 0.03 in 2015 to 0.04) in inequality.

Five and Ten Percent Transit Use

Table 19 and Table 20 depict the changes in accessibility measures when 5% and 10% of Commerce households are assumed to use transit. In these scenarios, improvements in access to government and legal offices are not as significant as the previous scenario while accessibility of retail stores show larger changes.

Table 19. Commerce Accessibility Measures after Implementation of Measures R and M, Five Percent of Households Using Transit

Facility Type & Change Since 2017 (%)	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	0.88	0.53	0.47	4,525	0.06	4,245	1.44	0.39	0.56
Percent Change since 17	0	0	0	0	0	0	0	0	0
Employment	0.17	0.66	0.11	131,656	0.06	123,935	0.23	0.60	0.14
Percent Change since 17	0	0	0	0	0	0	0	0	0
Healthcare	0.87	0.51	0.44	10,531	0.06	9,872	1.15	0.44	0.51
Percent Change since 17	0	0	0	0	0	0	0	0	0
Social Activities	0.63	0.51	0.32	6,143	0.06	5,765	0.96	0.40	0.38
Percent Change since 17	0	0	0	0	0	0	0	0	0
Retail: Food & Bev.	0.53	0.53	0.28	13,057	0.05	12,352	0.69	0.47	0.32
Percent Change since 17	0	0	0	0	0	0	0	0	0
Retail: All Other	0.48	0.54	0.26	18,559	0.06	17,512	0.68	0.46	0.31
Percent Change since 17	0	0	0	0	0	0	0	-2	-2
Govt. & Legal Offices	1.99	0.50	1.00	1,080	0.05	1,028	2.24	0.48	1.08
Percent Change since 17	-1	-2	-3	0	0	0	0	0	0
Banks & Financial Inst.	1.53	0.48	0.73	3,543	0.06	3,320	1.86	0.44	0.82
Percent Change since 17	0	0	0	0	0	0	0	0	0
	Average Time to Facilities within Ten-Mile Radius								
Employment	16.21	0.23	3.73						
Percent Change since 17	-19	-38	-50						

The additional employment accessibility measure also reveals an interesting trend. Table 18 in previous section indicated that implementation of transit projects causes 50% improvement in average travel time and 33% improvement in access disadvantage while not affecting the inequality index in a scenario where everyone uses transit. However, as Table 19 and Table 20 suggest, when only a portion of population use transit, 5% and 10% respectively, Measure R and M projects in fact lower access inequality by more than 30%. The improvement in average travel time to employment centers is not as bold as the previous scenario. Yet, decrease in Gini coefficient offsets that and eventually results in about 50% improvement in access disadvantage index.

Table 20. Commerce Accessibility Measures after Implementation of Measures R and M, Ten Percent of Households Using Transit

Facility Type & Change Since 2017 (%)	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	1.24	0.63	0.78	4,284	0.11	3,803	1.98	0.52	1.03
Percent Change since 17	0	0	0	0	0	0	0	0	0
Employment	0.25	0.72	0.18	124,641	0.11	111,067	0.32	0.67	0.21
Percent Change since 17	0	0	0	0	0	0	0	0	0
Healthcare	1.13	0.58	0.66	9,970	0.11	8,847	1.52	0.54	0.82
Percent Change since 17	0	0	0	0	0	0	0	0	0
Social Activities	0.85	0.59	0.50	5,816	0.11	5,166	1.31	0.52	0.68
Percent Change since 17	0	0	0	0	0	0	0	0	0
Retail: Food & Bev.	0.72	0.61	0.44	12,360	0.10	11,068	0.94	0.57	0.54
Percent Change since 17	0	0	0	0	0	0	0	0	0
Retail: All Other	0.64	0.62	0.40	17,585	0.11	15,720	0.92	0.56	0.52
Percent Change since 17	-2	0	-2	0	0	0	-1	-2	-3
Govt. & Legal Offices	2.74	0.60	1.64	1,041	0.08	956	3.10	0.58	1.80
Percent Change since 17	-2	-2	-4	0	0	0	-1	-2	-3
Banks & Financial Inst.	2.17	0.59	1.28	3,369	0.11	3,000	2.62	0.56	1.47
Percent Change since 17	0	0	0	0	0	0	0	0	0
	Average Time to Facilities within Ten-Mile Radius								
Employment	20.33	0.36	7.32						
Percent Change since 17	-30	-31	-51						

Proxy for Actual Transit Use

In this scenario, 11.2% of households in Commerce, the percentage of households with no vehicles in 2015, are considered as transit users. As Table 21 shows, the results are very similar to the 5% and 10% of households using transit that was presented in previous section. Access to retail stores, other than food and beverage stores, improves with Measure R and M projects. Although the improvement is small, it is consistent throughout all three variables in methods A and C. Access to government and legal offices is also improved with a 2%- 3% reduction in travel time to the closest office and lower Gini coefficients in the same methods.

Table 21. Commerce Accessibility Measures after Implementation of Measures R and M, Households with No Vehicles Using Transit

Facility Type & Change Since 2017 (%)	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Education	1.44	0.66	0.95	4,204	0.13	3,659	2.22	0.56	1.24
Percent Change since 17	0	0	0	0	0	0	0	0	0
Employment	0.27	0.72	0.19	122,291	0.13	106,836	0.36	0.68	0.24
Percent Change since 17	0	0	0	0	0	0	0	0	0
Healthcare	1.25	0.60	0.75	9,784	0.13	8,512	1.68	0.57	0.96
Percent Change since 17	0	0	0	0	0	0	0	0	0
Social Activities	0.92	0.60	0.55	5,707	0.13	4,970	1.45	0.55	0.80
Percent Change since 17	0	0	0	0	0	0	0	0	0
Retail: Food & Bev.	0.79	0.62	0.49	12,122	0.12	10,640	1.02	0.58	0.59
Percent Change since 17	0	0	0	0	0	0	0	0	0
Retail: All Other	0.70	0.62	0.43	17,255	0.12	15,126	1.01	0.59	0.60
Percent Change since 17	-1	-2	-3	0	0	0	-2	0	-2
Govt. & Legal Offices	3.15	0.63	1.98	1,041	0.08	955	3.46	0.61	2.11
Percent Change since 17	-3	-3	-6	0	0	0	-2	-2	-4
Banks & Financial Inst.	2.32	0.60	1.39	3,308	0.13	2,890	2.83	0.58	1.64
Percent Change since 17	0	0	0	0	0	0	0	0	0
	Average Time to Facilities within Ten-Mile Radius								
Employment	21.93	0.39	8.55						
Percent Change since 17	-32	-29	-52						

While the changes in other accessibility measures in methods A, B, and C are all less than 10%, the additional employment accessibility measure shows significant improvements with Measures R and M. When access to employment is measured by average time to the places of employment within a ten-mile radius, both travel time and the Gini coefficient decrease by 30% while the access disadvantage index is reduced by half.

Conclusions

Comparing accessibility measures before and after implementation of Measures R and M transit expansion projects does not show considerable change in travel times, Gini coefficients, access disadvantage, and welfare indices as measured in methods A, B, and C. Accessibility of most facilities remains the same for Commerce residents except government and legal offices as well as retail stores (other than food and beverage stores). It should be noted that access to governmental and legal offices was shown to be the lowest and associated with the highest level of access disadvantage in 2017. Therefore, Measures R and M help improve access to the category with the worst accessibility measures. Table 22 shows how the two measures affect overall accessibility and composite indices using various weighting methods. For a summary of assigned weights in each weighting method refer to Table 16 in Chapter 5.

Table 22. Composite Indices of Accessibility in Commerce after Measures R and M Projects, Households with No Vehicles Using Transit

Weighting Method & Change Since 2017 (%)	Method A		Method B		Method C		Method A with Alternative Employment Accessibility Measure	
	Gini Coeff.	Access Disadvg.	Gini Coeff.	Welfare Index	Gini Coeff.	Access Disadvg.	Gini Coeff.	Access Disadvg.
Equal Weights	0.63	0.90	0.12	20,121	0.59	1.08	0.59	2.09
Percent Change since 17	-1	-2	0	0	0	-1	-4	-39
AHP Inverse Linear Method	0.64	0.80	0.12	25,986	0.59	0.99	0.58	2.47
Percent Change since 17	0	-2	0	0	0	-1	-6	-43
AHP Linear Method	0.65	0.72	0.13	31,526	0.60	0.91	0.57	2.85
Percent Change since 17	0	-1	0	0	0	-1	-7	-45
AHP Power Method	0.66	0.66	0.13	37,439	0.60	0.85	0.56	3.29
Percent Change since 17	0	0	0	0	0	0	-8	-47
Trip Frequency Based	0.66	0.59	0.13	43,388	0.61	0.75	0.53	3.68
Percent Change since 17	0	-1	0	0	0	0	-10	-48
Extreme Scenario A	0.67	0.66	0.13	45,406	0.61	0.84	0.54	4.01
Percent Change since 17	0	-1	0	0	0	0	-11	-48
Extreme Scenario B	0.69	0.57	0.13	55,248	0.62	0.74	0.53	4.75
Percent Change since 17	0	0	0	0	0	0	-13	-49

Based on the three methods of measuring the Gini coefficient, access disadvantage, and the welfare index of accessibility, transportation Measures R and M have marginal effects on the distribution of accessibility regardless of the weighting method used (only 1%-2% improvement in some categories). In fact, a review of the composite Gini coefficients derived from the different weighting methods show that the selection of weights does not affect the inequality indices and the Gini coefficients are quite consistent. There is between 5%-11% variation in the Gini coefficient across all weighting methods.

The composite access disadvantage and welfare indices, however, are more sensitive to the choice of weights and vary significantly based on the weighting scheme. As we move away from equal weights to more extreme weighting scenarios, the access disadvantage indices decrease and the welfare indices increase in methods A, B, and C. This change is caused by categories with low accessibility measures, such as government and legal offices, which have smaller weights in the extreme scenarios.

When access to the closest employment center is replaced with the alternative employment accessibility measure, as represented in the last column, greater changes are observed in the composite Gini coefficients and access disadvantage indices. The large changes in access disadvantage, ranging from a 39% to 49% decrease dependent on the weighting method used, is derived from the large reduction in average travel time and access disadvantage of places of employment as shown in Table 21. The next chapter includes a discussion of all these results and the factors that might be leading to such small marginal differences.

CHAPTER SEVEN: DISCUSSION AND CONCLUSIONS

This study is unique in its multidimensional approach to measuring accessibility. What also sets it apart from other research in this field is that it evaluates the distribution of accessibility throughout communities and evaluates inequality in access. Different methods of measuring accessibility and access inequality have been tested here to answer the research questions using Los Angeles County and City of Commerce as case studies.

Research Questions

The main research objective of this study was to develop methods to measure unequal distribution of access that leads to social exclusion. After deriving a transport-related exclusion framework based on the academic literature and reviewing the existing transportation inequality measures several research questions were posed:

- What are the advantages and limitations of transportation inequality measures currently available in the literature?
- What is a feasible multi-dimensional set of indicators of transportation inequality with regard to social exclusion?
- What is the extent of transportation inequality in Los Angeles County measured by using the developed indices before and after implementation of Measures R and M?

Literature on transportation inequality and accessibility cover an extensive range of issues. The ultimate objective of transportation equity is to provide equal access to social and economic opportunity by providing equitable levels of access to all places (Sánchez, Stolz, & Ma, 2003). Researchers have also focused on just distribution of transportation costs and benefits as well as government investment in transportation.

Metrics developed to identify and measure the concept of transportation inequality are varied. In the U.S., concern about providing equal access to social and economic opportunities has mostly centered on the issue of access to employment (Kain, 1968; Holzer, 1991; Sánchez, Stolz, & Ma, 2003), healthcare (Todd, Seekins, Krichbaum, & Harvey, 1991; Luo & Wang, 2003; Mao & Nekorchuk, 2013), and healthy food (Smoyer-Tomic, Spence, & Amrhein, 2006; Coveney & O'Dwyer, 2009; Beaulac, Kristjansson, & Cummins, 2009; Ver Ploeg, 2010; Gordon, et al., 2011). This study, however, situates the concept of access and accessibility in the context of transport-related social exclusion and covers access to a combination of different services and destinations. Social exclusion has been defined as a process that causes individuals or groups, who are geographically resident in a society, not to participate in the normal activities of citizens in that society for reasons beyond their control. Areas of normal activities of citizens include production, consumption, saving, political and social activities (Burchardt, Le Grand, & Piachaud, 1999). Education and healthcare have also been included in the normal activities of citizens in the literature (Lee & Murie, 1999). These seven types of services were selected as criteria to measure accessibility in this study.

Accessibility measures are often calculated using detailed travel diary datasets (Handy & Niemeier, 1997; Kwan & Weber, 2003; Joh, et al., 2008; Scott & Horner, 2008) or aggregate data at a larger scale such as traffic analysis zone (TAZ) (Benenson, Martens, & Rofé, 2010; Golub & Martens, 2014). The most commonly used accessibility measures in the literature include Hansen's gravity measure (Hansen, 1959) and its varieties, cumulative number of accessible opportunities, and distance to the closest facility.

The gravity-based model requires the unit of analysis to be geographical zones whether they are census blocks, ZIP codes, TAZs etc. There are a few problems with using any such area as the analysis unit. First, by working with zones, one assumes that all individuals/households in that zone share the same level of access and are all located in the centroid of the zone. Such assumptions compromise the accuracy of the resulting analysis. They ignore within-zone differences and result in inaccurate travel time/distance. Methods that use large areal units are also problematic because they do not allow for calculation of shortest distance/time to services. As the results here show, the closest destination in each category of services is usually just a few minutes from households. Therefore, an analysis that assumes all households are located at the centroid of an area likely leads to considerable errors when calculating shortest time/distance to destinations. Another issue caused by using simple area-based analysis is that it uses centroids of the selected geographic areas instead of people's residences as the trip generation point. Therefore, it can show alarmingly low levels of access in areas that do not have many residential parcels and access to services is not in fact needed. This study used households as the unit of analysis with residential units as origin points for trips. The measurements used here included travel time to the closest facility, average travel time to the three closest facilities, and number of facilities within 20 minutes of the origin. An additional accessibility measure was calculated to measure access to employment because most people do not work at the closest employment location. Therefore, average travel time to all places of employment within a ten-mile radius of the

City of Commerce boundary are calculated to replace travel time to the closest employment center.

In addition to calculating household level accessibility, actual travel time and distances are based on network analysis. With the exception of a few studies (Benenson, Martens, & Rofé, 2010), the academic literature has mostly used Euclidean methods and straight-line analysis to find accessible destinations. In straight-line analysis, the travel distance between origin and destination is calculated as the straight-line distance between the two points regardless of available roads. While this method provides ease of calculation and is more practical, it has two major shortcomings. It introduces error into calculation of travel time/distance and more importantly, it cannot be used for analysis of transit users' access levels. In this study, both network analysis and straight-line analysis were utilized in measuring accessibility so comparisons can be made between the results.

While access is a relative concept in the social exclusion context, not all accessibility studies evaluate the distribution of access. There are two main approaches taken in the academic literature to evaluate access inequality. One is by identifying disadvantaged areas/communities that do not meet pre-defined access levels to certain services. One instance of this approach is defining and identifying food deserts as low-income census tracts where a significant number (at least 500 people) or share (at least 33%) of the population is greater than half a mile from the nearest supermarket, supercenter, or large grocery store for an urban area or greater than ten miles for rural areas (USDA ERS, 2013). The other approach to evaluate access inequality used in the literature is to measure the gap between access levels of transit users versus drivers. This gap is often measured through the difference between, or the ratio of, transit users' travel time to drivers' travel time to certain destinations (Benenson, Martens, & Rofé, 2010; Golub & Martens, 2014). Since the studies that take this approach use area-based accessibility measurements they can only measure overall disadvantage of transit users compared to drivers regardless of the size of each group in the area. To overcome the generalization of these two approaches, this study used the well-known economic concepts of the Gini coefficient and welfare indices, for the first time to my knowledge, to measure access inequality. Additionally, a new index, the access disadvantage index, is introduced to combine average travel time and the Gini coefficient following the same rationale of welfare functions.

The Gini coefficient, access disadvantage, and Sen welfare index for accessibility calculated here show the feasibility of compiling such measures. The data required and used here has already been compiled by Southern California Association of Governments and LA County Office of the Assessor. Similar data would be available in different areas through MPOs and Assessor's Offices making it possible to use the methodology presented here nationwide. It should be noted that while no new surveys or data collection was needed for this study, the analysis process was a time intensive task. The long process of individual level GIS network analysis is why many studies in the academic literature have used straight-line area-based measures. However, this approach not only compromises accuracy but also makes it impossible to utilize other accessibility measures such as shortest travel time to a service or study variations in transit users' access levels. Therefore, analysis for the City of Commerce was done here as an illustration for multidimensional, network-based, household-level accessibility and equity analysis.

In the County of Los Angeles as a whole, access to employment, education, social activities, and government and legal offices has the most equal distribution while food and beverage stores and restaurants are the least equally distributed services and have the highest Gini coefficient. On the other hand, access disadvantage indices show that L.A. County has the highest access disadvantage for government and legal offices followed by financial institutions and healthcare facilities. Access to employment in the county ranks highest with the access disadvantage and the Gini coefficient.

When compared to the entire county, Commerce has a more equal distribution of access to all services. The average distance to the closest facilities for both the City of Commerce and the county are very similar with no difference greater than a quarter mile. The access disadvantage indices imply that Commerce residents have better access to all facilities compared to L.A. County.

When both transit users and drivers are considered, City of Commerce with 11.2% car-less households, has the relatively similar Gini coefficients for access to various services. However, the access disadvantage and welfare indices associated with each service differs in a wide range. Places of employment are the most accessible destinations with lowest access disadvantage and highest welfare levels whereas government and legal offices are the least accessible ones and provide the highest access disadvantage and lowest welfare indices for Commerce residents. Implementation of transportation programs such as Measures R and M were shown to have marginal effect on the distribution of accessibility measured as time to the closest facilities. In a scenario where households with no vehicles use transit, completion of the two measures' transit expansion projects improves the Gini coefficients and access disadvantage indices less than 1% as measured by methods A and C. However, when accessibility is measured as average travel time to all places of employment within ten miles, Measure R and M projects result in a 30% decrease in travel time and the Gini coefficient and a 52% decrease in employment access disadvantage.

Main Results

The results presented in previous chapters shed light on several important points. First, accessibility analysis using road and transit network GIS datasets is a time-intensive task even for a small city like Commerce with population of almost 13,000. To overcome this issue, one might suggest replacing network analysis with straight-line analysis. However, straight-line analysis is not associated with transit routes and can only represent driving distances. The comparisons between road network and straight-line analysis in the City of Commerce shows that the relative relation of accessibility of categories in straight-line analysis remains the same as network analysis, meaning that places of employment and retail stores are the most accessible destinations and government and legal offices and banks and financial institutions are the least accessible facilities using both methods. The number of accessible destinations can also be estimated closely using straight-line analysis if the threshold for accessibility (20 minutes, ten miles, etc.) is selected correctly. Correlation analysis also showed that the calculated travel time and distance are highly correlated for most facilities. However, there is no correlation between the Gini coefficients calculated with a road network analysis and the Gini coefficients calculated from a straight-line analysis. The coefficients are underestimated for some categories and overestimated for others.

Therefore, the straight-line analysis cannot replace network analysis when evaluating inequality and considering different modes including transit.

Another point that is highlighted by this research is that the choice of method used to measure accessibility will affect the study results as other researchers have previously argued as well (Martens & Golub, 2012a). Three different methods of measuring accessibility were tested here. The first method (method A) in this study measures accessibility as travel time in minutes to the closest destination (in each facility group). Method B calculates the number of facilities within 20 minutes travel time. Finally, method C measures accessibility as average travel time to the three closest facilities. Generally, methods A and C lead to similar results in terms of average value, Gini coefficient, and Sen welfare index. As is expected, the average time to the three closest facilities is higher than time to the closest facility. Hence, the average accessibility for method C is always slightly higher than method A. Gini coefficients calculated through method C, on the other hand, are always slightly lower than those of method A. This means that if access to the three closest facilities is selected, households' accessibility has a more equal distribution. On the other hand, the overall effect of average accessibility and Gini coefficient which is captured through the access disadvantage index is higher for method C.

However, numbers derived through using method B are different. When studying transit users only, the number of accessible facilities within 20 minutes is limited and does not exceed 500 for any of the categories. In fact, the number is less than 60 for all categories except places of employment. The Gini coefficients calculated for this range still show some variability between different categories and ranges between 0.20-0.42.

However, when the analysis is extended to include drivers, the number of accessible facilities increases dramatically and the maximum exceeds 100,000 for places of employment. With the increase in average number of accessible facilities, Gini coefficients decrease and do not show much variation between different categories. These numbers are far smaller than Gini coefficients of methods A and C and point at more equal and homogenous access for households when it comes to number of facilities accessible in 20 minutes. Since each method has the potential to represent a different aspect of accessibility, it is beneficial for studies in this area to utilize multiple methods and definitions and develop a multidimensional understanding on the issue.

Implications for Policy and Practice

In addition to outcomes of this study about methodology of measuring accessibility and evaluating inequality, some policy related conclusions can also be drawn. Access to employment opportunities and supermarkets are the two most studied subjects in the academic literature which have been discussed by researchers and policy makers. The importance of these categories was also highlighted through the interviews in this study. Yet, the results here suggest that households have more difficulty accessing other facilities such as banks, financial institutions, government, and legal offices. It is true that employment and food have a greater impact and importance on individuals' lives and transportation planners should focus on accessibility of relevant jobs to communities' skills and quality healthy food. However, they should not disregard issues of access to other services to ensure all individuals are included and engaged in political and economic transactions. In other words, transportation planners should focus on all aspects of accessibility to prevent social exclusion.

The study further suggests that while policies and measures such as R and M might have great consequences in terms of improvements in traffic, congestion relief, and pollution reduction they do not seem to be effective in addressing access to the closest facilities and the inequality in access distribution. The results here suggest that while the effects of Measure R and M projects on average travel time to places of employment within a ten-mile radius is significant, improvements in access to other close facilities and the number of accessible facilities are marginal. There is less than a 1% improvement in the composite Gini coefficients and less than a 2% improvement in the composite access disadvantage indices after implementation of Measure R and M projects based on accessibility measures calculated with methods A and C. There is no improvement observed in the Gini coefficient and the Sen welfare index with method B. These projects are shown to be the most effective on improving access to government and legal offices and retail stores (other than food and beverage stores). It should be noted that this study could not capture the effect of Measure R and M investment in transit operations and only focused on expansion projects that created new transit routes.

The distributional consequences of these policies are of concern since the nature of these measures is rather regressive subjecting everyone to the same half-cent sales tax. However, more research is needed to help formulate policies that can effectively target access inequality and social exclusion. One way of minimizing access inequality would be for more people to use the same travel mode. Because of negative environmental and health effects of higher rates of driving, it is not advisable to encourage more individuals to drive even if that leads to lower inequality rates. On the other hand, with current land use patterns and transit infrastructure it is not advisable to encourage everyone to use transit either. As it is shown in this study, more transit use results in greater access disadvantage and lower welfare levels because of the longer travel times. To resolve this conflict and ameliorate access inequality while keeping the welfare levels high, the gap in travel times for different travel modes should be tightened. Currently the gap between access levels of drivers and transit riders is alarmingly wide.

Currently a Commerce resident who drives can on average access 4,728 educational facilities, 137,545 places of employment, 11,003 healthcare facilities, 6,418 social activities, 13,641 food and beverage retail stores, 19,383 other retail stores, 1,117 government and legal offices, and 3,693 banks and financial institutions through a 20-minute trip. A transit user in the City of Commerce, on the other hand, has on average access to 6 educational facilities, 431 places of employment, 16 healthcare facilities, 14 social activities, 39 food and beverage retail stores, 58 other retail stores, 9 government and legal offices, and 6 banks and financial institutions travelling for the same 20-minute period. Average travel time of Commerce drivers to all places of employment within a ten-mile radius of the city is 13 minutes while the same number for a scenario where everyone uses transit is 184 minutes. To tighten this gap, we should invest in existing transit services and operations to reduce travel times, delay times, and increase frequency and quality.

The results also strongly emphasize the importance of an integrated land use-transportation policy to ensure essential destinations are distributed adequately and evenly throughout communities. The same methodology used in this study can be utilized to investigate the effect of adding a new service on accessibility levels, the Gini coefficients, and welfare indices. As an illustration, Table 23 shows how adding one healthcare facility in the City of Commerce will affect accessibility measures in the City.

Table 23. Commerce Healthcare Accessibility Measures, Households with No Vehicles Using Transit, Addition of One Healthcare Facility

Access to Healthcare Facilities	Time to Closest Facility (Method A)			Number of Facilities within 20 Minutes (Method B)			Average Time to Three Closest Facilities (Method C)		
	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)	Mean	Gini Coefficient	Welfare Index	Mean (Minute)	Gini Coefficient	Access Disadvantage (Minute)
Existing Facilities	1.25	0.60	0.75	9,784	0.13	8,512	1.68	0.57	0.96
Existing Facilities + 1	1.11	0.61	0.68	9,784	0.13	8,512	1.63	0.56	0.91
Percent Change after Adding One Facility	-11	2	-9	0	0	0	-3	-2	-5

As Table 23 shows, adding one healthcare facility in the City of Commerce has far greater impact on accessibility and access disadvantage levels compared to the Measure R and M transportation projects. While there is no significant change in the average number of facilitates accessible within 20 minutes, travel time to the closest healthcare facility and average travel time to the three closest facilities are decreased by 11% and 3% respectively. The access disadvantage indices are also improved by 9% and 5% for methods A and C. The Gini coefficient, however, does not change consistently.

In fact, evaluating impacts of land use change on accessibility has been previously promoted in the literature (Halden, 2002). Policy makers have also previously made successful efforts in increasing accessibility levels through incentive programs that promote new services such as supermarkets in disadvantaged areas. Examples of such policies are Pennsylvania Fresh Food Financing Initiative and federal government Healthy Food Financing Initiative (Kinney, 2016).

Study Limitations

Results here, however, should be interpreted with caution due to assumptions and limitations of the study. First, the unit of analysis in this study is households and therefore it ignores within household dynamics and inequalities. For example, households with one vehicle are categorized as drivers and their access is analyzed through road network analysis. Clearly not all individuals in a household can use the same vehicle at the same time, so some would likely use transit. As a result, the Gini coefficients, access disadvantage, and welfare indices calculated strictly present access inequality among households. More detailed analysis can be done to change the unit of analysis to adults and identify transit users based on individual vehicle ownership as opposed to household vehicle ownership.

Another limitation is that this study treats all destinations the same and does not consider the quality or volume of service provided. For example, all places of employment are treated similarly regardless of the number of employment opportunities they offer or the skill level required. The category covering food and beverage retail stores also does not identify providers of healthy food, which is core to much of the food desert literature. In order to refine studies like this, the size and quality of service provided at each destination should also be weighted and entered into the calculations. In other words, in addition to accessibility of destinations, the utility that individuals receive from accessing those destinations should be considered.

In addition to evaluating the quantity and quality of the service provided at each destination, equity analysis need to address particular needs and spatial contexts of the communities (Martens & Golub, 2012b). It is not enough for communities to have access to services but it should be services that match their needs and characteristics and they can translate into utility. For example, a highly educated professional does not derive any utility by accessing low-skill employment opportunities. Therefore, while measuring access to employment, matching of skills with employment opportunities should also be evaluated.

There are also some limitations to the study resulting from datasets used. SCAG road dataset, which was used to build the road network here, does not include all local roads. Therefore, the network analysis may well be underestimating access levels for drivers. On the other hand, the speed used to build the road network is the posted speed for each road segment. This information is used by GIS to calculate travel time. By using posted speed limits, the analysis ignores longer travel times caused by congestion and other traffic delays and therefore overestimates access levels during busy hours. Using posted speed limits also ignores speeding when traffic is not present.

Another data limitation is that the GTFS data that was used to build the transit network was compiled by LA Metro and does not include Metrolink or local bus routes. If these routes were included, specifically local buses such as Commerce Municipal Bus lines, transit users would have higher levels of access and the overall Gini coefficients would be less.

The assumption of ten-minute wait time before boarding public transportation also has the potential to underestimate access levels of transit users if true wait times are shorter. The effect of this assumption could be especially critical when studying the number of facilities accessible within 20 minutes. More research is needed to evaluate how this assumption affects the analysis and how results can vary with a change in this assumption.

Another assumption that was made and could have affected the study was limiting the analysis area to a ten-mile buffer around the City of Commerce. This decision was made to overcome GIS issues and to speed up the process; that is, it was designed merely to be representative. Yet, it could well affect the results, specifically the number of accessible facilities for drivers. It is possible that if the buffer is extended, accessibility measures in Method B show more variability among different categories and result in higher Gini coefficients.

Also, in studying the effects of Measures R and M on accessibility, I assumed that the share of transit users is the same before and after implementation of the projects. However, it is likely that more households decide to use transit or let go of their private vehicles as a result of new transit routes in the area. Therefore, this study does not capture any indirect effects of transit expansion projects on accessibility and access inequality.

Finally, this study has focused on physical access. Meanwhile evermore people are using electronic devices to meet their needs including shopping, banking, continuing education, etc. In fact, all services that are identified here as the seven essential destinations are increasingly being reached and utilized electronically in some form or another. Yet, not all individuals have the knowledge, skills, tools, or condition to do so. Hence, physical presence remains the main form of activity engagement for many individuals. This issue was also emphasized by several policy makers and community organizers that were interviewed as part of this research. More research is needed to develop accessibility frameworks that include other forms of access such as internet access.

Future Research

It is my hope that this study shows the usefulness of using composite measures in studying accessibility and its distribution through the Gini coefficient, access disadvantage, and the Sen welfare index. Because the Gini coefficient is unitless it can easily be compared across studies and geographies. However, to my knowledge, this study is the first to use the Gini coefficient to measure access inequality. Therefore, there is no point of reference to interpret and understand the Gini coefficients derived here. Assuming the households with no vehicles are transit users, we have learned that Commerce residents have a composite Gini coefficient of 0.6-0.7 in their access time to the closest essential facilities and a composite Gini coefficient of 0.12-0.13 in the number of facilities they can access within a 20-minute trip. However, we do not know how these numbers compare to equivalents in other cities. In this vein, as more studies use the Gini coefficient, access disadvantage, and welfare indices a frame of reference will form and researchers will gain a better understanding of how equally access is distributed. The research approach used here can be used to provide a better understanding of needs of communities in terms of access to services and provide a framework for measuring progress to support transportation planners and policy makers.

More work is needed to further develop the research approach presented here, and hopefully overcome some of its limitations. This study treats all destinations equally regardless of their size, quality of service, and the degree to which they match the needs of households. The next steps are to refine each category of service under study and define criteria for locations that can be included in the set of destinations. For instance, instead of including all food and beverage stores, researchers probably should pinpoint only supermarkets and grocery stores that supply healthy food and produce. Another possible approach is to weight places of employment or healthcare facilities based on their size so that proximity to a large center translates into higher accessibility levels compared to a smaller center at the same distance. One way to accomplish this would be to use Hansen's gravity-based accessibility measures (Hansen, 1959) and assume each service location is a zone itself. Therefore, the size of the facility/service can be entered into the equation as attractiveness of that zone (service location).

Analysis should not only calculate accessibility of services based on their size, but also based on how well they match the needs and characteristics of the community. Having access to locations from which individuals gain no or little utility does not yield them higher levels of access. A thoroughly-discussed case in point is measuring employment accessibility based on opportunities that match individuals' education and skill level. Affordability is also an important aspect when matching services with communities' needs. For instance, being adjacent to a high-end shopping center does not increase a low-income community's accessibility to shopping since such residents could hardly afford to shop at a center like that. Selecting the set of destinations to match households needs and characteristics is a complicated process and requires further studies to develop methods specific to each service type.

Another area for future research is to change the unit of analysis from households to individuals. The approach to measure accessibility and inequality based on residential parcels can remain the same. However, assumptions for average household size, household age composition, and car ownership should be made. The advantage of individual-based accessibility measures is that analysis will capture intra-household inequalities in addition to the inequality between households.

Another aspect of this research that can be expanded and built upon is incorporating more travel modes. In this study, all households were divided into drivers and transit users. With addition of other networks such as paratransit services, walking trails, and biking paths, the model could become more comprehensive and better represent real life. It should be noted that walking was included in the analysis performed here to complete transit users' trips from origin to transit station and from the station to their destination. As a result, in cases that walking to a destination was faster than going to a station and waiting to get on-board, the entire trip was registered as a walking trip. Yet, no distinction was made between walkable streets and walking trips that lacked continuous sidewalks. Walking trails also were not included in the study. Many MPOs have already compiled geo-coded data on other modes of transportation such as biking and walking and incorporating these into the model requires a few simple additional steps. However, the usefulness of such multi-modal models should be evaluated.

Another important area that requires more research is the connection between changes in land use and accessibility. The results presented in this study suggest that adding a new facility/service has considerable effects on accessibility and access inequality measures for facilities other than employment centers compared to transit expansion projects such as those included in Measures R and M. Future studies should focus on measuring effects of land use change on accessibility, finding ways to identify types and locations of land use changes that would have the maximum effect, and investigating policies and programs that can encourage the desirable changes.

Continuous research on issues related to transportation equity and access can develop accessibility-based measures to be used as performance measures, project assessment cost-benefit analysis, investment prioritization criteria and pave the way for incorporation of social justice considerations and measures into common practice of transportation planning and policy making.

APPENDICES

Appendix A: Script for Oral Consent (Telephone)

Good morning/afternoon. I am Bahareh Sehatzadeh, Ph.D. candidate in planning and public policy at Rutgers University. As part of my dissertation research I am working on developing a composite index of accessibility. This index will measure accessibility of various activities and services including employment, education, recreation, grocery stores, etc. in the County of Los Angeles. As a transportation professional, I would like to invite you to participate in this research study to identify and prioritize accessibility components.

Although you will not receive any direct benefit from participating in this conversation, your insights will help me better understand how access to various services affects residents of Los Angeles County.

Participation will last no longer than 30 minutes. Your participation is completely voluntary and you may choose not to answer any questions you are not comfortable answering and; if at any time during our conversation you wish to stop participating, you are completely free to do so.

There are no foreseeable risks to participation in this study. This research is confidential. Confidential means that the research records will include some information about you, such as your name, the agency where you work and your contact information. The research team and the Institutional Review Board at Rutgers University are the only parties that will be allowed to see the data, except as may be required by law. If a report of this study is published, or the results are presented at a professional conference, only group results will be stated. If the research team wants to directly attribute a remark made by you during these interviews, we will contact you first to seek permission.

I am also asking for your permission to allow me to audiotape our conversation as part of the research study. You do not have to agree to be recorded in order to participate in the main part of the study. The recording will be used to make sure that your responses are documented accurately. The recording will include your name and if you say anything that you believe at a later point may be hurtful and/or damage your reputation, then you can ask me to remove that part of recording or text from the dataset/ transcripts. The recording will be stored on a secure computer and linked with a code to your identity. The recordings will be kept for 2 years and destroyed upon completion of the study.

If you have any questions about the study or study procedures, you may contact me at (732) 325-5353 or by email at sehatzadeh@gmail.com. If you have any questions about your rights as a research subject, you may contact the IRB Administrator at Rutgers University at:

Rutgers, The State University of New Jersey
Office of Research Regulatory Affairs
335 George Street/Liberty Plaza/Suite 3200
New Brunswick, NJ 08901
Website: https://orra.rutgers.edu/artscipolicies

Do you have any questions? By participating in this study, you agree to be a study subject.

APPROVED
MAY 10 2016
Approved by the Rutgers IRB

Appendix B: Recruitment Email Notice

Dear XXX,

I am conducting research to develop a composite index of accessibility to measure transportation inequality. This index will measure access to various activities and services including employment, education, recreation, grocery stores, etc. in the County of Los Angeles. The objective of this study is to evaluate the effect of transportation projects funded through Measure R on accessibility and transportation inequality in L.A. County.

As a transportation professional/ scholar, I would like to invite you to participate in this research study through a phone interview to identify and prioritize accessibility components. Participation will last no longer than 30 minutes and attached you can find a brief explanation of the interview framework. I can also provide a more detailed description of the interview methodology if you are interested.

I would be grateful if you can respond back to this email with the best time and phone number to reach you for a short interview. I know how busy you are so I will follow up with a phone call in a few days to make sure this message has reached you. If you are unable to participate I would appreciate if you could recommend another individual in your organization who might be available.

Your time and consideration is truly appreciated.

Sincerely,

--

Bahareh Sehatzadeh
Ph.D. Candidate
Bloustein School of Planning and Public Policy
Rutgers, The State University of New Jersey

Appendix C: Recruitment Email Attachment

Measuring Transportation Inequality – Introduction for Interview Participants

Objective

The main objective of this study is to develop methods to measure the unequal distribution of access that leads to social exclusion. The development of such performance measures will enable decision makers to evaluate policies and programs, such as Los Angeles Measure R, from a social equity perspective. Measure R is a half-cent sales tax for Los Angeles County to finance new transportation projects and programs, and accelerate those already in the pipeline. In order to answer the question of how Measure R affects the ability of Angelenos to participate in and access activities and be socially included we need to first answer the question of how to measure transportation inequality before and after implementation of this or any other policy.

This research focuses on the distribution of access since accessibility is the link between transportation and social exclusion. Access has also been suggested by other researchers as the most appropriate measure of benefits from transportation plans and investments in equity evaluations. The academic literature has focused on issues of access to opportunities and services such as employment, health care, grocery stores, educational institutes, and recreational facilities and provides separate measures of accessibility. However, there has never been a multidimensional accessibility measure that includes multiple components of accessibility to various activities and services. In particular, there are trade-offs made between access to different activities and services. Most transportation planning decisions do not explicitly evaluate these trade-offs and the decisions made may not represent the perspective of the community.

The objective of this interview is to evaluate various aspects of access and identify the priorities of transportation professionals and decision makers in the case study area (County of Los Angeles).

Method

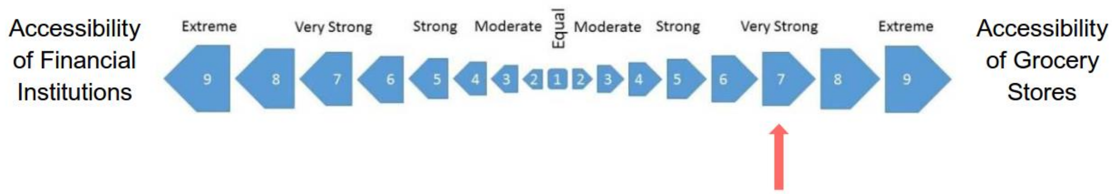
The interview process presented here is designed to obtain public or expert judgment on the importance of various components of accessibility. In this study I will use a process of weighting the various preferences that decision makers have on various components of accessibility.

Participants in this process will be presented with pairwise comparisons between accessibility components and express their preference for each component on a scale of one to nine. A preference of one indicates equality between two individual alternatives, while a preference of nine indicates that the individual alternative is absolutely more important than the other one (9 times more important). The table below shows a breakdown of these scales. This scaling system allows one to calculate the overall weight of each alternative and distills participants' collective judgment without having to reach a consensus on each of the judgments.

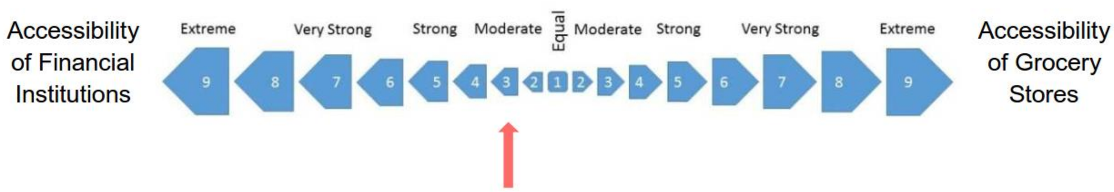
Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgement slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed

If you decide to participate in this research you will be contacted for a short phone interview (no longer than 30 minutes). Throughout the interview you will be asked some general questions on your transportation related experience and approach to issues of inequality and accessibility. You will also be asked to compare the importance of access to different services and activities using the scaling system shown in the table. As an example, you might be asked to compare the importance of access to grocery stores versus banks and other financial institutions. The question will be: using the scale values one to nine which of the two do you view as more important for the transportation system to provide access to?

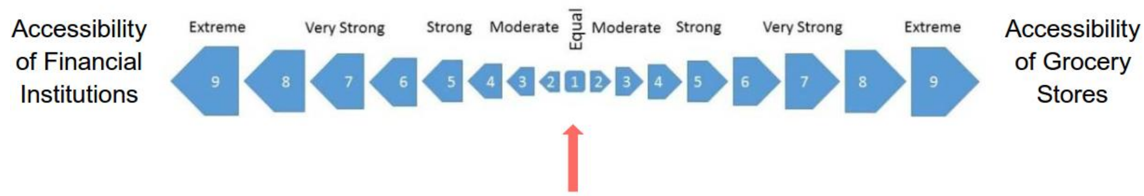
Below are examples to illustrate how the scaling system works.



If you believe that having access to grocery stores is more important and you favor it over having access to banks very strongly then your answer should be seven in favor of grocery stores.



However, if you slightly favor banks over grocery stores and believe that having access to financial institutions is more important for individuals then you should choose three in favor of banks.



You should choose one if you believe having access to banks and grocery stores is equally important for individuals.

All participants' comparisons will then be translated into numeric weights which will be used to develop a composite index of accessibility preferences.

Interviewee Sample

The overall sample for this study includes approximately 20 respondents. Public and private organizations that are either involved in transportation analysis and policy making or transportation related research, community development, and advocacy in the County of Los Angeles are chosen including Southern California Association of Governments, Caltrans, Metro, LA DOT, Great Street, Community Development Commission of the County of Los Angeles, Move LA, Bus Riders Union, Alliance for Community Transit-Los Angeles, Transportation Foundation of Los Angeles, METRANS Transportation Center, the UCLA Institute of Transportation Studies, and similar agencies. The sample will also cover researchers who have mainly focused on issues of transportation related social exclusion and accessibility.

Appendix D: Structured Interview Questionnaire

Introduction

(Read Script for Oral Consent, Appendix A)

General

- Can you please introduce yourself and briefly describe your experience in the field of transportation?
- Are you involved with equitable transportation in your day-to-day job? Please elaborate.
- Have you ever come across the concept of social exclusion?

Accessibility

In this section I will ask you questions about which activities, services, and destinations are important to be accessible to individuals to avoid social exclusion. Social exclusion is a term for what can happen when people are excluded from participating in normal activities of a society for reasons beyond their control such as lack of transportation infrastructures.

- In your opinion what are the normal activities of society and which services and destinations should be accessible to individuals?
- What policies or programs do you think are most effective at providing greater access to a variety of activities for individuals?

Next, we are going to compare seven major categories of these destinations in pairs considering their importance in affecting social exclusion. When comparing each pair please use a scale between one to nine. A scale of one represents equal importance of the two destinations, three represents one destination being slightly more important, five represents one being moderately more important, seven represents one being strongly more important, and nine represents one being absolutely more important. You can also choose intermediate values of two, four, six, and eight. There will be 21 pairwise comparisons in this section.

- Access to which one is more important: supermarkets, shopping centers and restaurants or places of employment? Please weight the importance on a scale of one to nine (one for being equally important, three for slightly, five for moderately, seven or strongly, nine for absolutely).
- Access to which one is more important: supermarkets, shopping centers and restaurants or banks and financial institutions? By what weight?
- Access to which one is more important: supermarkets, shopping centers and restaurants or polling centers, government offices and legal services? By what weight?
- Access to which one is more important: supermarkets, shopping centers and restaurants or social services, community organizations and recreational facilities? By what weight?
- Access to which one is more important: supermarkets, shopping centers and restaurants or child services and schools? By what weight?
- Access to which one is more important: supermarkets, shopping centers and restaurants or healthcare facilities? By what weight?
- Access to which one is more important: places of employment or banks and financial institutions? By what weight?
- Access to which one is more important: places of employment or polling centers, government offices and legal services? By what weight?

- Access to which one is more important: places of employment or social services, community organizations and recreational facilities? By what weight?
- Access to which one is more important: places of employment or child services and schools? By what weight?
- Access to which one is more important: places of employment or healthcare facilities? By what weight?
- Access to which one is more important: banks and financial institutions or polling centers, government offices and legal services? By what weight?
- Access to which one is more important: banks and financial institutions or social services, community organizations and recreational facilities? By what weight?
- Access to which one is more important: banks and financial institutions or child services and schools? By what weight?
- Access to which one is more important: banks and financial institutions or healthcare facilities? By what weight?
- Access to which one is more important: polling centers, government offices and legal services or social services, community organizations and recreational facilities? By what weight?
- Access to which one is more important: polling centers, government offices and legal services or child services and schools? By what weight?
- Access to which one is more important: polling centers, government offices and legal services or healthcare facilities? By what weight?

- Access to which one is more important: social services, community organizations and recreational facilities or child services and schools? By what weight?
- Access to which one is more important: social services, community organizations and recreational facilities or healthcare facilities? By what weight?
- Access to which one is more important: child services and schools or healthcare facilities? By what weight?

Closing Remarks

- Are there any issues that you would like to bring up or think would be valuable for us to consider as we move forward in our research? Please elaborate.
- Who else do you think I should interview?

Thank you for your participation in this interview.

Appendix E: Interview Results

BPMSG AHP Excel template with multiple inputs, version 2016.05.04, by Klaus Goepel (2013) was used in this study for all AHP data organization and analysis. Below is the template license information followed by AHP analysis summary sheets, reference tables, and eigenvalue solutions as presented by BPMSG Excel template.

http://bpmsg.com

Author: **Klaus D. Goepel**
http://bpmsg.com

Revisions

Date	Comment
3/5/2012	1st draft based on AHPcalc vers **27.8.11** (single input); allows input from max. 7 participants
11.12.2012 released	Algorithm of Power Method to solve Eigenvalue was modified (new sheet 8x8) **resulting in much higher accuracy**. By default 12 iterations
08.02.2013 released	final tests
2/19/2013	corrected formatting problem of weights in summary sheet
5/7/2013	Introduced weights for individual participants (weighted geometric mean) in sheet multInp Extend to **20 participants**
12/24/2013	For the 3 most inconsistent judgments **the ideal judgment** resulting in lowest inconsistency is displayed
5/9/2014	Change of check for convergence of power method
7/26/2014	corrected wrong ref in multInp (Matrix13)
4/9/2015	changed name of consol. Matrix from MatrixC to m_p0 CHOOSE in Summary sheet now p_sel+1 and m_p0 included (IF cond removed) changed the min of 3 to 2 criteria
6/7/2015	correction for 2 criteria: sheet 10x10 Cell M41 limit to 12 CGI in summary sheet to "n/a" for n=2, text (2 - 10)
5/4/2016	Corrected display of the selected scale in the summary sheet

AHP Analytic Hierarchy Process (EVM multiple inputs)

K. D. Goepel Version **04.05.2016** Free web based AHP software on: http://bpmsg.com

Only input data in the light green fields and worksheets!

n= 7 Number of criteria (2 to 10) Scale: 4 InvLin

N= 13 Number of Participants (1 to 20) α: 0.1 Consensus: 93.7%

p= 0 selected Participant (0=consol.) 2 7 Consolidated

Objective Prioritizing Accessibility Components in Social Exclusion Context

Author B. Sehatzadeh

Date 3-Sep-16 Thresh: 1E-07 Iterations: 4 EVM check: 9.1E-09

Table

	Criterion	Comment	Weights	Rk
1	Retail	Supermarkets, shopping centers, and restaurants	10.8%	5
2	Employment	Places of employment	20.0%	2
3	Banking	Banks and financial institutions	8.7%	7
4	Government	Polling centers, government offices and legal services	10.0%	6
5	Social Activities	Social services, community organizations and recreational facilities	11.8%	4
6	Education	Child services and schools	20.6%	1
7	Healthcare	Healthcare facilities	18.1%	3
8			0.0%	
9		for 9&10 unprotect the input sheets and expand the	0.0%	
10		question section ("+" in row 66)	0.0%	

Result

Eigenvalue lambda: 7.016

Consistency Ratio 0.37 GCI: 0.01 CR: 0.2%

Matrix

		Retail 1	Employment 2	Banking 3	Government 4	Social Activities 5	Education 6	Healthcare 7	0 8	0 9	0 10	normalized principal Eigenvector
Retail	1	-	1/2	1 2/5	1	1	1/2	3/5	-	-	-	10.78%
Employment	2	2	-	2 5/8	1 6/7	1 1/2	1	1	-	-	-	19.99%
Banking	3	5/7	3/8	-	1	4/5	4/9	1/2	-	-	-	8.68%
Government	4	1	1/2	1	-	5/6	1/2	1/2	-	-	-	10.03%
Social Activities	5	1	2/3	1 1/4	1 1/5	-	4/7	3/5	-	-	-	11.83%
Education	6	2 1/9	1	2 1/4	2	1 3/4	-	1 2/9	-	-	-	20.63%
Healthcare	7	1 5/8	1	2	1 5/6	1 2/3	4/5	-	-	-	-	18.07%
0	8	-	-	-	-	-	-	-	-	-	-	0.00%
0	9	-	-	-	-	-	-	-	-	-	-	0.00%
0	10	-	-	-	-	-	-	-	-	-	-	0.00%

AHP
bpmsg.com

Analytic Hierarchy Process
Multiple Input Summary Sheet

13 = k number of participants
7 = n number of criteria

Consolidated = Weighted geometric mean off participants

C Consolidated

	1	2	3	4	5	6	7	8	9	10
1		0.522	1.401	1.035	0.93	0.473	0.614	0	0	0
2	1.915		2.624	1.861	1.479	1.064	1.037	0	0	0
3	0.714	0.381		0.935	0.786	0.444	0.502	0	0	0
4	0.967	0.537	1.069		0.831	0.495	0.545	0	0	0
5	1.075	0.676	1.272	1.203		0.578	0.609	0	0	0
6	2.116	0.94	2.252	2.02	1.729		1.231	0	0	0
7	1.628	0.964	1.992	1.835	1.642	0.813		0	0	0
8	0	0	0	0	0	0	0		0	0
9	0	0	0	0	0	0	0	0		0
10	0	0	0	0	0	0	0	0	0	

1 Participant 1 | 1 | 5/23/2016

	1	2	3	4	5	6	7	8	9	10
1	1	1	2 1/4	2 1/4	1 4/5	2 1/4	1 2/7	0	0	0
2	1	1	1 4/5	1 4/5	1 2/7	2 1/4	1 1/8	0	0	0
3	4/9	5/9	1	7/9	2/3	2/3	5/9	0	0	0
4	4/9	5/9	1 2/7	1	1	4/9	5/9	0	0	0
5	5/9	7/9	1 1/2	1	1	1 1/2	5/9	0	0	0
6	4/9	4/9	1 1/2	2 1/4	2/3	1	2/3	0	0	0
7	7/9	8/9	1 4/5	1 4/5	1 4/5	1 1/2	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

2 Participant 2 | 1 | 6/1/2016

	1	2	3	4	5	6	7	8	9	10
1	1	1 2/7	1 1/8	1 1/2	1 4/5	1	1 1/8	0	0	0
2	7/9	1	1	1 1/2	1 1/2	1	1 1/8	0	0	0
3	8/9	1	1	1 2/7	1 1/2	7/9	1	0	0	0
4	2/3	2/3	7/9	1	1 1/8	2/3	7/9	0	0	0
5	5/9	2/3	2/3	8/9	1	2/3	2/3	0	0	0
6	1	1	1 2/7	1 1/2	1 1/2	1	1 1/8	0	0	0
7	8/9	8/9	1	1 2/7	1 1/2	8/9	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

3 Participant 3 | 1 | 06/03/216

	1	2	3	4	5	6	7	8	9	10
1	1	4/9	1	2/3	5/9	1/3	1/3	0	0	0
2	2 1/4	1	9	2 1/4	2 1/4	1	1	0	0	0
3	1	1/9	1	7/9	8/9	5/9	4/9	0	0	0
4	1 1/2	4/9	1 2/7	1	7/9	5/9	5/9	0	0	0
5	1 4/5	4/9	1 1/8	1 2/7	1	4/9	2/3	0	0	0
6	3	1	1 4/5	1 4/5	2 1/4	1	1	0	0	0
7	3	1	2 1/4	1 4/5	1 1/2	1	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

4 Participant 4 | 1 | 6/22/2016

	1	2	3	4	5	6	7	8	9	10
1	1	2/9	3	1	1	1/3	1/3	0	0	0
2	4 1/2	1	9	1 4/5	1 2/7	1	1 2/7	0	0	0
3	1/3	1/9	1	1	5/9	5/9	1/3	0	0	0
4	1	5/9	1	1	5/9	1/3	1/3	0	0	0
5	1	7/9	1 4/5	1 4/5	1	5/9	5/9	0	0	0
6	3	1	1 4/5	3	1 4/5	1	1 4/5	0	0	0
7	3	7/9	3	3	1 4/5	5/9	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

5 Participant 5 | 1 | 6/24/2016

	1	2	3	4	5	6	7	8	9	10
1	1	1/3	5/9	2/3	1 1/2	1/3	5/9	0	0	0
2	3	1	3	2 1/4	1 1/2	1 4/5	1	0	0	0
3	1 4/5	1/3	1	1 2/7	1 2/7	5/9	7/9	0	0	0
4	1 1/2	4/9	7/9	1	7/9	5/9	7/9	0	0	0
5	2/3	2/3	7/9	1 2/7	1	7/9	5/9	0	0	0
6	3	5/9	1 4/5	1 4/5	1 2/7	1	1	0	0	0
7	1 4/5	1	1 2/7	1 2/7	1 4/5	1	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

6 Participant 6 | 1 | 6/29/2016

	1	2	3	4	5	6	7	8	9	10
1	1	5/9	1 4/5	4/9	1/3	4/9	4/9	0	0	0
2	1 4/5	1	1 4/5	1 4/5	1	1	1 1/8	0	0	0
3	5/9	5/9	1	5/9	5/9	4/9	4/9	0	0	0
4	2 1/4	5/9	1 4/5	1	8/9	5/9	2/3	0	0	0
5	3	1	1 4/5	1 1/8	1	8/9	8/9	0	0	0
6	2 1/4	1	2 1/4	1 4/5	1 1/8	1	1	0	0	0
7	2 1/4	8/9	2 1/4	1 1/2	1 1/8	1	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

7 Participant 7 | 1 | 6/30/2016

	1	2	3	4	5	6	7	8	9	10
1	1	1 2/7	2 1/4	1	7/9	2/9	1	0	0	0
2	7/9	1	2 1/4	1 4/5	1	5/9	7/9	0	0	0
3	4/9	4/9	1	7/9	5/9	1/9	4/9	0	0	0
4	1	5/9	1 2/7	1	7/9	4/9	4/9	0	0	0
5	1 2/7	1	1 4/5	1 2/7	1	2/9	5/9	0	0	0
6	4 1/2	1 4/5	9	2 1/4	4 1/2	1	1 2/7	0	0	0
7	1	1 2/7	2 1/4	2 1/4	1 4/5	7/9	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

8 Participant 8 | 1 | 7/1/2016

	1	2	3	4	5	6	7	8	9	10
1	1	1/3	1 2/7	7/9	1	5/9	7/9	0	0	0
2	3	1	3	3	1 4/5	1 2/7	1	0	0	0
3	7/9	1/3	1	1	2/3	1/3	1/3	0	0	0
4	1 2/7	1/3	1	1	8/9	1/3	1/3	0	0	0
5	1	5/9	1 1/2	1 1/8	1	5/9	5/9	0	0	0
6	1 4/5	7/9	3	3	1 4/5	1	1	0	0	0
7	1 2/7	1	3	3	1 4/5	1	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

9 Participant 9 | 1 | 7/6/2016

	1	2	3	4	5	6	7	8	9	10
1	1	1/3	1 4/5	1 4/5	1 2/7	1/3	1	0	0	0
2	3	1	1 4/5	1 4/5	1 2/7	1	1	0	0	0
3	5/9	5/9	1	1 4/5	7/9	1/3	5/9	0	0	0
4	5/9	5/9	5/9	1	1	5/9	5/9	0	0	0
5	7/9	7/9	1 2/7	1	1	1/3	7/9	0	0	0
6	3	1	3	1 4/5	3	1	1	0	0	0
7	1	1	1 4/5	1 4/5	1 2/7	1	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

10 Participant 10 | 1 | 7/6/2016

	1	2	3	4	5	6	7	8	9	10
1	1	5/9	2 1/4	1 2/7	1 1/8	2/3	1	0	0	0
2	1 4/5	1	2 1/4	1 2/7	1 2/7	1	1 1/8	0	0	0
3	4/9	4/9	1	7/9	7/9	5/9	4/9	0	0	0
4	7/9	7/9	1 2/7	1	1 1/2	7/9	8/9	0	0	0
5	8/9	7/9	1 2/7	2/3	1	7/9	8/9	0	0	0
6	1 1/2	1	1 4/5	1 2/7	1 2/7	1	1 1/8	0	0	0
7	1	8/9	2 1/4	1 1/8	1 1/8	8/9	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

11 Participant 11 | 1 | 7/11/2016

	1	2	3	4	5	6	7	8	9	10
1	1	1/3	4/9	5/9	7/9	2/9	1/3	0	0	0
2	3	1	1 1/8	1 2/7	1 2/7	7/9	8/9	0	0	0
3	2 1/4	8/9	1	7/9	1 2/7	5/9	5/9	0	0	0
4	1 4/5	7/9	1 2/7	1	7/9	4/9	5/9	0	0	0
5	1 2/7	7/9	7/9	1 2/7	1	2/3	5/9	0	0	0
6	4 1/2	1 2/7	1 4/5	2 1/4	1 1/2	1	1 1/2	0	0	0
7	3	1 1/8	1 4/5	1 4/5	1 4/5	2/3	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

12 Participant 12 | 1 | 7/11/2016

	1	2	3	4	5	6	7	8	9	10
1	1	7/9	1 1/8	7/9	8/9	7/9	7/9	0	0	0
2	1 2/7	1	1 2/7	1	1 1/8	1	1 1/8	0	0	0
3	8/9	7/9	1	8/9	7/9	7/9	1	0	0	0
4	1 2/7	1	1 1/8	1	1	1	1	0	0	0
5	1 1/8	8/9	1 2/7	1	1	1	8/9	0	0	0
6	1 2/7	1	1 2/7	1	1	1	1 1/8	0	0	0
7	1 2/7	8/9	1	1	1 1/8	8/9	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

13 Participant 13 | 1 | 7/11/2016

	1	2	3	4	5	6	7	8	9	10
1	1	4/9	1 4/5	3	5/9	1/3	2/9	0	0	0
2	2 1/4	1	9	4 1/2	4 1/2	1	1	0	0	0
3	5/9	1/9	1	1	5/9	2/9	2/9	0	0	0
4	1/3	2/9	1	1	1/3	2/9	2/9	0	0	0
5	1 4/5	2/9	1 4/5	3	1	2/9	2/9	0	0	0
6	3	1	4 1/2	4 1/2	4 1/2	1	4 1/2	0	0	0
7	4 1/2	1	4 1/2	4 1/2	4 1/2	2/9	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	0	0	1

Calculation of Consensus Indicator based on RGGM results

		1	2	3	4	5	6	7	8	9	10			
												1.0311	β	
RGGM	1	22%	19%	9%	9%	12%	11%	18%	-	-	-			
results	2	17%	15%	15%	11%	10%	17%	15%	-	-	-			
	3	7%	25%	7%	10%	11%	20%	19%	-	-	-			
	4	9%	25%	6%	8%	12%	22%	19%	-	-	-			
	5	8%	24%	12%	10%	11%	18%	17%	-	-	-			
	6	8%	18%	8%	13%	17%	19%	18%	-	-	-			
	7	11%	13%	6%	9%	11%	33%	17%	-	-	-			
	8	10%	23%	7%	8%	11%	20%	20%	-	-	-			
	9	12%	19%	9%	9%	11%	23%	16%	-	-	-			
	10	14%	19%	8%	13%	12%	17%	16%	-	-	-			
	11	6%	16%	12%	11%	12%	23%	19%	-	-	-			
	12	12%	16%	12%	15%	14%	16%	14%	-	-	-			
	13	8%	26%	4%	4%	8%	30%	21%	-	-	-			
	14	-	-	-	-	-	-	-	-	-	-			
	15	-	-	-	-	-	-	-	-	-	-			
	16	-	-	-	-	-	-	-	-	-	-			
	17	-	-	-	-	-	-	-	-	-	-			
	18	-	-	-	-	-	-	-	-	-	-			
	19	-	-	-	-	-	-	-	-	-	-			
	20	-	-	-	-	-	-	-	-	-	-			
	p-avg	0.111	0.198	0.089	0.102	0.116	0.207	0.176	0	0	0	6.4545	α	Dα
Shannon	1	0.331	0.315	0.213	0.222	0.259	0.247	0.305	-	-	-	1.89305		6.6
Entropy	2	0.304	0.289	0.281	0.245	0.231	0.298	0.282	-	-	-	1.92984		6.9
	3	0.19	0.346	0.191	0.233	0.243	0.322	0.318	-	-	-	1.84304		6.3
AHP cor	4	0.211	0.346	0.162	0.198	0.255	0.333	0.317	-	-	-	1.82155		6.2
4.01	5	0.207	0.342	0.254	0.236	0.238	0.307	0.302	-	-	-	1.88541		6.6
7.66	6	0.204	0.306	0.197	0.264	0.3	0.314	0.309	-	-	-	1.89412		6.6
1.91	7	0.246	0.265	0.163	0.218	0.24	0.366	0.302	-	-	-	1.79998		6.0
	8	0.228	0.34	0.192	0.206	0.241	0.323	0.322	-	-	-	1.85264		6.4
	9	0.255	0.317	0.222	0.214	0.239	0.34	0.297	-	-	-	1.88362		6.6
	10	0.278	0.312	0.208	0.27	0.257	0.305	0.29	-	-	-	1.92013		6.8
	11	0.172	0.294	0.259	0.247	0.249	0.34	0.316	-	-	-	1.87651		6.5
	12	0.258	0.292	0.258	0.285	0.28	0.289	0.28	-	-	-	1.94159		7.0
	13	0.198	0.348	0.136	0.132	0.2	0.361	0.325	-	-	-	1.70063		5.5
	14	-	-	-	-	-	-	-	-	-	-	0		1.0
	15	-	-	-	-	-	-	-	-	-	-	0		1.0
	16	-	-	-	-	-	-	-	-	-	-	0		1.0
	17	-	-	-	-	-	-	-	-	-	-	0		1.0
	18	-	-	-	-	-	-	-	-	-	-	0		1.0
	19	-	-	-	-	-	-	-	-	-	-	0		1.0
	20	-	-	-	-	-	-	-	-	-	-	0		1.0
	p-avg*ln(p-avg)	0.245	0.321	0.215	0.232	0.25	0.326	0.306	0	0	0	6.6553	γ	

AHP Analytic Hierarchy Process (10x10 Matrix)

Power Method (Dominant Eigenvalue)

	7

	1	2	3	4	5	6	7	8	9	10	Iterations 0	12
1	1.00	0.52	1.40	1.03	0.93	0.47	0.61	-	-	-	0.60	3.66
2	1.91	1.00	2.62	1.86	1.48	1.06	1.04	-	-	-	1.10	6.80
3	0.71	0.38	1.00	0.94	0.79	0.44	0.50	-	-	-	0.48	2.95
4	0.97	0.54	1.07	1.00	0.83	0.49	0.55	-	-	-	0.54	3.41
5	1.08	0.68	1.27	1.20	1.00	0.58	0.61	-	-	-	0.64	4.02
6	2.12	0.94	2.25	2.02	1.73	1.00	1.23	-	-	-	1.13	7.02
7	1.63	0.96	1.99	1.83	1.64	0.81	1.00	-	-	-	0.99	6.15
8	-	-	-	-	-	-	-	1.00	-	-	0.10	0.00
9	-	-	-	-	-	-	-	-	1.00	-	0.10	0.00
10	-	-	-	-	-	-	-	-	-	1.00	0.10	0.00
Sum (col)	9.4144	5.0208	11.611	9.8884	8.3975	4.8668	5.5379	0	0	0		

Scaling

0.53	0.52
0.97	0.97
0.42	0.42
0.48	0.49
0.57	0.57
1.00	1.00
0.87	0.88
0.09	0.00
0.09	0.00
0.09	0.00
5.11	4.85

										Normalization	
0.11	0.10	0.12	0.10	0.11	0.10	0.11	-	-	-	0.1035	0.107761
0.20	0.20	0.23	0.19	0.18	0.22	0.19	-	-	-	0.1902	0.199912
0.08	0.08	0.09	0.09	0.09	0.09	0.09	-	-	-	0.0825	0.086801
0.10	0.11	0.09	0.10	0.10	0.10	0.10	-	-	-	0.0943	0.100293
0.11	0.13	0.11	0.12	0.12	0.12	0.11	-	-	-	0.1111	0.118268
0.22	0.19	0.19	0.20	0.21	0.21	0.22	-	-	-	0.1955	0.206276
0.17	0.19	0.17	0.19	0.20	0.17	0.18	-	-	-	0.1710	0.180688
-	-	-	-	-	-	-	-	-	-	0.0173	1.29E-12
-	-	-	-	-	-	-	-	-	-	0.0173	1.29E-12
-	-	-	-	-	-	-	-	-	-	0.0173	1.29E-12
										Eigenvalue:	7.015517

Check	9E-09		
	err:	1.0E-07	2.65E-22
	Iterations:	4.0E+00	6.25E-24
	check:	9.11E-09	2.15E-23
			4.05E-24
			5.41E-24
			7.53E-24
			2.29E-23
			1.76E-23
			5.98E-23
			5.98E-23
			5.98E-23

I*l

7.0155									
	7.0155								
		7.0155							
			7.0155						
				7.0155					
					7.0155				
						7.0155			
							7.0155		
								7.0155	
									7.0155

A-I*l

-6.016	0.52	1.40	1.03	0.93	0.47	0.61	-	-	-
1.91	-6.016	2.62	1.86	1.48	1.06	1.04	-	-	-
0.71	0.38	-6.016	0.94	0.79	0.44	0.50	-	-	-
0.97	0.54	1.07	-6.02	0.83	0.49	0.55	-	-	-
1.08	0.68	1.27	1.20	-6.02	0.58	0.61	-	-	-
2.12	0.94	2.25	2.02	1.73	-6.02	1.23	-	-	-
1.63	0.96	1.99	1.83	1.64	0.81	-6.02	-	-	-
-	-	-	-	-	-	-	-6.016	-	-
-	-	-	-	-	-	-	-	-6.016	-
-	-	-	-	-	-	-	-	-	-6.016

(A-I*l)x	1E-10	1E-10	1E-10	1E-10	1E-10	1E-10	1E-10	1E-10	1E-10	1E-10

Appendix F: List of Facility Sub-Categories with NAICS Codes

Type of Facility*	Sub-Category NAICS 6		Number of Facilities in L.A. County
	Code	Title	
Education	611110	Elementary and Secondary Schools	6,960
	611210	Junior Colleges	78
	611310	Colleges, Universities, and Professional Schools	894
	611410	Business and Secretarial Schools	312
	611420	Computer Training	168
	611430	Professional and Management Development Training	140
	611511	Cosmetology and Barber Schools	672
	611512	Flight Training	64
	611513	Apprenticeship Training	6
	611519	Other Technical and Trade Schools	185
	611610	Fine Arts Schools	1,699
	611620	Sports and Recreation Instruction	1,729
	611630	Language Schools	131
	611691	Exam Preparation and Tutoring	1,013
	611692	Automobile Driving Schools	545
	611699	All Other Miscellaneous Schools and Instruction	741
	611710	Educational Support Services	1,153
	624410	Child Day Care Services	4,433
	TOTAL		20,923
Healthcare	621111	Offices of Physicians (except Mental Health Specialists)	18,709
	621112	Offices of Physicians, Mental Health Specialists	13
	621210	Offices of Dentists	10,963
	621310	Offices of Chiropractors	3,288
	621320	Offices of Optometrists	1,740
	621330	Offices of Mental Health Practitioners (except Physicians)	1,893
	621340	Offices of Physical, Occupational and Speech Therapists, and Audiologists	2,060
	621391	Offices of Podiatrists	621
	621399	Offices of All Other Miscellaneous Health Practitioners	7,373
	621410	Family Planning Centers	55
	621420	Outpatient Mental Health and Substance Abuse Centers	2
	621491	HMO Medical Centers	2
	621492	Kidney Dialysis Centers	144
	621493	Freestanding Ambulatory Surgical and Emergency Centers	2,400
	621498	All Other Outpatient Care Centers	412
	621511	Medical Laboratories	1,127
	621512	Diagnostic Imaging Centers	517
	621610	Home Health Care Services	1,890
	621910	Ambulance Services	271
	621991	Blood and Organ Banks	40

Type of Facility*	Sub-Category NAICS 6		Number of Facilities in L.A. County
	Code	Title	
	621999	All Other Miscellaneous Ambulatory Health Care Services	3,371
	622110	General Medical and Surgical Hospitals	563
	622210	Psychiatric and Substance Abuse Hospitals	568
	622310	Specialty (except Psychiatric and Substance Abuse) Hospitals	44
	TOTAL		58,066
Social Activities	512131	Motion Picture Theaters (except Drive-Ins)	359
	512132	Drive-In Motion Picture Theaters	10
	624110	Child and Youth Services	1,415
	712110	Museums	601
	712120	Historical Sites	7
	712130	Zoos and Botanical Gardens	34
	712190	Nature Parks and Other Similar Institutions 781	1,281
	713110	Amusement and Theme Parks	76
	713120	Amusement Arcades	57
	713210	Casinos (except Casino Hotels)	0
	713290	Other Gambling Industries	71
	713910	Golf Courses and Country Clubs	379
	713920	Skiing Facilities	2
	713930	Marinas	308
	713940	Fitness and Recreational Sports Centers	2,716
	713950	Bowling Centers	115
	713990	All Other Amusement and Recreation Industries	1,040
	813110	Religious Organizations	11,478
	813211	Grantmaking Foundations	35
	813212	Voluntary Health Organizations	266
	813219	Other Grantmaking and Giving Services	134
	813311	Human Rights Organizations	498
	813312	Environment, Conservation and Wildlife Organizations	81
	813319	Other Social Advocacy Organizations	2,693
	813410	Civic and Social Organizations	2,793
	TOTAL		26,449
Retail (Food & Beverage Stores and Eating & Drinking Places)	445110	Supermarkets and Other Grocery (except Convenience) Stores	5,603
	445120	Convenience Stores	1,769
	445210	Meat Markets	583
	445220	Fish and Seafood Markets	191
	445230	Fruit and Vegetable Markets	624
	445291	Baked Goods Stores	0
	445292	Confectionery and Nut Stores	447
	445299	All Other Specialty Food Stores	2,162
	445310	Beer, Wine, and Liquor Stores	2,734
	722410	Drinking Places (Alcoholic Beverages)	1,417
	722511	Full-Service Restaurants	31,579
	722513	Limited-Service Restaurants	821
	722514	Cafeterias, Grill Buffets, and Buffets	332
	722515	Snack and Nonalcoholic Beverage Bars	4,605
	TOTAL		52,867
	442110	Furniture Stores	2,894

Type of Facility*	Sub-Category NAICS 6		Number of Facilities in L.A. County
	Code	Title	
Retail (All Other Stores)	443141	Household Appliance Stores	1,556
	443142	Electronics Stores	7,839
	444110	Home Centers	562
	444120	Paint and Wallpaper Stores	422
	444130	Hardware Stores	727
	444190	Other Building Material Dealers	5,449
	444210	Outdoor Power Equipment Stores	272
	444220	Nursery, Garden Center, and Farm Supply Stores	875
	446110	Pharmacies and Drug Stores	3,624
	446120	Cosmetics, Beauty Supplies, and Perfume Stores	1,927
	446130	Optical Goods Stores	971
	446191	Food (Health) Supplement Stores	1,398
	446199	All Other Health and Personal Care Stores	667
	448110	Men's Clothing Stores	1,069
	448120	Women's Clothing Stores	3,739
	448130	Children's and Infants' Clothing Stores	962
	448140	Family Clothing Stores	3,697
	448150	Clothing Accessories Stores	1,582
	448190	Other Clothing Stores	2,941
	448210	Shoe Stores	2,362
	448310	Jewelry Stores	3,629
	448320	Luggage and Leather Goods Stores	270
	451110	Sporting Goods Stores	2,565
	451120	Hobby, Toy, and Game Stores	1,586
	451130	Sewing, Needlework, and Piece Goods Stores	637
	451140	Musical Instrument and Supplies Stores	870
	451211	Book Stores	906
	451212	News Dealers and Newsstands	276
	452111	Department Stores (except Discount Department Stores)	922
	452112	Discount Department Stores	782
	452910	Warehouse Clubs and Supercenters	109
	452990	All Other General Merchandise Stores	2,005
	453110	Florists	2,259
	453210	Office Supplies and Stationery Stores	829
	453220	Gift, Novelty, and Souvenir Stores	4,059
	453310	Used Merchandise Stores	2,310
	453910	Pet and Pet Supplies Stores	939
	453920	Art Dealers	1,218
	453991	Tobacco Stores	1,196
	453998	All Other Miscellaneous Store Retailers (except Tobacco Stores)	4,046
	TOTAL		76,948
Government & Legal Offices	921110	Executive Offices	410
	921120	Legislative Bodies	3,976
	921130	Public Finance Activities	207
	921140	Executive and Legislative Offices, Combined	0
	921150	American Indian and Alaska Native Tribal Governments	0
	921190	Other General Government Support	229

Type of Facility*	Sub-Category NAICS 6 Code	Title	Number of Facilities in L.A. County
	922110	Courts	177
	922120	Police Protection	679
	922130	Legal Counsel and Prosecution	168
	TOTAL		5,846
Banks and Financial Institutions	522110	Commercial Banking	6,131
	522120	Savings Institutions	14
	522130	Credit Unions	610
	522190	Other Depository Credit Intermediation	0
	522210	Credit Card Issuing	0
	522291	Consumer Lending	2,444
	522292	Real Estate Credit	4,592
	522298	All Other Nondepository Credit Intermediation	419
	522310	Mortgage and Nonmortgage Loan Brokers	79
	522320	Financial Transactions Processing, Reserve, and Clearinghouse Activities	1,350
	522390	Other Activities Related to Credit Intermediation	111
	523930	Investment Advice	5,365
	TOTAL		21,115

* All places of employment in L.A. County were used in analysis therefore no sub-categories were selected and included in this table. 416,654 places of employment were located in L.A. County per SCAG 2011 employment data. 360,774 of those had two or more employees and were used in the analysis.

Appendix G: Stata Code

LA County Variables

AssessorID	Assessor's Parcel Number
Units	Number of Units on Each Parcel
A_L_01_A	Distance to Closest Facility: Education
A_L_01_C	Average Distance to the 3 Closest Facilities: Education
A_L_02_A	Distance to Closest Facility: Employment
A_L_02_C	Average Distance to the 3 Closest Facilities: Employment
A_L_03_A	Distance to Closest Facility: Healthcare
A_L_03_C	Average Distance to the 3 Closest Facilities: Healthcare
A_L_04_A	Distance to Closest Facility: Social Activities
A_L_04_C	Average Distance to the 3 Closest Facilities: Social Activities
A_L_05F_A	Distance to Closest Facility: Retail, Food and Beverage
A_L_05F_C	Average Distance to the 3 Closest Facilities: Retail, Food and Beverage
A_L_05O_A	Distance to Closest Facility: Retail, All Others
A_L_05O_C	Average Distance to the 3 Closest Facilities: Retail, All Others
A_L_06_A	Distance to Closest Facility: Government and Legal Offices
A_L_06_C	Average Distance to the 3 Closest Facilities: Government and Legal Offices
A_L_07_A	Distance to Closest Facility: Banks and Financial Institutions
A_L_07_C	Average Distance to the 3 Closest Facilities: Banks and Financial Institutions

LA County Stata Code

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. log using "M:\BSehat\2015 LA County Linear Analysis\STATA\LA County Stata Log.smcl"
. describe
. summarize

. ineqdeco A_L_01_A, s
. ineqdeco A_L_01_C, s
. ineqdeco A_L_02_A, s
. ineqdeco A_L_02_C, s
. ineqdeco A_L_03_A, s
. ineqdeco A_L_03_C, s
. ineqdeco A_L_04_A, s
. ineqdeco A_L_04_C, s
. ineqdeco A_L_05F_A, s
. ineqdeco A_L_05F_C, s
. ineqdeco A_L_05O_A, s
. ineqdeco A_L_05O_C, s
. ineqdeco A_L_06_A, s
. ineqdeco A_L_06_C, s
. ineqdeco A_L_07_A, s
. ineqdeco A_L_07_C, s
. generate  A_L_01_A_Inverse = 1/ A_L_01_A
. generate  A_L_01_C_Inverse = 1/ A_L_01_C
. generate  A_L_02_A_Inverse = 1/ A_L_02_A
. generate  A_L_02_C_Inverse = 1/ A_L_02_C
. generate  A_L_03_A_Inverse = 1/ A_L_03_A
. generate  A_L_03_C_Inverse = 1/ A_L_03_C
. generate  A_L_04_A_Inverse = 1/ A_L_04_A
. generate  A_L_04_C_Inverse = 1/ A_L_04_C
. generate  A_L_05F_A_Inverse = 1/ A_L_05F_A
. generate  A_L_05F_C_Inverse = 1/ A_L_05F_C
. generate  A_L_05O_A_Inverse = 1/ A_L_05O_A
. generate  A_L_05O_C_Inverse = 1/ A_L_05O_C
. generate  A_L_06_A_Inverse = 1/ A_L_06_A
. generate  A_L_06_C_Inverse = 1/ A_L_06_C
. generate  A_L_07_A_Inverse = 1/ A_L_07_A
. generate  A_L_07_C_Inverse = 1/ A_L_07_C
. ineqdeco A_L_01_A_Inverse, w
. ineqdeco A_L_01_C_Inverse, w
. ineqdeco A_L_02_A_Inverse, w
. ineqdeco A_L_02_C_Inverse, w
. ineqdeco A_L_03_A_Inverse, w
. ineqdeco A_L_03_C_Inverse, w
. ineqdeco A_L_04_A_Inverse, w
. ineqdeco A_L_04_C_Inverse, w
. ineqdeco A_L_05F_A_Inverse, w
. ineqdeco A_L_05F_C_Inverse, w
. ineqdeco A_L_05O_A_Inverse, w
. ineqdeco A_L_05O_C_Inverse, w
. ineqdeco A_L_06_A_Inverse, w
. ineqdeco A_L_06_C_Inverse, w
. ineqdeco A_L_07_A_Inverse, w
. ineqdeco A_L_07_C_Inverse, w

. log close
```

<u>City of Commerce Variables</u>

AssessorID	Assessor's Parcel Number
Units	Number of Units on Each Parcel
YearBuilt	Year Built
SQFTmain	Area Calculated from the 5 Entries of Building Information Maintained
LandValue	Land Value
TotalValue	Total Land and Improvement Value
NetTaxable	Taxable Value of Land and Improvements (Total Minus Exemptions)
TractID	Census Tract ID
NoVhclPer	Census Tracts' Percentage of Households with No Vehicles
RanVar	Random Uniform Variable Used for 5% and 10% Shares of Transit Users
RanVar_Tract 02	Random Uniform Variable for Census Tract 532302
RanVar_Tract 03	Random Uniform Variable for Census Tract 532303
RanVar_Tract 04	Random Uniform Variable for Census Tract 532304
Transit_User	Randomly Selected Transit Users Based on No-Vehicle Households Share in Census Tracts
A_L_01_A	Straight-Line Distance to Closest Facility: Education
A_L_01_B	Straight-Line Number of Facilities in 10 Miles: Education
A_L_01_C	Straight-Line Average Distance to the 3 Closest Facilities: Education
A_L_02_A	Straight-Line Distance to Closest Facility: Employment
A_L_02_B	Straight-Line Number of Facilities in 10 Miles: Employment
A_L_02_C	Straight-Line Average Distance to the 3 Closest Facilities: Employment
A_L_03_A	Straight-Line Distance to Closest Facility: Healthcare
A_L_03_B	Straight-Line Number of Facilities in 10 Miles: Healthcare
A_L_03_C	Straight-Line Average Distance to the 3 Closest Facilities: Healthcare
A_L_04_A	Straight-Line Distance to Closest Facility: Social Activities
A_L_04_B	Straight-Line Number of Facilities in 10 Miles: Social Activities
A_L_04_C	Straight-Line Average Distance to the 3 Closest Facilities: Social Activities
A_L_05F_A	Straight-Line Distance to Closest Facility: Retail, Food and Beverage
A_L_05F_B	Straight-Line Number of Facilities in 10 Miles: Retail, Food and Beverage
A_L_05F_C	Straight-Line Average Distance to the 3 Closest Facilities: Retail, Food and Beverage
A_L_05O_A	Straight-Line Distance to Closest Facility: Retail, All Others
A_L_05O_B	Straight-Line Number of Facilities in 10 Miles: Retail, All Others
A_L_05O_C	Straight-Line Average Distance to the 3 Closest Facilities: Retail, All Others
A_L_06_A	Straight-Line Distance to Closest Facility: Government and Legal Offices
A_L_06_B	Straight-Line Number of Facilities in 10 Miles: Government and Legal Offices
A_L_06_C	Straight-Line Average Distance to the 3 Closest Facilities: Government and Legal Offices
A_L_07_A	Straight-Line Distance to Closest Facility: Banks and Financial Institutions
A_L_07_B	Straight-Line Number of Facilities in 10 Miles: Banks and Financial Institutions
A_L_07_C	Straight-Line Average Distance to the 3 Closest Facilities: Banks and Financial Institutions
A_N_01_A	Road Network Time to Closest Facility: Education
A_N_01_B	Road Network Number of Facilities in 20 Minutes: Education
A_N_01_C	Road Network Average Time to the 3 Closest Facilities: Education
A_N_02_A	Road Network Time to Closest Facility: Employment
A_N_02_B	Road Network Number of Facilities in 20 Minutes: Employment
A_N_02_C	Road Network Average Time to the 3 Closest Facilities: Employment
A_N_03_A	Road Network Time to Closest Facility: Healthcare
A_N_03_B	Road Network Number of Facilities in 20 Minutes: Healthcare
A_N_03_C	Road Network Average Time to the 3 Closest Facilities: Healthcare
A_N_04_A	Road Network Time to Closest Facility: Social Activities
A_N_04_B	Road Network Number of Facilities in 20 Minutes: Social Activities
A_N_04_C	Road Network Average Time to the 3 Closest Facilities: Social Activities

A_N_05F_A	Road Network Time to Closest Facility: Retail, Food and Beverage
A_N_05F_B	Road Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
A_N_05F_C	Road Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage
A_N_05O_A	Road Network Time to Closest Facility: Retail, All Others
A_N_05O_B	Road Network Number of Facilities in 20 Minutes: Retail, All Others
A_N_05O_C	Road Network Average Time to the 3 Closest Facilities: Retail, All Others
A_N_06_A	Road Network Time to Closest Facility: Government and Legal Offices
A_N_06_B	Road Network Number of Facilities in 20 Minutes: Government and Legal Offices
A_N_06_C	Road Network Average Time to the 3 Closest Facilities: Government and Legal Offices
A_N_07_A	Road Network Time to Closest Facility: Banks and Financial Institutions
A_N_07_B	Road Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
A_N_07_C	Road Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions
T_N_01_A	Transit Network Time to Closest Facility: Education
T_N_01_B	Transit Network Number of Facilities in 20 Minutes: Education
T_N_01_C	Transit Network Average Time to the 3 Closest Facilities: Education
T_N_02_A	Transit Network Time to Closest Facility: Employment
T_N_02_B	Transit Network Number of Facilities in 20 Minutes: Employment
T_N_02_C	Transit Network Average Time to the 3 Closest Facilities: Employment
T_N_03_A	Transit Network Time to Closest Facility: Healthcare
T_N_03_B	Transit Network Number of Facilities in 20 Minutes: Healthcare
T_N_03_C	Transit Network Average Time to the 3 Closest Facilities: Healthcare
T_N_04_A	Transit Network Time to Closest Facility: Social Activities
T_N_04_B	Transit Network Number of Facilities in 20 Minutes: Social Activities
T_N_04_C	Transit Network Average Time to the 3 Closest Facilities: Social Activities
T_N_05F_A	Transit Network Time to Closest Facility: Retail, Food and Beverage
T_N_05F_B	Transit Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
T_N_05F_C	Transit Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage
T_N_05O_A	Transit Network Time to Closest Facility: Retail, All Others
T_N_05O_B	Transit Network Number of Facilities in 20 Minutes: Retail, All Others
T_N_05O_C	Transit Network Average Time to the 3 Closest Facilities: Retail, All Others
T_N_06_A	Transit Network Time to Closest Facility: Government and Legal Offices
T_N_06_B	Transit Network Number of Facilities in 20 Minutes: Government and Legal Offices
T_N_06_C	Transit Network Average Time to the 3 Closest Facilities: Government and Legal Offices
T_N_07_A	Transit Network Time to Closest Facility: Banks and Financial Institutions
T_N_07_B	Transit Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
T_N_07_C	Transit Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions
T5_N_01_A	5% Households on Transit Network Time to Closest Facility: Education
T5_N_01_B	5% Households on Transit Network Number of Facilities in 20 Minutes: Education
T5_N_01_C	5% Households on Transit Network Average Time to the 3 Closest Facilities: Education
T5_N_02_A	5% Households on Transit Network Time to Closest Facility: Employment
T5_N_02_B	5% Households on Transit Network Number of Facilities in 20 Minutes: Employment
T5_N_02_C	5% Households on Transit Network Average Time to the 3 Closest Facilities: Employment

T5_N_03_A	5% Households on Transit Network Time to Closest Facility: Healthcare
T5_N_03_B	5% Households on Transit Network Number of Facilities in 20 Minutes: Healthcare
T5_N_03_C	5% Households on Transit Network Average Time to the 3 Closest Facilities: Healthcare
T5_N_04_A	5% Households on Transit Network Time to Closest Facility: Social Activities
T5_N_04_B	5% Households on Transit Network Number of Facilities in 20 Minutes: Social Activities
T5_N_04_C	5% Households on Transit Network Average Time to the 3 Closest Facilities: Social Activities
T5_N_05F_A	5% Households on Transit Network Time to Closest Facility: Retail, Food and Beverage
T5_N_05F_B	5% Households on Transit Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
T5_N_05F_C	5% Households on Transit Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage
T5_N_05O_A	5% Households on Transit Network Time to Closest Facility: Retail, All Others
T5_N_05O_B	5% Households on Transit Network Number of Facilities in 20 Minutes: Retail, All Others
T5_N_05O_C	5% Households on Transit Network Average Time to the 3 Closest Facilities: Retail, All Others
T5_N_06_A	5% Households on Transit Network Time to Closest Facility: Government and Legal Offices
T5_N_06_B	5% Households on Transit Network Number of Facilities in 20 Minutes: Government and Legal Offices
T5_N_06_C	5% Households on Transit Network Average Time to the 3 Closest Facilities: Government and Legal Offices
T5_N_07_A	5% Households on Transit Network Time to Closest Facility: Banks and Financial Institutions
T5_N_07_B	5% Households on Transit Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
T5_N_07_C	5% Households on Transit Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions
T10_N_01_A	10% Households on Transit Network Time to Closest Facility: Education
T10_N_01_B	10% Households on Transit Network Number of Facilities in 20 Minutes: Education
T10_N_01_C	10% Households on Transit Network Average Time to the 3 Closest Facilities: Education
T10_N_02_A	10% Households on Transit Network Time to Closest Facility: Employment
T10_N_02_B	10% Households on Transit Network Number of Facilities in 20 Minutes: Employment
T10_N_02_C	10% Households on Transit Network Average Time to the 3 Closest Facilities: Employment
T10_N_03_A	10% Households on Transit Network Time to Closest Facility: Healthcare
T10_N_03_B	10% Households on Transit Network Number of Facilities in 20 Minutes: Healthcare
T10_N_03_C	10% Households on Transit Network Average Time to the 3 Closest Facilities: Healthcare
T10_N_04_A	10% Households on Transit Network Time to Closest Facility: Social Activities
T10_N_04_B	10% Households on Transit Network Number of Facilities in 20 Minutes: Social Activities
T10_N_04_C	10% Households on Transit Network Average Time to the 3 Closest Facilities: Social Activities
T10_N_05F_A	10% Households on Transit Network Time to Closest Facility: Retail, Food and Beverage

T10_N_05F_B	10% Households on Transit Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
T10_N_05F_C	10% Households on Transit Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage
T10_N_05O_A	10% Households on Transit Network Time to Closest Facility: Retail, All Others
T10_N_05O_B	10% Households on Transit Network Number of Facilities in 20 Minutes: Retail, All Others
T10_N_05O_C	10% Households on Transit Network Average Time to the 3 Closest Facilities: Retail, All Others
T10_N_06_A	10% Households on Transit Network Time to Closest Facility: Government and Legal Offices
T10_N_06_B	10% Households on Transit Network Number of Facilities in 20 Minutes: Government and Legal Offices
T10_N_06_C	10% Households on Transit Network Average Time to the 3 Closest Facilities: Government and Legal Offices
T10_N_07_A	10% Households on Transit Network Time to Closest Facility: Banks and Financial Institutions
T10_N_07_B	10% Households on Transit Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
T10_N_07_C	10% Households on Transit Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions
T_Share_N_01_A	No-Vehicle Households on Transit Network Time to Closest Facility: Education
T_Share _N_01_B	No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Education
T_Share _N_01_C	No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Education
T_Share _N_02_A	No-Vehicle Households on Transit Network Time to Closest Facility: Employment
T_Share _N_02_B	No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Employment
T_Share _N_02_C	No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Employment
T_Share _N_03_A	No-Vehicle Households on Transit Network Time to Closest Facility: Healthcare
T_Share _N_03_B	No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Healthcare
T_Share _N_03_C	No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Healthcare
T_Share _N_04_A	No-Vehicle Households on Transit Network Time to Closest Facility: Social Activities
T_Share _N_04_B	No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Social Activities
T_Share _N_04_C	No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Social Activities
T_Share _N_05F_A	No-Vehicle Households on Transit Network Time to Closest Facility: Retail, Food and Beverage
T_Share _N_05F_B	No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
T_Share _N_05F_C	No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage
T_Share _N_05O_A	No-Vehicle Households on Transit Network Time to Closest Facility: Retail, All Others
T_Share _N_05O_B	No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Retail, All Others
T_Share _N_05O_C	No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Retail, All Others

T_Share _N_06_A	No-Vehicle Households on Transit Network Time to Closest Facility: Government and Legal Offices
T_Share _N_06_B	No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Government and Legal Offices
T_Share _N_06_C	No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Government and Legal Offices
T_Share _N_07_A	No-Vehicle Households on Transit Network Time to Closest Facility: Banks and Financial Institutions
T_Share _N_07_B	No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
T_Share _N_07_C	No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions
FT_N_01_A	Future Transit Network Time to Closest Facility: Education
FT_N_01_B	Future Transit Network Number of Facilities in 20 Minutes: Education
FT_N_01_C	Future Transit Network Average Time to the 3 Closest Facilities: Education
FT_N_02_A	Future Transit Network Time to Closest Facility: Employment
FT_N_02_B	Future Transit Network Number of Facilities in 20 Minutes: Employment
FT_N_02_C	Future Transit Network Average Time to the 3 Closest Facilities: Employment
FT_N_03_A	Future Transit Network Time to Closest Facility: Healthcare
FT_N_03_B	Future Transit Network Number of Facilities in 20 Minutes: Healthcare
FT_N_03_C	Future Transit Network Average Time to the 3 Closest Facilities: Healthcare
FT_N_04_A	Future Transit Network Time to Closest Facility: Social Activities
FT_N_04_B	Future Transit Network Number of Facilities in 20 Minutes: Social Activities
FT_N_04_C	Future Transit Network Average Time to the 3 Closest Facilities: Social Activities
FT_N_05F_A	Future Transit Network Time to Closest Facility: Retail, Food and Beverage
FT_N_05F_B	Future Transit Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
FT_N_05F_C	Future Transit Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage
FT_N_05O_A	Future Transit Network Time to Closest Facility: Retail, All Others
FT_N_05O_B	Future Transit Network Number of Facilities in 20 Minutes: Retail, All Others
FT_N_05O_C	Future Transit Network Average Time to the 3 Closest Facilities: Retail, All Others
FT_N_06_A	Future Transit Network Time to Closest Facility: Government and Legal Offices
FT_N_06_B	Future Transit Network Number of Facilities in 20 Minutes: Government and Legal Offices
FT_N_06_C	Future Transit Network Average Time to the 3 Closest Facilities: Government and Legal Offices
FT_N_07_A	Future Transit Network Time to Closest Facility: Banks and Financial Institutions
FT_N_07_B	Future Transit Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
FT_N_07_C	Future Transit Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions
FT5_N_01_A	Future 5% Households on Transit Network Time to Closest Facility: Education
FT5_N_01_B	Future 5% Households on Transit Network Number of Facilities in 20 Minutes: Education
FT5_N_01_C	Future 5% Households on Transit Network Average Time to the 3 Closest Facilities: Education
FT5_N_02_A	Future 5% Households on Transit Network Time to Closest Facility: Employment
FT5_N_02_B	Future 5% Households on Transit Network Number of Facilities in 20 Minutes: Employment
FT5_N_02_C	Future 5% Households on Transit Network Average Time to the 3 Closest Facilities: Employment

FT5_N_03_A	Future 5% Households on Transit Network Time to Closest Facility: Healthcare
FT5_N_03_B	Future 5% Households on Transit Network Number of Facilities in 20 Minutes: Healthcare
FT5_N_03_C	Future 5% Households on Transit Network Average Time to the 3 Closest Facilities: Healthcare
FT5_N_04_A	Future 5% Households on Transit Network Time to Closest Facility: Social Activities
FT5_N_04_B	Future 5% Households on Transit Network Number of Facilities in 20 Minutes: Social Activities
FT5_N_04_C	Future 5% Households on Transit Network Average Time to the 3 Closest Facilities: Social Activities
FT5_N_05F_A	Future 5% Households on Transit Network Time to Closest Facility: Retail, Food and Beverage
FT5_N_05F_B	Future 5% Households on Transit Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
FT5_N_05F_C	Future 5% Households on Transit Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage
FT5_N_05O_A	Future 5% Households on Transit Network Time to Closest Facility: Retail, All Others
FT5_N_05O_B	Future 5% Households on Transit Network Number of Facilities in 20 Minutes: Retail, All Others
FT5_N_05O_C	Future 5% Households on Transit Network Average Time to the 3 Closest Facilities: Retail, All Others
FT5_N_06_A	Future 5% Households on Transit Network Time to Closest Facility: Government and Legal Offices
FT5_N_06_B	Future 5% Households on Transit Network Number of Facilities in 20 Minutes: Government and Legal Offices
FT5_N_06_C	Future 5% Households on Transit Network Average Time to the 3 Closest Facilities: Government and Legal Offices
FT5_N_07_A	Future 5% Households on Transit Network Time to Closest Facility: Banks and Financial Institutions
FT5_N_07_B	Future 5% Households on Transit Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
FT5_N_07_C	Future 5% Households on Transit Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions
FT10_N_01_A	Future 10% Households on Transit Network Time to Closest Facility: Education
FT10_N_01_B	Future 10% Households on Transit Network Number of Facilities in 20 Minutes: Education
FT10_N_01_C	Future 10% Households on Transit Network Average Time to the 3 Closest Facilities: Education
FT10_N_02_A	Future 10% Households on Transit Network Time to Closest Facility: Employment
FT10_N_02_B	Future 10% Households on Transit Network Number of Facilities in 20 Minutes: Employment
FT10_N_02_C	Future 10% Households on Transit Network Average Time to the 3 Closest Facilities: Employment
FT10_N_03_A	Future 10% Households on Transit Network Time to Closest Facility: Healthcare
FT10_N_03_B	Future 10% Households on Transit Network Number of Facilities in 20 Minutes: Healthcare
FT10_N_03_C	Future 10% Households on Transit Network Average Time to the 3 Closest Facilities: Healthcare
FT10_N_04_A	Future 10% Households on Transit Network Time to Closest Facility: Social Activities
FT10_N_04_B	Future 10% Households on Transit Network Number of Facilities in 20 Minutes: Social Activities

FT10_N_04_C	Future 10% Households on Transit Network Average Time to the 3 Closest Facilities: Social Activities
FT10_N_05F_A	Future 10% Households on Transit Network Time to Closest Facility: Retail, Food and Beverage
FT10_N_05F_B	Future 10% Households on Transit Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
FT10_N_05F_C	Future 10% Households on Transit Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage
FT10_N_05O_A	Future 10% Households on Transit Network Time to Closest Facility: Retail, All Others
FT10_N_05O_B	Future 10% Households on Transit Network Number of Facilities in 20 Minutes: Retail, All Others
FT10_N_05O_C	Future 10% Households on Transit Network Average Time to the 3 Closest Facilities: Retail, All Others
FT10_N_06_A	Future 10% Households on Transit Network Time to Closest Facility: Government and Legal Offices
FT10_N_06_B	Future 10% Households on Transit Network Number of Facilities in 20 Minutes: Government and Legal Offices
FT10_N_06_C	Future 10% Households on Transit Network Average Time to the 3 Closest Facilities: Government and Legal Offices
FT10_N_07_A	Future 10% Households on Transit Network Time to Closest Facility: Banks and Financial Institutions
FT10_N_07_B	Future 10% Households on Transit Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
FT10_N_07_C	Future 10% Households on Transit Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions
FT_Share_N_01_A	Future No-Vehicle Households on Transit Network Time to Closest Facility: Education
FT_Share _N_01_B	Future No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Education
FT_Share _N_01_C	Future No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Education
FT_Share _N_02_A	Future No-Vehicle Households on Transit Network Time to Closest Facility: Employment
FT_Share _N_02_B	Future No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Employment
FT_Share _N_02_C	Future No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Employment
FT_Share _N_03_A	Future No-Vehicle Households on Transit Network Time to Closest Facility: Healthcare
FT_Share _N_03_B	Future No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Healthcare
FT_Share _N_03_C	Future No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Healthcare
FT_Share _N_04_A	Future No-Vehicle Households on Transit Network Time to Closest Facility: Social Activities
FT_Share _N_04_B	Future No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Social Activities
FT_Share _N_04_C	Future No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Social Activities
FT_Share _N_05F_A	Future No-Vehicle Households on Transit Network Time to Closest Facility: Retail, Food and Beverage
FT_Share _N_05F_B	Future No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Retail, Food and Beverage
FT_Share _N_05F_C	Future No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Retail, Food and Beverage

FT_Share _N_05O_A	Future No-Vehicle Households on Transit Network Time to Closest Facility: Retail, All Others
FT_Share _N_05O_B	Future No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Retail, All Others
FT_Share _N_05O_C	Future No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Retail, All Others
FT_Share _N_06_A	Future No-Vehicle Households on Transit Network Time to Closest Facility: Government and Legal Offices
FT_Share _N_06_B	Future No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Government and Legal Offices
FT_Share _N_06_C	Future No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Government and Legal Offices
FT_Share _N_07_A	Future No-Vehicle Households on Transit Network Time to Closest Facility: Banks and Financial Institutions
FT_Share _N_07_B	Future No-Vehicle Households on Transit Network Number of Facilities in 20 Minutes: Banks and Financial Institutions
FT_Share _N_07_C	Future No-Vehicle Households on Transit Network Average Time to the 3 Closest Facilities: Banks and Financial Institutions

City of Commerce STATA Code

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. log using "M:\BSehat\Commerce Stata\Commerce Stata Log.smcl"
. describe
. summarize

* STRAIGHT-LINE ANALYSIS
ineqdeco A_L_01_A , s
ineqdeco A_L_01_B , s w
ineqdeco A_L_01_C , s
ineqdeco A_L_02_A , s
ineqdeco A_L_02_B , s w
ineqdeco A_L_02_C , s
ineqdeco A_L_03_A , s
ineqdeco A_L_03_B , s w
ineqdeco A_L_03_C , s
ineqdeco A_L_04_A , s
ineqdeco A_L_04_B , s w
ineqdeco A_L_04_C , s
ineqdeco A_L_05F_A , s
ineqdeco A_L_05F_B , s w
ineqdeco A_L_05F_C , s
ineqdeco A_L_05O_A , s
ineqdeco A_L_05O_B , s w
ineqdeco A_L_05O_C , s
ineqdeco A_L_06_A , s
ineqdeco A_L_06_B , s w
ineqdeco A_L_06_C , s
ineqdeco A_L_07_A , s
ineqdeco A_L_07_B , s w
ineqdeco A_L_07_C , s

. generate  A_L_01_A_Inverse = 1/ A_L_01_A
. generate  A_L_01_C_Inverse = 1/ A_L_01_C
. generate  A_L_02_A_Inverse = 1/ A_L_02_A
. generate  A_L_02_C_Inverse = 1/ A_L_02_C
. generate  A_L_03_A_Inverse = 1/ A_L_03_A
. generate  A_L_03_C_Inverse = 1/ A_L_03_C
. generate  A_L_04_A_Inverse = 1/ A_L_04_A
. generate  A_L_04_C_Inverse = 1/ A_L_04_C
. generate  A_L_05F_A_Inverse = 1/ A_L_05F_A
. generate  A_L_05F_C_Inverse = 1/ A_L_05F_C
. generate  A_L_05O_A_Inverse = 1/ A_L_05O_A
. generate  A_L_05O_C_Inverse = 1/ A_L_05O_C
. generate  A_L_06_A_Inverse = 1/ A_L_06_A
. generate  A_L_06_C_Inverse = 1/ A_L_06_C
. generate  A_L_07_A_Inverse = 1/ A_L_07_A
. generate  A_L_07_C_Inverse = 1/ A_L_07_C

. ineqdeco A_L_01_A_Inverse, w
. ineqdeco A_L_01_C_Inverse, w
. ineqdeco A_L_02_A_Inverse, w
. ineqdeco A_L_02_C_Inverse, w
. ineqdeco A_L_03_A_Inverse, w
. ineqdeco A_L_03_C_Inverse, w
. ineqdeco A_L_04_A_Inverse, w
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. ineqdeco A_L_04_C_Inverse, w
. ineqdeco A_L_05F_A_Inverse, w
. ineqdeco A_L_05F_C_Inverse, w
. ineqdeco A_L_05O_A_Inverse, w
. ineqdeco A_L_05O_C_Inverse, w
. ineqdeco A_L_06_A_Inverse, w
. ineqdeco A_L_06_C_Inverse, w
. ineqdeco A_L_07_A_Inverse, w
. ineqdeco A_L_07_C_Inverse, w

* ROAD NETWORK ANALYSIS
. ineqdeco A_N_01_A , s
. ineqdeco A_N_01_B , s w
. ineqdeco A_N_01_C , s
. ineqdeco A_N_02_A , s
. ineqdeco A_N_02_B , s w
. ineqdeco A_N_02_C , s
. ineqdeco A_N_03_A , s
. ineqdeco A_N_03_B , s w
. ineqdeco A_N_03_C , s
. ineqdeco A_N_04_A , s
. ineqdeco A_N_04_B , s w
. ineqdeco A_N_04_C , s
. ineqdeco A_N_05F_A , s
. ineqdeco A_N_05F_B , s w
. ineqdeco A_N_05F_C , s
. ineqdeco A_N_05O_A , s
. ineqdeco A_N_05O_B , s w
. ineqdeco A_N_05O_C , s
. ineqdeco A_N_06_A , s
. ineqdeco A_N_06_B , s w
. ineqdeco A_N_06_C , s
. ineqdeco A_N_07_A , s
. ineqdeco A_N_07_B , s w
. ineqdeco A_N_07_C , s

. generate  A_N_01_A_Inverse = 1/ A_N_01_A
. generate  A_N_01_C_Inverse = 1/ A_N_01_C
. generate  A_N_02_A_Inverse = 1/ A_N_02_A
. generate  A_N_02_C_Inverse = 1/ A_N_02_C
. generate  A_N_03_A_Inverse = 1/ A_N_03_A
. generate  A_N_03_C_Inverse = 1/ A_N_03_C
. generate  A_N_04_A_Inverse = 1/ A_N_04_A
. generate  A_N_04_C_Inverse = 1/ A_N_04_C
. generate  A_N_05F_A_Inverse = 1/ A_N_05F_A
. generate  A_N_05F_C_Inverse = 1/ A_N_05F_C
. generate  A_N_05O_A_Inverse = 1/ A_N_05O_A
. generate  A_N_05O_C_Inverse = 1/ A_N_05O_C
. generate  A_N_06_A_Inverse = 1/ A_N_06_A
. generate  A_N_06_C_Inverse = 1/ A_N_06_C
. generate  A_N_07_A_Inverse = 1/ A_N_07_A
. generate  A_N_07_C_Inverse = 1/ A_N_07_C

. ineqdeco A_N_01_A_Inverse, w
. ineqdeco A_N_01_C_Inverse, w
. ineqdeco A_N_02_A_Inverse, w
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. ineqdeco A_N_02_C_Inverse, w
. ineqdeco A_N_03_A_Inverse, w
. ineqdeco A_N_03_C_Inverse, w
. ineqdeco A_N_04_A_Inverse, w
. ineqdeco A_N_04_C_Inverse, w
. ineqdeco A_N_05F_A_Inverse, w
. ineqdeco A_N_05F_C_Inverse, w
. ineqdeco A_N_05O_A_Inverse, w
. ineqdeco A_N_05O_C_Inverse, w
. ineqdeco A_N_06_A_Inverse, w
. ineqdeco A_N_06_C_Inverse, w
. ineqdeco A_N_07_A_Inverse, w
. ineqdeco A_N_07_C_Inverse, w

* TRANSIT NETWORK ANALYSIS
. ineqdeco T_N_01_A , s
. ineqdeco T_N_01_B , s w
. ineqdeco T_N_01_C , s
. ineqdeco T_N_02_A , s
. ineqdeco T_N_02_B , s w
. ineqdeco T_N_02_C , s
. ineqdeco T_N_03_A , s
. ineqdeco T_N_03_B , s w
. ineqdeco T_N_03_C , s
. ineqdeco T_N_04_A , s
. ineqdeco T_N_04_B , s w
. ineqdeco T_N_04_C , s
. ineqdeco T_N_05F_A , s
. ineqdeco T_N_05F_B , s w
. ineqdeco T_N_05F_C , s
. ineqdeco T_N_05O_A , s
. ineqdeco T_N_05O_B , s w
. ineqdeco T_N_05O_C , s
. ineqdeco T_N_06_A , s
. ineqdeco T_N_06_B , s w
. ineqdeco T_N_06_C , s
. ineqdeco T_N_07_A , s
. ineqdeco T_N_07_B , s w
. ineqdeco T_N_07_C , s

. generate  T_N_01_A_Inverse = 1/ T_N_01_A
. generate  T_N_01_C_Inverse = 1/ T_N_01_C
. generate  T_N_02_A_Inverse = 1/ T_N_02_A
. generate  T_N_02_C_Inverse = 1/ T_N_02_C
. generate  T_N_03_A_Inverse = 1/ T_N_03_A
. generate  T_N_03_C_Inverse = 1/ T_N_03_C
. generate  T_N_04_A_Inverse = 1/ T_N_04_A
. generate  T_N_04_C_Inverse = 1/ T_N_04_C
. generate  T_N_05F_A_Inverse = 1/ T_N_05F_A
. generate  T_N_05F_C_Inverse = 1/ T_N_05F_C
. generate  T_N_05O_A_Inverse = 1/ T_N_05O_A
. generate  T_N_05O_C_Inverse = 1/ T_N_05O_C
. generate  T_N_06_A_Inverse = 1/ T_N_06_A
. generate  T_N_06_C_Inverse = 1/ T_N_06_C
. generate  T_N_07_A_Inverse = 1/ T_N_07_A
. generate  T_N_07_C_Inverse = 1/ T_N_07_C
```

```
. ineqdeco T_N_01_A_Inverse, w
. ineqdeco T_N_01_C_Inverse, w
. ineqdeco T_N_02_A_Inverse, w
. ineqdeco T_N_02_C_Inverse, w
. ineqdeco T_N_03_A_Inverse, w
. ineqdeco T_N_03_C_Inverse, w
. ineqdeco T_N_04_A_Inverse, w
. ineqdeco T_N_04_C_Inverse, w
. ineqdeco T_N_05F_A_Inverse, w
. ineqdeco T_N_05F_C_Inverse, w
. ineqdeco T_N_05O_A_Inverse, w
. ineqdeco T_N_05O_C_Inverse, w
. ineqdeco T_N_06_A_Inverse, w
. ineqdeco T_N_06_C_Inverse, w
. ineqdeco T_N_07_A_Inverse, w
. ineqdeco T_N_07_C_Inverse, w

* OVERALL NETWROK ANALYSIS WHEN 5% OF HOUSEHOLDS USE TRANSIT
. ineqdeco T5_N_01_A , s
. ineqdeco T5_N_01_B , s w
. ineqdeco T5_N_01_C , s
. ineqdeco T5_N_02_A , s
. ineqdeco T5_N_02_B , s w
. ineqdeco T5_N_02_C , s
. ineqdeco T5_N_03_A , s
. ineqdeco T5_N_03_B , s w
. ineqdeco T5_N_03_C , s
. ineqdeco T5_N_04_A , s
. ineqdeco T5_N_04_B , s w
. ineqdeco T5_N_04_C , s
. ineqdeco T5_N_05F_A , s
. ineqdeco T5_N_05F_B , s w
. ineqdeco T5_N_05F_C , s
. ineqdeco T5_N_05O_A , s
. ineqdeco T5_N_05O_B , s w
. ineqdeco T5_N_05O_C , s
. ineqdeco T5_N_06_A , s
. ineqdeco T5_N_06_B , s w
. ineqdeco T5_N_06_C , s
. ineqdeco T5_N_07_A , s
. ineqdeco T5_N_07_B , s w
. ineqdeco T5_N_07_C , s

. generate  T5_N_01_A_Inverse = 1/ T5_N_01_A
. generate  T5_N_01_C_Inverse = 1/ T5_N_01_C
. generate  T5_N_02_A_Inverse = 1/ T5_N_02_A
. generate  T5_N_02_C_Inverse = 1/ T5_N_02_C
. generate  T5_N_03_A_Inverse = 1/ T5_N_03_A
. generate  T5_N_03_C_Inverse = 1/ T5_N_03_C
. generate  T5_N_04_A_Inverse = 1/ T5_N_04_A
. generate  T5_N_04_C_Inverse = 1/ T5_N_04_C
. generate  T5_N_05F_A_Inverse = 1/ T5_N_05F_A
. generate  T5_N_05F_C_Inverse = 1/ T5_N_05F_C
. generate  T5_N_05O_A_Inverse = 1/ T5_N_05O_A
. generate  T5_N_05O_C_Inverse = 1/ T5_N_05O_C
```

```
. generate  T5_N_06_A_Inverse = 1/ T5_N_06_A
. generate  T5_N_06_C_Inverse = 1/ T5_N_06_C
. generate  T5_N_07_A_Inverse = 1/ T5_N_07_A
. generate  T5_N_07_C_Inverse = 1/ T5_N_07_C

. ineqdeco T5_N_01_A_Inverse, w
. ineqdeco T5_N_01_C_Inverse, w
. ineqdeco T5_N_02_A_Inverse, w
. ineqdeco T5_N_02_C_Inverse, w
. ineqdeco T5_N_03_A_Inverse, w
. ineqdeco T5_N_03_C_Inverse, w
. ineqdeco T5_N_04_A_Inverse, w
. ineqdeco T5_N_04_C_Inverse, w
. ineqdeco T5_N_05F_A_Inverse, w
. ineqdeco T5_N_05F_C_Inverse, w
. ineqdeco T5_N_05O_A_Inverse, w
. ineqdeco T5_N_05O_C_Inverse, w
. ineqdeco T5_N_06_A_Inverse, w
. ineqdeco T5_N_06_C_Inverse, w
. ineqdeco T5_N_07_A_Inverse, w
. ineqdeco T5_N_07_C_Inverse, w

* OVERALL NETWROK ANALYSIS WHEN 10% OF HOUSEHOLDS USE TRANSIT
. ineqdeco T10_N_01_A , s
. ineqdeco T10_N_01_B , s w
. ineqdeco T10_N_01_C , s
. ineqdeco T10_N_02_A , s
. ineqdeco T10_N_02_B , s w
. ineqdeco T10_N_02_C , s
. ineqdeco T10_N_03_A , s
. ineqdeco T10_N_03_B , s w
. ineqdeco T10_N_03_C , s
. ineqdeco T10_N_04_A , s
. ineqdeco T10_N_04_B , s w
. ineqdeco T10_N_04_C , s
. ineqdeco T10_N_05F_A , s
. ineqdeco T10_N_05F_B , s w
. ineqdeco T10_N_05F_C , s
. ineqdeco T10_N_05O_A , s
. ineqdeco T10_N_05O_B , s w
. ineqdeco T10_N_05O_C , s
. ineqdeco T10_N_06_A , s
. ineqdeco T10_N_06_B , s w
. ineqdeco T10_N_06_C , s
. ineqdeco T10_N_07_A , s
. ineqdeco T10_N_07_B , s w
. ineqdeco T10_N_07_C , s

. generate  T10_N_01_A_Inverse = 1/ T10_N_01_A
. generate  T10_N_01_C_Inverse = 1/ T10_N_01_C
. generate  T10_N_02_A_Inverse = 1/ T10_N_02_A
. generate  T10_N_02_C_Inverse = 1/ T10_N_02_C
. generate  T10_N_03_A_Inverse = 1/ T10_N_03_A
. generate  T10_N_03_C_Inverse = 1/ T10_N_03_C
. generate  T10_N_04_A_Inverse = 1/ T10_N_04_A
. generate  T10_N_04_C_Inverse = 1/ T10_N_04_C
```

```
. generate  T10_N_05F_A_Inverse = 1/ T10_N_05F_A
. generate  T10_N_05F_C_Inverse = 1/ T10_N_05F_C
. generate  T10_N_05O_A_Inverse = 1/ T10_N_05O_A
. generate  T10_N_05O_C_Inverse = 1/ T10_N_05O_C
. generate  T10_N_06_A_Inverse = 1/ T10_N_06_A
. generate  T10_N_06_C_Inverse = 1/ T10_N_06_C
. generate  T10_N_07_A_Inverse = 1/ T10_N_07_A
. generate  T10_N_07_C_Inverse = 1/ T10_N_07_C

. ineqdeco T10_N_01_A_Inverse, w
. ineqdeco T10_N_01_C_Inverse, w
. ineqdeco T10_N_02_A_Inverse, w
. ineqdeco T10_N_02_C_Inverse, w
. ineqdeco T10_N_03_A_Inverse, w
. ineqdeco T10_N_03_C_Inverse, w
. ineqdeco T10_N_04_A_Inverse, w
. ineqdeco T10_N_04_C_Inverse, w
. ineqdeco T10_N_05F_A_Inverse, w
. ineqdeco T10_N_05F_C_Inverse, w
. ineqdeco T10_N_05O_A_Inverse, w
. ineqdeco T10_N_05O_C_Inverse, w
. ineqdeco T10_N_06_A_Inverse, w
. ineqdeco T10_N_06_C_Inverse, w
. ineqdeco T10_N_07_A_Inverse, w
. ineqdeco T10_N_07_C_Inverse, w

* OVERALL NETWROK ANALYSIS WHEN HOUSEHOLDS WITH NO VEHICLES USE TRANSIT
(BASED ON SHARE OF HOUSEHOLDS WITH NO VEHICLES IN CENSUS TRACTS)
. ineqdeco T_Share_N_01_A , s
. ineqdeco T_Share_N_01_B , s w
. ineqdeco T_Share_N_01_C , s
. ineqdeco T_Share_N_02_A , s
. ineqdeco T_Share_N_02_B , s w
. ineqdeco T_Share_N_02_C , s
. ineqdeco T_Share_N_03_A , s
. ineqdeco T_Share_N_03_B , s w
. ineqdeco T_Share_N_03_C , s
. ineqdeco T_Share_N_04_A , s
. ineqdeco T_Share_N_04_B , s w
. ineqdeco T_Share_N_04_C , s
. ineqdeco T_Share_N_05F_A , s
. ineqdeco T_Share_N_05F_B , s w
. ineqdeco T_Share_N_05F_C , s
. ineqdeco T_Share_N_05O_A , s
. ineqdeco T_Share_N_05O_B , s w
. ineqdeco T_Share_N_05O_C , s
. ineqdeco T_Share_N_06_A , s
. ineqdeco T_Share_N_06_B , s w
. ineqdeco T_Share_N_06_C , s
. ineqdeco T_Share_N_07_A , s
. ineqdeco T_Share_N_07_B , s w
. ineqdeco T_Share_N_07_C , s

. generate  T_Share_N_01_A_Inverse = 1/ T_Share_N_01_A
. generate  T_Share_N_01_C_Inverse = 1/ T_Share_N_01_C
. generate  T_Share_N_02_A_Inverse = 1/ T_Share_N_02_A
```

```
. generate  T_Share_N_02_C_Inverse = 1/ T_Share_N_02_C
. generate  T_Share_N_03_A_Inverse = 1/ T_Share_N_03_A
. generate  T_Share_N_03_C_Inverse = 1/ T_Share_N_03_C
. generate  T_Share_N_04_A_Inverse = 1/ T_Share_N_04_A
. generate  T_Share_N_04_C_Inverse = 1/ T_Share_N_04_C
. generate  T_Share_N_05F_A_Inverse = 1/ T_Share_N_05F_A
. generate  T_Share_N_05F_C_Inverse = 1/ T_Share_N_05F_C
. generate  T_Share_N_05O_A_Inverse = 1/ T_Share_N_05O_A
. generate  T_Share_N_05O_C_Inverse = 1/ T_Share_N_05O_C
. generate  T_Share_N_06_A_Inverse = 1/ T_Share_N_06_A
. generate  T_Share_N_06_C_Inverse = 1/ T_Share_N_06_C
. generate  T_Share_N_07_A_Inverse = 1/ T_Share_N_07_A
. generate  T_Share_N_07_C_Inverse = 1/ T_Share_N_07_C

. ineqdeco T_Share_N_01_A_Inverse, w
. ineqdeco T_Share_N_01_C_Inverse, w
. ineqdeco T_Share_N_02_A_Inverse, w
. ineqdeco T_Share_N_02_C_Inverse, w
. ineqdeco T_Share_N_03_A_Inverse, w
. ineqdeco T_Share_N_03_C_Inverse, w
. ineqdeco T_Share_N_04_A_Inverse, w
. ineqdeco T_Share_N_04_C_Inverse, w
. ineqdeco T_Share_N_05F_A_Inverse, w
. ineqdeco T_Share_N_05F_C_Inverse, w
. ineqdeco T_Share_N_05O_A_Inverse, w
. ineqdeco T_Share_N_05O_C_Inverse, w
. ineqdeco T_Share_N_06_A_Inverse, w
. ineqdeco T_Share_N_06_C_Inverse, w
. ineqdeco T_Share_N_07_A_Inverse, w
. ineqdeco T_Share_N_07_C_Inverse, w

* FUTURE TRANSIT NETWORK ANALYSIS
. ineqdeco FT_N_01_A , s
. ineqdeco FT_N_01_B , s w
. ineqdeco FT_N_01_C , s
. ineqdeco FT_N_02_A , s
. ineqdeco FT_N_02_B , s w
. ineqdeco FT_N_02_C , s
. ineqdeco FT_N_03_A , s
. ineqdeco FT_N_03_B , s w
. ineqdeco FT_N_03_C , s
. ineqdeco FT_N_04_A , s
. ineqdeco FT_N_04_B , s w
. ineqdeco FT_N_04_C , s
. ineqdeco FT_N_05F_A , s
. ineqdeco FT_N_05F_B , s w
. ineqdeco FT_N_05F_C , s
. ineqdeco FT_N_05O_A , s
. ineqdeco FT_N_05O_B , s w
. ineqdeco FT_N_05O_C , s
. ineqdeco FT_N_06_A , s
. ineqdeco FT_N_06_B , s w
. ineqdeco FT_N_06_C , s
. ineqdeco FT_N_07_A , s
. ineqdeco FT_N_07_B , s w
. ineqdeco FT_N_07_C , s
```

```
. generate  FT_N_01_A_Inverse = 1/ FT_N_01_A
. generate  FT_N_01_C_Inverse = 1/ FT_N_01_C
. generate  FT_N_02_A_Inverse = 1/ FT_N_02_A
. generate  FT_N_02_C_Inverse = 1/ FT_N_02_C
. generate  FT_N_03_A_Inverse = 1/ FT_N_03_A
. generate  FT_N_03_C_Inverse = 1/ FT_N_03_C
. generate  FT_N_04_A_Inverse = 1/ FT_N_04_A
. generate  FT_N_04_C_Inverse = 1/ FT_N_04_C
. generate  FT_N_05F_A_Inverse = 1/ FT_N_05F_A
. generate  FT_N_05F_C_Inverse = 1/ FT_N_05F_C
. generate  FT_N_05O_A_Inverse = 1/ FT_N_05O_A
. generate  FT_N_05O_C_Inverse = 1/ FT_N_05O_C
. generate  FT_N_06_A_Inverse = 1/ FT_N_06_A
. generate  FT_N_06_C_Inverse = 1/ FT_N_06_C
. generate  FT_N_07_A_Inverse = 1/ FT_N_07_A
. generate  FT_N_07_C_Inverse = 1/ FT_N_07_C

. ineqdeco FT_N_01_A_Inverse, w
. ineqdeco FT_N_01_C_Inverse, w
. ineqdeco FT_N_02_A_Inverse, w
. ineqdeco FT_N_02_C_Inverse, w
. ineqdeco FT_N_03_A_Inverse, w
. ineqdeco FT_N_03_C_Inverse, w
. ineqdeco FT_N_04_A_Inverse, w
. ineqdeco FT_N_04_C_Inverse, w
. ineqdeco FT_N_05F_A_Inverse, w
. ineqdeco FT_N_05F_C_Inverse, w
. ineqdeco FT_N_05O_A_Inverse, w
. ineqdeco FT_N_05O_C_Inverse, w
. ineqdeco FT_N_06_A_Inverse, w
. ineqdeco FT_N_06_C_Inverse, w
. ineqdeco FT_N_07_A_Inverse, w
. ineqdeco FT_N_07_C_Inverse, w

* FUTURE OVERALL NETWROK ANALYSIS WHEN 5% OF HOUSEHOLDS USE TRANSIT
. ineqdeco FT5_N_01_A , s
. ineqdeco FT5_N_01_B , s w
. ineqdeco FT5_N_01_C , s
. ineqdeco FT5_N_02_A , s
. ineqdeco FT5_N_02_B , s w
. ineqdeco FT5_N_02_C , s
. ineqdeco FT5_N_03_A , s
. ineqdeco FT5_N_03_B , s w
. ineqdeco FT5_N_03_C , s
. ineqdeco FT5_N_04_A , s
. ineqdeco FT5_N_04_B , s w
. ineqdeco FT5_N_04_C , s
. ineqdeco FT5_N_05F_A , s
. ineqdeco FT5_N_05F_B , s w
. ineqdeco FT5_N_05F_C , s
. ineqdeco FT5_N_05O_A , s
. ineqdeco FT5_N_05O_B , s w
. ineqdeco FT5_N_05O_C , s
. ineqdeco FT5_N_06_A , s
. ineqdeco FT5_N_06_B , s w
```

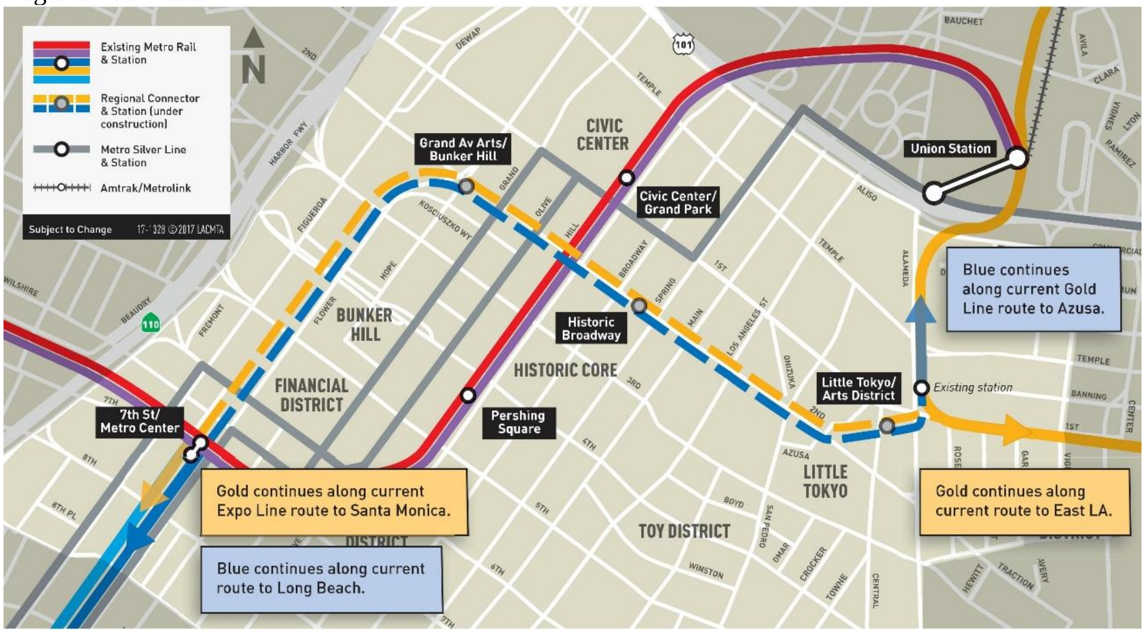
```
. ineqdeco FT5_N_06_C , s
. ineqdeco FT5_N_07_A , s
. ineqdeco FT5_N_07_B , s w
. ineqdeco FT5_N_07_C , s

. generate  FT5_N_01_A_Inverse = 1/ FT5_N_01_A
. generate  FT5_N_01_C_Inverse = 1/ FT5_N_01_C
. generate  FT5_N_02_A_Inverse = 1/ FT5_N_02_A
. generate  FT5_N_02_C_Inverse = 1/ FT5_N_02_C
. generate  FT5_N_03_A_Inverse = 1/ FT5_N_03_A
. generate  FT5_N_03_C_Inverse = 1/ FT5_N_03_C
. generate  FT5_N_04_A_Inverse = 1/ FT5_N_04_A
. generate  FT5_N_04_C_Inverse = 1/ FT5_N_04_C
. generate  FT5_N_05F_A_Inverse = 1/ FT5_N_05F_A
. generate  FT5_N_05F_C_Inverse = 1/ FT5_N_05F_C
. generate  FT5_N_05O_A_Inverse = 1/ FT5_N_05O_A
. generate  FT5_N_05O_C_Inverse = 1/ FT5_N_05O_C
. generate  FT5_N_06_A_Inverse = 1/ FT5_N_06_A
. generate  FT5_N_06_C_Inverse = 1/ FT5_N_06_C
. generate  FT5_N_07_A_Inverse = 1/ FT5_N_07_A
. generate  FT5_N_07_C_Inverse = 1/ FT5_N_07_C

. ineqdeco FT5_N_01_A_Inverse, w
. ineqdeco FT5_N_01_C_Inverse, w
. ineqdeco FT5_N_02_A_Inverse, w
. ineqdeco FT5_N_02_C_Inverse, w
. ineqdeco FT5_N_03_A_Inverse, w
. ineqdeco FT5_N_03_C_Inverse, w
. ineqdeco FT5_N_04_A_Inverse, w
. ineqdeco FT5_N_04_C_Inverse, w
. ineqdeco FT5_N_05F_A_Inverse, w
. ineqdeco FT5_N_05F_C_Inverse, w
. ineqdeco FT5_N_05O_A_Inverse, w
. ineqdeco FT5_N_05O_C_Inverse, w
. ineqdeco FT5_N_06_A_Inverse, w
. ineqdeco FT5_N_06_C_Inverse, w
. ineqdeco FT5_N_07_A_Inverse, w
. ineqdeco FT5_N_07_C_Inverse, w

* FUTURE OVERALL NETWORK ANALYSIS WHEN 10% OF HOUSEHOLDS USE TRANSIT
. ineqdeco FT10_N_01_A , s
. ineqdeco FT10_N_01_B , s w
. ineqdeco FT10_N_01_C , s
. ineqdeco FT10_N_02_A , s
. ineqdeco FT10_N_02_B , s w
. ineqdeco FT10_N_02_C , s
. ineqdeco FT10_N_03_A , s
. ineqdeco FT10_N_03_B , s w
. ineqdeco FT10_N_03_C , s
. ineqdeco FT10_N_04_A , s
. ineqdeco FT10_N_04_B , s w
. ineqdeco FT10_N_04_C , s
. ineqdeco FT10_N_05F_A , s
. ineqdeco FT10_N_05F_B , s w
. ineqdeco FT10_N_05F_C , s
. ineqdeco FT10_N_05O_A , s
```

```
. ineqdeco FT10_N_05O_B , s w
. ineqdeco FT10_N_05O_C , s
. ineqdeco FT10_N_06_A , s
. ineqdeco FT10_N_06_B , s w
. ineqdeco FT10_N_06_C , s
. ineqdeco FT10_N_07_A , s
. ineqdeco FT10_N_07_B , s w
. ineqdeco FT10_N_07_C , s

. generate  FT10_N_01_A_Inverse = 1/ FT10_N_01_A
. generate  FT10_N_01_C_Inverse = 1/ FT10_N_01_C
. generate  FT10_N_02_A_Inverse = 1/ FT10_N_02_A
. generate  FT10_N_02_C_Inverse = 1/ FT10_N_02_C
. generate  FT10_N_03_A_Inverse = 1/ FT10_N_03_A
. generate  FT10_N_03_C_Inverse = 1/ FT10_N_03_C
. generate  FT10_N_04_A_Inverse = 1/ FT10_N_04_A
. generate  FT10_N_04_C_Inverse = 1/ FT10_N_04_C
. generate  FT10_N_05F_A_Inverse = 1/ FT10_N_05F_A
. generate  FT10_N_05F_C_Inverse = 1/ FT10_N_05F_C
. generate  FT10_N_05O_A_Inverse = 1/ FT10_N_05O_A
. generate  FT10_N_05O_C_Inverse = 1/ FT10_N_05O_C
. generate  FT10_N_06_A_Inverse = 1/ FT10_N_06_A
. generate  FT10_N_06_C_Inverse = 1/ FT10_N_06_C
. generate  FT10_N_07_A_Inverse = 1/ FT10_N_07_A
. generate  FT10_N_07_C_Inverse = 1/ FT10_N_07_C

. ineqdeco FT10_N_01_A_Inverse, w
. ineqdeco FT10_N_01_C_Inverse, w
. ineqdeco FT10_N_02_A_Inverse, w
. ineqdeco FT10_N_02_C_Inverse, w
. ineqdeco FT10_N_03_A_Inverse, w
. ineqdeco FT10_N_03_C_Inverse, w
. ineqdeco FT10_N_04_A_Inverse, w
. ineqdeco FT10_N_04_C_Inverse, w
. ineqdeco FT10_N_05F_A_Inverse, w
. ineqdeco FT10_N_05F_C_Inverse, w
. ineqdeco FT10_N_05O_A_Inverse, w
. ineqdeco FT10_N_05O_C_Inverse, w
. ineqdeco FT10_N_06_A_Inverse, w
. ineqdeco FT10_N_06_C_Inverse, w
. ineqdeco FT10_N_07_A_Inverse, w
. ineqdeco FT10_N_07_C_Inverse, w

* FUTURE OVERALL NETWORK ANALYSIS WHEN HOUSEHOLDS WITH NO VEHICLES USE
TRANSIT (BASED ON SHARE OF HOUSEHOLDS WITH NO VEHICLES IN CENSUS TRACTS)
. ineqdeco FT_Share_N_01_A , s
. ineqdeco FT_Share_N_01_B , s w
. ineqdeco FT_Share_N_01_C , s
. ineqdeco FT_Share_N_02_A , s
. ineqdeco FT_Share_N_02_B , s w
. ineqdeco FT_Share_N_02_C , s
. ineqdeco FT_Share_N_03_A , s
. ineqdeco FT_Share_N_03_B , s w
. ineqdeco FT_Share_N_03_C , s
. ineqdeco FT_Share_N_04_A , s
. ineqdeco FT_Share_N_04_B , s w
```

```
. ineqdeco FT_Share_N_04_C , s
. ineqdeco FT_Share_N_05F_A , s
. ineqdeco FT_Share_N_05F_B , s w
. ineqdeco FT_Share_N_05F_C , s
. ineqdeco FT_Share_N_05O_A , s
. ineqdeco FT_Share_N_05O_B , s w
. ineqdeco FT_Share_N_05O_C , s
. ineqdeco FT_Share_N_06_A , s
. ineqdeco FT_Share_N_06_B , s w
. ineqdeco FT_Share_N_06_C , s
. ineqdeco FT_Share_N_07_A , s
. ineqdeco FT_Share_N_07_B , s w
. ineqdeco FT_Share_N_07_C , s

. generate  FT_Share_N_01_A_Inverse = 1/ FT_Share_N_01_A
. generate  FT_Share_N_01_C_Inverse = 1/ FT_Share_N_01_C
. generate  FT_Share_N_02_A_Inverse = 1/ FT_Share_N_02_A
. generate  FT_Share_N_02_C_Inverse = 1/ FT_Share_N_02_C
. generate  FT_Share_N_03_A_Inverse = 1/ FT_Share_N_03_A
. generate  FT_Share_N_03_C_Inverse = 1/ FT_Share_N_03_C
. generate  FT_Share_N_04_A_Inverse = 1/ FT_Share_N_04_A
. generate  FT_Share_N_04_C_Inverse = 1/ FT_Share_N_04_C
. generate  FT_Share_N_05F_A_Inverse = 1/ FT_Share_N_05F_A
. generate  FT_Share_N_05F_C_Inverse = 1/ FT_Share_N_05F_C
. generate  FT_Share_N_05O_A_Inverse = 1/ FT_Share_N_05O_A
. generate  FT_Share_N_05O_C_Inverse = 1/ FT_Share_N_05O_C
. generate  FT_Share_N_06_A_Inverse = 1/ FT_Share_N_06_A
. generate  FT_Share_N_06_C_Inverse = 1/ FT_Share_N_06_C
. generate  FT_Share_N_07_A_Inverse = 1/ FT_Share_N_07_A
. generate  FT_Share_N_07_C_Inverse = 1/ FT_Share_N_07_C

. ineqdeco FT_Share_N_01_A_Inverse, w
. ineqdeco FT_Share_N_01_C_Inverse, w
. ineqdeco FT_Share_N_02_A_Inverse, w
. ineqdeco FT_Share_N_02_C_Inverse, w
. ineqdeco FT_Share_N_03_A_Inverse, w
. ineqdeco FT_Share_N_03_C_Inverse, w
. ineqdeco FT_Share_N_04_A_Inverse, w
. ineqdeco FT_Share_N_04_C_Inverse, w
. ineqdeco FT_Share_N_05F_A_Inverse, w
. ineqdeco FT_Share_N_05F_C_Inverse, w
. ineqdeco FT_Share_N_05O_A_Inverse, w
. ineqdeco FT_Share_N_05O_C_Inverse, w
. ineqdeco FT_Share_N_06_A_Inverse, w
. ineqdeco FT_Share_N_06_C_Inverse, w
. ineqdeco FT_Share_N_07_A_Inverse, w
. ineqdeco FT_Share_N_07_C_Inverse, w

. log close
```

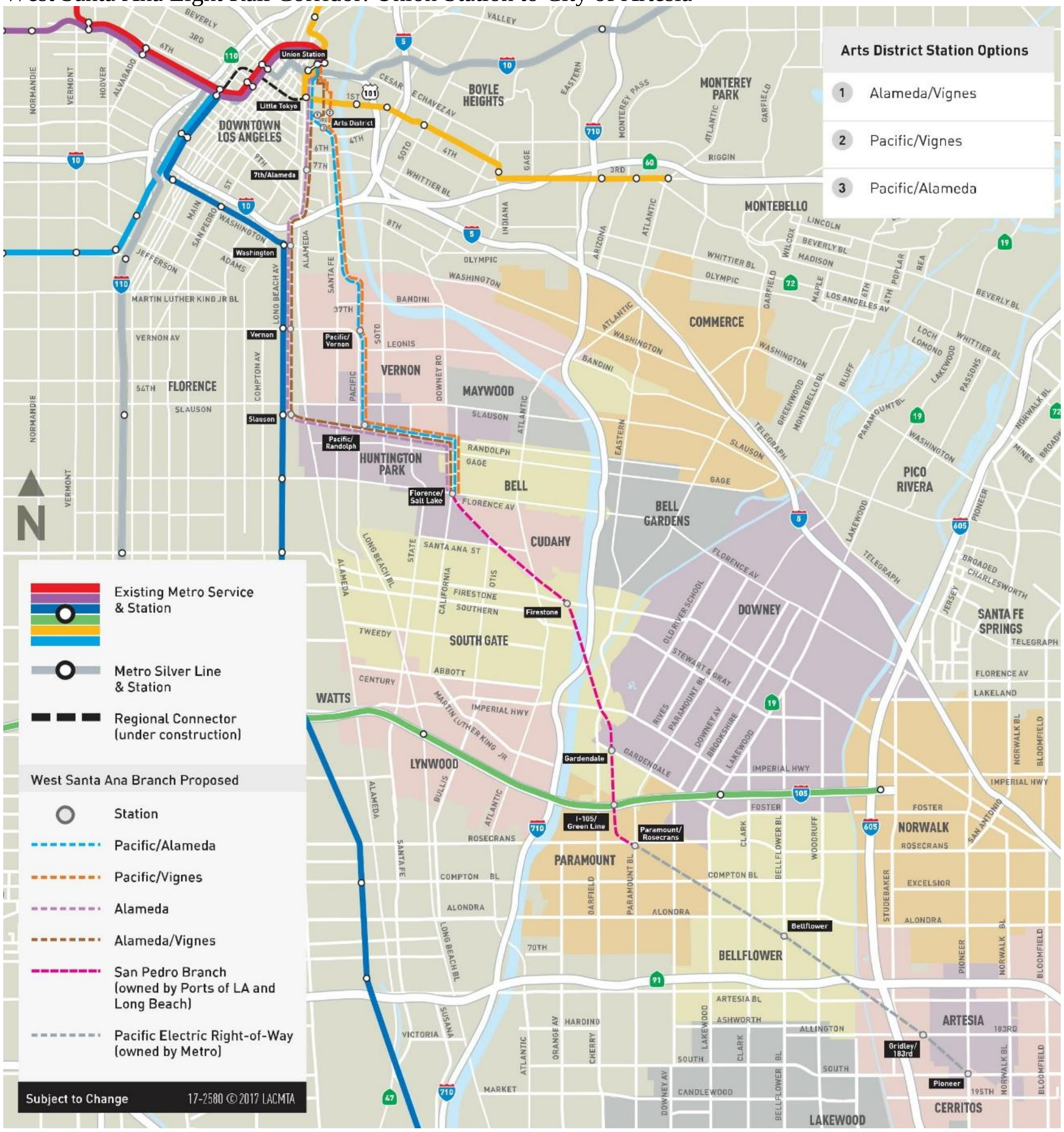
Appendix H: Measure R and M Project Maps

Regional Connector



Crenshaw Transit Corridor

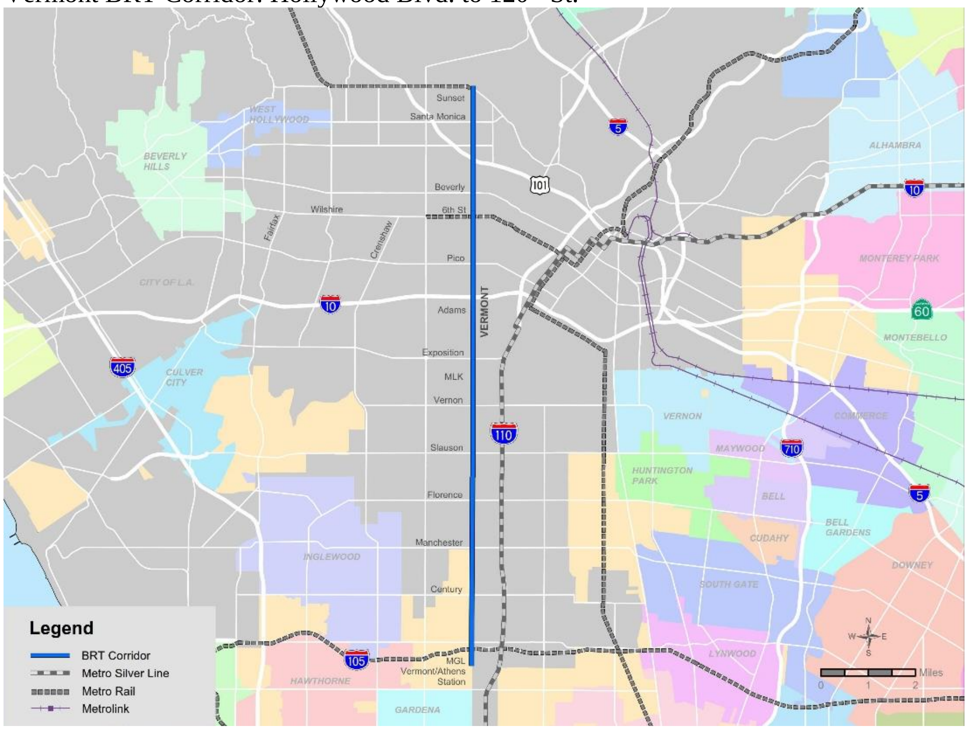
West Santa Ana Light Rail Corridor: Union Station to City of Artesia



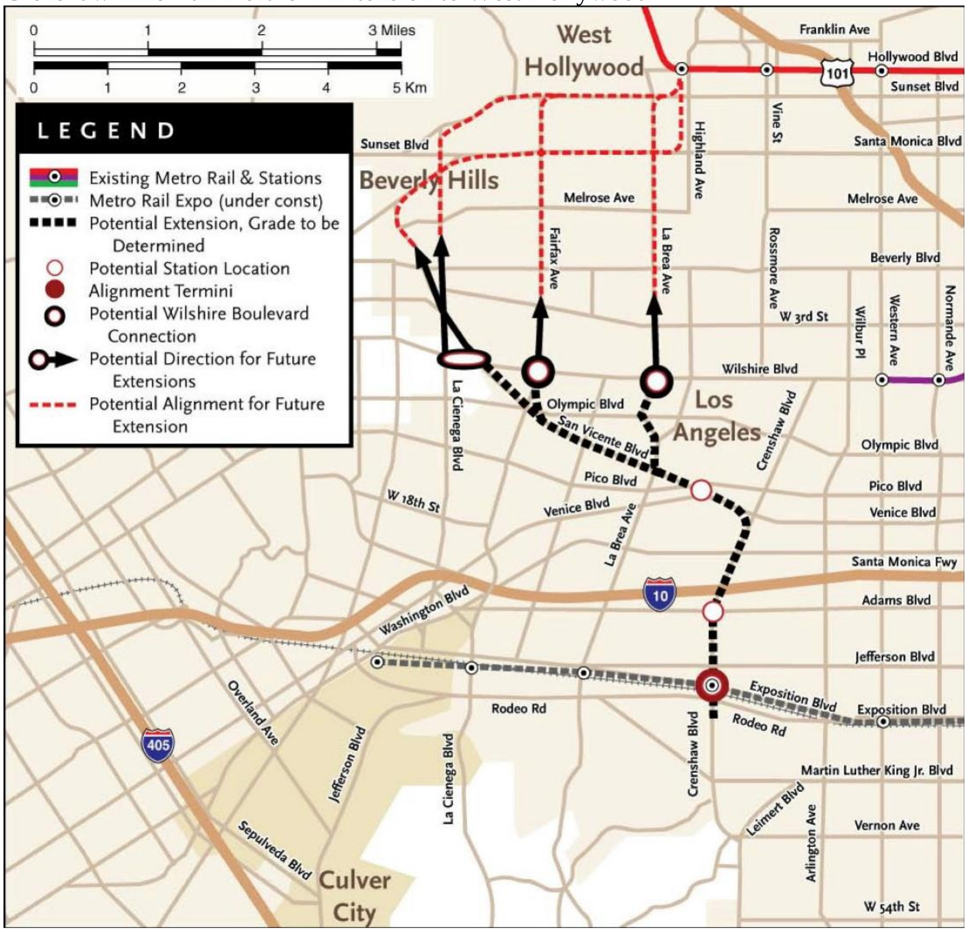
Selected Option: Pacific /Vignes

Green Line Rail Extension to Norwalk Metrolink Station

Vermont BRT Corridor: Hollywood Blvd. to 120th St.



Crenshaw Line Rail Northern Extension to West Hollywood



Selected Option: Fairfax Ave.

Orange Line BRT Connector to Gold Line Rail

Selected Option: Freeway Alignment

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Burchardt, T., Le Grand, J., & Piachaud, D. (1999). Social Exclusion in Britain 1991-1995 in Social Policy and Administration. *33(3)*, 227-244.

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